

Fostering Youth Soccer Players' Action Competence through
Learning-Supportive Coaching and Learning-Oriented Assessment

An Investigation within the German Talent Development Program

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Summary

The development of talent is a central task and a major challenge in elite youth sports. At its core, a key question is how individuals with promising potential to achieve elite performance in adulthood can be effectively supported in their development. In the context of soccer, talent research has advanced our understanding of the broad range of performance factors that serve as predictors of players' future success (Williams et al., 2020). Since many of these performance factors underpin action competence in soccer, this knowledge not only helps practitioners identify talented players but also provides insights into which attributes should be particularly fostered in youth soccer.

Talent Development Environments (TDEs) play a fundamental role in cultivating the competencies required for elite performance (Gagné, 2021; Hauser et al., 2022). A core element of TDEs is the learning support provided by coaches. However, optimizing this support for youth players requires a deeper understanding of effective coaching strategies in this context. To address this gap, this dissertation aims to generate scientific knowledge on how the acquisition of action competence in youth soccer players can be effectively fostered within TDEs. This overarching objective is examined through seven empirical studies that offer complementary perspectives, structured around two research foci:

1. *Learning-supportive coaching (Studies 1-3)*: Examining the contribution of different coaching strategies to fostering the acquisition of action competence in soccer.
2. *Learning-oriented assessment (Studies 4-7)*: Investigating the potential of different assessment methods for evaluating soccer skills and competencies in TDEs.

All individual studies were part of the research project *Scientific Support of the German Football Association's (DFB) Talent Development Program* and conducted in close collaboration with this applied initiative (for details, see DFB, 2022a).

Learning-supportive coaching (Research Focus I) is a key component of TDEs aiming to facilitate players' action competence in soccer. However, coaches often face challenges in selecting the most effective strategies from a wide range of available approaches. To address this issue, a systematic review with a quantitative synthesis consolidated existing knowledge from field-based interventions evaluating the effectiveness of coaching approaches in soccer (**Study 1**). Considerable effect sizes suggest that various approaches may foster perceptual-motor and perceptual-cognitive outcomes. Yet, due to the limited methodological quality of the included studies, conclusions regarding the effectiveness of these approaches should be drawn with caution. Moreover, optimizing the effective implementation of coaching strategies in soccer TDEs requires a deeper understanding of their underlying mechanisms and the rationales behind their use.

To explore learning-supportive strategies and experts' rationales for their use within soccer TDEs, a qualitative study was conducted with highly experienced international youth soccer coaches, coach educators, and researchers (**Study 2**). The interviews focused on the design of supportive TDEs, effective practice tasks to address specific learning goals, and learning-conducive coaching interventions. The findings detail the effectiveness of different approaches, such as, complementing a game-centred main philosophy by further practice activities (e.g., drill-based practices) and coaching interventions (e.g., guided reflections). These strategies, along with participants' justifications, contribute to a discussion that integrates different theoretical perspectives.

Building on Studies 1 and 2, a research-informed coach education program (CEP) was developed for approximately 1.300 coaches within the *DFB Talent Development Program*. Based on a multiplier approach to coach education, the CEP transferred theoretical knowledge on skill learning, empirical evidence on effective learning support, and

specific recommendations for coaching practice. The program evaluation integrated the perspectives of participating coaches and multipliers through a quantitative survey and qualitative interviews (**Study 3**). The findings indicate that the CEP was perceived as meaningful for enhancing coaches' learning support, while also highlighting areas for further improvement. Moreover, although the recommended coaching strategies largely aligned with coaches' existing beliefs, some practitioners experienced challenges in applying them, particularly in differentiating their use in response to players' learning needs. To assist coaches in tailoring their support to players' needs, assessments of relevant performance factors can be used. Beyond facilitating talent identification, such instruments can also serve as *learning-oriented assessments (Research Focus II)*. Yet, their formative potential to enhance coaches' learning support depends on both the assessment approach and its psychometric properties. In this regard, the *DFB Talent Development Program* combines both objective and subjective assessments (DFB, 2022b): An objective motor test battery provides an isolated evaluation of speed abilities and position-independent technical skills. To better support coaches in guiding player learning, subjective coach ratings were implemented to evaluate players within specific competence areas and to generate position-specific insights for outfield players and goalkeepers (GKs). While various studies have confirmed the psychometric properties of the motor test battery, including its predictive validity (e.g., Höner et al., 2017; 2019), available knowledge regarding coach ratings is limited to a single study involving male outfield players (Höner et al., 2021). As such, a deeper understanding of how these instruments can complement each other to serve as learning-oriented assessments requires further evaluation. To address this gap, this dissertation evaluates the assessments with other target groups in TDEs, namely female players and GKs. In addition, since the motor test

battery primarily addresses the action competence of outfield players, an objective, GK-specific assessment is introduced to complement the existing instruments.

To better understand the combined contribution of the motor test battery and competency-based coach ratings as learning-oriented assessments, a prospective cohort study examined their predictive validity among U15 female players for their success in U17 and in adulthood (**Study 4**). Both assessments demonstrated predictive power and their combination increased the explained variance for two of the three selection levels considered. Yet, multivariate analyses indicated limited incremental validity of different predictors, and particularly the coach ratings. These findings highlight challenges coaches face when evaluating competencies across distinct areas, thereby limiting the potential to derive specific implications for coaching practice from subjective ratings. At the same time, the study highlights the value of objective tests, as they allow for nuanced evaluations of individual predictors and are less affected by biases inherent in coaches' evaluations.

To determine the suitability of the objective and subjective assessments for GKs, another prospective cohort study investigated their predictive validity for selection by a youth academy (YA) after three seasons (**Study 5**). The study confirmed the predictive validity of position-independent motor tests, ratings of GK-specific technical and tactical skills, and GKs' overall performance level. Their combined consideration increased the explanatory power, with at least one significant objective and subjective predictor. Yet, the findings similarly suggest that coach ratings tend to be less differentiated, thereby limiting their formative potential to facilitate tailored learning support. Moreover, although the position-independent motor test battery demonstrated predictive power, an objective evaluation of GK-specific attributes is likely to advance the current assessment approach by providing more nuanced insights into talent predictors relevant to this playing position.

Given the limited availability of objective GK-specific assessments suitable for use in soccer TDEs, a novel test battery was developed. Its focus on domain-specific attributes of motor coordination was perceived as an important addition, as this represents one relevant ability underpinning the development of GK-specific competencies. Following an initial pilot study (**Study 6**), the test battery was further developed, and expert ratings confirmed its content validity, face validity, and practical feasibility. In a subsequent evaluation (**Study 7**), the overall test score demonstrated good test-retest reliability, although some individual tests showed lower coefficients. The assessment also revealed concurrent validity as more talented GKs outperformed less-talented GKs. While the findings highlight the need for further refinement to address psychometric limitations, they also support the test battery's potential to complement the existing assessment approach.

Overall, this dissertation provides actionable insights into learning-supportive coaching strategies for fostering the acquisition of action competence in soccer, as well as into the possibilities of using assessments to support coaches in this process. The **general discussion** integrates findings from all studies and is organized around six areas: *First*, coaching approaches are compared and evaluated with regard to their effectiveness in supporting player learning. *Second*, these coaching strategies are interpreted in light of different theoretical perspectives on learning. *Third*, the opportunities and limitations of various test instruments are examined concerning their function as learning-oriented assessments. *Fourth*, theoretical perspectives related to the broader soccer TDE are examined to shed light on potential moderating influences on the development of relevant performance factors. *Fifth*, selected findings from this dissertation are translated into implications for research-informed coach education and development. *Sixth*, future research directions at the intersection of talent and coaching research are outlined.

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1. Introduction

*We, as coaches, have to equip the player with the tools that enable them to face any single situation in a game in the most efficient way. We have to prepare the players for that.*¹

This statement made by Arsène Wenger, FIFA's Chief of Global Football Development, during a talk about talent pathways highlights a core objective in youth soccer: cultivating performance factors that enable players to master game situations at the highest level. In essence, he clarifies the overarching goal in youth soccer – facilitating *action competence*, which refers to a player's capability to solve distinct tasks within the game (Höner, 2005; 2012a; Schreiner, 2021; Williams & Hodges, 2005).

When considering players who exemplify such competence, the current captains of the German women's and men's national teams stand out as prime examples. Giulia Gwinn and Joshua Kimmich have long been recognized for consistently delivering exceptional performances in both defensive and offensive roles. Among other qualities, they embody technical finesse, creativity, optimal decision-making, as well as cleverness and robustness required in defensive duels. These and other attributes undeniably mark them as world-class players.

Beyond their individual qualities and roles as captains of the national teams, Gwinn and Kimmich share another commonality: both were identified as 'talented' during early adolescence through the *DFB Talent Development Program*. Gwinn was promoted at the Base Camp (BC; 'Stützpunkt') in Wangen, while Kimmich at the BC in Aldingen. Reflecting on their careers, both players have recently emphasized the crucial role this component of their *Talent Development Environment* (TDE) played in their progression. In particular, they emphasized the support provided by their youth coaches at DFB BCs, which they

¹ <https://www.fifatrainingcentre.com/en/community/expert-knowledge/wenger-on-talent-pathways.php>

retrospectively describe as essential in shaping their development.² The structured support Gwinn and Kimmich received at these BCs played a key role in their progression to the youth teams of professional clubs and their selection for the DFB's youth national teams, where their pathways to professional soccer continued.

The career trajectories of Gwinn and Kimmich underline Wenger's emphasis on the crucial role of youth soccer coaches in fostering the competencies required for elite performance. However, despite the success stories of these and many other players, the debate on how to provide players with optimal support in TDEs remains ongoing (Hauser et al., 2022). Discussions about the relevance of environmental factors extend far beyond recent decades and have long been a point of contention in both academic and practical contexts. This is exemplified by a nearly fifty-year-old debate in the renowned academic journal *Nature* concerning the predominant influence of individual versus environmental factors on elite athletic performance. Bondi (1978, p. 204) unequivocally argued that "environment must have a commanding part in establishing complex human physical achievements." In a response letter titled *Training or talent?*, Reeve (1978, p. 490) contended that "fostering athletic achievement is based on the early identification of 'talent' and the provision of every facility for the training and development of that 'talent'."

Since then, consensus has been reached that both the identification of individuals with promising potential to reach high performance *and* optimal environmental support are crucial (Fransen & Güllich, 2019; Güllich, 2022; Hohmann, 2009; Höner et al., 2023). Literature reviews of *talent research in sport* highlight the sustained and growing academic

² For reflections about their promotion in the *DFB Talent Development Program*: <https://www.zdf.de/kultur/rolemodels/giulia-gwinn-frauenfussball-100.html> and <https://training-service.fussball.de/spieler/bis-u-11-spielerin/artikel/joshua-kimmich-bei-rb-leipzig-im-profifussball-beweisen-270/#/>

interest in this topic, especially into the interplay of individual and environmental factors (Baker et al., 2020). This is also evident in soccer with literature reviews demonstrating the vibrant research interest to better understand a) relevant talent predictors (Murr et al., 2018a; 2018b; Williams et al., 2020), and b) how environmental factors may shape youth players' development (Dunn et al., 2024; Hauser et al., 2022; Verbeek et al., 2023). Despite flourishing research activities in the sport of soccer, these reviews consistently emphasize that several fundamental questions regarding the design of supportive TDEs remain unresolved and continue to challenge practitioners in their work.

Returning to Wenger's statement and the crucial role of youth soccer coaches – as also emphasized by Gwinn and Kimmich – one central question is how the development of relevant performance factors that underpin action competence in soccer can be effectively supported in TDEs. This includes the challenges coaches face in selecting the most supportive strategies from a wide range of available coaching approaches, as well as in tailoring these strategies to the individual learning needs of their players. The complexity of this task is reflected in the vast and sometimes conflicting body of academic and applied literature on how to best promote learning in youth soccer (e.g., Bell, 2021; Bisanz & Gerisch, 2010; Brinkschröder, 2020; O'Sullivan et al., 2021; Verheijen, 2020; Wade, 1967; Wein, 2004; Wolf, 2024; Worthington, 1974). Against this background, the present dissertation aims to expand the empirical knowledge base on how to effectively foster the acquisition of action competence in elite youth soccer players.

1.1 Research Context

Globally, soccer associations and clubs invest considerable resources to continuously enhance the support provided to youth players (FIFA, 2021a; Reeves & Roberts, 2020).

These initiatives focus on a better understanding of effective strategies for identifying and developing youth players, with the aim of professionalizing key stakeholders involved in these processes (e.g., coaches and scouts; Ford et al., 2020). Despite this shared objective, international comparisons of talent development structures and strategies reveal considerable variation (see Kelly et al., 2024, for an overview). These differences pertain to, for example, whether talent identification and development are primarily organized by clubs or national programs, the timing of initial selection, the volume and philosophy of practice and coaching, and the structure of competition across age groups. Such structural differences may arise from various factors, including national sports systems, the popularity of soccer in a country, and the availability of resources. As a result of this multitude of influences, Kelly et al. (2024, p. 257) conclude that:

[D]eveloping soccer talent is not a ‘one-size-fits-all’ approach. [...] [R]esearchers and practitioners are encouraged to evaluate how sociocultural influences could impact talent pathways before collaboratively designing and implementing policies into their own practice.

This conclusion highlights two key implications for the present dissertation: *First*, it speaks to the importance of recognizing and reflecting upon the respective research context as talent development structures can influence the process of knowledge generation. *Second*, it emphasizes the value of close collaboration between researchers and practitioners in designing studies, interpreting findings, and transferring selected insights into practice (see also Lyle, 2018). This dissertation seeks to adhere to both aspects, having been conducted in close collaboration with the *DFB Talent Development Program* as part of a broader research project forming its scientific support. Consequently, the program serves as the fundamental research context for this work, warranting a closer ex-

amination of its structure and objectives. Additionally, it is important to consider the areas of work addressed by the research project since its initiation in 2008, in order to show how this dissertation both builds upon and extends beyond previous research.

In Germany, soccer is by far the most popular sport (German Olympic Sports Confederation, 2024). During the 2023/2024 season, approximately 1.3 million children and adolescents actively participated in organized soccer (DFB, 2024a). The developmental pathway of these youth soccer players in Germany is structured around phases in which different institutions are involved (*Figure 1*). The foundation of the developmental pyramid represents the so-called *Basic Development Stage* that is further divided into two sub-phases (1 and 2; ages 3-10). This first stage is followed by the *Talent Development Stage* (3; ages 11-14) and, finally, the *Elite Promotion Stage* (4; ages 15-18). After progressing through these stages, players may advance to elite adult soccer (5-7).

	Focus		Age		Talent Development Structures	
7	Sustain Peak Performance	Elite-players	30			7
6	Master Peak Performance		21-29			6
5	Prepare for Peak Performance	Perspective-players	19/20 17/18		International Competitions Bundesliga, 2./3. Leagues National Team	5
4	Specialize	U18/U19 U16/U17	15-18		Licensed Clubs Elite Schools of Soccer Youth National Teams (U19-U21) Higher Amateur Level	4
3	Learn Developing foundational soccer-specific competencies	U14/U15 U12/U13	11-14		YAs and Elite Schools of Soccer Youth National Teams (U15 – U18) Regional Associations and Local Clubs	3
2	Play	U10/U11 U9/U10	7-10		DFB Talent Development Program Various Sporting Activities and Soccer-Specific Free-Play in Clubs and Schools	2
1	Move	U7	3-6		Movement and versatile Play in Clubs, Kindergarten, and Schools	1

Figure 1. Talent development structures in German soccer (adapted and translated from DFB, 2009, p. 5, 14; see also DFB, 2014, p. 13; DFB, 2022a, pp. 67-68; DFB, 2024b, pp. 4-6). With permission from the DFB.

This dissertation primarily focuses on the *Talent Development Stage* with its emphasis on facilitating players' long-term learning (highlighted with yellow shading in *Figure 1*). This phase aims to provide youth players (U12-U15) with individualized developmental support to acquire and refine foundational soccer-specific competencies. At its core, this stage is designed to guide youth soccer players toward reaching their potential. Additionally, stakeholders of non-sport settings (e.g., schools, parents) also contribute to functional features of the broader TDE. Players in the *Talent Development Stage* are promoted through one of two pathways: They either attend Youth Academies (YAs) of professional clubs or BCs of the *DFB Talent Development Program*. One structural objective of the DFB BCs is to prepare players for a potential transition to a YA during the *Talent Development Stage* or afterward, as the program ends after the U15 age group.

The pathway through DFB BCs is of particular relevance to this dissertation, having provided the context for the individual studies. Across Germany, approximately 14.000 youth players, representing the best 4% of their age groups, participate in one of approximately 350 BCs (DFB, 2022a). Their identification and development within these nationwide structures is ensured by 1.300 coaches, each required to hold at least a UEFA B-License. The coaches are further supported and coordinated by 29 regional coach coordinators. These coach coordinators, employed on a full-time basis, are also responsible for ongoing further education and development of BC coaches in their regions, ensuring consistent knowledge transfer into coaching practice.

A guiding framework for the work with players at DFB BCs is the Personalization-Analysis-Coaching-Evaluation (PACE) model (Dugandzic, 2023; *Figure 2*). Based on a four-step process, the model provides a reference for how the overarching objective at DFB BCs can be achieved. It illustrates how players can receive the most individual and effective

developmental support possible. This should be achieved through optimal coach-player pairings, for example, by aligning players' developmental goals with coaches' competencies (see 'Personalization'). A detailed analysis of a player's strengths and weaknesses represents the basis for tailored coaching as a critical foundation for the development of action competence in soccer. The model further emphasizes the critical role of ongoing evaluations of youth players' progress. This provides a basis for determining whether the support provided has been effective or requires improvement.



Figure 2. PACE-Model illustrating the process of individual support to facilitate talent development by integrating objective and subjective assessment data (Dugandzic, 2023). With permission from the DFB.

The PACE-model indicates that supporting talent development effectively requires the coordinated interplay of various environmental support measures. At the heart of the *DFB Talent Development Program*, the players are offered one additional practice session per week at BCs designed to supplement their promotion in home clubs. These sessions are delivered in small practice groups (coach-to-player ratio of approximately 1:8), following a nationwide philosophy and competency-based learning goals (DFB, 2022a; 2024b). A core strength of the DFB BCs lies in the support coaches receive from the program's organizational structure to create optimal learning conditions. For instance, the absence of

regular competitive matches between BCs helps coaches to fully concentrate on establishing a ‘practice-to-learn environment’ (DFB, 2024b; Kelly et al., 2024).

Another key component of the program is the annual assessment of talent predictors (for details see DFB, 2022b). These assessments were explicitly mentioned in *Figure 2* under the element ‘Analysis’, as they aim to provide coaches and players in the program with relevant information. The combined use of objective and subjective assessment methods serves a dual purpose: first, to assist coaches in identifying the most talented players; second, to provide a scientific basis for delivering individualized learning support. Specifically, the assessments are intended to help analyze each player’s strengths and areas for improvement in order to tailor coaching to individual needs, and to monitor the development of performance factors over time (see also ‘Evaluate’ in *Figure 2*).

To support these activities within the *DFB Talent Development Program*, the overarching research project has provided scientific support since 2008 aiming to generate scientific knowledge that can further enhance practitioners’ work.³ This scientific support can be broadly structured around two main lines of research. The first line of research concerns *talent identification and development*, including investigations into relevant talent predictors and appropriate assessment methods for evaluating these attributes in applied settings (e.g., Höner et al., 2015; 2021; Leyhr et al., 2018; Wachsmuth et al., 2024). Beyond a contribution to identifying talented players, respective research findings provide a scientific base for the integration of test results into the work with players as suggested by the PACE-model. The second, closely related line of research concerns *coach development*, recognizing that coaches’ support is a core component of TDEs. This includes research into three interrelated areas of coaches’ work in soccer TDEs: motivational

³ For more information on the research project see <https://uni-tuebingen.de/en/218829>

coaching (e.g., Raabe et al., 2019; 2020), the coach-player relationship (e.g., Wachsmuth et al., 2021), and coaching strategies to support player learning (e.g., Bergmann et al., 2021; 2024). Based on participatory research approaches (Vaughn & Jacquez, 2020), this work also addresses the translation of scientific knowledge into practical coaching recommendations and the development of effective formats for knowledge transfer within the nationwide talent development program (Wachsmuth et al., 2022). This dissertation sits at the intersection of the project's two lines of research by investigating how coaches' learning support can effectively foster players' action competence, and how assessments can contribute to practitioners' work with their players.

Taken together, this dissertation is embedded within a highly structured, nationwide soccer talent development program. It specifically addresses the U12 to U15 age groups with the focus on supporting players' long-term learning. A critical contributor to this objective is the learning support provided by coaches during the weekly practice sessions, which are guided by competency-based learning goals applied nationwide. This support is complemented by annual assessments of talent predictors which offer coaches both relevant information for their work (e.g., tailoring practice and coaching) and allow for the evaluation and monitoring of how relevant performance factors develop over time.

1.2 Dissertation Outline

This cumulative dissertation is structured into five parts. *Chapter 1* aims to briefly introduce the overarching question of how to effectively foster the development of action competence in youth soccer players. This 'practical problem' served as the starting point of the dissertation, with the research being contextually embedded in the *DFB Talent Development Program* as part of a broader research project.

Chapter 2 presents theoretical frameworks and the current state of research, thereby connecting three key perspectives relevant to this dissertation: *talent in soccer*, *action competence in soccer*, as well as *learning and coaching in soccer*. While the first two perspectives draw substantially on prior work conducted in the broader research project, the novelty lies in integrating these perspectives with the area of learning and coaching. Furthermore, theoretical considerations on learning and coaching were applied to the specific context of soccer TDEs.

The chapter begins by outlining theoretical perspectives on *talent in soccer*, aiming to systematize relevant talent predictors and the factors that influence their development, one of which is the learning support provided by coaches. Methodological challenges associated with investigating these talent predictors are discussed, along with the strengths and weaknesses of assessment approaches that intend to provide practitioners with relevant information for their work. Subsequently, an action-theoretical perspective is introduced which views soccer players' actions in the game as intentionally organized behaviors shaped by individual, environmental, and task-related demands. This perspective provides a foundation for defining *action competence in soccer* as overarching developmental outcome in soccer TDEs and for conceptualizing the coach's role in facilitating learning processes. Subsequently, the chapter presents theoretical perspectives and empirical insights into *learning and coaching*. This section focuses on how different learning theories can explain the underlying mechanisms of players' competence acquisition and, in turn, justify the effectiveness of different coaching approaches. Different research directions on learning and coaching in soccer are outlined, along with approaches for integrating assessment data to tailor coaching strategies in applied settings.

Finally, gaps at the intersection of talent research and coaching research are presented, forming the foundation for the research objectives of this dissertation.

Chapter 3 comprises the main part of this cumulative dissertation, presenting the individual manuscripts of the seven empirical studies published in scientific journals. The studies are structured around two closely interrelated research foci:

Research focus I presents three studies concerning *learning-supportive coaching* to foster the acquisition of action competence in soccer. This includes a systematic review with a quantitative synthesis of intervention research (Study 1) and a context-bound qualitative exploration of expert recommendations (Study 2). These studies served as a foundation to develop a research-informed Coach Education Program (CEP) to transfer theoretical knowledge, empirical findings, and practical coaching implications into the nationwide *DFB Talent Development Program* which is evaluated in a mixed-methods design (Study 3). A synthesis of the findings across the individual studies is presented. Furthermore, factors that limit practitioners in applying the practical recommendations are outlined, mainly related to challenges coaches face in tailoring coaching strategies to the individual learning needs of players. These insights raise implications for the role of formative assessments in supporting player learning within soccer TDEs.

These implications lead into Research Focus II, which includes four empirical studies focusing on *learning-oriented assessments*. While the assessment of relevant talent predictors is well-established in soccer TDEs, discussions often focus on their contribution to talent identification and selection. However, such assessments also hold potential to provide coaches with meaningful information on a player's skill and competence levels, enabling them to tailor their learning support more effectively. This potential to function

as learning-oriented assessment relates not only to the assessment method (e.g., objective or subjective) but also to its psychometric properties. While a considerable body of research has investigated the psychometric properties of various assessments in soccer TDEs, including their predictive validity, this work has predominantly focused on male outfield players. This dissertation therefore aims to extend the existing empirical knowledge by evaluating the assessments already used in the *DFB Talent Development Program* with two widely overlooked populations in talent research, namely female players (Study 4) and goalkeepers (GKs; Study 5). Moreover, a novel GK-specific objective motor test is introduced and evaluated that may complement the existing assessment approach in the future (Studies 6 & 7). After presenting the individual manuscripts, the main findings are synthesized. Particular attention is placed on the assessments' psychometric properties, especially their predictive and incremental validity, as a relevant foundation for discussing the possibilities of providing coaches with meaningful information for their work.

Chapter 4 presents a general discussion of the findings across Research Foci I and II. The discussion is structured around six key areas, and aims to synthesize and integrate scientific insights into how action competence in soccer can be effectively fostered. Beyond discussing how different coaching strategies can contribute to competence acquisition within soccer TDEs, particular attention is given to the potential of objective and subjective assessments to provide a scientific basis for tailored learning support. Based on these insights, directions for future research at the intersection of talent and coaching research are outlined.

Finally, *Chapter 5* presents the conclusion, summarizing the main findings of this dissertation and briefly highlighting their key practical implications.

2. Theoretical Background and State of Research

2.1 Talent in Soccer

The evergrowing literature on talent in sports is marked by inconsistent terminology which hinders efforts to translate scientific insights into practical strategies (Johnston et al., 2023, for a discussion). This highlights the need to establish a clear and consistent definition of talent within this dissertation based on the literature (Cobley et al., 2012; Güllich, 2022; Hohmann, 2009; Höner et al., 2023; Huijgen et al., 2014). *Talent* is defined as a domain-specific construct, meaning it is tied to a particular sport such as soccer. In addition, a *broad* understanding of talent has been established emphasizing the need to consider a wide range of relevant performance characteristics (e.g., skills, physical, and psychological attributes) and external factors (e.g., family support, access to high-quality coaching). Moreover, a *dynamic* understanding of talent is recommended that accounts for the longitudinal development of these performance factors. Drawing on existing literature (cf. Höner et al., 2023, p. 550), *talent in soccer* can be defined as individuals who:

- Still find themselves developing toward their highest performance level.
- Considering their practical experience, are athletically above average in comparison to players at a similar biological stage of development and with similar living habits.
- Can be justifiably trusted to achieve soccer peak performance in a later stage of development, taking into account internal performance conditions and available contextual support.

Regarding talent identification and development in soccer, Williams et al. (2020, p. 1200) distinguish six interrelated processes (*Figure 3*). A player's organized *participation* in soccer is considered as a crucial precondition for the *identification* of children and adolescents with superior performance potential compared to their reference group. Talented

children who do not systematically participate need to be *detected* at alternative sporting contexts. These processes serve as entry points into talent *development* programs designed to systematically promote youth players. Talent development is inherently linked to *selection* into higher levels of a talent system and *deselection*. Once being deselected, this does not preclude the possibility of reidentifying these players at a later stage.

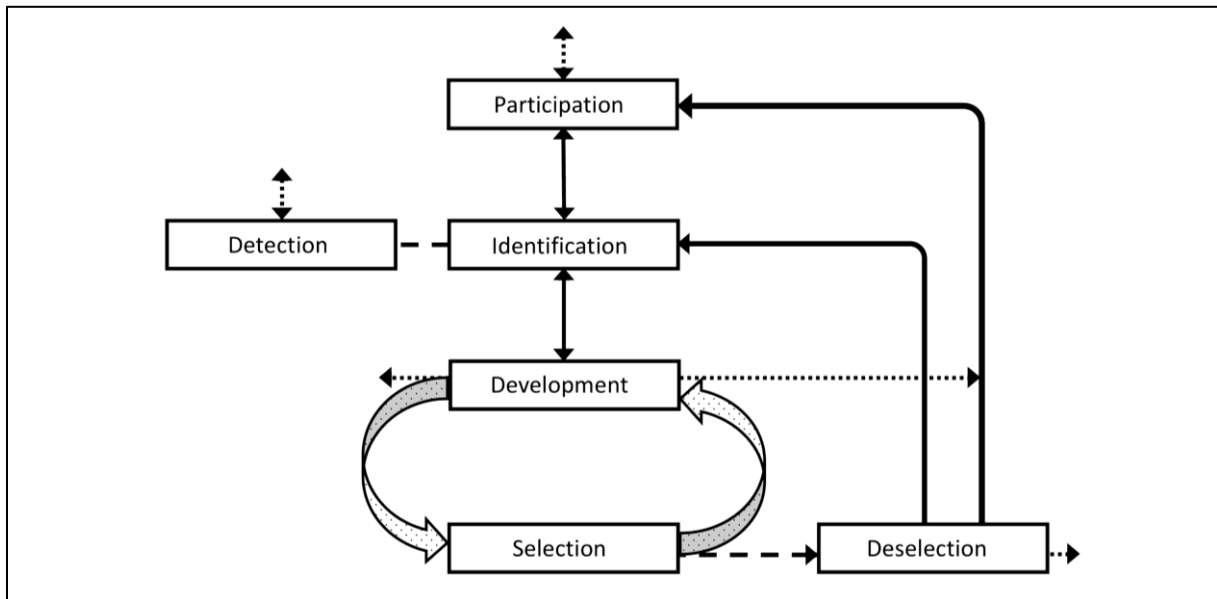


Figure 3. Model of interrelated processes linked to talent in soccer (Williams et al., 2020, p. 1200). With permission from Taylor & Francis.

During the *Talent Development Stage* (U12 to U15; see *Chapter 1.1*), DFB BC coaches' primary responsibilities are the systematic identification and (de-)selection of youth players already participating in soccer, as well as fostering their development. While the process of talent development is the primary focus of this dissertation, the bidirectional arrows in *Figure 3* highlight its close interrelation to talent identification, warranting a more detailed examination of their specific characteristics (Zhao et al., 2024, for a review). Talent identification involves recognizing soccer players who possess the potential to excel. Once involved in TDEs, talent development entails a systematic combination of coaching, training, and match play to enhance players' skills and competencies (Williams et

al., 2020). Yet, a relevant knowledge base essential to both talent identification and development consists of performance factors with predictive power for future success (e.g., Larkin & O'Connor, 2017). This knowledge plays a crucial role in both processes, as it not only serves as a foundation for identifying talented players but also defines key developmental outcomes to be fostered in youth soccer (Höner et al., 2023).

In this regard, theoretical models that structure the developmental process toward expertise in sports into phases identify the early adolescence as a critical period marked by a shift in learning environments. This shift involves moving away from a focus on diversified experiences and informal, deliberate play toward more structured, sport-specific learning activities (Balyi et al., 2013; Côté, 1999; Côté et al., 2007; Côté & Erickson, 2015). This is reflected in the overarching developmental objective of fostering foundational soccer-specific competencies at the individual level within DFB BCs (DFB, 2022a). As such, effective talent development in the sport of soccer “implies that players are provided with a suitable learning environment so that they have the opportunity to realize their potential” (Williams & Reilly, 2000, p. 658).

To facilitate a systematic perspective on how a youth soccer player’s potential can be transformed into high performance, this chapter continues by introducing a theoretical model that systematizes the process of talent development and identifies the key factors influencing it. Building on this, the current empirical evidence on relevant talent predictors in soccer is presented, along with their moderating and mediating factors. This body of research leads into methodological challenges associated with investigating these talent predictors. Finally, assessment approaches for evaluating and monitoring relevant talent predictors are introduced, placing emphasis on their strengths and weaknesses to provide practitioners’ with information to manage different processes in soccer TDEs.

2.1.1 Transforming Potential into Performance

A relevant basis for providing and investigating effective learning support in soccer TDEs is a sound understanding of how sporting potential can be transformed into sport-specific performance as well as which factors influence this process. A consistent assumption across different theoretical models on talent development is the influence of various interacting endogenous (individual) and exogenous (environmental) factors (for reviews, see Fransen & Güllich, 2018; Preckel et al., 2020; Subotnik et al., 2011; 2012). Much of the research conducted as part of the *DFB Talent Development Program*'s scientific support is guided by the *Differentiated Model of Giftedness and Talent (DMGT; Gagné, 2021)*. As this model seeks to structure the talent development process and its influencing factors, it also serves as a guiding framework for this dissertation.

The *DMGT* conceptualizes (innate) giftedness as a person's performance potential on the basis of which specific competencies can be systematically developed (*Figure 4*). Therefore, a key assumption of this model is the distinction between domain-specific giftedness and the actual talent that emerges through a structured developmental process. This is illustrated by the three core components of the *DMGT*: a developmental process (D), based on gifts (G), leading to the development of talent (T). This developmental trajectory is influenced by intrapersonal (I) and environmental (E) catalysts. The ultimate goal of the talent development process represents the acquisition or refinement of competencies that enable an individual to master tasks within a specific field – in the case of this dissertation, soccer. Additionally, the model includes a frame surrounding G, D, I, and E termed *chance* (C), which encompasses factors beyond individual or environmental control but also affecting the talent development process.

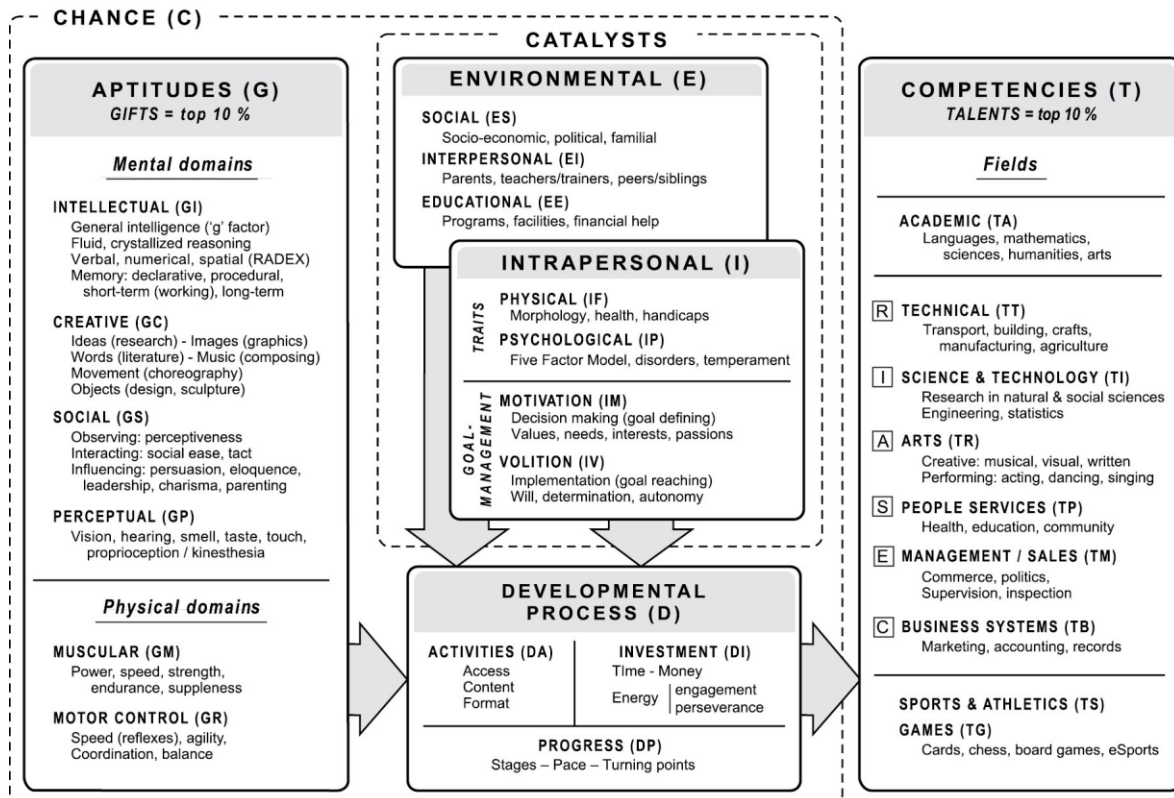


Figure 4. The Differentiated Model of Giftedness and Talent (DMGT; Gagné, 2021, p. 9). With permission from Routledge (Taylor & Francis Group).

When applied to soccer, the *DMGT* emphasizes the importance of identifying gifted individuals who exhibit promising potential for developing soccer-specific competencies. This potential may – but does not necessarily – manifest as exceptional performance at early developmental stages. Beyond identifying individuals with substantial potential, a key objective of talent development programs is to establish optimal environmental conditions that facilitate the development of such competencies (Dunn et al., 2024; Höner et al., 2023). Building on the *DMGT*'s five major components, the model offers a structured perspective on the various factors that influence a player's competence acquisition in TDEs. With regard to the overarching objective of this dissertation, it facilitates to

[...] analyze any type of learning with these five major components [i.e., G, D, E, I, T]. Indeed, what is learning basically? It consists of acquiring a set of competencies in a specific field by calling upon relevant aptitudes and taking advantage of internal and external resources. Moreover, keep in mind that this system pursues a unique goal: to model as precisely as possible the growth of competencies and talents. (Gagné, 2021, p. 10)

Focusing on the *developmental activities* (DAs) that shape this process, the *DMGT* specifies three key dimensions: *access*, *content*, and *format* (*Figure 4*). These dimensions can be applied to the *DFB Talent Development Program*: The program aims to systematically enhance players' *access* to high-quality DAs by selecting players with promising potential for targeted promotion at DFB BCs (DFB, 2009; 2022a). Furthermore, it provides content guidelines through nationwide, competency-based learning goals that assist practitioners in creating practice and coaching. Additionally, *format* guidelines include, for example, methodological aspects of the learning support (DFB, 2022a; Wolf, 2024). In light of the *DMGT*, this dissertation seeks to further develop the scientific foundation for these formats, thereby optimizing the learning support provided. However, understanding how DAs embedded within the TDE shape a player's competence acquisition also requires considering intrapersonal characteristics which may act as moderating variables. To name one example, a player's motivation ('IM' in *Figure 4*) may moderate the effectiveness of the learning support provided by coaches. Yet, the close interaction of individual and environmental factors is illustrated as a player's motivation is, in turn, influenced by the motivational support offered within TDEs (Gjesdal, 2025; Raabe et al., 2020). Therefore, evaluating the effects of DAs on competence acquisition should take into account the complex interplay between environmental and intrapersonal factors.

While the *DMGT* provides comprehensive insights into the objectives and influencing factors of talent development, it does not offer concrete implications regarding a) specific attributes that characterize talent in soccer and b) which and how particular environmental factors can effectively support players' competence acquisition. The following chapter therefore presents current empirical evidence on relevant talent predictors in soccer, along with existing knowledge on potential mediating and moderating factors.

2.1.2 Empirical Evidence on Talent Predictors

Talent research in the sport of soccer is a vibrant field, with several literature reviews synthesizing the available knowledge on relevant talent predictors (Ivarsson et al., 2020; Murre et al., 2018a, 2018b; Verbeek et al., 2023; Williams et al., 2020). The review conducted by Williams et al. (2020) specifically examined prospective studies that investigated the predictive power of various attributes for success in adulthood. Drawing on this body of research, an empirically-informed model was developed, categorizing soccer-specific talent predictors into physical, skill-related, psychological, and sociological domains (*Figure 5*). Furthermore, the model categorizes moderating and mediating factors on the attributes' predictive validity as these factors can, for example, influence the development of relevant performance factors. The model presented by Williams et al. (2020) can thus be understood as an empirical and soccer-specific complement of the *DMGT* as it organizes the current knowledge on talent predictors along with individual, environmental, and chance factors that can influence their development.

Attributes that demonstrated at least some degree of predictive validity (highlighted in bold) are found across the physical, skill-related, and psychological domains. This model thus supports the importance of considering multiple talent predictors from diverse disciplinary perspectives. In addition, the model identifies various moderating and mediating factors, assigning them to four distinct areas. One of such factor addressed in this dissertation is the development environment, specifically coaching and training (O'Connor & Larkin, 2017). Consequently, the model proposed by Williams et al. (2020) emphasizes the importance of this core component of the TDE for the development of relevant performance factors. It thereby underlines the need to better understand how to optimize the influence of these environmental factors to effectively support talent development.

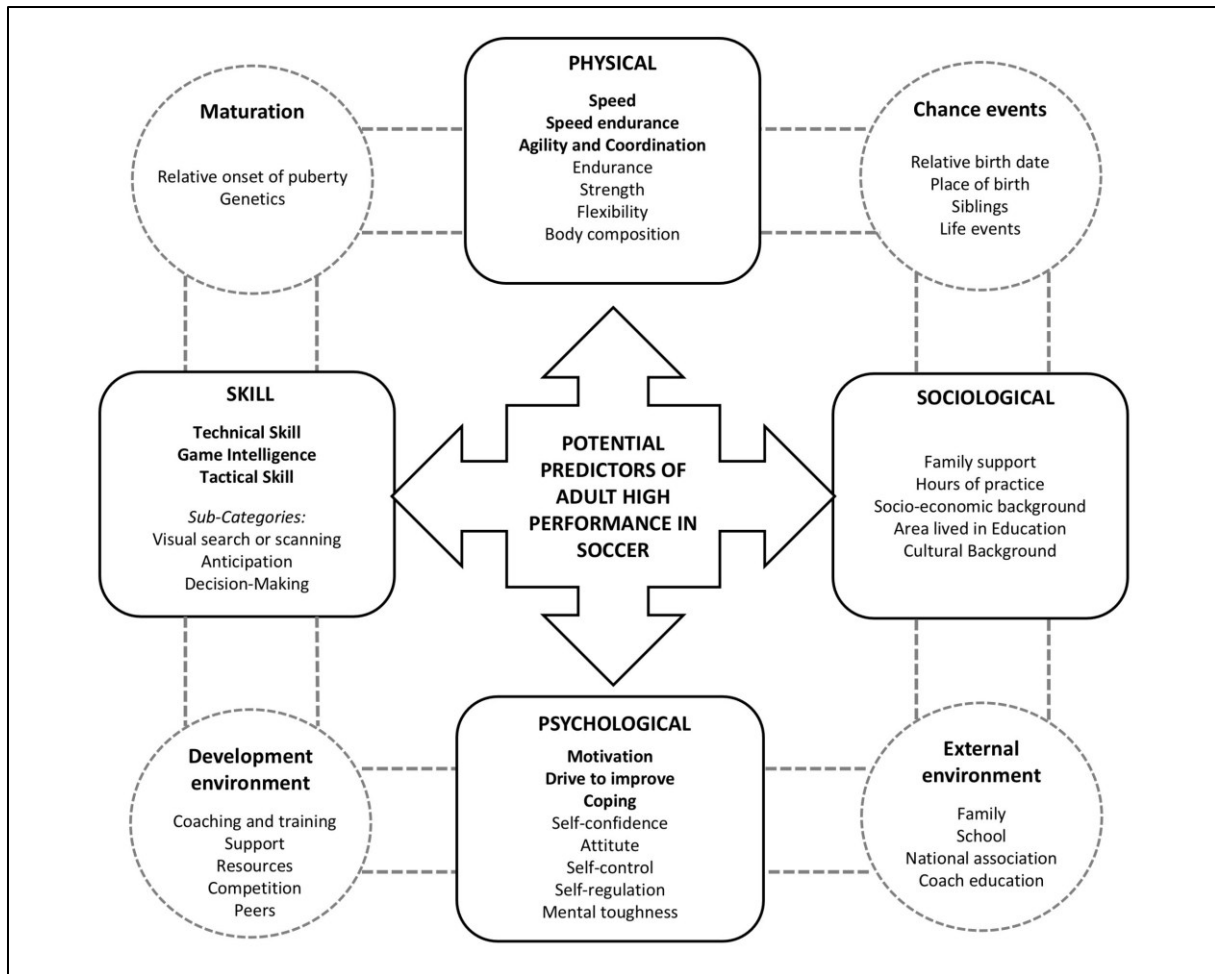


Figure 5. Potential predictors of adult high performance in soccer with moderating and mediating factors. Bold predictors denote those with at least some empirical evidence for their predictive value for success in adulthood (Williams et al., 2020, p. 1204). With permission from Taylor & Francis.

From the perspective of this dissertation, a closer examination of attributes with predictive power during early adolescence is warranted. Regarding *motor abilities* (see ‘physical’ domain), there is substantial empirical support for the predictive power of players’ speed across nearly all developmental phases in youth soccer. This includes linear sprint speed, repeated sprint ability, and various forms of agility in terms of change of direction speed (CODS; Murr et al., 2018b). While endurance is not identified by Williams et al. (2020) as a predictor with empirically supported validity for adult success, other reviews indicate the prognostic relevance of this motor ability (Bergkamp et al., 2019; Murr et al., 2018b). This apparent inconsistency in findings can be explained by the moderating role

of the prognostic periods and criterion variables. Specifically, some reviews also include studies that examine predictive validity for future success in youth soccer, where endurance has demonstrated some prognostic power. In addition, some studies point to the predictive power of motor coordination for players' future success (Deprez et al., 2014). Yet, coordination has received less attention compared to other motor abilities, and existing studies show considerable variation in theoretical frameworks and assessment methods (e.g., tests with and without a ball; Faber et al., 2014; O'Brien Smith et al., 2019). There is also evidence in the skill-related domain which encompasses various *technical skills* and *tactical skills*. Regarding technical skills, empirical support exists for the predictive validity of the 'core' soccer skills passing and first touch, dribbling, and shooting for achieving different levels of future success (Bergkamp et al., 2019; Murr et al., 2018a; Williams et al., 2020). Regarding tactical skills, a wide range of predictors have been studied, including decision-making, positioning, and anticipation, as well as pure knowledge-based performance factors (e.g., tactical knowledge; for a review Triggs et al., 2025). While only a few of these attributes have demonstrated predictive power for success in adult soccer (e.g., decision-making, game intelligence; Williams et al., 2020), there is some evidence supporting their prognostic relevance for different selection levels in youth soccer (Ivarsson et al., 2020; Murr et al., 2018a). Yet, a limitation in the area of tactical skills is that these were often evaluated using self-report assessments and not within real game situations due to the scarce availability of adequate tests. Notably, current knowledge on the predictive relevance of technical and tactical skills is almost exclusively limited toward skills required in the attacking play. Moreover, further technical skills undeniably required in the game, such as heading or lofted passes (Hughes et al., 2012), have received little attention in the available prospective talent research.

The model presented by Williams et al. (2020) also refers to some more generic attributes, some of which were highlighted as predictively valid, while others are not. In general, soccer-specific performance factors tend to exhibit stronger predictive power than generic attributes. This is apparent, for example, when comparing the relevance of soccer-specific cognitive skills (e.g., decision-making in game situations) with generic cognitive abilities (e.g., executive functions; for a meta-analysis Kalén et al., 2021). Furthermore, several psychological characteristics including players' achievement motivation (e.g., hope for success), task-orientation, and coping have been identified as predictors for future success (Ivarsson et al., 2020; Williams et al., 2020). Supporting the greater explanatory power of sport-specific attributes, the relevance of these characteristics seems to depend on whether they are measured using generic self-report questionnaires from outside of the sport context or via instruments adapted specifically for use in soccer TDEs (for discussions Feichtinger & Höner, 2015; Wachsmuth et al., 2024).

Altogether, current evidence supports the predictive validity of various talent predictors, providing guidance on relevant attributes for talent identification and selection, as well as on performance factors to be purposefully developed within soccer TDEs. At the same time, Williams et al. (2020) emphasize that there is still absent evidence concerning the predictive validity of several performance factors and limited empirical knowledge on relevant moderating and mediating factors. However, lacking knowledge should not be misinterpreted as evidence of the irrelevance of these factors; rather it likely reflects gaps or limitations in the available research. The still limited knowledge can be explained as making predictions in soccer TDEs, as in other fields, poses inherent challenges (Nolting & Paulus, 2018; in transfer to talent research Höner et al., 2023). These challenges include the selection of appropriate assessments, consideration of the stability of personal and

situational factors, and the application of probabilistic statements to individual cases. Consequently, a more detailed examination of these and other domain-specific methodological challenges in soccer TDEs is essential for generating more nuanced insights into performance factors with predictive power in future studies, and on relevant moderating and mediating factors. At the very least, understanding these challenges is essential to identify suitable assessment approaches that can provide coaches with relevant information to support talent development in applied settings.

2.1.3 Methodological Challenges in (Prospective) Research

The knowledge presented in the previous chapter has been gathered by prospective studies that assess potential talent predictors in youth soccer and track players' progress over time. This type of study design allows to evaluate the predictors' relationship with indicators of future success, thereby enabling inferences about the predictive power of specific attributes (Williams et al., 2020). Yet, designing thorough prospective studies poses considerable challenges. In most of these studies, pre-selected and therefore rather homogeneous study samples were examined. As a consequence, *restriction of range of talent* issues can arise, making it difficult to detect meaningful performance differences among already skilled youth players, although they may achieve varying levels of success later in their careers (Ackerman, 2014; Bergkamp et al., 2019). Such findings should not inadvertently lead to the conclusion that the assessed performance factors lack predictive power in general. Rather, the issue may lie in the limited capacity of these performance factors and/or the assessments used to measure them to differentiate between players who already demonstrate high performance levels in youth soccer.

A closely related challenge is that achieving the required *sensitivity of statistical analysis* to detect meaningful effect sizes is often difficult in highly selective samples (Hecksteden et al., 2022). Essentially, this relates to the difficulty of conducting studies with sufficiently large sample sizes of high-performing individuals. This issue is further compounded by the typically low number of players ultimately selected at later time points, resulting in an unbalanced sample between selected and non-selected individuals. This issue becomes even more pronounced when investigating underrepresented groups in soccer TDEs, such as female players or specific positional roles like GKs. While literature reviews have criticized the limited inclusion of these populations in talent research (Andrew et al., 2024a; Curran et al., 2019; Emmonds et al., 2024; Vahia & Kelly, 2024), the scarcity of empirical studies should not be interpreted as an indication of their lack of relevance. Rather, it highlights the specific methodological challenges involved in conducting robust research within these target groups.

Furthermore, there are various purposes for assessments of talent predictors used in TDEs, some of which impose specific demands on psychometric properties. If assessments are designed primarily for *discriminative purposes* – such as identifying the most talented players in a larger pool of individuals – ‘relative reliability’ is, in principle, more important than ‘absolute reliability’ (de Vet et al., 2006). When assessments are intended for *longitudinal evaluations* (e.g., Leyhr et al., 2018), high ‘absolute reliability’ is relevant (de Vet et al., 2006; Mokkink et al., 2020). Moreover, reliability requirements are generally higher for individual comparisons than for group comparisons as group comparisons allow for some degree of error aggregation (Höner & Roth, 2002). That is, if assessments of talent predictors should not only be used to analyze a player’s skill level at a specific point in time in comparison to other players, but also to monitor development over time, high

absolute reliability is essential. A closely related topic concerns that TDEs cater to children and youths during highly dynamic developmental phases (e.g., puberty). Such developmental changes can impact the *differential stability* of talent predictors (i.e., the stability of interindividual differences over time) due to a range of personal and environmental factors (Feichtinger & Höner, 2015). Beyond affecting an assessment's concurrent and predictive validity, these influences can make it difficult to differentiate between performance improvements resulting from natural development (e.g., maturation) or those driven by targeted interventions in TDEs, such as practice and coaching.

Lastly, one of the most critical challenges in soccer TDEs with the overarching aim to provide players' with individualized developmental support lies in *applying probabilistic statements to individual cases*. While analyses of predictive validity typically rely on mean differences across groups, coaches are required to make decisions at the level of the individual player. This transfer requires the *ceteris paribus* condition to be met; that is, all other factors influencing the predictor's relevance must remain constant (cf. Tack, 1994, p. 31). In applied sport settings where a wide range of contextual influences exists, this condition is rarely fulfilled (for a discussion Höner et al., 2023). Consequently, although empirical findings from talent research can offer valuable guidance, practitioners' judgment remains the most relevant component for effective talent identification and development (Christensen, 2009; Ford et al., 2020).

From the perspective of this dissertation, accounting for these methodological aspects is crucial, as they influence how individual test results can be thoughtfully used to support talent development processes, while also acknowledging their inherent limitations. Since the integration of test results to support developmental processes represents a

central focus of this work, the following chapter places particular emphasis on the challenges associated with the availability and selection of appropriate assessment approaches (Höner et al., 2023; Nolting & Paulus, 2018). Given the wide range of assessments used in soccer TDEs (Williams et al., 2020), a detailed examination of different approaches remains essential.

2.1.4 Assessment Approaches

Considering common processes relating to talent identification and development in soccer, the use of assessments can serve different purposes. One key purpose is that players' participation in assessments helps establish a systematic approach to talent identification, for example, by comparing individual test results to reference values (Datson et al., 2020; Höner et al., 2015). Another purpose is that individual test results can aid coaches' in supporting talent development, for example, by tailoring coaching interventions based on insights into a player's strengths and weaknesses (Höner et al., 2020). Beyond their psychometric properties (e.g., reliability and predictive validity), the contribution of assessments for these purposes can be discussed in relation to the *assessment methods* used, their extent of *representativeness* for game demands, and whether they focus on *individual predictors* or *adopt a holistic view* on a player's talent.

Assessment methods can broadly be categorized as either objective (e.g., motor tests) or subjective (e.g., coach ratings). While practical decision-making should ultimately be grounded in practitioners' subjective evaluations (Buekers et al., 2015; Christensen, 2009; Höner, 2013), numerous studies have shown that objective tests also possess predictive validity, albeit typically with small to moderate effect sizes (Murr et al., 2018a;

2018b; Verbeek et al., 2023; Williams et al., 2020).⁴ The complementary nature of these different methods is supported by prospective studies that combine objective motor tests with subjective coaching ratings, demonstrating that such assessment approaches can improve the predictive power for future success (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a). Beyond achieving better predictions, these findings highlight the value of purposefully combining different assessment methods to capture a wide range of talent predictors in a practically feasible manner.

Beyond the consistent findings about the contribution from combining objective and subjective assessments, the studies have also identified strengths and limitations associated with each method. For instance, Dugdale et al. (2020) found that coach ratings are effective at distinguishing the best and worst players but less precise when it comes to differentiating between players of similar performance levels. Additionally, Höner et al. (2021) reported strong predictive validity for coach ratings, possibly because such ratings incorporate practitioners' experience and intuition (see also Larkin & O'Connor, 2017; Roberts et al., 2019a). At the same time, objective motor tests are particularly useful for evaluating specific performance factors, as they are less influenced by biases that may affect subjective judgments (Höner et al., 2021). Balancing the respective strengths and limitations of these approaches may therefore contribute to a more comprehensive evaluation of talent predictors in youth soccer.

Another ongoing debate in the literature concerns the degree to which assessments used in TDEs can and should reveal *representativeness* for game demands (den Hartigh et al.,

⁴ This is sometimes referred to as the 'sensitivity' of an assessment. To avoid confusion with the sensitivity of statistical analyses, this dissertation consistently refers to the concurrent and predictive validity specified by their effect sizes. The only exception is in the context of ROC-analyses where sensitivity and specificity form an assessments diagnostic accuracy (see, e.g., in Bergmann et al., 2024a).

2018; Koopmann et al., 2020). Bergkamp et al. (2019) categorized assessment methods used in soccer talent research, finding that 38 out of 40 studies employed assessments with low representativeness. The reviewed studies primarily applied isolated tests of technical skills or assessments targeting physical predictors (e.g., linear sprinting). In contrast, only five studies (12.5%) were classified as (also) applying highly representative assessments, typically involving systematic observations in small-sided games (SSGs; Bennett et al., 2018; Fenner et al., 2016; Goto et al., 2015; Waldron & Murphy, 2013; Waldron & Worsfold, 2010). A closer look at these studies reveals that some do not provide insight into predictive validity due to their cross-sectional design (e.g., Fenner et al., 2016). Moreover, the assessments used are generally time-consuming, and a recurring challenge is ensuring sufficient standardization while accounting for teammates and opponents during game situations (Bennett et al., 2018). Therefore, although objective motor tests may fall short in capturing the complexity and contextual demands of actual game performance, it remains uncertain whether more representative assessments would necessarily provide greater predictive validity and thus offer a more substantial contribution to talent identification and development.

Finally, there is an ongoing debate on whether assessments should focus on individual predictors and their multivariate combinations, or whether they should adopt a holistic view of talent. Charbonnet and Conzelmann (2023) argue that this debate is shaped by two opposing worldviews, although these are typically inferred from research questions and study designs, rather than being explicitly stated in the literature:

- A mechanistic worldview aims to explain variance in future success through linear relationships between individual predictors and developmental outcomes, and is thus typically associated with variable-oriented approaches.

- A relational worldview emphasizes non-decomposability and holism, aiming to account for interactions between talent predictors and environmental influences. This perspective is more closely aligned with person-oriented approaches, which aim to identify different player types.

Determining whether one approach is superior remains challenging, as only a limited number of studies have adopted person-oriented approaches (e.g., Zibung & Conzelmann, 2013) or directly compared them to variable-oriented approaches. The scarcity of studies employing a relational worldview may be attributed to the complexity of evaluating talent holistically without relying on a broad array of individual attributes considered in combination (i.e., multidimensional approach). As a practical alternative, some studies have employed single-item ratings of overall in-game performance, which have shown considerable predictive validity (e.g., Sieghartsleitner, 2019a). These approaches offer a pragmatic means of evaluating players holistically, enabling practitioners to draw on their experience and intuition (Bar-Eli et al., 2024; Buekers et al., 2015; Lath et al., 2021; Roberts et al., 2019a). Despite their potential contribution to talent identification, single-item ratings lack granularity and therefore offer limited insight into specific player profiles or targeted guidance for the individualization of developmental support within TDEs.

Taken together, a variety of assessment approaches are available for use in soccer TDEs, each possessing different strengths and limitations. Therefore, the contribution of any given assessment should be discussed in relation to its intended practical purpose and is ultimately influenced by its psychometric properties. A fundamental basis for the selection and possible combination of different assessments lies in a comprehensive understanding of the targeted outcome. This leads to the introduction of the concept of action competence in soccer, which is conceptualized as the overarching developmental objective for players participating in the *DFB Talent Development Program*.

2.2 Action Competence in Soccer

Both the *DMGT* as a generic model on the talent development process (Gagné, 2021), and the *DFB Talent Development Program* use the term ‘competence’ to define the desired developmental outcomes (DFB, 2022b). This reflects the growing use of this term to describe developmental objectives across various sport-related contexts (for reviews, see Möhrle, 2024; Töpfer et al., 2025). Yet, the actual meaning of an individual’s competence is tied to its theoretical conceptualization and ultimately depends on the specific domain in which it is applied (Gogoll, 2022; Sygusch et al., 2022). As this dissertation focuses on the domain of soccer, it is essential to conceptualize competence in relation to this particular sport.

In the department where this dissertation has been conducted and within the scientific support of the *DFB Talent Development Program*, soccer players are considered as individuals whose actions are influenced by the situational context (e.g., Höner, 2000; 2005; 2012a). To this end, an action theoretical perspective is introduced that considers human action as intentionally organized behaviors within a given context shaped by individual, task-related, and environmental factors. Subsequently, this fundamental understanding is linked to the specific performance demands of soccer, resulting in a domain-specific understanding of action competence in soccer. A distinction is drawn between learning, understood as the process of competence acquisition, and performance, defined as the successful use of action competence to effectively solve specific tasks within a soccer game. The chapter concludes by outlining how the current assessment approach within the *DFB Talent Development Program* seeks to capture action competence in soccer by distinguishing between different competence areas.

2.2.1 An Action-Theoretical Perspective

Sport psychological *Action Theory* provides an integrative theoretical framework on the parameters that influence a person's action (Nitsch, 1975; 2004). One contribution of this framework is to facilitate the integration of theories that address various aspects of human action, helping to identify their functional relationships (Nitsch, 2004). In particular, action psychology strives to conceptualize action situations from a meta-theoretical perspective, avoiding a single disciplinary view on performance (in detail Nitsch, 2009). Therefore, action theory serves as a guiding framework for intra- and interdisciplinary integration of theories which is based on the assumption that the complexity of human action cannot be sufficiently analyzed from the perspective of a single scientific discipline. Action theory postulates that "human performance is (1) a highly complex phenomenon, that is (2) attributed to an active agent who (3) processes a task within (4) the given environmental setting" (Nitsch & Hackfort, 2016, p. 16). In one of the first international publications introducing the action-theoretical perspective, Nitsch (1985, p. 267) illustrated these assumptions using the example of soccer player's action in the game:

[F]or example, the action situation of a soccer player is determined by his own hopes and fears, his specific skills and intentions (personal factors), furthermore by the tactical role he has to play (task factor) and by climatic conditions, the positions of his teammates and the behavior of his opponents (environmental factors).

Since then, the theoretical perspective has been further developed, while still being based on fundamental postulates. First and foremost, human behavior is understood as intentionally organized (*Primacy of Action*) and characterized by the functional architecture of its underlying processes (*Functional Primacy of Action*; Nitsch, 2004). The foundation of every action is the person-environment relationship, meaning that every action aimed at solving a task represents an integrated response by the individual, influenced

by their own dispositions and determined the (ecological) action space (*Action as a System Process*; Nitsch, 2004). Consequently, every action is inherently linked to its situational context – referred to as the *action space* – that emerges from the functional interplay between the person, the environment, and the task. That is, every action is embedded within a situation, inherently influences this situation, and thereby creates new situations (*Action as a Situative Process*; Nitsch, 2004). Action theory further postulates that psychological states and processes are functionally related to human actions, leading to a subjective definition of the situation by the involved person (Nitsch, 2004). As such, action is “not primarily determined by objective causes, but rather by subjective purposes” (Nitsch, 1985, p. 266).

These theoretical assumptions can be transferred to and further elaborated using the example of a youth soccer player shown in *Figure 6* who receives a pass from a teammate while getting pressure from an opponent. According to the action-theoretical perspective, the acting player inherently strives to solve the game situation optimally. The player’s action in this game situation, as displayed in the right image, is related to both the *valence* (i.e., perceived urgency and importance) and *competence* (i.e., perceived degree of controllability). From the valence-competence-interrelation, the player’s decision to take the ball with the first touch behind the opponent emerges. From the player’s subjective perspective, this action is ultimately driven by the intention to optimize situational conditions; here the aim to overcome the opponent pressure and introduce attacking play. However, this is shaped by individual player characteristics (e.g., technical skills with left foot to execute the first touch precisely in the back of his opponent player) and environmental factors (e.g., scope of action, such as the distance to the defender) in relation to a specific task in the game (e.g., progressing toward the opponent’s goal).

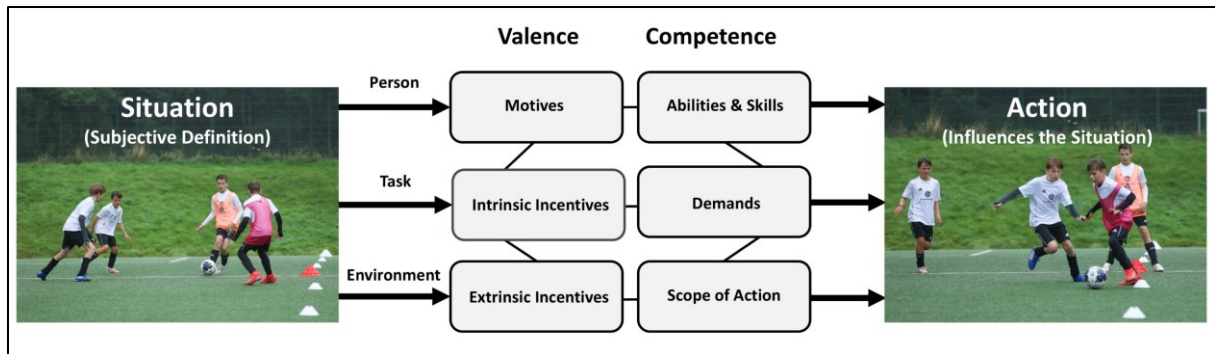


Figure 6. Parameters influencing a soccer player's subjective definition of a situation, based on an action-theoretical perspective structured around person, task, and environmental characteristics (adapted from Höner, 2012, p. 19 citing Nitsch, 2004, p. 16). With permission from the author.

This conceptual framework facilitates a systematic analysis of the factors that influence whether a soccer player successfully masters a given situation in the game. The required *action competence* represents an individual's capacity to solve specific tasks in the game within given environmental circumstances. In transfer to sport-specific learning processes, Nitsch and Munzert (1997, p. 164; translated) state: "From an action-theoretical perspective, learning encompasses the acquisition, optimization, and, as a special case, the reduction of action competence. [...] This is not primarily about developing individual skills rather than on optimizing the way in which situations are mastered." Consequently, action competence is characterized by a *functional understanding* that widely aligns with definitions of competence in educational psychology and sports science (Gogoll, 2022; Töpfer, 2022). These definitions similarly emphasize the role of competence in enabling individuals to solve domain-specific tasks. Although differences among theoretical conceptualizations exist, a prevalent perspective is to view competence as the functional interplay of skills, knowledge, and volitional aspects (Weinert, 2001).

The action theoretical perspective has provided a relevant basis for theoretically-driven research on technical skill learning (Nitsch & Neumaier, 1997) and decision-making in soccer (Höner, 2000; 2005; 2012a). The main assumptions emphasize the role of

coaches in designing learning situations that elicit specific actions from their players. Player involvement in these situations is expected to facilitate the acquisition of action competence. To effectively support player learning, coaches can intentionally shape *how* these situations influence action shaped by the person, environment, and task interplay. In particular, coaches can take into account individual characteristics, such as *players'* current skill levels. This information can support them in designing targeted practice *tasks*, using a range of tools to constrain and modify the learning situation in ways that systematically elicit desired outcomes (for a review Clemente et al., 2021a). In light of the competence-valence relationship, it is crucial to adjust task difficulty to the player's competence level and manipulate key constraints in order to influence the valence for the desired actions (e.g., integrating incentives). Moreover, coaches play a vital role in shaping the broader *environment*, which not only includes applying effective coaching strategies to facilitate learning, but also to address other relevant outcomes, such as player motivation (for reviews Hauser et al., 2022; Larkin et al., 2022).

2.2.2 Action Competence and Game Performance

This understanding of human action and a person's action competence need to be linked to distinct performance factors relevant to a sport which allows to define action competence in soccer. This is facilitated by the *Model of Complex Game Performance* (Figure 7; dt. 'Modell der komplexen Spielleistung'; Hohmann & Brack, 1983). While being principally applicable to all invasion team sports, this model not only helps to structure relevant performance factors but also illustrates their hierarchical relationship (as applied to soccer, e.g., Höner, 2012a; Rudingsdorfer, 2023).

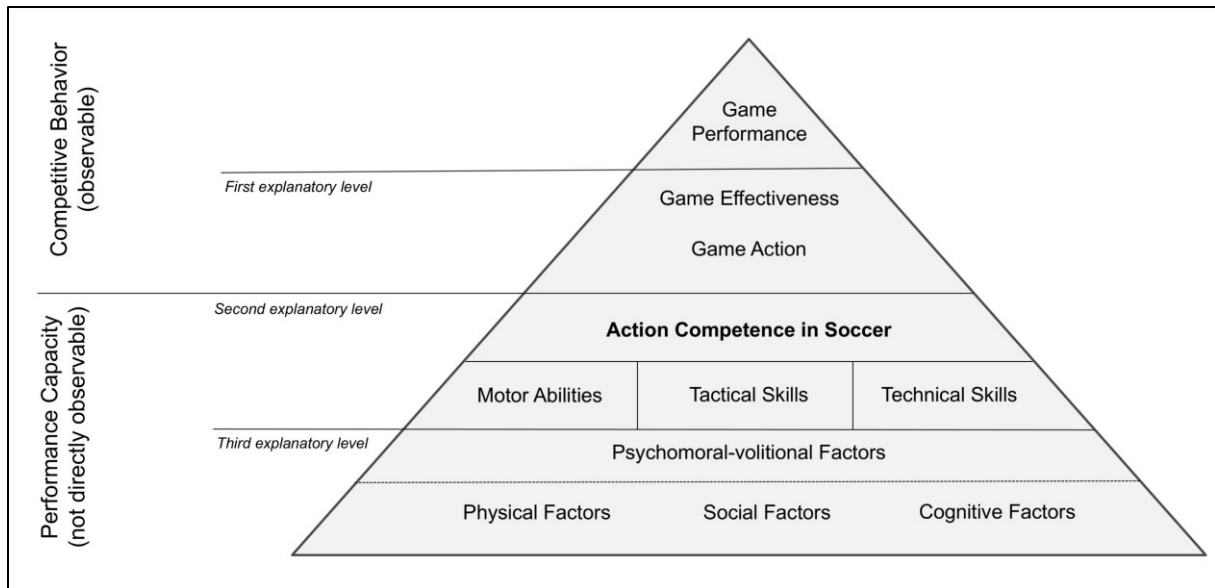


Figure 7. Model of Complex Game Performance (adapted and modified based on Höner, 2012a, p. 17; citing Hohmann & Brack, 1983, p. 9).⁵ With permission from the author.

The model is structured around three explanatory levels: The first level, at the top of the pyramid, represents a player's *game performance*. This is characterized by observable behavior and can be quantified in terms of a player's overall game effectiveness in solving specific tasks. Among other influences (e.g., opponents), this effectiveness is underpinned by the functional interplay of various performance factors, organized within the model's second and third explanatory levels. The second level represents a player's *action competence in soccer*, which determines a player's latent performance capacity. This is not directly observable, as it involves the functional interplay between soccer-specific skills and more general performance factors both of which are organized hierarchically. In line with the applied literature, this covers multiple soccer-specific technical and tactical skills, as well as motor abilities required in the game (e.g., Bisanz & Gerisch,

⁵ In the original publication, the German term "Spielfähigkeit" (Hohmann & Brack, 1983, p. 9) is used instead of action competence. Yet, the meanings of both terms are highly compatible, particularly in light of their shared functional understanding of a player's capability in solving specific tasks within the game. Consequently, the action-theoretical perspective (Nitsch & Hackfort, 2016) and the competency-based understanding established within the *DFB Talent Development Program* (DFB, 2022b; 2025) align with the model's main assumptions.

2010; DFB, 2014; Hughes et al., 2012; Wormuth, 2011). This level encompasses many of the soccer-specific performance factors identified by Williams et al. (2020) as relevant talent predictors for future success. The third level comprises more *generic performance factors*, such as general cognitive, physical, or volitional attributes.

In early adolescence, the overarching goal within soccer TDEs is to help players expand their performance capacity (i.e., supporting player learning; DFB, 2014; 2022a). That is, the main focus lies in further developing their action competence in soccer which is situated at the model's second explanatory level. This can be defined as *a player's capability to solve game-specific tasks in light of environmental conditions, that is underpinned by the functional interplay motor attributes (e.g., technical skills, motor abilities), cognitive factors (e.g., individual tactical skills), and psychosocial characteristics (e.g., motivation, volition; DFB, 2022b; Hohmann & Brack, 1983; Höner, 2012a; Nitsch & Munzert, 1997).*

In order to achieve a more nuanced understanding of action competence in soccer and to systematize the learning support provided, the *DFB Talent Development Program* has outlined competency-based learning goals to be addressed (DFB, 2022a; Kelly et al., 2024). In early adolescent age groups, these learning goals are structured around the three tasks to be solved in a soccer game: *Keeping Ball Possession, Creating Scoring Chances, and Scoring Goals* (DFB, 2022a).⁶ In line with the aforementioned definition of action competence, solving these game tasks effectively requires the functional interplay of performance factors from *motor, cognitive, and psychosocial competence areas* (DFB, 2022b, p. 2). *Figure 8* presents exemplary learning goals for outfielders (6a) and GKs (6b).

⁶ A videoclip illustrating these learning goals can be accessed here: <https://osf.io/r82c6/>



Figure 8. Exemplary competency-based learning goals for outfield players and GKs in the U13 age group structured around motor, cognitive, and psychosocial competence areas (adapted from DFB, 2022b; with permission from the DFB).

Across all tasks in the game, players must be capable of choosing and executing the most appropriate action. This includes competent decision-making, meaning players must select the most promising solution while considering their own strengths and weaknesses in relation to the task demands (cognitive competence area). Additionally, players should develop functional technical skills that allow for variability and adaptability in their execution (motor competence area) while also demonstrating resilience to apply these skills effectively under high-pressure situations (psychosocial competence area). The learning

goals are progressively structured from the U12 to U15 age groups. Yet, player development across these age groups is consistently addressed without emphasizing fixed positions of play. The only exception is the position of GKs, who already receive learning support tailored to the specific game tasks *Goal Defense*, *Space Defense*, and *Attacking Play* (DFB, 2022b; see also Otte et al., 2023).

2.2.3 Learning and Performance

The *Model of Complex Game Performance* (Hohmann & Brack, 1983) illustrates the hierarchical relationship between action competence in soccer – a person’s latent performance capacity – and the actual game performance. Therefore, the model implies a crucial distinction that is relevant in both research and practice: the one between *learning* and *performance*. Understanding this distinction alongside how these concepts relate to each other is essential for designing effective learning situations and selecting appropriate methodological approaches for their investigation (Williams & Hodges, 2023).

According to Soderstrom and Bjork (2015), *learning* is defined as relatively permanent changes in comprehension, understanding, and skills that support long-term retention and transfer. *Performance* refers to the effectiveness with which an individual completes a task which can be influenced by temporary fluctuations in behavior (e.g., cause by acute effects of coach instruction). Given these differences, Williams and Hodges (2023, p. 835) state:

[C]oaches do not always “see what they get”; observed behaviour (e.g., good performance) during practice can create a false sense of security that learning is being facilitated and vice versa, poor performance does not imply that no learning is taking place.

Consequently, awareness of these concepts is essential, particularly because facilitating short-term performance or long-term learning are both common, but probably even

conflicting objectives in different coaching contexts (e.g., primarily developmental contexts versus high-performance contexts; O'Connor, 2022). Recognizing the distinction between learning and performance is also critical for research aiming to assess these outcomes. While performance can, in principle, be observed at a single time point as far as measurable performance indicators were available, learning cannot be directly observed. Instead, learning must be inferred from continuous changes in performance over time once potential temporary effects of practice and coaches' learning support have dissipated (cf. Williams & Hodges, 2023, pp. 834-835). Specifically, learning can be inferred if behavioral changes persist after a period of rest and if these changes transfer to other contexts and/or to the competitive environment (Soderstrom & Bjork 2015).

A comprehensive body of empirical research has explored the relationship between learning and performance in sports, leading to guiding principles on how to support these outcomes in athletes. One established theoretical model is the *Challenge Point Framework* (Guadagnoli & Lee, 2004; Hodges & Lohse, 2022). This illustrates how the task difficulty, and resulting effects on an athlete's performance, can lead to different outcomes in athletes. If the goal of practice is to promote learning, this model suggests practice tasks with a moderate level of functional difficulty. The term 'functional' highlights that task difficulty must be determined based on a person's characteristics (e.g., skill level), meaning that the same task can pose different levels of challenge across learners. Given the assumption that effective learning environments must incorporate considerable amount of challenges, this model implies that good performance during practice is not always expected at all stages of the learning process (Hodges & Lohse, 2022). Rather, coaches are required to purposefully scale the challenge of a practice tasks in the pursuit of finding 'desirable difficulties' for each learner (in detail Bjork & Bjork, 2020).

In TDEs, managing the interplay between performance and learning can represent a challenge for coaches due to systemic influences resulting from the performance-oriented context and ongoing selection procedures (e.g., Gjesdal et al., 2025; Raabe et al., 2020). These can create conflicting goal pursuits: on the one hand, players aim to demonstrate their current capabilities through observable performance; on the other hand, engaging in challenging situations – necessary for long-term learning – can temporarily impair their performance. Therefore, it seems crucial for practitioners working in TDEs to cultivate a culture that contributes to players engaging in challenges and exposing their weaknesses (Williams & Hodges, 2023). This emphasizes the importance of the overall learning climate in TDEs, which is closely linked to both the overarching organizational culture and the practice environment directly shaped by coaches (Larkin et al., 2022).

Ultimately, making purposeful decisions as a coach about how to facilitate learning requires a nuanced understanding of a player's current level of competence and its development over time. This is particularly challenging, as multiple performance factors interact in soccer (Hohmann & Brack, 1983), also demonstrated by the empirical evidence suggesting that various attributes possess predictive power for future success (Williams et al., 2020). As a result, it is likely that different players participating within the same training group may have varying learning needs, requiring coaches to differentiate appropriately (cf. Williams & Hodges, 2023, p. 835). Consequently, assessments of a player's current level of skill and competence can help practitioners to comprehend individual learning needs and their development over time. Yet, this necessitates an understanding of a) which attributes should be prioritized at specific stages of development based on their relevance for players' future success (see *Chapter 2.1.2*), b) whether potential dif-

ferences arise in their relevance for different positions of play due to specific game demands (e.g., outfield players vs. GKs), and c) which assessment strategies are most appropriate to evaluate these attributes in applied settings. In response to these aspects, the following chapter introduces the assessment approach used in the *DFB Talent Development Program* that aims to capture players' action competence holistically and by targeting individual performance factors across distinct competence areas.

2.2.4 Assessment of Competence in the DFB Talent Development Program

In the *DFB Talent Development Program*, the assessment of an individual's competence is intended to support both the identification of talented players and the generation of relevant insights to facilitate their development (DFB, 2022b; Höner et al., 2020). Yet, as outlined in *Chapter 2.2.2*, a player's action competence is not directly observable. Consequently, it must be inferred from an individual's performance in purposefully designed assessments, allowing to capture various indicators. To achieve this, the program's assessment strategy seeks to balance the strengths and limitations of various assessment approaches established in soccer TDEs (see *Chapter 2.1.4*). This is pursued through a combination of objective and subjective assessment methods (in detail *Figure 9*):

- *An objective motor test battery* which measures speed abilities and position-independent technical skills via five isolated tests.
- *Subjective coach ratings* based on observations during practice evaluate players' in motor, cognitive, and psychosocial competence areas, as well as their current and future performance levels holistically.

CRITERIA OF SUBJECTIVE PERFORMANCE EVALUATION AND OBJECTIVE MOTOR TEST BATTERY			
AREA OF COMPETENCE	DIMENSION	CRITERIA FOR THE RATING OF PERFORMANCE	
		subjective	objective
Motor skills	Technique	▶ Kicking Techniques ▶ Heading ▶ Techniques from a standing position ▶ Diving techniques ▶ Techniques for crosses ▶ Techniques for distribution and restarting play	▶ Ball control ▶ Dribbling ▶ Juggling
	Physiology	▶ Endurance	▶ Sprint ▶ Agility
Cognition	Tactical skills	▶ Individual tactical behaviour in offensive situations before, during and after ball-related actions ▶ Individual tactical behaviour in defensive situations before, during and after ball-related actions ▶ Game intelligence	
		▶ Positioning ▶ Behaviour in 1 v 1 situations	
Psychosocial skills	Motivation, volition, social skills	▶ Motivational skills ▶ Volitional skills ▶ Social skills	

= for all players
 = for outfield players
 = for goalkeepers

Figure 9. Assessments of competence used within the *DFB Talent Development Program* (DFB, 2022b, p. 2). With permission from the DFB.

The motor test battery has been used nationwide since the inception of the program (Höner et al., 2015; Lottermann et al., 2003). The subjective coach ratings were introduced in the 2015/2016 season in close collaboration with the program's scientific support (DFB, 2022b). One of the aims of introducing the coach ratings was to better capture players' action competence to solve game-specific tasks, an area not fully addressed by isolated motor tests with a focus on measuring individual predictors in the motor competence area (Figure 9). The implementation of these ratings was also intended to address perceived challenges reported by DFB BC coaches, particularly in relation to the tasks of talent identification and the individual guidance of player learning (in detail Schreiner et al., 2018). In particular, coaches' systematic observation and evaluation of competencies across distinct areas, as supported by the detailed test manual (DFB, 2022b), should provide a foundation for addressing players' strengths and weaknesses through tailored practice and coaching.

Besides these nuanced insights into different competence areas, the subjective assessment allows for a holistic evaluation of an individual's current performance level which is ultimately determined by an individual's overall level of action competence. Another relevant feature of the coach ratings is that they allow for position-specific evaluations, taking into account the distinct task demands placed on outfield players and GKs. This is particularly important as *Figure 9* illustrates that no objective GK-specific assessment is currently used. While the assessment strategy generally aims for a purposeful combination of objective and subjective methods, this can be explained by the lacking availability of objective GK-specific tests suitable for use in soccer TDEs during early adolescence.

The integration of test results from the objective and subjective assessments, as recommended by the PACE model (Dugandzic, 2023), is supported by the systematic feedback provided to players and coaches. For the objective motor test battery, feedback is visualized in a performance profile, enabling players to compare their results with those of same-aged teammates and national reference values (Höner et al., 2020). This helps identify strengths and weaknesses at a given point in time ('Analyze'; Dugandzic, 2023).⁷ For players with repeated testings, a development profile is available. This supports a deeper understanding of individual progress and indicates whether previously identified strengths or weaknesses have evolved over time ('Evaluate'; Dugandzic, 2023). Feedback is also provided for the subjective assessments conducted annually by BC coaches based on systematic observation during training sessions. A feedback form provides insights into players' performance across motor, cognitive, and psychosocial competence areas (DFB, 2022b). The assessment results should be used to initiate exchange between coaches and players to collaboratively define individual development goals.

⁷ For more information see <https://www.dfb-akademie.de/best-practice/-/id-11011310/>

Several prospective studies have evaluated the objective motor test battery scientifically involving male (Höner et al., 2015; 2017; Höner & Votteler, 2016; Leyhr et al., 2018) and female outfield players (Höner et al., 2019; Leyhr et al., 2020). Overall, these studies support its predictive validity regarding different selection levels within German youth soccer and for reaching professional level in adulthood. These studies also reported acceptable levels of further psychometric properties (e.g., reliability, differential stability, factorial validity), reinforcing not only the relevance of the tested predictors, but they also justify the use of individual results to inform practice and coaching.

To date, however, only one study has examined the predictive validity of competency-based coach ratings, demonstrating that combining objective motor tests with subjective ratings enhances the predictive power (Höner et al., 2021). At the same time, the study “suggests that coaches’ subjective ratings differentiate less between theoretical distinct constructs than objective assessments” (ibid., p. 14). This finding is particularly notable given that the coach ratings evaluate the players across three distinct competence areas, whereas the position-independent test battery is limited to the motor competence area (*Figure 9*). Consequently, these initial findings reveal limitations in coaches’ diagnostic competencies to conduct nuanced evaluations of their players which, in turn, represents a relevant foundation for providing targeted and effective learning support.

Beyond a strong research focus on the motor test battery, there is a strong emphasis on male outfield players in existing studies. While this reflects the broader trend in current talent research (Curran et al., 2019; Emmonds et al., 2024; Vahia & Kelly, 2024), it also underscores the limited possibility to apply scientific findings to other target groups within TDEs. Consequently, a knowledge gap remains regarding the potential of both assessment methods, and particularly competency-based coach ratings, to support talent

identification and development in female players and GKs. For GKs, evaluating competency-based coach ratings is particularly important, as they currently represent the sole position-specific assessment targeting their unique game demands.

Taken together, the DFB *Talent Development Program* combines objective and subjective assessments with the aim to capture different performance factors across three competence areas. Several studies – although with a predominant focus on male outfield players – demonstrate their predictive validity for future success. In the context of talent development, these assessments should provide coaches with meaningful information that can be translated into implications for tailored learning support. Yet, greater understanding of the potential of this assessment approach, along with its current limitations, is required. Furthermore, effective developmental support does primarily rely on the assessments, but rather that this knowledge is linked to coaching strategies that effectively foster players' action competence. Consequently, the following chapter introduces core theoretical concepts on learning and coaching, along with the current empirical basis on effective strategies to foster action competence in youth soccer players. The chapter concludes by presenting the concept of learning-oriented assessment which aims to integrate assessment information with learning-supportive coaching strategies.

2.3 Learning and Coaching in Soccer

The identification of strategies to effectively support learning in sport has been a topic of sustained academic interest over decades (e.g., Bielefelder Sportpädagogen, 1998; Grupe, 1971; O'Connor, 2022; Roth, 1983; 2005a; Vogt, 2020; Weinberg, 1976; Wendeborn et al., 2020). As a result, there is an ever-growing body of work in the research

field of *learning, teaching and coaching in sport* (dt. ‘*Lehren und Lernen im Sport*’).⁸ Literature reviews synthesizing available research across various contexts emphasize the interdisciplinary nature of the field as one of its core characteristics (e.g., Davids et al., 1994; Gilbert & Trudel, 2004; Griffo et al., 2019; Nichol et al., 2019; Rangeon et al., 2012). At the same time, this diversity of perspectives poses challenges for establishing a coherent scientific foundation for coaching as differing theoretical viewpoints may lead to conflicting practical implications (Büsch, 2024; Nitsch & Neumaier, 1997). The coexistence of multiple concepts and the lack of theoretical integration prompted Willimczik (2021, p. 16; citing Schiebl, 2007, p. 133) to metaphorically describe the field of learning and coaching in sport as a “marketplace of theories”. In a similar vein, Cushion and Lyle (2016, p. 128) characterize the field of coaching as “ill-defined and undertheorized”, highlighting the need for a guiding definition in the context of this dissertation.

The *International Council for Coaching Excellence (ICCE)* offers a widely applicable definition across sports: “Coaching is a process of guided improvement and development in a single sport at identifiable stages of athlete development” (ICCE, 2012, p. 10). This definition frames coaching as a relational process that involves close interaction between coaches and athletes with the overarching goal of facilitating athletes’ development (Côté & Gilbert, 2009; Lara-Bercial et al., 2017). To achieve this, the ICCE emphasizes a key function: “Central to coaching in all contexts is the creation of practice and competition opportunities that result in desired outcomes for athletes” (ICCE, 2012, p. 9). These definitions highlight that coaching players and designing effective practice activities can

⁸ Much of the work originally focused on teaching (e.g., in PE), but has produced insights that are also relevant to other learning contexts. Accordingly, many of these references have been integrated into this dissertation. Given the focus on coaching within soccer TDEs within this dissertation, the term *learning and coaching* will be used hereafter to refer to the broader research field.

be considered as central tasks in the work of coaches within soccer TDEs. Building on this, three core concepts relevant to this dissertation can be distinguished: learning, coaching, and practice (see also Nitsch & Munzert, 1997; Nitsch & Neumaier, 1997):

- *Learning* refers to sustained changes in a player's action competence.
- *Coaching* encompasses all interactions between coaches and players aimed at developing a player's action competence as targeted developmental outcome.
- One central task of coaches is conducting *practice*, which includes defining session objectives and designing practice tasks with the aim to foster player learning.

While coaching and practice should represent structured and intentionally designed processes by coaches, learning can also occur in unstructured ways, such as through incidental learning (e.g., Roth, 2000).

In order to gain a deeper understanding of how coaching and the practice design can effectively support player learning, insights from the historical development of the research field are presented. These insights provide a foundation for introducing and contrasting different learning theories as well as established coaching approaches. Subsequently, different lines of research in soccer coaching are examined, focusing on their respective strengths and limitations, to highlight the complementary value of integrating multiple research methods for a more comprehensive understanding of how to effectively support player learning in TDEs. Finally, the concept of learning-oriented-assessment is introduced, with particular emphasis on formative assessments ('assessments for learning') as a scientific foundation to tailoring coaches' learning support.

2.3.1 Historical Perspectives on an Interdisciplinary Research Field

In the pursuit of developing a scientific foundation for coaching, insights can be drawn from the long-standing tradition of the research field. To address the intersection of learning, teaching, and coaching, the evolution of sports science in Germany reflects ongoing efforts to integrate knowledge from various academic disciplines (for an historical overview, see Krug et al., 2023). Such interdisciplinary research was directed toward both physical educators and coaches, thereby highlighting the overlap between these areas of applied work (Wendeborn et al., 2020). Yet, as sports science became increasingly fragmented into specialized disciplines (Grupe, 1996; Hägele, 1996), genuinely interdisciplinary research on learning and coaching remains relatively rare (for exceptions, e.g., Hohmann & Pietzonka, 2017; Nitsch & Munzert, 1997; Nitsch & Neumaier, 1997). Internationally, *Sport Coaching Research* is often regarded as an own academic discipline:

Grounded in psychology, sociology, education, and sport sciences, sport coaching research has progressively developed as a discipline in its own right. It broadly comprises studies on the coaching process (e.g., planning), relationship development (e.g., leadership, coach-athlete relationships), coaching practices (e.g., effectiveness, efficacy, behaviors), and coach education and development (e.g., learning, expertise, and coach developers). (North et al., 2021, p. 405)

Despite these institutional differences, the academic discourse on learning and coaching continuously sparked vibrant debates. One example is the debate surrounding *Differential Learning* (DL), which caused intense discussions between its proponents (Schöllhorn, 1999; 2022) and critics (e.g., Künzell & Hossner, 2012). Although this debate raised ethical concerns and left both theoretical and empirical issues unresolved, it underscored the necessity of critically examining the epistemological assumptions underpinning research on learning and coaching in sport (Schmidt & Hennig, 2012; Willimczik, 2013). A relevant implication is that theories in this field are rarely universally ‘true’ or ‘false’; rather they may hold explanatory power for specific cases of application (in detail

Höner, 2001; 2002; Neumaier, 1997). In the context of learning and coaching in sports, this perspective – aligned with the *Non-Statement View* – may “not only better reflect scientific practice but also provide a superior foundation for ethical conduct” (Willimczik, 2013, p. 59; translated).

Much of the coaching research, including the debate on *DL*, appears to be strongly aligned with only a single theoretical perspective, often by disregarding the potential explanatory contribution of alternative viewpoints. This underlying adherence is evident in ongoing discussions within the international sport coaching discourse and has prompted scholars to publish critical commentaries. For instance, Cope and Cushion (2020, p. 1) critique literature in which “direct instruction has been branded as an approach that coaches should avoid”. Similarly, Collins et al. (2025, p. 870) state, “[w]e support elements of ecological dynamics but suggest that it is insufficient as a *sole* means to guide applied practice.” In the same direction, Bobrownicki et al. (2023, p. 2) emphasize:

For us, a significant issue when translating motor learning scholarship is strict adherence to any *one* theoretical stance to inform specific facets of practice [...] rather than consideration of how such issues will fit within the complexities of the wider coaching process.

Similar tendencies are also evident in the applied coaching literature. A notable example is Verheijen’s (2020) *Football Coaching Theory*, which explicitly rejects Gibson’s (1979) theory of direct perception – a frequently cited paradigm in the current coaching literature (e.g., Renshaw et al., 2019): “This thinking is based on the ecological psychology concepts of Gibson. For example, he introduced the reference of ‘perception-action’. [...] I will falsify this reference in three steps” (Verheijen, 2020, p. 66).

Theoretical progress in these debates may require a detailed analysis of the individual assumptions underlying various theories and particularly how learning theories connect

to practice design and coaching behavior (Willimczik, 2021). Such an analysis could contribute to a comprehensive understanding of areas of conflict while also revealing potential alignments among certain assumptions. Furthermore, it may demonstrate that different theories hold explanatory power for distinct cases of application and therefore do not necessarily conflict, as they address different phenomena or levels of analysis. While this theoretical analysis lies beyond the scope of this dissertation, it could be guided by meta-theoretical concepts, one of which is structuralism (as applied to sports science Höner, 2001; 2002; 2008). This approach aims at the rational reconstruction of theories by analyzing them mathematically as ordered sets of theoretical elements, thereby enabling a nuanced analysis of individual assumptions.

Another implication for advancing the research field lies in the development of comprehensive research programs designed to enhance understanding of effective coaching strategies along with the underlying theoretical explanations for their effectiveness. According to Willimczik (2003), sports science comprises multiple research programs, as conceptualized by Herrmann (1994), who differentiates between *basic scientific research programs* and *technological research programs*. Basic scientific research programs primarily aim to explain phenomena by addressing fundamental questions such as ‘What?’, ‘Why?’, and ‘In what respect?’. In contrast, technological research programs focus on improving the effectiveness of practical strategies through scientific insights. Both types of research programs are of equal scientific value and importance. As Willimczik (in press, p. 73) notes, “the goal of interdisciplinary science is to bring these two levels together.” Accordingly, a central objective in this interdisciplinary research

field is to establish meaningful links between basic scientific research focused on understanding learning processes, and technological research aimed at developing effective strategies to support learning in applied contexts (cf. Willimczik, 2003, pp. 118-127).

These brief and necessarily selective historical insights yield two overarching implications for future research. *First*, a central objective is to integrate perspectives from various disciplines within sports science and to promote interdisciplinarity by establishing links between basic and technological research. *Second*, engaging with different theoretical perspectives (e.g., on learning) is crucial, even when they appear incommensurable. This is particularly important in light of recurring criticism that the research field remains fragmented into a range of coexisting but often unconnected theories and coaching approaches (Cushion & Lyle, 2016; Göbbling, 2007; Schiebl, 2007; Willimczik, 2021). The following chapter therefore presents different theoretical perspectives on learning that may offer explanatory power regarding the mechanisms underlying coaching approaches.

2.3.2 Theoretical Perspectives on Learning

Practical decision-making in sport coaching requires balancing and integrating multiple parameters that emerge from the specific coaching context (Lyle & Cushion, 2017). Beyond being shaped by the available resources, this decision-making process is frequently conceptualized as the interplay between goals, content, and methods (e.g., Neuber, 2023). Building on these interacting decision parameters, Kurz (1998) proposed three guiding questions that instructors should ask when designing learning situations: ‘For what?’ (goals), ‘What?’ (content), and ‘How?’ (methods). Krug et al. (2023) added the question ‘Why?’, emphasizing the importance of understanding the rationale behind coaching strategies. A scientific response to the ‘Why-question’ requires theories that

explain the underlying mechanisms of player learning, as these can help elucidate the effectiveness of coaching strategies.

When attempting to explain the underlying mechanisms of learning in general, a key theoretical distinction lies between *implicit and explicit learning*. According to Kleynen et al. (2014), learning is considered explicit as far as it generates verbal knowledge and involves working memory. In contrast, implicit learning occurs with little or no increase in verbal knowledge and without conscious awareness. While this distinction is widely accepted, Masters et al. (2020) state that purely explicit or implicit learning rarely exists in sports. Instead, learners typically develop at least some task-relevant knowledge, reinforcing the idea that explicit and implicit learning form the endpoints of a continuum (for similar assumptions and their application to sport coaching see Roth, 2005a).

Over the past decades, extensive research has investigated implicit and explicit motor learning in sports (e.g., Masters, 1992; Masters et al., 2020). In the context of motor skill acquisition, evidence suggests that implicit learning may offer particular advantages, especially in promoting the stability and transferability of skills in dynamic and unpredictable environments (Masters, 2000; Maxwell et al., 2003; Masters et al., 2020). However, much of this research has focused on novice learners, leaving open questions regarding the effectiveness of implicit and explicit learning in more advanced athletes (Collins et al., 2023). Moreover, while much literature focused on motor skill acquisition, soccer-specific action competence depends on the functional interplay of performance factors across various competence areas (DFB, 2022b; Hohmann & Brack, 1983). With regard the cognitive competence area (e.g., tactical skills), for example, the applied coaching literature suggests the value of developing explicit understanding of why and how to solve game situations (Almond, 2015; Gréhaigne & Godbout, 2005; Price & Collins, 2024).

Consequently, these findings suggest that both implicit and explicit learning can offer advantages and highlight the need for research that explores how these types of learning can be effectively addressed and balanced in soccer TDEs. The contribution of these learning types must be considered in light of the multifaceted nature of soccer, a sport in which motor and cognitive demands are deeply intertwined. As such, it is neither practical nor theoretically sound to identify any one learning type as universally superior. Moreover, explaining the underlying mechanisms behind learning outcomes in these domains remains complex. This complexity is reflected in the partially conflicting theories that have evolved from research on *motor control and learning* which have sparked considerable debate within coaching research. In addition, references to *classical learning theories* have often been used to explain mechanisms underlying coaching strategies aimed at enhancing outcomes in the cognitive competence area (e.g., tactical skills).

2.4.2.1 Motor Control and Learning

Research on motor control and learning addresses questions concerning how goal-directed human movement can be explained and optimized (Abernethy & Sparrow, 1992; Aune et al., 2008). This includes investigating the mechanisms underlying the coordination and regulation of movement (i.e., motor control) and examining whether permanent changes in motor control processes occur, for example, as a result of sport-specific practice (i.e., motor learning; Magill & Anderson, 2021; Schmidt et al., 2019). Since theories of motor learning are often grounded in assumptions about motor control, these two subfields are difficult to separate (for detailed discussions Schmidt et al., 2019; Schott et al., 2019). Consequently, it is essential to explore whether distinct paradigms have emerged within the field of motor control and learning that can serve as theoretical foundations for applied practice and coaching strategies.

Historically, different research periods can be identified based on prevailing theoretical paradigms. Recent historical reviews of the literature have classified theories and models according to either an *information-processing* or a *dynamical-systems* perspective (for reviews Anson et al., 2005; Christina, 2017; Schott et al., 2019; Whittall et al., 2020a). These competing paradigms have shaped the field for decades, a discourse often referred to as the motor-action controversy (Aune et al., 2008; Meijer & Roth, 1988). Moreover, these theoretical perspectives exert considerable influence on the coaching literature, particularly with regard to their, at times, conflicting implications for how to effectively support learning of sport-specific skills (Anson et al., 2005; Schöllhorn et al., 2022).

Information-processing approaches – also referred to as ‘process-oriented’, ‘representation-based’, or ‘symbol processing’ approaches (Christina, 2017; Herrebrøden et al., 2024; Kennedy & O’Brien, 2024; Köster et al., 2024) – originated during the cognitive turn of the 1960s (Schmidt et al., 2019). This perspective is characterized by the assumption that internal cognitive factors and processes underpin motor control and learning. A central illustration of this viewpoint is the computer metaphor in which the brain is conceptualized as a processor that organizes human movement based on mentally represented, hierarchical structures. The foundational information-processing model was traditionally described as consisting of three stages: stimulus identification, response selection, and response programming (in detail Schmidt et al., 2019).

Building upon these main assumptions, several specific theoretical conceptualizations emerged, among which two particularly influential examples are the *closed-loop theory of motor learning* (Adams, 1971) and the *schema theory of discrete motor learning* (Schmidt, 1975). These theories, including their assumptions about how movements are

controlled and how learning takes place, also laid the groundwork for practical implications for the design of practice and coaching. For example, Schmidt's (1975) schema theory suggests that motor skills are composed of invariant features which are stored as mental representations in so-called generalized motor programs (GMPs). The adaptability of GMPs across dynamic situations – such as executing a pass in a dynamic game situation in soccer – is achieved through their parameterization via recall and recognition schemata. From these assumptions, the variability-of-practice approach was developed (e.g., Hall & Magill, 1995; van Merriënboer, 2012). Furthermore, the information-processing perspective has served as the foundation for various *phase models of skill learning* (Fitts & Posner, 1967; Roth, 2005b). Based on the assumption that cognitive involvement changes across different learning phases, these models have informed strategies for effectively supporting learning at each stage.

While this viewpoint has considerably contributed to the understanding of motor control and learning, historical reviews of the literature highlight a range of criticisms. Beyond concerns about specific theories (e.g., 'storage problems' due to limited capacity for various motor programs), broader critiques target the core assumptions of the information-processing perspectives and the dominating methodological approaches used in this line of research (Christina, 2017; Schöllhorn et al., 2022, for detailed discussions). Given the scope of this dissertation, two main criticisms directly relevant to sport coaching will be addressed. From an explanatory perspective, a key concern relates to the dominance of sequential processing in information-processing models, which conceptualize the brain as a 'central executive' responsible for selecting and parameterizing mentally stored GMPs (Koester, 2023; Nitsch & Munzert, 1997). This approach has been criticized for insufficiently accounting for parallel processing, especially given the multiple interacting

factors in real-life environments. In dynamic sports settings, such as a soccer game, where environmental influences as well as intra- and inter-individual variations in skill execution are common, this model appears to have limited explanatory power (Gray, 2020). From a methodological perspective, many theoretical assumptions were primarily tested in laboratory settings, often focusing on relatively simple movement tasks. As a result, insights derived from these studies often lacked direct applicability to learning of complex skills in real-world sport environments (Farrow & Robertson, 2017).

An alternative to the information-process approach and its limitations is the *dynamical systems approach* (for reviews Christina, 2017; Schott et al., 2019; Whittall et al., 2020a). This perspective is grounded in the assumption that motor control and learning are driven by decentralized self-organization processes, resulting from the interaction between the individual and the environment (e.g., Kelso, 1995; 2001). A key distinction from the information-processing viewpoint is that cognition, especially internal processing, does not play a central role in motor control and learning. Instead, this decentralized perspective posits that no central control entity governs movement, instead the properties of the body itself contribute to movement control. The dynamical systems approach seeks to mathematically describe changes in system states over time, with movement being fully determined by current and previous states, thereby contrasting with approaches that emphasize the role of internal mental representations. The idea of self-organization in complex, dynamic systems originates in physics and was later applied to motor control and learning (Haken et al., 1985; Kugler et al., 1980). According to Newell's (1986) constraints-based framework, movement emerges through the interaction of the individual, the task, and the environment. Such interaction facilitates the exploration of functional movement solutions. This perspective might also be influenced by Bernstein's (1967)

work on the degrees of freedom problem, which emphasized that movement patterns repeat functionally to achieve a desired outcome but not in identical form, an idea captured in his notions on ‘repetition without repetition’.⁹

Especially in the applied coaching literature, assumptions related to self-organization processes proposed by the dynamical systems theory (Kelso, 1995; 2001) are often linked to ecological psychology, particularly Gibson’s (1979) theory of direct perception. While these represent distinct paradigms with origins physics and biomechanics (dynamical systems) and the field of visual perception in psychology (ecological approach), a shared emphasis is placed on the dynamic interaction between the individual and their environment. This shared perspective led to their integration within the so-called *Ecological Dynamics Framework* (Araújo et al., 2006; 2019; Button et al., 2021; Davids et al., 2012; 2015; Renshaw et al., 2009). This framework considers individuals as self-organizing systems, acquiring and refining sport-specific skills through direct interaction with the environment. The concept of attractors plays a crucial role in this process, defined as “fixed points in which all initial conditions converge to some stable rest state.” (Kelso, 2001, p. 13845). The framework emphasizes the emergence of functional movement patterns in sport-specific skills, characterized by intra-individual variability. The substantial impact of this perspective on coaching literature may be attributed to its stronger emphasis on applied, field-based research as well as learning and refining complex sport skills. Despite its influence in motor control and learning research, the dynamical systems perspective, and the *Ecological Dynamics Framework* specifically, has been subject to criticism. A major point of contention concerns inconsistencies in terminology, especially in

⁹ The extent to which Bernstein (1967) influenced the dynamical systems viewpoint remains unclear, as his original publications were written in Russian and German and were later translated into English.

how the integration of dynamical systems theory and ecological psychology occurred (for commentaries Collins et al., 2025; Kennedy & O'Brien, 2024). Critics argue that while these perspectives share commonalities, they address fundamentally different concepts in form of deterministic explanations for system behaviors on the one hand and perception-action coupling on the other hand (Koester, 2023). At the theoretical level, an unresolved issue is how transitions between attractor states occur, a question that also carries implications for understanding the role of errors in the learning process (Kennedy & O'Brien, 2024). This is reinforced as ecological approaches lack a detailed process theory of learning, leaving open the question of how learning occurs at a mechanistic level (for a detailed discussion, see Nitsch, 2009). Another concern relates to the limited consideration of neurobiological and cognitive processes (e.g., mental representations) for motor learning (Kennedy & O'Brien, 2024; Nitsch, 2009). While ecological approaches emphasize the interaction between the individual and the environment, they may underestimate the role of cognitive processes, for example, the development of knowledge structures in the learning process. Finally, despite a greater focus on field-based research, literature reviews contend the still limited empirical support for the ecological dynamics framework and its proposed coaching implications (e.g., Collins et al., 2025).

Taken together, theories from both the information-processing and dynamical systems perspectives have largely contributed to explaining motor control and learning. However, much of the discourse has been dominated by the contrasting assumptions and conflicting implications of these approaches for the practice design and coaching while their potential complementarities have been largely overlooked (e.g., the role of variability, the relevance of game-representative practice; see also Anson et al., 2005; Kearney et al., 2024). From an action-theoretical viewpoint, Nitsch and Munzert (1997) argue that both

perspectives offer valuable insights into different aspects of skill learning and urge to recognize the strengths of each paradigm, while remaining aware of their inherent incommensurabilities. This is reflected by Nitsch's (2009, p. 163) comment on Fajen et al.'s (2009) adaptation of Gibson's Theory of Direct Perception to the field of motor learning:

[T]hey made no point on their understanding of learning, thus, avoiding to have to deal with a critical problem: learning without developing corresponding internal representation. In my opinion, the essential point is not to reject or endorse the role of cognitions and internal representations, but to specify the conditions under which they are or are not necessary and useful.

This statement has important implications for coaching practice as a foundational understanding of different theoretical viewpoints might help coaches to critically evaluate various coaching strategies and their potential effects on learning. As a consequence, such reflective processes can only be facilitated by acknowledging the contribution of different perspectives rather than strictly adhering to a single theoretical viewpoint (for similar assumptions cf. Neumaier, 1997, p. 174).

2.4.2.2 Classical Learning Theories

In the context of team sports, such as soccer, action competence depends on the functional interplay of performance factors across various competence areas (see *Chapter 2.2.2*). With regard to the development cognitive performance factors, further relevant insights can be drawn from classical learning theories which primarily originate from psychology. Compared to theories of motor control and learning, these perspectives have received relatively limited attention in coaching research. Nevertheless, theoretical frameworks from outside the field of sports science can offer valuable contributions toward understanding the underlying mechanisms of coaching practices (Collins et al., 2023; Harvey & Cope, 2025; Jones, 2006; Pill & SueSee, 2021).

From an instructional design perspective, Ertmer and Newby (2013) categorize classical learning theories into three distinct paradigms: behaviorism, cognitivism, and constructivism. *Behaviorist* learning theories suggest that knowledge exists independently of the learner and reflects an objective reality with learning occurring through stimulus-response associations. *Cognitivist* learning theories propose that learning is underpinned by the acquisition of knowledge and internal mental structures. Learners are considered active participants, organizing and integrating information into hierarchical relationships. *Constructivist* learning theories argue that knowledge is created through the learner's experiences. According to this view, learning is shaped by individual interpretations, meaning that knowledge is constructed rather than transmitted.

Considering the available coaching research in teams sports, classical learning theories have gained recognition in the development of tactical skills (Hallé-Petiot et al., 2021; Roberts & Potrac, 2014) and especially in ongoing discussions about the theoretical underpinnings of game-based approaches (GBAs; in detail Harvey & Cope, 2025). The primary focus on tactical skills may be due to their origin outside of the sport context, revealing greater explanatory power for cognitive outcomes compared to outcomes in the motor domain. Based on a literature review, Hallé-Petiot et al. (2021, p. 11) argue that especially “[c]ognitivism and constructivism can notably satisfy the needs of learning in a context of competition and highly demanding training activities like is the case in soccer academies.” In the coaching literature, explicit associations with constructivist assumptions can be found particularly in coaching approaches that emphasize the relevance for players of collecting experiences in game-realistic scenarios combined with the aim to facilitate players' game understanding (e.g., Gréhaigne & Godbout, 2005). Many coaching

implications specifically draw on social-constructivist perspectives, suggesting the importance of incorporating players' viewpoints through periods of dialogue (e.g., through questioning strategies). These aim to stimulate reflective engagement by encouraging players to consider questions such as 'What to do?' and 'How to do it?' in the game (Almond, 2015; see also Höner, 2000 and Roth, 1989 on 'What-Decisions' and 'How-Decisions'). By placing emphasis on intentional decision-making processes, this is expected to enhance learning by supporting players' understanding and recognizing typical, recurring behavioral patterns in the game that can promote effective gameplay. Based on a historical overview, Harvey and Cope (cf. 2025, p. 2) emphasize that social constructivism was highly influential in explaining learning processes within many GBAs. However, they also highlight its limitations in fully accounting for the mechanisms behind the development of skillful gameplay. Other learning theories, such as those from cognitive science, may also support the effectiveness of the derived coaching implications, prompting the authors to advocate for the consideration of multiple theoretical perspectives rather than reliance on a single framework (see also Collins et al., 2025).

As illustrated in the literature review by Hallé Petiot et al. (2021), behaviorist learning theories receive comparatively little attention in current soccer coaching research with an applied focus. This is particularly surprising, given the explanatory value of stimulus-response relationships for many processes commonly observed in applied coaching contexts (e.g., praise from a coach as a form of positive reinforcement). The explanatory power of stimulus-response relationships in applied learning settings can also be considered in light of further perspectives as, for example, in social-cognitive learning theories associated with behaviorist and cognitivist assumptions (Bandura, 1986; see also Weigelt et al., 2020). Moreover, it can be assumed that learning in social environments such

as team sports is influenced by the learner's observation of peers or coach demonstrations (Hodges & Ste-Marie, 2013). While laboratory-based research supports the benefits of such observational learning (for a review Hodges, 2017), empirical investigations in applied soccer coaching settings – particularly regarding how practitioners can systematically employ these strategies – have received limited academic attention.

As a general observation, the relationship between classical learning theories and applied coaching strategies is often described ambiguously in the literature. Cope and Cushion (2020) highlight this lack of clarity, particularly in coaching approaches labeled as constructivist, which often exclude methods such as direct instruction without sufficient justification (for a similar discussion in classroom-based teaching, cf. Hattie, 2009, p. 26). Direct instruction is often criticized for offering limited benefits and being solely rooted in behaviorist principles, overlooking its potential cognitive contributions to knowledge construction. Conversely, questioning strategies are frequently and perhaps uncritically linked to a constructivist paradigm. According to Cushion (2013), these inconsistencies also result from varying interpretations of constructivism. O'Connor et al. (2021a, p. 11) emphasize the complexity of establishing connections between learning theories and coaching strategies, noting that the appropriateness of a particular method depends on the extent to which learners are expected to actively construct knowledge versus being guided toward specific learning outcomes:

This may be an example of a naïve form of constructivism whereby coaches' use instructional questions and believe they are effective (as they are questioning rather than telling them what to do), however, they may actually be limiting the players knowledge [...]. As such, the 'power' of learning is still with the coach who is making the decisions and determining the subsequent player actions.

Taken together, although connections between coaching strategies and classical learning theories can be found in the literature, their nuanced relationships remain a topic of

ongoing debate. Nevertheless, the consideration of classical learning theories in explaining learning processes in soccer appears highly relevant, especially since players' action competence in games is based on the functional interplay of performance factors across motor, cognitive, and psychosocial competence areas (DFB, 2022b).

2.3.3 Coaching Approaches

The literature presents a range of coaching approaches that aim to provide conceptual guidance for designing practice activities and supporting learning through specific coaching behaviors. However, many of these approaches offer (partially) conflicting practical recommendations which can pose challenges for practitioners attempting to identify the most effective strategies. Moreover, inconsistencies in how these approaches are described and linked to their theoretical underpinnings (e.g., learning theories) further impede theory-based research on their effectiveness. Given these challenges, it is essential to provide a narrative overview of existing approaches that are principally applicable to soccer coaching in TDEs, as they can offer valuable guidance for practitioners. Such an overview should account for: (1) the contextual origins of these approaches, (2) their theoretical foundations, and (3) the recommended strategies for practice design and coaching behavior.

To support the classification and understanding of learning situations in sport, Roth (2005a) proposed a framework based on three dimensions:

- *Type of learning* ranges along a continuum from implicit to explicit, as introduced in *Chapter 2.3.2*.
- *Complexity* varies from low to high, depending on the involvement and interaction of perceptual-motor and perceptual-cognitive demands. This allows implication

about the activity's specificity in terms of how it reflects motor- and sensory-related parameters of competition (see in detail Farrow & Robertson, 2017).

- The degree of *standardization* reflects whether a practice activity is open (low standardization) or closed (high). This is influenced, for example, by the number of teammates and opponents involved, as well as the nature of the gameplay (e.g., continuous play vs. start-stop activities).

In addition, Otte et al. (2020) organize coaching behaviors into two primary categories:

- *Manipulation of constraints*, where coaches role is to adapt the practice tasks and/or the learning environment.
- *Provision of external information*, which includes various forms of verbal instruction and feedback (e.g., augmented feedback, questioning etc.).

Figure 10 presents a timeline of available coaching approaches and their initial publication in either German or English ranging from 1976 to 2024. While this overview is narrative in nature and therefore necessarily incomplete to some extent, the approaches included were identified through systematic reviews and meta-analyses (Abad Robles, 2020; Clemente et al., 2021b; González-Valero et al., 2024; Manninen et al., 2025; Ortiz et al., 2023; Tassignon et al., 2021), as well as through manual database searches for applied and academic publications. To be included in this overview, an approach must provide overarching or conceptual guidance for coaching practice. Excluded from this list, despite their practical relevance, are publications that primarily offer examples of practice activities and coaching strategies for specific learning objectives, such as principles of play (Imran, 2022), or solving 2v1 situations (Peters & Schumacher, 2020). In some cases, such as the recently introduced *Practice Philosophy Germany* (Wolf, 2024), this distinction was not entirely clear, as it primarily provides practical examples (4v4 SSGs), while also attempting to provide general guidance. Given the relevance of this approach in the *DFB Talent Development Program*, it has been included to this overview.

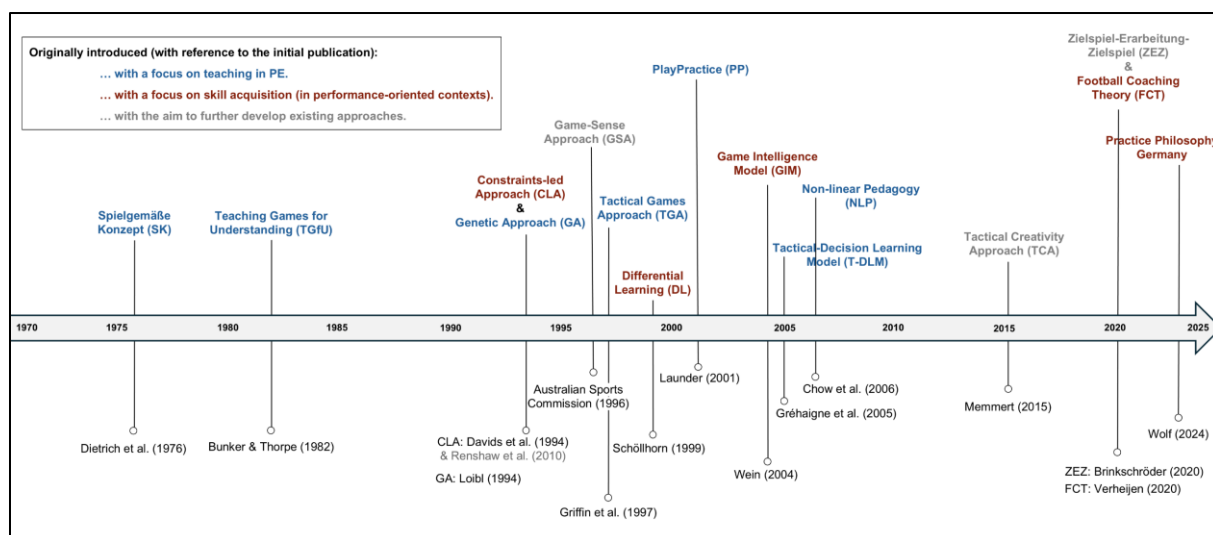


Figure 10. Overview of coaching approaches presented in the literature with reference to the first publication in German or English language.

Note. Regarding the CLA, it is referred to Davids et al. (1994) as this paper is described in the most recent publication as “[...] the beginning of a prolonged period of theoretical work that re-conceptualised the nature of athletes’ relationships with specific performance environments” (Renshaw et al., 2019, p. 16). That is, the first publication that explicitly name the CLA (Renshaw et al., 2010a) is built upon Davids et al. (1994). For some approaches originally published in German, the original term is retained, as a translation would be difficult and potentially lead to confusion (e.g., “Spielgemäßes Konzept”; Dietrich et al., 1976).

With regard to the *contextual origins of these approaches* three distinct groups can be broadly distinguished:

- The *first* group consists of approaches initially introduced for teaching in PE (Bunker & Thorpe, 1982; Chow et al., 2006; Dietrich et al., 1976; Gréhaigne et al., 2005; Griffin et al., 1997; Launder, 2001; Loibl, 1994).
- The *second* group comprises approaches providing recommendations for coaching with a primary focus on skill acquisition in primarily performance-oriented contexts (e.g., Davids, 1994; Renshaw et al., 2010a; 2010b; Schöllhorn, 1999; Verheijen, 2020; Wein, 2004; Wolf, 2024).
- The *third* group consists of approaches that built upon and further develop existing frameworks, either by adapting them to specific contexts (e.g., extracurricular or performance sport; Australian Sports Commission, 1996; Brinkschröder, 2020) or by emphasizing specific outcomes (e.g., creativity; Memmert, 2015).

Many of these approaches across all three categories emerged in response to perceived shortcomings in established coaching and teaching practices. In particular, early proponents criticized the dominance of isolated, drill-based activities and instead advocated for game-centered approaches that prioritize SSGs, which are designed and adapted to target specific learning outcomes (Bunker & Thorpe, 1982; Dietrich et al., 1976).

A recurring debate within the academic discourse concerns the degree of interrelation between various coaching approaches (Harvey et al., 2018; Renshaw et al., 2016; Schöllhorn et al., 2022). Especially in the third group, the authors explicitly acknowledge the influence of earlier models. For example, the *Game Sense Approach* (GSA) has been described as an ‘Australian version’ of *TGfU* (cf. Pill, 2018, p. 42). However, considerable debate persists regarding the relationship between *TGfU* and the *Constraints-Led Approach* (CLA), particularly around the claim that the later-developed CLA may simply represent ‘old wine in new bottles’ (Harvey et al., 2018; Renshaw et al., 2016). Similar debates surround the contextual origins between *DL* and the CLA (Schöllhorn et al., 2022).

In terms of *theoretical foundations*, these are not always clearly articulated in the original publication and continue to be a subject of academic debate (Collins et al., 2025; Harvey et al., 2018; Renshaw et al., 2016). As many of these approaches have evolved over time, they were associated with different theoretical perspectives. Coaching approaches focused on skill acquisition are often grounded in motor control and learning theories or embedded within broader frameworks (e.g., *Ecological Dynamics*; Button et al., 2021). Examples are *Nonlinear Pedagogy* (NLP; Chow et al., 2006), the CLA (Davids et al., 1994; Renshaw et al., 2019), and *DL*, which has been underpinned by dynamical systems theory since its introduction (Schöllhorn, 1999). Moreover, GBAs that emphasize the develop-

ment of game understanding have frequently been associated with classical learning theories, particularly constructivist perspectives (e.g., Australian Sports Commission, 1996; Gréhaigne et al., 2005). A prominent example is *TGfU*, which was linked to constructivism throughout its evolution (Harvey et al., 2018). Furthermore, *Genetic Learning (GL)* originated in non-sport educational contexts as, for example, reflected by its association with Montessori pedagogy and Gestalt Psychology, before being adapted for use in sport (cf. Sinnig, 2010, p. 58). This exemplifies how the varied theoretical foundations of these approaches are often rooted in their distinct contextual origins. Furthermore, underpinnings relating to motor control and learning and classical learning theories are not inherently contradictory at the explanatory level. Yet, one potential area of tension can represent their implications for promoting either implicit or explicit learning. For example, *NLP* and *CLA* assert that “learners do not need to engage in significant amounts of ‘cognitive processing’ before they can discover and explore a performance solution” (Renshaw et al., 2016, p. 469). In contrast, *TGfU*, the *Tactical Decision-Learning Model (TDL-M)*, *GSA*, and *Zielspiel-Erarbeitung-Zielspiel (ZEZ)* posit that deliberate reflection on tactical principles fosters deeper game understanding and, consequently, intentional decision-making (Almond, 2015; Brinkschröder, 2020; Gréhaigne & Godbout, 1995; Harvey et al., 2018).

In terms of the *recommended strategies for practice design and coaching behavior*, several commonalities can be identified across the approaches. The earliest framework included in this overview is the *Spielgemäßes Konzept (SK)* (Dietrich et al., 1976) which emphasized the importance of purposefully designed SSG-centered practices, a principle that continues to be widely endorsed in contemporary coaching literature (Brinkschröder, 2020; Griffin et al., 1997; Wein, 2004; Wolf, 2024). Consequently, there is common agreement on the particular relevance of engaging in learning situations that offer high

specificity. While further approaches (e.g., *CLA*; *DL*; *NLP*) are not game-based in a strict sense, their application in elite youth soccer often involves the predominant use of SSGs (Bell, 2021; Machado et al., 2019; O’Sullivan et al., 2021; Santos et al., 2016).

Inconsistencies arise concerning the (additional) use of drill-based practices to facilitate technical skills. For instance, *TGfU*, *TGA*, and *GSA* explicitly integrate drills within cyclical session models that combine gameplay, tactical reflection, and targeted technical skill practice (i.e., ‘What to do?’ & ‘How to do it?’; e.g., Griffin et al., 1997). Conversely, other approaches like the *TDL-M* explicitly state that learning in game-representative situations should not “be confounded with traditional drills” (Gréhaigne et al., 2005, p. 257). In the same direction, Wein (2004, p. 5) states: “A coach who teaches his players the correct technique using special, frequently repeated drills is neglecting to teach them why, when and where they need to use technique to deal with a given game situation.” Going further, recommendations across approaches vary regarding the level of movement variability, ranging from repetitive and constant to differential activities (Schöllhorn et al., 2022).

Further differences are evident in views on the coaching behaviors in the learning process. *CLA* proponents advocate a ‘hands-off’ coaching style, minimizing verbal instruction in favor of modifying task constraints to guide player learning (Renshaw et al., 2019). In contrast, *TGfU*, *TDL-M*, and *GSA* promote guided discovery, often facilitated through explicit questioning and coach-player dialogue (Brinkschröder, 2020; Bunker & Thorpe, 1982; Gréhaigne et al., 2005; Griffin et al., 1997). The *Tactical Creativity Approach* (*TCA*; Memmert, 2015) recommends limiting direct instruction to a strategic use, for example, to encourage creative play or provide tactical cues when aligned with a player’s individual capabilities. Meanwhile, *DL* discourages explicit movement instruction, contending that it may interfere with self-organizing processes (Schöllhorn, 1999).

To summarize, this chapter presented a narrative overview of coaching approaches discussed in the literature which can, in principle, offer valuable guidance for coaching within soccer TDEs. Yet, there remains a need for a more thorough examination of the existing empirical research that investigated the approaches' contribution to player learning. In particular, it is important to identify which of these approaches have been scientifically evaluated, the specific learning outcomes assessed, and the methodological strategies employed to investigate their effectiveness.

2.3.4 *Lines of Research*

Various empirical studies have investigated how different coaching strategies contribute to player learning. In soccer-specific coaching research, these studies can be broadly categorized into five main methodological lines of research (in detail *Figure 11*). The coaching approaches outlined in the previous chapter provide a useful point of reference for organizing the existing research landscape. Many studies seek to apply and adapt these approaches to soccer-specific contexts, either by contemplating their impact in (1) theoretical contributions or by (2) evaluating their effectiveness through intervention research. These coaching approaches also function as 'normative' reference points for interpreting findings derived from (3) expert interviews, and (4) systematic observation studies. Some of these lines of research were connected within (5) mixed-methods designs. While Studies 1, 2, and 3 of this dissertation will place greater emphasis on specific findings from these lines of research and their implications for coaching practice, it is essential to first elucidate their methodological strengths and weaknesses.

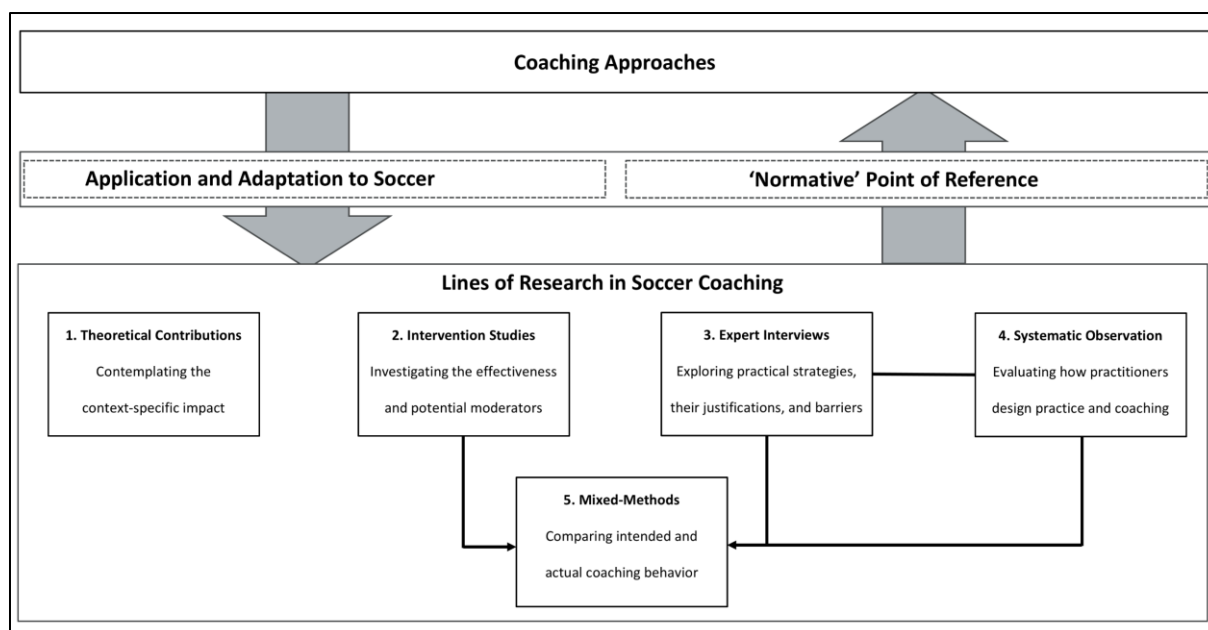


Figure 11. Lines of empirical research on soccer coaching, categorized by methodological approaches and their corresponding objectives.

Based on various theoretical perspectives relevant to soccer coaching (e.g., skill acquisition, motivation), *theoretical contributions* aim to provide practitioners in specific contexts with research-informed guidelines for their coaching practice. Recent publications have addressed different aspects of practice and coaching, including the periodization of skill learning (Farrow & Robertson, 2017; Otte et al., 2019), instructional strategies (Otte et al., 2020), and the development of creativity (Santos et al., 2016). Additionally, with a specific focus on youth age groups, several authors have contemplated how to integrate street-soccer learning conditions, characterized by unstructured, child-led free play, into formal training environments (Machado et al., 2019; Uehara et al., 2018). Many of these contributions, often grounded in an *Ecological Dynamics Framework* (Button et al., 2021), explicitly address soccer TDEs and offer practical recommendations for translating theoretical insights into coaching strategies. For instance, O’Sullivan et al. (2021) illustrate how a *CLA* can be applied to support learning across different developmental

stages in soccer YAs. Their justification for this approach is based on the diverse experiences players gain within the game and the functional application of technical skills. While this research direction enhances the understanding of how specific coaching approaches can be applied in soccer TDEs and why they may be effective from a theoretical standpoint, the actual effects on player learning remain unknown.

The effectiveness of these coaching approaches has been examined through *intervention studies*. While laboratory-based intervention research has contributed to a more nuanced understanding of learning processes, its frequent focus on isolated soccer skills learned by novice participants limits their practical implications for coaching more skilled learners (Farrow & Robertson, 2017; Roth, 2005a; 2005b; Schiebl, 2007). In contrast, field-based studies that evaluate the effectiveness of interventions in youth soccer offer greater practical implications. Several of the coaching approaches introduced in the previous chapter have already been empirically investigated. For instance, individual studies have reported positive effects on both perceptual-motor and perceptual-cognitive outcomes for *DL* (e.g., Santos et al., 2018; Schöllhorn et al., 2012), *TGfU* (e.g., Práxedes et al., 2016), and *NLP* (e.g., Roberts et al., 2020). In addition, further intervention studies have addressed specific topics without being explicitly grounded in a single coaching approach. These include investigations into the effects of drill- versus game-based practice designs, different types of coach instructions, and the effectiveness of enrichment training programs aimed at improving technical skills (e.g., Arslan et al., 2020; Guilherme et al., 2015a; Schwab et al., 2019; Zago et al., 2016). Overall, this line of research demonstrates that various coaching approaches can be effective in the context of youth soccer. However, the explanatory power of the studies seems to depend on the targeted learning outcome (e.g., motor and/or cognitive), how they were assessed (e.g., isolated skill test

vs. in-game performance), and a range of moderating variables (e.g., control conditions, players' skill levels, intervention length). To date, a synthesis of this research that allows for a systematic analysis of these aspects and a comparison of the effectiveness of different coaching approaches remains lacking.

Systematic observation research provides valuable insights into the current state of practice activities and coaching behavior in real-world contexts (for a review Cope et al., 2017). These studies have increasingly focused on soccer coaching in TDEs, shedding light on the types of practice activities and instructional behaviors used by practitioners. Several studies have identified a predominant reliance on decomposed, technically focused practice, often accompanied by prescriptive, movement-related instructions (for a review Cushion et al., 2012a). This approach to practice and coaching is believed to contradict the complex and dynamic nature of the game (e.g., Partington & Cushion, 2013; Partington et al., 2014). However, more recent research suggests a shift in soccer coaching toward greater use of game-representative activities (e.g., O'Connor et al., 2017; 2018; Roca & Ford, 2020) and an increasing emphasis on guided-discovery instructional methods (O'Connor et al., 2017; 2018; Ford & Whelan, 2016; Roca & Ford, 2020). These trends are likely influenced by the coaching philosophies of soccer associations and clubs as well as the educational background of the coaches (for cross-national comparisons Feng et al., 2023; Roca & Ford, 2020). Nonetheless, it is important to recognize that most of these studies capture coaches' behavioral data without adequately accounting for the context-specific justifications underlying their decisions. This represents a major limitation, as coaches' decisions are likely shaped by a range of contextual factors (e.g., learning goals, player characteristics, resources etc.; Lyle & Cushion, 2017).

Expert interviews facilitate better comprehension about practitioners' strategies while also considering their underlying reasoning, intentions, and beliefs. These studies have addressed a wide range of topics offering valuable insights into the decision-making processes of coaches in TDEs (e.g., Hohmann & Pietzonka, 2017). Among the key areas explored are the rationale behind incorporating SSGs into soccer practice (e.g., Alves et al., 2017), strategies to enhance players' strategic understanding (e.g., Price et al., 2020), and coaching behaviors to foster motivational outcomes in players (e.g., Gjesdal, 2025; Raabe et al., 2020). The studies offer valuable insights as they demonstrate the general need for different coaching approaches to adequately address the variety of relevant outcomes in soccer. Furthermore, one of the major contributions of these qualitative studies is their potential to uncover the justifications for employing specific coaching strategies. That is, these studies contribute to a better understanding of the context-specific suitability and adaptability to contextual circumstances. However, these qualitative explorations often represent "best-case scenarios" (Raabe et al., 2020, p. 238) as they typically do not examine constraints to the recommended coaching strategies and fail to account for potential discrepancies between coaches' intentions and their actual behaviors.

A few studies have adopted *mixed-methods* designs specifically combining systematic observations with qualitative interviews (O'Connor et al., 2017; Partington & Cushion, 2013; Partington et al., 2014). These studies primarily aimed to examine the extent to which actual coaching behaviors (i.e., observed practices) align with practitioners' stated intentions, beliefs, and experiences. Some of these studies revealed a disconnect between coaches' intended and actual behaviors in practice (O'Connor et al., 2017; Partington & Cushion, 2013). One such gap pertains to the contradiction between coaches'

stated intention to promote player exploration and their simultaneous tendency to prescribe solutions through high levels of explicit instruction. This suggests that while coaches may conceptually endorse players' self-organized learning, their practical behaviors may still be shaped by prescriptive coaching strategies. Furthermore, a small number of mixed-methods studies have evaluated the feasibility of interventions by integrating systematic observation methods (Práxedes et al., 2019; Roberts et al., 2020). These studies provide valuable insights into how interventions are implemented in real-world settings, highlighting the extent of intervention adherence and offering comprehensive insights into the practical application of coaching approaches in applied contexts.

In summary, research on youth soccer coaching has been approached by employing a range of methodological approaches and study designs. However, due to the complexity of the topic and the limitations inherent in individual studies, it remains challenging to derive clear and reliable implications for coaching practice. To advance our understanding of effective learning support and the rationale behind different strategies, it is crucial to integrate findings across the presented lines of research. Furthermore, it is particularly relevant to interpret the practical meaning of these findings in conjunction with the applied expertise of practitioners. Such integration holds promise for developing actionable recommendations on how to support learning in soccer TDEs that are both scientifically grounded and informed by real-world coaching experience. Furthermore, the effectiveness of different coaching strategies seems to highly depend on the pursued learning outcomes. Consequently, it seems essential to conduct a thorough analysis of a player's individual learning needs in order to tailor practice and coaching accordingly. This highlights the potential value of systematically assessing relevant performance factors to provide coaches with the information needed to deliver individualized learning support.

2.3.5 Learning-Oriented Assessment to Support Talent Development

In the pursuit of tailoring coaches' learning support to a player's individual strengths and weaknesses, the *DFB Talent Development Program* employs assessments with the explicit aim of using the data to support developmental processes (DFB, 2022b; Höner et al., 2020). Such a use of assessments to support developmental processes aligns with the concept of *learning-oriented assessment* (Carless, 2007), which distinguishes between summative and formative approaches (for a review Zeng et al., 2018). Summative assessments are commonly used after a learning process to determine if, and to what extent, learning has occurred. Consequently, this type of assessments does not influence the learning process itself. In contrast, formative assessments are integrated during developmental processes allowing learners and instructors to integrate the results into the learning process. The literature distinguishes three types of learning-oriented assessments being displayed with their meaning and purpose in *Table 1*.

Table 1. *Different types of learning-oriented assessment, their meaning and purposes (based on Carless, 2007; Zeng et al., 2018).*

Type	Meaning	Purpose
Assessment of Learning	Summative Assessment of the learning outcomes	Evaluating the effectiveness of a learning period based on current performance.
Assessment for Learning	Formative assessment which aims to facilitate the support of learning	Providing information to modify and differentiate learning activities and feedback.
Assessment as Learning	Any assessment that directly affects learning.	Directly supporting learning through participation in the assessment itself.

Assessment of Learning is the most common approach in educational contexts. Its primary purpose is to inform decisions about learners such as access to development programs, grading, or evaluating learning interventions. In transfer to TDEs, this corresponds

to using test results to support talent identification and (de-)selection as well as to monitor individual progress in a summative manner. *Assessment for Learning*, in contrast, focuses on optimizing support for learners by providing differentiated, individualized feedback based on individual test results. Often referred to as the ‘improvement approach’, this type of assessment aims to enhance learning by tailoring instructional activities and helping learners to better understand their own strengths and weaknesses. In TDEs, this includes the integration of results to individualize practice and coaching. *Assessment as Learning* implies that the assessment process itself contributes to learning. The effectiveness of “assessment tasks as learning tasks” (Carless, 2007, p. 65) largely depends on the design of the tasks and the intended learning objectives (for a review addressing educational contexts, see Murphy et al., 2023).

The connection of test data and coaches’ learning support is illustrated by the ASPIRE-model for deliberate skill development in applied settings (Ford & Coughlan, 2020). It structures the goal-oriented process of practice and coaching, highlighting two stages where assessments can be integrated (*Figure 12*). While not yet empirically validated, the model offers a systematic approach for supporting long-term player development and should receive greater attention in future research. Aligning with the PACE-model utilized in the *DFB Talent Development Program* (Dugandzic, 2003), the first stage *Analyze* (‘A’) involves identifying a player’s strengths and weaknesses to define developmental goals. Ford and Coughlan (2020) emphasize using age-specific reference values to reliably evaluate current skill and competence levels. This stage aligns with *Assessment for Learning*, as it helps coaches and players identify key areas for improvement and adapt subsequent practice and coaching accordingly (stages S, P, I, R). If assessments are conducted regularly, they can be used to *Evaluate* (‘E’) progress over time. This reflects *Assessment of*

Learning, as it allows for determining whether learning has occurred. In this way, differentiated practice and coaching strategies can be adapted based on evolving needs of the learners. As a key component of *Assessment for Learning*, these insights also strengthen players' understanding of their development and encourage active engagement with performance criteria (cf. Carless, 2007, p. 60).

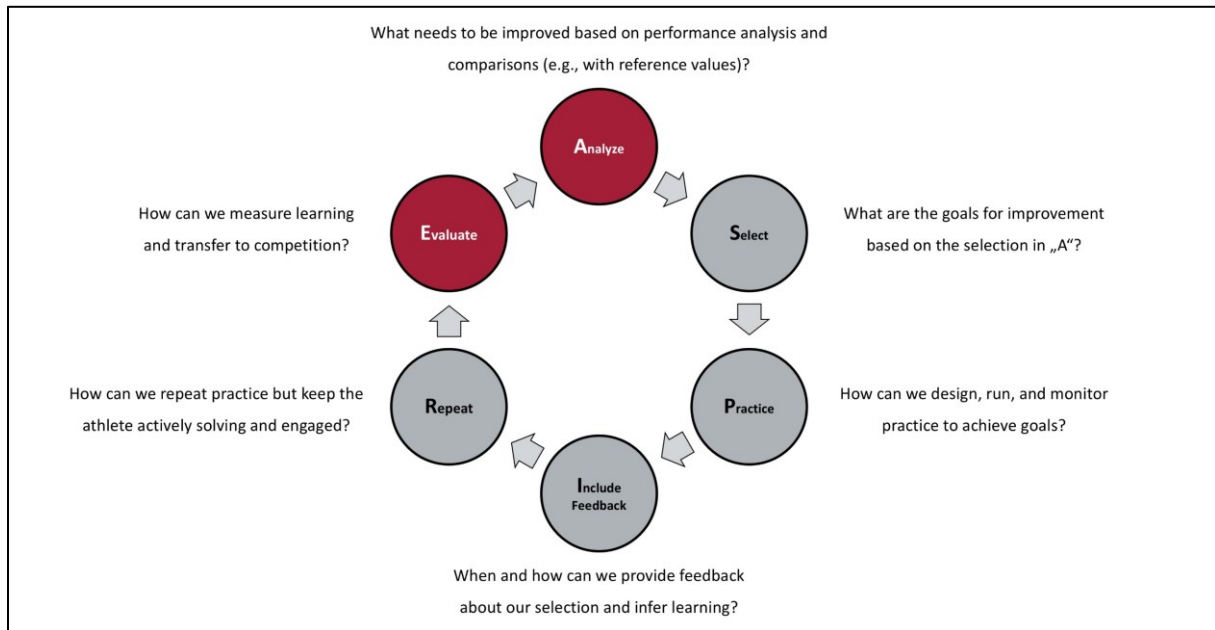


Figure 12. The ASPIRE model for systematizing deliberate skill practice in applied environments (Ford & Coughlan, 2020; adapted from Williams & Hodges, 2023, p. 839; emphasis added by the author). With permission from Taylor & Francis.

Overall, there is a pressing need to better understand how players' action competence in soccer TDEs can be effectively fostered. As illustrated by the ASPIRE-model, this likely involves the functional interplay of various support measures, such as effective practice design and coaching strategies, whose tailored application can be facilitated by the purposeful integration of assessment data. While the broader field of learning and coaching has generated valuable insights, context-specific knowledge in soccer TDEs remains limited. The following chapter will outline specific research gaps, thereby laying the foundation for the empirical studies conducted within this dissertation.

2.4 Identified Research Gaps

To further advance talent development practices, there is an overarching need to better understand of how the acquisition of action competence in soccer can be effectively fostered through *learning-supportive coaching*. However, the broad range of relevant performance factors in soccer presents a major challenge for coaches, often resulting in diverse learning needs among players within a single training group. Consequently, a key responsibility for coaches is to consider each player's strengths and weaknesses, and how these develop over time, in order to provide targeted learning support. In this realm, the concept of *learning-oriented assessment* – and particularly assessments for learning – can hold considerable potential to assist practitioners in delivering tailored support.

Linking the fields of talent research and coaching research to uncover and integrate complementary insights may offer a promising avenue for advancing scientific knowledge in these areas. This is supported by Williams et al. (2020, p. 1206), who emphasize that despite considerable progress in soccer talent research, “sports scientists should attempt to [...] develop new robust methods in an effort to provide stronger evidence for the causal effects of potential interventions on player development.” Addressing this call to foster a more sophisticated understanding of the causal effects on player development may benefit from employing different research designs suitable to the respective inquiry. A purposeful combination of research designs and methods may help to evaluate if and how coaching strategies support player learning and also provide a better understanding of the rationales behind their use. Furthermore, given that scientific insights are inherently shaped by the research context, field-based studies that account for the complex and dynamic nature of applied coaching environments are particularly valuable.

In light of these general limitations of the available scientific knowledge, the following specific research gaps have been identified as central to guiding the empirical studies conducted in this dissertation:

- Given the wide range of potential coaching approaches, there is a need for intervention research that provides empirical evidence of their effectiveness in fostering different player outcomes (O'Connor et al., 2021b; Williams et al., 2020). Beyond this general need, there is currently no **comprehensive literature review of field-based interventions** that consolidates existing knowledge. Such a synthesis could help clarify which approaches have been empirically tested in soccer, which theoretical frameworks informed those interventions, and which factors may moderate their effectiveness.
- A deeper understanding of the **rationales behind the application of coaching strategies** in TDEs is needed, particularly given the numerous, and often competing, decision-making parameters coaches face in practice (Lyle & Cushion, 2017). Investigating expert perspectives on how player learning should be supported is therefore essential. Methodologically, these insights are best gained through qualitative research that seeks to uncover the underlying intentions, justifications, and beliefs guiding expert decision-making.
- To facilitate the transfer of research findings into practice, it is essential to **integrate insights from different lines of research** in order to identify areas of complementarity and conflict. Such an integration can support the development of research-informed principles to guide coaches in their everyday coaching practice (Kearney et al., 2024). Participatory research approaches, which emphasize close collaboration between researchers and practitioners, represent a promising strategy for generating contextually relevant and practically applicable coaching recommendations (Lyle, 2018).
- At the same time, a deeper understanding is required of the **factors that influence or hinder coaches in providing effective learning support** within TDEs. This includes examining the extent to which research-informed principles align with coaches' intentions, beliefs, and competencies, and how these factors

shape the implementation of coaching strategies in real-world environments (Kinnerk et al., 2018; Richardson et al., 2024; Stodter & Cushion, 2019).

- A frequent challenge in TDEs is **aligning coaching strategies to support learning with the individual strengths and weaknesses of players** (e.g., Schreiner et al., 2018). Within the *DFB Talent Development Program*, this alignment is intended to be supported by objective and subjective assessments of relevant talent predictors (DFB, 2022b; Höner et al., 2020). While initial evidence exists from a study involving male outfield players (Höner et al., 2021), the potential of such combined assessment approach to function as learning-oriented assessment, and particularly as assessment for learning, requires further investigation.
- A more nuanced understanding of how these **instruments can function as learning-oriented assessments** may be gained through further empirical investigation. Building on existing findings from male outfield players (Höner et al., 2021), such insights could be expanded by examining target groups that have received limited attention in previous research, including female players and the specific positional group of GKs. This is particularly relevant given the inclusion of position-specific coach ratings for both outfield players and GKs. Such investigations would contribute to a more comprehensive understanding of the strengths and limitations of both objective and subjective assessments in providing coaches with meaningful information to support their practice.
- Finally, assessments used in soccer TDEs should aim to capture attributes that underpin action competence in this sport. In the case of GKs, however, a diagnostic gap remains with regard to an objective, position-specific assessment that accounts for their substantially different demands during a soccer game. Developing such a **GK-specific objective assessment** would therefore represent a valuable advancement of the current assessment approach. With the aim of purposefully integrating test data into talent development practices, such an assessment would enable coaches to more accurately capture the attributes underpinning action competence in GKs through both objective and subjective instruments.

3. Empirical Studies

3.1 Research Objectives and Related Individual Studies

The identified research gaps form the foundation of the empirical part of this cumulative dissertation. By connecting the fields of talent research and coaching research, the overarching objective of this work is to *generate scientific knowledge on how the acquisition of action competence in soccer can be effectively fostered within TDEs*. This research objective is addressed through seven individual studies:

- 1) **Bergmann, F.**, Gray, R., Wachsmuth, S., & Höner, O. (2021a). Perceptual-Motor and Perceptual-Cognitive Skill Acquisition in Soccer: A Systematic Review on the Influence of Practice Design and Coaching Behavior. *Frontiers in Psychology*, 12: 772201. <https://doi.org/10.3389/fpsyg.2021.772201>
- 2) **Bergmann, F.**, Wachsmuth, S., O'Connor, D., Larkin, P., Dugandzic, D., & Höner, O. (2025a). Practice Design and Coaching to Support Learning in Elite Youth Soccer Players: Recommendations from International Coaches, Coach Educators, and Researchers. *International Sport Coaching Journal*, 12(3), 362-375. <https://doi.org/10.1123/iscj.2023-0079>
- 3) **Bergmann, F.**, Wachsmuth, S., Metke, C., O'Connor, D., Dugandzic, D., & Höner, O. (2025b). Fostering Learning-Supportive Coaching in a Nationwide Talent Development Program: Mixed-Methods Evaluation of a Research-Informed Soccer Coach Education Initiative. *Physical Education and Sport Pedagogy*. <https://doi.org/10.1080/17408989.2025.2541637>
- 4) Leyhr, D., **Bergmann, F.**, Raabe, J., & Höner, O. (2025). Multidimensional Performance Assessments in U15 Female Soccer: The Predictive Validity for Different Selection Levels in U17 and Success in Adulthood. *European Journal of Sport Science*. <https://doi.org/10.1002/ejsc.12335>

- 5) Höner, O., **Bergmann, F.**, & Leyhr, D. (2025). “Don’t Forget the Number 1 in Soccer Talent Research!” – Predictive Validity of Objectively Tested Motor Attributes and Subjectively Rated Position-Specific Skills in Elite Youth Goalkeepers. *Journal of Sports Sciences*. <https://doi.org/10.1080/02640414.2025.2517974>
- 6) **Bergmann, F.**, Danner, J., Schultz, F., Pollmann, D., & Höner, O. (2021b). Talentdiagnostik von Fußballtorhütern. Entwicklung und Evaluation eines sensomotorischen Koordinationstests [Talent Assessment in Soccer Goalkeepers. Development and Evaluation of a Motor Coordination Test]. *Leistungssport*, 51(1), 50-55.
- 7) **Bergmann, F.**, Schultz, F., Fransen, J., & Höner, O. (2024a). Evaluation of a Goalkeeper-Specific Motor Coordination Assessment in Youth Football. *Science and Medicine in Football*. <https://doi.org/10.1080/24733938.2024.2429486>

In addition to Studies 6 and 7, two editions of a test manual presenting a novel, objective GK-specific assessment were published in German. The second edition introduces the further developed test battery that was evaluated within Study 7. This manual serves as the foundation for the nationwide implementation of this test battery within the *DFB Talent Development Program* which is planned for 2026:

- Bergmann, F.**, Danner, J., Schultz, F., Pollmann, D., Kompodietas, E., & Höner, O. (2021c). *Testmanual. Sensomotorischer Koordinationstest zur Talentdiagnostik von Fußballtorhütern*. Eberhard Karls Universität Tübingen. www.leistungssport.net/Testmanual_Sensomotorischer_Koordinationstest
- Bergmann, F.**, Danner, J., Schultz, F., Dugandzic, D., Kompodietas, E., & Höner, O. (2024b). *Testmanual. Ballgebundener Koordinationstest zur Talentdiagnostik von Fußballtorhütern in der frühen Adoleszenz (U11-U15)* (2nd Ed.). Eberhard Karls Universität Tübingen. <https://uni-tuebingen.de/de/218829#c1428696>

Further scientific outputs related to this dissertation are listed in *Appendix 1*. These include a pre-registered PRISMA-Protocol (Bergmann et al., 2020) and a book chapter comparing soccer talent development programs across several countries (Kelly et al., 2024).

A journal article examined relative-age related biases in the test results of both the position-independent objective motor test battery and the subjective coach ratings within the *DFB Talent Development Program* (Leyhr et al., 2021). In addition, selected work from this dissertation has been presented in twelve conference contributions.

The empirical studies of this dissertation can be organized based on the *three perspectives* outlined in the theoretical background and state of research (*Chapters 2.1-2.3*):

1. The studies can be situated within existing *talent research in soccer*, as synthesized in the model of relevant talent predictors along with their moderating and mediating factors by Williams et al. (2020).
2. The focus on developing youth players' *action competence in soccer* can be illustrated by embedding this work within an action-theoretical perspective and established models of relevant performance factors in soccer (Hohmann & Brack, 1983; Höner, 2012a; Nitsch, 2004).
3. The aim of linking theoretical perspectives on *learning and coaching* with empirical insights into the contribution of coaching strategies is facilitated by recommendations to connect basic scientific research (e.g., on learning theories) with technological research aimed at identifying effective strategies to advance applied work in specific contexts (Willimczik, 2003; 2021).

Based on *existing talent research in soccer*, the seven individual studies can be organized into two interrelated research foci (see *Figure 13*). Research Focus I investigates how relevant performance factors can be effectively fostered through *learning-supportive coaching*, which is considered a core element of the development environment. Research Focus II examines the potential of assessment instruments to evaluate these talent predictors that are associated with different competence areas. A particular emphasis is placed on their potential to function as *learning-oriented assessments*, especially with regard to the formative use of test data (i.e., assessment for learning). While previous

studies predominantly focused on male outfield players, the studies expand this knowledge base by evaluating the psychometric properties of the assessments used in the *DFB Talent Development Program* with female players and GKs. Furthermore, since the objective motor test battery primarily addresses game demands of outfield players, a novel GK-specific motor test is introduced that may complement the existing assessment approach in the future.

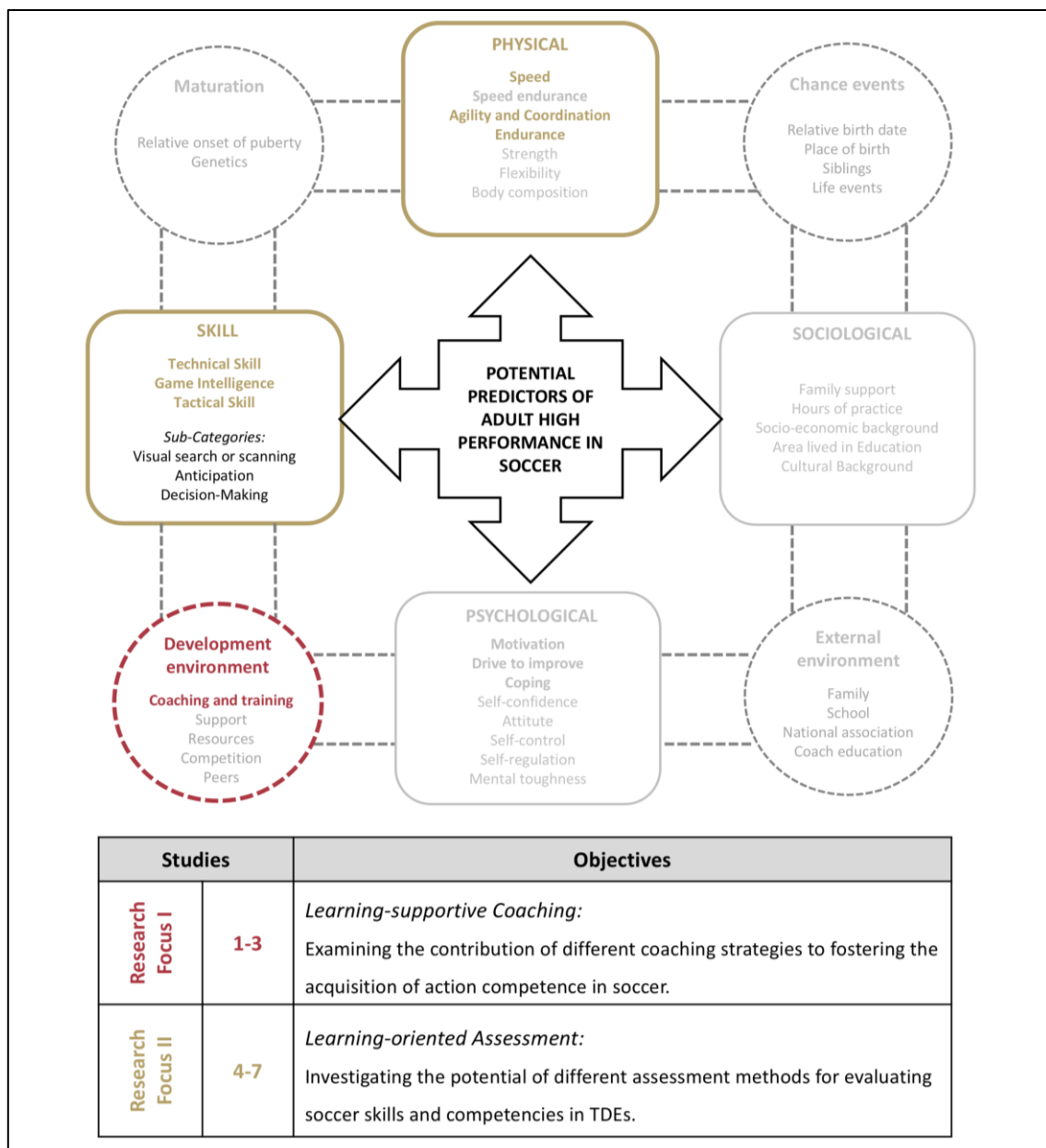


Figure 13. Categorization of Research Focus I and II based on the model of relevant talent predictors and their moderating and mediating factors (Williams et al., 2020, p. 1204). With permission from Taylor & Francis.

Altogether, the studies across Research Foci I and II aim to contribute to a scientific understanding of how a player's *action competence in soccer* can be effectively fostered. Representing the overarching developmental objective in TDEs, this action competence reflects a player's capability to solve game-specific tasks in light of environmental conditions (Hohmann & Brack, 1983; Höner, 2012a; Nitsch & Munzert, 1997). Accordingly, the studies' shared focus can be situated at the second explanatory level of the *Model of Complex Game Performance* (see Figure 14).

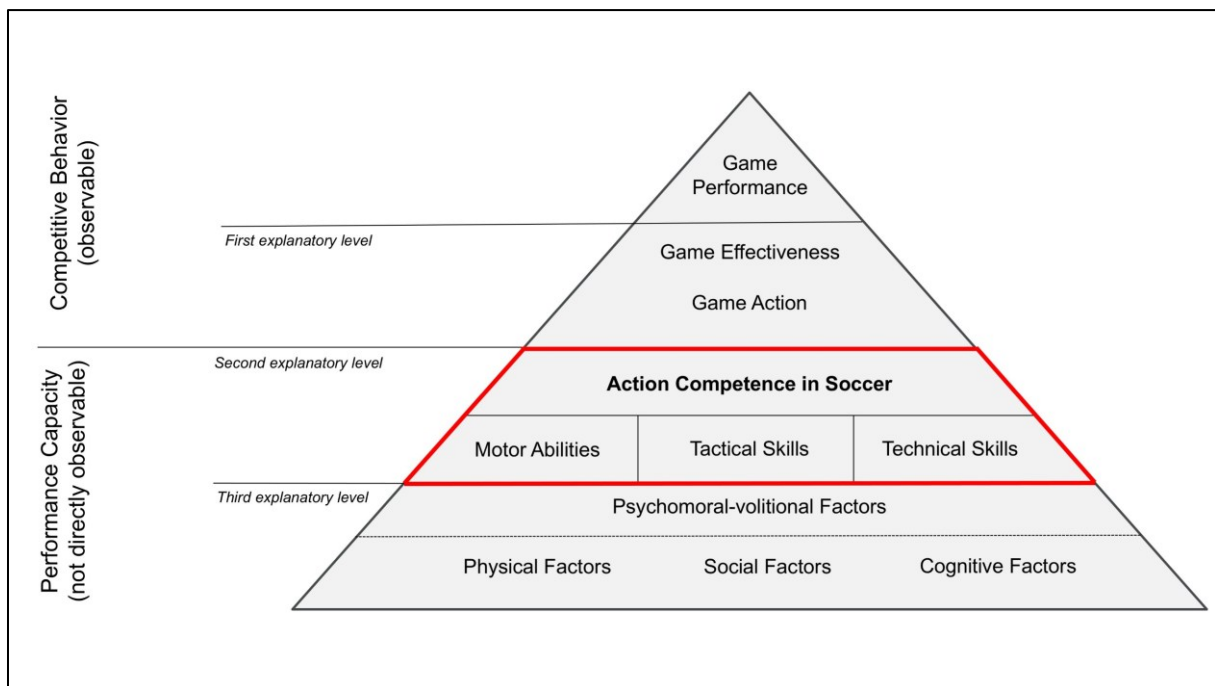


Figure 14. Focus of this dissertation with regard to the Model of Complex Game Performance (Höner, 2012a, p. 17 citing Hohmann & Brack, 1983, p. 9). With permission from the author.

While addressing this shared focus, the seven studies presented in this dissertation pursue distinct objectives and employ a variety of methodological study designs. In doing so, they aim to generate complementary insights that can be integrated to derive scientifically informed practical implications for advancing applied work in soccer TDEs. *Table 2* provides a detailed overview of the individual study objectives and the corresponding methodological designs.

RESEARCH OBJECTIVES & RELATED INDIVIDUAL STUDIES

Table 2. Overview of the individual study objectives and their corresponding methodological designs.

Study		Objectives	Study Design	Journal [Impact Factor]
Research Focus I: Learning-supportive Coaching	1	Synthesize the available scientific knowledge regarding the – <i>theoretical background</i> of interventions evaluating the influence of practice design and coaching behavior in soccer, – <i>quality in reporting and risk of bias</i> of published research, – <i>effectiveness</i> of different coaching methods to facilitate perceptual-motor and perceptual-cognitive skill acquisition in soccer.	Systematic review with quantitative synthesis	<i>Frontiers in Psychology</i> [IF: 4.2]
	2	Explore recommendations from experienced soccer coaches, coach educators, and researchers on <i>how to facilitate learning</i> during practice in elite adolescent soccer players, including underlying rationales.	Qualitative study employing semi-structured expert interviews	<i>International Sport Coaching Journal</i> [IF: 1.8]
	3	Develop, implement, and evaluate a research-informed coach education program (CEP) to <i>transfer scientific knowledge on learning-supportive coaching</i> into the DFB Talent Development Program.	Mixed-methods approach combining quantitative surveys and semi-structured interviews	<i>Physical Education and Sport Pedagogy</i> [IF: 3.0; 5-year: 4.2]
Research Focus II: Learning-oriented Assessment	4	Examine the predictive validity of <i>isolated objective motor tests and competency-based subjective ratings</i> for U15 female youth soccer players future success to evaluate the potential of integrating the data in practical work.	Prospective cohort study	<i>European Journal of Sport Science</i> [IF: 3.0]
	5	Investigate the predictive validity of <i>objectively tested motor attributes</i> and <i>subjectively rated position-specific skills and competencies</i> on GKs' future success to evaluate the potential of integrating the data in practical work.	Prospective cohort study	<i>Journal of Sports Sciences</i> [IF: 2.5; 5-year: 3.5]
	6	Develop and evaluate a novel <i>GK-specific motor coordination assessment</i> with respect to its reliability and concurrent validity, in order to examine its potential to complement the currently used assessment approach.	Cross-sectional study	<i>Leistungssport</i> [B-category journal]
	7	Evaluate the further developed <i>GK-specific motor-coordination assessment</i> regarding the content and face validity, reliability and agreement, as well as structural validity and concurrent validity.	Cross-sectional cohort study	<i>Science and Medicine in Football</i> [IF: 3.5; 5-year: 3.6]

Finally, a central objective of this dissertation is to establish connections between the theoretical foundations of *learning and coaching*, as introduced in *Chapter 2.3*, and empirical insights into how players' action competence can be supported within soccer TDEs. This objective is based on the assumption that progress in the research field can be achieved by linking scientific knowledge about the contribution of coaching strategies to fostering learning in applied contexts with theories capable of explaining the underlying mechanisms of these strategies. In line with Willimczik (2003; 2021), this responds to calls for examining the explanatory power of learning theories, often originating in basic scientific research, in relation to coaching strategies that have been identified as beneficial for supporting learning in applied settings.

Accordingly, the general discussion in *Chapter 4* integrates the findings across studies and aims to establish connections between the theoretical perspectives introduced earlier and the empirical findings presented in the subsequent chapters. This synthesis is intended to provide a scientific foundation for deriving practical implications regarding how to effectively foster action competence in youth soccer players. Particular emphasis is placed on the complementary potential of learning-supportive coaching and learning-oriented assessment in achieving this overarching developmental objective within TDEs.

3.2 Research Focus I: Learning-Supportive Coaching

3.2.1 *Perceptual-Motor and Perceptual-Cognitive Skill Acquisition in Soccer: A Systematic Review on the Influence of Practice Design and Coaching Behavior (Study 1)*

This chapter contains the manuscript accepted for publication in *Frontiers in Psychology* on 02 December 2021. The full reference of the published article is:

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Prior to conducting the systematic review, a PRISMA-Protocol was pre-registered on the *Open Science Framework*. The protocol can be accessed via the following citation:

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Abstract

Facilitating players' skill acquisition is a major challenge within sport coaches' work which should be supported by evidence-based recommendations outlining the most effective practice and coaching methods. This systematic review aimed at accumulating empirical knowledge on the influence of practice design and coaching behavior on perceptual-motor and perceptual-cognitive skill acquisition in soccer. A systematic search was carried out according to the PRISMA guidelines across the databases SPORTDiscus, PsycInfo, MEDLINE, and Web of Science to identify soccer-specific intervention studies conducted in applied experimental settings (search date: 22nd November 2020). The systematic search yielded 8,295 distinct hits which underwent an independent screening process. Finally, 34 eligible articles, comprising of 35 individual studies, were identified and reviewed regarding their theoretical frameworks, methodological approaches and quality, as well as the interventions' effectiveness. These studies were classified into the following two groups: Eighteen studies investigated the theory-driven instructional approaches Differential Learning, Teaching Games for Understanding, and Non-Linear Pedagogy. Another seventeen studies, most of them not grounded within a theoretical framework, examined specific aspects of practice task design or coaches' instructions. The Downs & Black checklist and the Template for Intervention Description and Replication were applied to assess the quality in reporting, risk of bias, and the quality of interventions' description. Based on these assessments, the included research was of moderate quality, however, with large differences across individual studies. The quantitative synthesis of results revealed empirical support for the effectiveness of coaching methodologies aiming at encouraging players' self-exploration within representative scenarios to

promote technical and tactical skills. Nevertheless, ‘traditional’ repetition-based approaches also achieved improvements with respect to players’ technical outcomes, yet, their impact on match-play performance remains widely unexplored. In the light of the large methodological heterogeneity of the included studies (e.g., outcomes or control groups’ practice activities), the presented results need to be interpreted by taking the respective intervention characteristics into account. Overall, the current evidence needs to be extended by theory-driven, high-quality studies within controlled experimental designs to allow more consolidated and evidence-based recommendations for coaches’ work.

Keywords: football, talent development, ecological dynamics, dynamical systems, information-processing

Introduction

Sport coaches face multiple challenges, one of which is to facilitate athletes' skill acquisition to improve performance (Gould & Mallett, 2021). Due to the dynamic and interactive character of team sports games, a plethora of skills is required to act successfully during gameplay. In soccer, these skills specifically encompass perceptual-motor (e.g., technical) and perceptual-cognitive (e.g., tactical) components (Williams et al., 2020). Knowledge about these and further relevant performance factors is not only important to identify talented players, it is also essential for developing these performance factors systematically through effective practice and coaching. While recent systematic reviews document the growing body of knowledge about soccer-specific performance characteristics and talent predictors, less is known on how to promote these factors effectively, reinforcing the call for intervention research (O'Connor et al., 2021b; Williams et al., 2020).

Most intervention research on the development of performance factors in soccer is concerned with the players' physical fitness and physiological capabilities (for overviews see Bujalance-Moreno et al., 2018; Zouhal et al., 2020). Considerably fewer studies investigated the promotion of soccer-specific skills based on psychological and motor learning theories (Williams & Hodges, 2005). This smaller scope of scientific work is primarily attributed to methodological challenges in assessing behavioral changes in players, especially in highly dynamic and unpredictable match-play situations. For this reason, laboratory-based research on the acquisition of closed soccer skills has made the primary contribution to our general understanding of skill acquisition (e.g., Anderson & Sidaway, 1994; Hodges et al., 2005). Often conducted with novice participants, those studies

seem to not only lack transferability to a pitch-based coaching context but also to superior skill-level players (Farrow & Robertson, 2017; Wulf & Shea, 2002). As a possible consequence, there is an emerging trend towards intervention studies anchored in more representative settings and with more experienced players (e.g., Práxedes et al., 2016; Roberts et al., 2020).

Theoretical perspectives on skill acquisition

Besides methodological difficulties in designing intervention research, also the theoretical underpinnings of skill acquisition pose challenges for developing effective practice. There are different perspectives on the organization and development of skills, possibly leading to contradictory implications for coaches' work. Historically, substantial advances have been made with regards to understanding the processes linked to skill acquisition, but it remains a dynamic and disputed topic among researchers (Whitall et al., 2020a; 2020b).

In current research, two influential theoretical perspectives can be distinguished that emerged from cognitive psychology, on the one hand, and ecological psychology/dynamical systems theory, on the other hand (Anson et al., 2005).¹⁰ According to an understanding grounded in *cognitive 'information-processing'* theories, there is an ideal way to perform a skill that is to be learned through a stage-linear process (Fitts & Posner, 1967). Based on the schema theory of motor learning (Schmidt, 1975), a skill consists of invariants that are stored through mental representations in so-called generalized motor programs (GMPs). For utilizing GMPs in dynamic game-related situations, players must learn to parameterize the skill, that means, learn how to adjust the skill to the requirements of any respective situation. Within this theoretical perspective, performing a game action

¹⁰ For further explanations see for example: <https://www.youtube.com/watch?v=cCsezh7ijzs>

relates to a subsequent three-stage process from stimulus identification (i.e., perception), response selection (i.e., decision), and response programming (i.e., action; Schmidt et al., 2019).

A different, opposing view to this often called ‘traditional’ standpoint emerges from an *ecological/dynamical systems* perspective where skill acquisition is considered a process of exploration and self-organization. Based on Newell’s (1986) constraints-based model, individuals interact with the environment and the tasks of the given situation by exploring individual movement solutions in a non-linear fashion. In this approach, there is no one ideal, “correct” technique for performing a skill. Rather, there is substantial variability both across and within individuals (i.e., ‘repetition without repetition’; Bernstein, 1967). According to this viewpoint, performing game actions depends on the direct perception of affordances from the environment, implying that perception and action are considered inherently coupled (Gibson, 1979).

Practice and coaching methods to promote skill acquisition in soccer

In searching for the most supportive methods to improve players’ skills, it is worthwhile to look at the early stages of playing soccer during childhood: In these stages, the process of skill acquisition can occur in an implicit and unstructured way within informal and child-led settings, such as street soccer (Uehara et al., 2018). There is evidence that a high amount of such self-organized soccer gameplays, as well as multi-sport practice in childhood, is positively associated with achieving excellence in adult soccer (Forsman et al., 2016; Güllich et al., 2021). However, when looking at the pathways of elite players, it is indisputable that formal soccer-specific and coach-led practice is indispensable to improve and sustain players’ skill level, too (Hendry & Hodges, 2019; Sieghartsleitner et

al., 2018). In this goal-directed process, coaches are challenged by a variety of methodological decisions relating to the skill itself but also contextual factors, such as the athlete's performance level, age, or available time to achieve an outcome (Côté & Gilbert, 2009). Therefore, coaches likely need a 'blended tool kit' (Price et al., 2019, p. 126), equipped with practice and coaching methods in order to find effective context-specific solutions to facilitate player learning and performance.

To describe these 'tools', the terms *training form* (i.e., decontextualized repetitive drills) and *playing form* (i.e., game-related, representative situations) are commonly used to classify practice activities in soccer (Ford et al., 2010; O'Connor et al., 2018). Yet, these terms only provide a broad picture of the accompanying task demands so that more sophisticated differentiation is needed. One of that is the degree of variability within (i.e., trial-to-trial) and between (i.e., contextual interference) practiced skills that can be scaled in drills and game-based tasks (Magill & Anderson, 2021; Stratton et al., 2004). Further, the specificity describes whether practice conditions reflect competitive demands in terms of motor- and sensory-related parameters (Farrow & Robertson, 2017; Proteau, 1992). Besides practice activities, there is also a wide array of coaching behaviors, such as demonstrations, instructions, and feedback which are used to accentuate the practice demands (Hendry et al., 2015; Otte et al., 2020). For instance, instructive behaviors may differ depending on whether explicit or implicit learning processes should be promoted in the players.

Insights to which extent coaches make use of the outlined tools during pitch-based work are given by systematic observations in 'real-world' coaching contexts (Cushion et al., 2012a; Partington & Cushion, 2013; Partington et al., 2014). Many of these studies have displayed the 'challenging tradition' of practice, instruction, and skill acquisition in terms

of the predominant use of unrepresentative drill-based activities and a high amount of prescriptive instructions by the coaches (Williams & Hodges, 2005). More recent studies show a trend towards more game-realistic activities which are more closely aligned to competitive demands (O'Connor et al., 2018; Roca & Ford, 2020). Nonetheless, there still seems to be potential towards greater consideration of skill acquisition research within soccer coaches' work (Farrow, 2021; O'Connor et al., 2017).

In contrast to the outlined traditional approach, characterized by the predominant use of decontextualized drill-based activities and directive instructions, instructional approaches providing alternative strategies have gained increasing popularity in soccer. Grounded in an educative and constructivist perspective, *Teaching Games for Understanding (TGfU)* (Bunker & Thorpe, 1982) is a game-centered approach that aims to improve tactical intelligence through simplified, game-related situations. The accompanying guided discovery approach to coaching is intended to explicitly enhance players in solving tactical problems. As another approach, *non-linear pedagogy (NLP)* (Chow et al., 2011) provides key principles to practice and coaching and is shaped by an ecological dynamics viewpoint. According to *NLP*, functional variability of skills can be achieved through perception-action couplings during practice, by applying representative learning designs, and a hands-off facilitative approach to coaching. *NLP* aims to support players in finding individual movement solutions through a non-linear process of learning. Lastly, based on dynamical systems theory, *Differential Learning (DL)* (Schöllhorn, 1999) assumes that athletes need to adapt to constant perturbations in dynamic competitive environments. Thus, practicing skills with additional random fluctuations ('noise') offers the opportunity to explore and self-organize individual functional movement patterns.

Considering the wide array of possible practice and coaching approaches, O'Connor et al. (2021) and Williams et al. (2020) call for intervention research on soccer players' skill acquisition to get a deeper insight into the effectiveness of different methods. Recent systematic reviews and meta-analyses within these and related fields pooled intervention research from educational settings (Abad Robles et al., 2020), focused on the effectiveness of one instructional approach (e.g., *DL*; Tassignon et al., 2021), or merely examined one specific outcome (e.g., decision-making; Silva et al., 2020). While these reviews included studies from various sports and often different experimental settings, there is no systematic review accumulating evidence on the effectiveness of practice and coaching methods grounded in different theoretical perspectives to skill acquisition from a soccer-specific viewpoint.

The present study

This systematic review aims to pool empirical knowledge from intervention research on the effectiveness of different practice and coaching methods on skill acquisition in soccer. In contrast to previous systematic reviews and meta-analyses, the current review is explicitly set out to focus on the following attributes: First, it focuses on intervention research conducted in applied ("pitch-based") experimental settings which included experienced soccer players as participants rather than novices. Such studies provide the ecological validity necessary to offer the most pertinent support for soccer coaches' actual work. Next, it was deemed vital to investigate studies grounded in different theoretical skill acquisition approaches to explore how different assumptions impact an interventions' design as well as to discuss the effectiveness of different approaches regarding the acquisition and learning of soccer-specific skills. Finally, considering both perceptual-motor and perceptual-cognitive skills as outcomes was perceived mandatory due to their

interrelationship during matchplay. As there is no overview of intervention research in soccer considering these aspects, knowledge on the methodological characteristics and rigor is required to estimate the current potential for drawing evidence-based recommendations for coaches' work.

To this end, soccer-specific intervention studies conducted in applied experimental settings with soccer players were reviewed to answer the following research questions considering three overarching perspectives:

1. *Theoretical perspective*: What were the interventions' underlying frameworks to skill acquisition? How did these impact the practice design and coaches' behavior?
2. *Methodological perspective*: What study designs, participant samples, instruments, and statistical methods were applied? What was the quality in reporting and risk of bias within studies?
3. *Outcome-related perspective*: To what degree did the interventions contribute to effective perceptual-motor and perceptual-cognitive skill acquisition in the players?

Method

A systematic review was conducted according to the guidelines of preferred reporting items for systematic review and meta-analyses (PRISMA; Moher et al., 2009). On November 4th 2020, a PRISMA-Protocol (PRISMA-P; Moher et al., 2015) was pre-registered in the Open Science Framework, outlining the objectives of this systematic review, the systematic search strategy, methods for assessing the methodological quality of individual studies, as well as predetermined methods for data extraction and synthesis in detail (Bergmann et al., 2020).

Systematic search and eligibility criteria

On November 22nd 2020, a systematic search was conducted across the databases SPORTDiscus, PsycInfo, MEDLINE (via EBSCOHost, respectively), and Web of Science (considering the categories Sports Science and Psychology). Each database was searched for peer-reviewed academic articles in English language without limitations for publication year. The systematic search strategy was developed by the research group in consultation with two librarians who helped to optimize search terms and to identify the most appropriate databases to best address the objectives of this systematic review (Harari et al., 2020). The following terms and operators were searched in each database considering titles and keywords (further details of the systematic database search and the respective settings of each database are documented within Supplement I):

(football* OR soccer)

AND

(intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing")

NOT

(novice OR referee OR injur* OR pupil* OR class OR goalkeep* OR NFL OR "american football" OR "australian football")

The inclusion criteria for study selection are presented in *Table 3* according to the PICOS components. In accordance with Spittle's (2021) classification of intervention research, only studies in at least applied settings were included. Additionally, studies were excluded if they examined novices, goalkeepers, referees, or athletes with mental or physical disabilities. Besides that, interventions focusing on injury prevention or rehabilitation

(including warm-up programs), as well as interventions that only included physical or physiological training exercises without a ball (i.e., fitness training), were not considered. This was also true for such studies which only assessed physical or physiological outcomes. Due to the lower ecological validity, laboratory research designs, but also imagery or virtual-reality interventions, were also excluded.

Table 3. *Specification of inclusion criteria regarding the components participants, interventions, comparators, outcomes, and study designs (PICOS).*

Component	Inclusion criteria
P	• Healthy and injury-free soccer players (i.e., with previous soccer experience) of all age groups and sexes.
I	• Soccer-specific interventions conducted in applied (i.e., pitch-based) settings (cf. Spittle, 2021, p. 10).
C	• Studies without CG were included for review but only analyzed regarding theoretical frameworks as well as methodological characteristics and quality (i.e., perspectives 1 & 2). In terms of the interventions' effectiveness (i.e., perspective 3), only controlled designs including non-active and/or active control groups were considered.
O	• Soccer-specific perceptual-motor and/or perceptual-cognitive skills.
S	• Any type of quantitative (i.e., quasi-experimental and experimental) intervention study investigating the effectiveness of practice and coaching methods with regard to the acquisition or learning of the aforementioned soccer-specific skills.

Note. CG = control group

Article screening

The search results were exported to and managed with EndNote (Version X9.3). EndNote was also used to remove duplicates automatically. Additionally, the first author and a trained research assistant screened all titles independently to remove previously missed duplicates manually. Throughout an independent screening process following the PRISMA guidelines, potentially eligible articles were checked against the inclusion and

exclusion criteria by both reviewers. The inter-rater agreement (IRA) was calculated using the percentage of agreement as well as Cohen's Kappa (κ ; Hallgren, 2012).

The PRISMA flowchart in *Figure 15* displays the systematic search results. The initial database search yielded 13,318 hits. Three articles were additionally added through other sources (Bozkurt, 2018; Hossner et al., 2016; Ozuak & Çağlayan, 2019). After removing 5,026 duplicates, 8,295 titles were screened independently by the first author and a trained research assistant. The previously initiated reviewer training comprised an independent title screening of approximately 10% of identified records and a subsequent discussion of all differently categorized articles based on the inclusion and exclusion criteria. After screening all titles independently, the IRA yielded a sufficient agreement between the two reviewers (97.58%; $\kappa = 0.56$). If at least one reviewer argued for inclusion at this stage, the article was moved into the next stage of abstract screening. At this point, 338 potentially relevant abstracts were examined and an excellent IRA was reached (94.67%; $\kappa = 0.92$). In case of initial disagreement, study records were discussed by the two reviewers and a decision for or against full-text screening was made. Lastly, 70 full texts were screened independently, the IRA was again found to be excellent (91.43%; $\kappa = 0.87$). Uncertainties were discussed with the whole project group. Within this process, 33 articles were identified and one more article was found through manual reference list screening (Schöllhorn et al., 2012). Finally, 34 articles were included for systematic review.

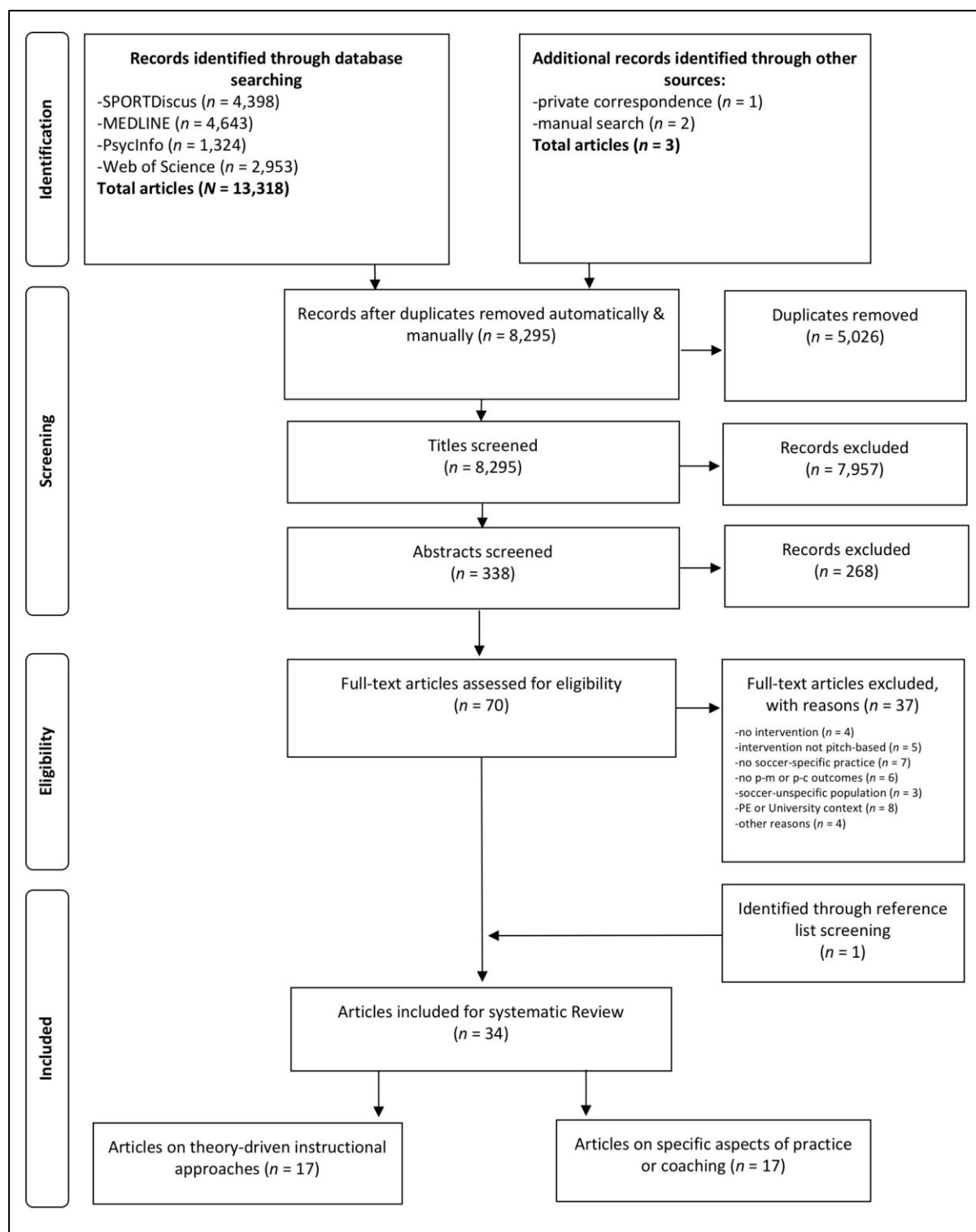


Figure 15. PRISMA flowchart for the documentation of the systematic search process.

Note. The 17 articles on theory-driven instructional approaches include 18 individual studies. PE = Physical Education; p-c = perceptual-cognitive; p-m = perceptual-motor.

Data extraction

The data of included studies were extracted using a Microsoft Excel spreadsheet. All accessible information about the study, participant characteristics, intervention characteristics, instruments, outcome variables, as well as statistical techniques used to assess outcome effects were extracted. To determine whether a quantitative synthesis is possible based on reported data, descriptive and inferential statistics were also extracted. Necessary missing data was requested from the corresponding authors.

Assessment of quality in reporting and risk of bias

To judge the quality in reporting and the risk of bias in individual studies, all studies underwent a detailed assessment using an augmented version of the *Downs & Black Checklist* (Downs & Black, 1998) as well as a slightly modified version of the *Template for Intervention Description and Replication* (TIDieR; Hoffmann et al., 2014).¹¹

The Downs & Black Checklist (Downs & Black, 1998) was developed for the rating of both randomized and non-randomized studies and has been recently used within systematic reviews and meta-analyses in sports sciences (Davies et al., 2017; Grgic et al., 2018; Ramos et al., 2020). Conventions for the studies' quality scores used in previous reviews were adopted but transferred to percentage as not all items were applicable to all studies. Good methodological quality is represented by a score $\geq 70\%$. A score $\leq 35\%$ represents a low methodological quality. Scores between these thresholds were considered as moderate.

¹¹ The modified checklists, including further specifications of the items, are accessible in the OSF project for this publication (<https://osf.io/85tjg/>).

The TIDieR (Hoffmann et al., 2014) consists of 12 items to assess the quality in reporting of interventions. With the objectives of this systematic review in mind, a detailed intervention description is essential to interpret the results, allow potential replications, and provide coaches with evidence-based recommendations for their work.

To provide a reliable assessment, a similar procedure as for the systematic screening process was applied. An excellent IRA for both the Downs & Black checklist (95.76% [90.91, 100%]; $\kappa = .91$ [.71, 1]) and the TIDieR (96.43% [81.1, 100%]; $\kappa = .92$ [.71, 1]) was achieved. Results for both scales were reported by mean (*M*), standard deviation (*SD*), median (*Mdn*), and range.

Narrative and quantitative synthesis

The study characteristics and results were synthesized narratively for all included studies to provide a descriptive overview of the existent research. Based on this narrative synthesis as well as the judgement of quality in reporting and risk of bias, it was discussed whether an additional quantitative synthesis is possible according to criteria outlined in the PRISMA-P (Bergmann et al., 2020).

Performing a meta-analysis was deemed inappropriate due to the heterogeneity of dependent variables and study designs (e.g., randomized/non-randomized studies; parallel-group/cross-over designs), as well as differences in the studies' quality. More specifically, pooling the effects as done within a meta-analysis was thought to lead to a comparison of dissimilar studies, the inclusion of poorly designed studies, and thus, to invalidate results (Deeks et al., 2021; Tod, 2019). However, to estimate the intervention effect sizes in controlled studies, the effect size *d* was calculated in two different ways based on the reported data in the original publications. *First*, if the effectiveness was analyzed by group x time interactions, *d* was calculated from the interaction effect according to

Cohen (1988). *Second*, if differences between groups at pre- and post-test were used to analyze the effectiveness (i.e., acquisition effects), d_{ppc2} was computed (see Equations 1-3; Morris, 2008, p. 369):

$$d_{ppc2} = c_P \left[\frac{(M_{post,T} - M_{pre,T}) - (M_{post,C} - M_{pre,C})}{SD_{pre}} \right] \quad (1)$$

where the pooled standard deviation is defined as

$$SD_{pre} = \sqrt{\frac{(n_T - 1)SD_{pre,T}^2 + (n_C - 1)SD_{pre,C}^2}{n_T + n_C - 2}} \quad (2)$$

and

$$c_P = 1 - \frac{3}{4(n_T + n_C - 2) - 1} \quad (3)$$

The d_{ppc2} was also applied when multivariate statistics were used to classify effects for single outcome variables. If a retention-test was conducted and all relevant data was available, d_{ppc2} was calculated using pre- and retention-test data to estimate learning effects.

To consider the intervention duration as a potential moderator, studies were classified as short- (i.e., ≤ 6 sessions or 180 minutes), mid- (i.e., ≤ 24 sessions or 720 minutes), and long-term (i.e., ≥ 25 sessions or 2250 minutes) interventions. Similar approaches to synthesize intervention effects quantitatively were recently used within systematic reviews in sports science research (e.g., Demetriou & Höner, 2012; Raabe et al., 2019). Results are reported by the range of significant and non-significant effects, the percentage of significant effects, as well as the median when three or more effect sizes were found. Recommendations by Cohen (1988) were used to classify small ($d \geq .20$), medium ($d \geq .50$), and large effects ($d \geq .80$). Effects displayed as positive values represent improvements in the respective outcome in favor of the intervention groups (IGs), while negative values represent greater improvements in control groups (CGs)

Results

From the 34 identified articles, 85.7% were published between 2010 and 2020, revealing an increase in the number of relevant publications in recent years. The publication by (Schöllhorn et al., 2006) includes two studies so that in total 35 individual studies were reviewed. All 35 studies were analyzed regarding their theoretical frameworks and methodological approaches (objectives 1 & 2). To investigate and compare the effectiveness (objective 3), only the 27 controlled studies were considered, while 8 studies without a CG were excluded.

Theoretical frameworks and intervention content (perspective 1)

The studies can be grouped into two overarching categories (see *Figure 15*). The *first group* ($n = 18$) represents studies in which interventions were designed based on theory-driven instructional approaches to practice and coaching. The *second group* ($n = 17$) includes studies investigating specific aspects of either the practice design or coaching behavior and interventions were mostly not grounded in theoretical frameworks

In the *first group of studies*, interventions were based on mainly three different theoretical and methodological underpinnings, namely *DL*, *TGfU*, and *NLP* (see *Table 4*). With nine studies, most utilized the *DL* approach. Of these nine studies, seven compared *DL* to *traditional learning* (*TL*) methods. Additionally, Coutinho et al. (2018) compared an enrichment program of *DL* to a non-active CG, and Gaspar et al. (2019) investigated acute effects after *DL* and *TL* sessions in a single group design.

TGfU was investigated in five studies. Two of these compared *TGfU* with *TL*, primarily applying technical drill practices supported by direct instructions (Práxedes et al., 2016; Sierra-Ríos et al., 2020). The further *TGfU*-studies without CGs only investigated within-group changes.

The remaining four studies in this first group investigated *NLP*. Roberts et al. (2020) compared *NLP* to promote youth academy attackers' individual learning objectives to a practice program grounded in information-processing theory. Práxedes, Del Villar, et al. (2018) compared *NLP* to a drill-based and technically focused *TL* program. Two studies without CG investigated the effects of *NLP* in a single-group design (Práxedes et al., 2019) or by comparing the effects in different performance groups (Práxedes, Moreno, et al., 2018).

Within the *second group of studies*, specific aspects of practice and coaching were investigated (see *Table 5*). Only four studies reported skill acquisition frameworks or discussed the results in the light of theoretical considerations (Haaland & Hoff, 2003; Raastad et al., 2016; Schwab et al., 2019; Weigelt et al., 2000).

Sixteen studies focused on the design of practice tasks, whereby a multitude of different aspects and outcomes were pursued. For instance, seven studies examined the effects of drill-based practices on technical outcomes. Within this group, two interventions only included deliberate technical drill practices (Montesano & Mazzeo, 2019; Weigelt et al., 2000). Others applied drill-based practices with subsequent game-based situations (e.g., Holt et al., 2012; Miranda et al., 2013) or combined it with coordination exercises (Boraczyński et al., 2019; Kösal et al., 2020).

Another five studies examined technical drill-practice programs focusing on the players' non-dominant leg performance (e.g., Teixeira et al., 2003). Finally, two studies examined game-based interventions (Arslan et al., 2020; Radziminski et al., 2013), and another two the effects of practicing with modified ball sizes (Bekris et al., 2012; Raastad et al., 2016). Lastly, as the only study on coaches' behavior, Schwab et al. (2019) compared the effects of internal and external focus feedback for learning the knuckle ball freekick technique.

Table 4. Characteristics of studies investigating theory-driven instructional approaches to practice and coaching ($n = 18$).

Author (year)	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Differential Learning (DL; n = 9)							
Bozkurt (2018)	TUR	Pre- to post- test design with CG	15 (2)	Age = 15	n. r.	n. r.	A supplemental drill-based <i>DL</i> program to improve passing, dribbling, and feet-juggling was compared to a drill-based <i>TL</i> program with corrective feedback.
Coutinho et al. (2018)	POR	Pre- to post- test design with CG	30 (4)	$M_{DLU15}=14.2 \pm 0.8$ $M_{DLU17}=15.8 \pm 0.8$ $M_{CGU15}=13.9 \pm 0.5$ $M_{CGU17}=16.1 \pm 0.7$	male	RL	An enrichment <i>DL</i> program to improve attackers’ technical skills and creativity was compared to a non-active CG. <i>DL</i> included physical literacy, technical exercises, and SSGs.
Gaspar et al. (2019)	POR	Pre- to post- test design	20 (1)	$M=13.8 \pm 0.6$	n. r.	RL	Acute effects of a session blocked DL in comparison to a session blocked <i>TL</i> with movement feedback. Both sessions aimed at improving goal-shooting velocity and accuracy.
Hossner et al. (2016)	GER	Pre- to post- test design with CG	28 (3)	$M=13.8 \pm 1.1$ Range: 12-15	male	RL	Comparison of drill-based <i>DL</i> without augmented feedback, <i>DL</i> with augmented feedback, and methodologically structured <i>TL</i> to promote players’ shooting accuracy.
Ozuak & Çağlayan (2019)	TUR	Pre- to post- test design with CG	52	$M_{IG}=12.03 \pm 0.44$ $M_{CG}=12.05 \pm 0.46$ Range: 12-13	n. r.	AL	Drill-based <i>DL</i> , implemented in the regular practice schedule, was compared to a CG that participated in the regular <i>TL</i> practice.
Santos et al. (2018)	POR	Pre- to post- test design with CG	40 (4)	$M_{DLU13}=11.1 \pm 0.5$ $M_{DLU15}=13.1 \pm 0.3$ $M_{CGU13}=11.4 \pm 0.5$ $M_{CGU15}=13.0 \pm 0.8$	n. r.	RL	Game-based <i>DL</i> , focusing on intertrial variability, was compared to game-based practice supported by specific instructions and error correction of a coach. The practice programs are aimed at improving the players’ creativity.
Schöllhorn et al. (2006; study 1)	GER	Pre- to post- test design with CG	8 (2)	Adult	n. r.	5 th Div.	Drill-based <i>DL</i> to improve passing accuracy was compared to <i>TL</i> based on little inter-trial variability and descriptions of the ideal movement technique.
Schöllhorn et al. (2006; study 2)	GER	Pre-, to post-, and ret-test design with CG	18 (2)	Adult	male	5 th & 7 th Div.	Blocked <i>DL</i> to improve goal shooting accuracy was compared to <i>TL</i> based on a high number of repetitions and corrective feedback.
Schöllhorn et al. (2012)	GER	Pre-, post-, ret-test de- sign with CG	12 (3)	$M_{DLB}=24.5 \pm 2.1$ $M_{DLR}=24.5 \pm 2.1$ $M_{CG}=23.8 \pm 3.9$	n. r.	8 th Div.	Random and blocked <i>DL</i> to improve ball control and shooting accuracy was compared to blocked <i>TL</i> focusing on an ideal movement technique and error corrections.

Teaching Games for Understanding (TGfU; n = 5)							
Barquero-Ruiz et al. (2021)	SPA	Pre-test to post-test design	20 (1) ^a	$M = 9.74 \pm 0.79$	male & female	LL	The <i>TGfU</i> intervention focused on principles of play in defense and the attack. Each session started with a game form followed by a teaching for understanding period. Technical skills were practiced in drills before returning to a modified game form.
Harvey et al. (2010)	UK	Multiple baseline quasi-experimental design	34 (2)	Range _{First year} : 14-15 Range _{Varsity} : 14-18	male	RC & CP	A <i>TGfU</i> intervention focusing on: “defending as a unit of three players” was conducted. SSGs, phases of play (e.g., offensive vs. defensive on one goal), and functional technical/tactical practice were applied.
Práxedes et al. (2016)	SPA	Quasi-experimental design with CG	18 (2)	$M = 10.7 \pm 0.60$	n. r.	YL	<i>TGfU</i> , based on modified games and questioning of the coach to improve the players’ offensive tactical behavior, was compared to <i>TL</i> , primarily including technical drills that differed from real game situations.
Práxedes Pizarro et al. (2017)	SPA	Intra-group quasi-experimental design	9 (1)	$M = 10.55 \pm 0.52$	male	RL	A <i>TGfU</i> intervention, including a question-and-answer approach by the coach, to improve the players’ decision-making and skill execution was applied. The complexity of the practice program increased progressively during the intervention period.
Sierra-Ríos et al. (2020)	SPA	Non-probabilistic inter-subject case design	30 (2)	$M_{TGfU} = 10.1 \pm 0.10$ $M_{DI} = 10.60 \pm 0.57$	n. r.	CP	<i>TGfU</i> , based on modified games, was compared to a direct instructional model based on technical and analytical exercises. Interventions aimed at improving players’ on- and off-the-ball decision-making and skill execution.
Non-linear pedagogy (NLP; n = 4)							
Práxedes Moreno et al. (2018)	SPA	Quasi-experimental design	19 (2)	$M_{av.} = 10.55 \pm 0.51$ $M_{low} = 10.66 \pm 0.50$	n. r.	av. & low	Two <i>NLP</i> interventions to develop players’ decision-making and skill execution were applied. In the first intervention, SSGs with numerical superiority in attack (+1 player) were conducted. In the second intervention, SSGs with numerical equality were applied.
Práxedes, Del Villar et al. (2018)	SPA	Quasi-experimental design with CG	19 (2)	$M_{NLP} = 10.55 \pm 0.51$ $M_{TL} = 11.77 \pm 0.66$	male	LL	The effects of a <i>NLP</i> -intervention, using SSGs with numerical superiority in the attack, were compared to <i>TL</i> , prioritizing technical components. The <i>NLP</i> exercises referred to a principle of play (e.g., maintaining possession of the ball).

Práxedes et al. (2019)	SPA	Intra-group quasi-experimental design	19	$M = 10.63 \pm 0.49$	n. r.	av. to low	Intervention based on the principles of <i>NLP</i> to improve the players' tactical decision-making and skill execution performance. SSCGs with numerical superiority were applied focusing on a tactical principle of play.
Roberts et al. (2020)	UK	Randomized cross-over trial	22 (2)	$M_{IG} = 16.4 \pm 0.4$ $M_{CG} = 16.1 \pm 0.2$	n. r.	YA	<i>NLP</i> , based on representative learning designs and perception-action couplings, was compared to a linear information-processing practice program regarding the promotion of attackers' individual learning objectives.

Note. If authors did not sufficiently report the applied study design, the research decided on an appropriate descriptive terminology. AL = Amateur Leagues; Av. = average; CG = control group; Div. = division; *DL* = differential learning; DLB = differential learning blocked; DLR = differential learning random; IG. = intervention Group; LL = local level; *NLP* = non-linear pedagogy; n. r. = not reported; PL = performance level; RL = regional level; *TGfU* = Teaching Games for Understanding; *TL* = traditional learning YA = youth academy; YL = Spanish youth football league.

^a The 20 participants were randomly divided into two groups that practiced the same content, but the coaches changed between the groups to reduce clustering effects.

Table 5. *Characteristics of studies investigating specific aspects of practice or coaching (n = 17).*

Author (year)	Country (ISO code)	Study design	Participants				Study description
			N (groups)	Age (years)	Sex	PL	
Effects of technical drill practice (with subsequent SSGs or coordination exercises; <i>n</i> = 7)							
Boraczyński et al. (2019)	POL	Single-center, parallel, partially group matched, controlled, and longitudinal design	75 (3)	Range: 10.1-11.9	male	n. r.	Proprioceptive-coordination training (PCT; including 24 technical exercises in combination with coordination exercises) on the players' soccer-specific motor performance was compared to a usual care and a non-active CG.
Holt et al. (2012)	UK	Single subject, multiple baseline experiment	5 (1)	Range: 10-12	male	YA	The effectiveness of the passing-square to promote awareness, passing, and first touch skills was investigated. Based on criteria for successful technical execution, the intervention included individual goal setting, peer-assessed feedback, and group contingency.

Kösal et al. (2020)	TUR	Pre- to post-test design with CG	45 (3)	Range: 10-13	male	n. r.	An additional practice program, including combined technical and coordination exercises to promote soccer-specific technical skills, was compared to regular and unstructured practice CGs.
Miranda et al. (2013)	BRA	Pre- to post-test design	13 (1)	Age = 17	n. r.	NL	The effects of a practice program, including position-specific technical and tactical exercises, as well as gameplay situations on the players' technical performance, were investigated.
Montesano & Mazzeo (2019)	ITA	Pre- to post-design with CG	20 (2)	$M = 16 \pm 0.5$	n. r.	CP	The effects of additional technical practice on the players' passing and shooting performance were investigated and compared to a CG without additional practice.
Weigelt et al. (2000)	UK	Pre- to post-test design with CG	20 ^a (2)	Range: 19-20	male	IM	Learning and transfer effects of additional, individual foot-juggling practice without any specific guidance or learning strategies were investigated and compared to a non-active CG.
Zago et al., (2016) ^c	ITA	Pre- to post-test design with CG	20 (2)	$M = 11.5 \pm 0.3$	male	RL	Practice, including technical drills and phases of play situations by using tape matrix structures as three-dimensional spatio constraints was compared to a CG that participated in technical drills, SSGs, and situation games without such spatio constraints.
Practice to reduce lateral asymmetries or improve the non-dominant leg performance (n = 5)							
Guilherme et al. (2015a)	POR	Randomized cross-over design	50 (2)	$M = 9.54 \pm 1.86$	male	EL	The intervention period included additional drill-based practices for improving soccer-specific technical skills in the non-preferred leg. The control period did not include additional exercises.
Guilherme et al. (2015b)	POR	Pre- to post-test design with CG	71 (6)	$M = 14.44 \pm 1.04$ Range: 11-16	male	CP	The IG participated in drill-based and technically focused practice with a more frequent use of the non-dominant leg. The CG participated in a practice program by using both legs equally.
Haaland & Hoff (2003)	NOR	Pre- to post-test design with CG	39 (2)	Range: 15-21	male	CP	The IG participated in an increased volume of non-preferred leg practice within the team practice context. The effects were compared to a usual care CG.
Teixeira et al. (2003)	BRA	Pre- to post-test design with CG	24 (2)	Range: 12-14	n. r.	n. r.	The 'non-preferred leg group' practiced 45 minutes in three out of five weekly sessions including drills and SSGs by only using the non-preferred leg. The 'preferred-leg group' used both legs equally.

Witkowski et al. (2011)	POL	Pre- to post-test design with CG	37 (3)	Age = 13	male	EL	One group predominantly used the non-dominant leg in technical drills, while another group used both legs equally. The effects were compared to a regular practice CG.
Effects of game-base practice programs (n = 2)							
Arslan et al. (2020)	TUR	Experimental parallel matched group design	20 (2)	$M = 14.2 \pm 0.5$	male	YA	The effects of game-based practice by using various forms of SSGs were compared to a running-based HIIT training program were compared.
Radziminski et al. (2013)	POL	Pre- to post-test design with CG	20 (2)	$M_{SSG} = 15.1 \pm 0.67$ $M_{RG} = 15.0 \pm 0.46$	n. r.	n. r.	The effects of a practice program including various forms of 3v3 SSGs on the players' technical actions were investigated and compared to a running-based HIIT program.
Practice with modified ball sizes (n = 2)							
Bekris et al. (2012)	GRE	Pre- to post-test design with CG	54 (4)	$M = 11 \pm 0.6$	n. r.	n. r.	The effects of technical practice with a size-2 ball in different frequencies and with different content were compared to a CG that practiced with a size-4 ball.
Raastad et al. (2016)	NOR	Pre- to post-test design	17 ^b (2)	$M = 16.6 \pm 0.93$ Range: 16-19	male & female	RL	Two groups practiced soccer juggling in two different conditions: One group practiced with a smaller size 1 ball. The other group practiced with a larger size 4 ball. The test ball was a size 3 ball.
Internal and external focus feedback (n = 1)							
Schwab et al. (2019)	GER	Pre- to post-, & ret-test design with CG	56 (4)	Adol.: U15-U17 Adults: n. r.	male	LL	The effects of external compared to internal focus feedback on learning the knuckle ball free-kick technique were investigated. Specific instructions were delivered after every third free kick.

Note. If authors did not sufficiently report the study design, the research decided on an appropriate descriptive terminology. Adol. = adolescents; CG = control group; CP = competitive players; EG = experimental group; EL = elite level; EP = FD = first division; HIIT = High-intensity interval training; IG = intervention group; IM = intermediate level; LL = Local level; LSPT = Loughborough Soccer Passing Test; NL = national level; n. r. = not reported; RG = running group; RL = regional level; SSG = small-sided games; YA = youth academy.

^a Weigelt et al. (2000): the sample was reduced from 26 to 20 participants as two players did not participate in every session and goalkeepers were excluded from analyses.

^b Raastad et al. (2016): the sample was reduced from 22 to 17 participants that completed the practice sessions and were not injured.

^c Zago et al. (2016): the sample was reduced from 26 to 20 participants that were able to participate in every session and test.

Methodological approaches (perspective 2)

Study designs

Various study designs were used to investigate the influence of practice design and coaching behavior on soccer players' skill acquisition (see *Tables 4* and *5*). Single-group ($n = 7$; 20.0%), as well as multi-groups designs with two ($n = 19$; 54.3%), three ($n = 6$; 17.1%), four ($n = 2$; 5.7%) or six groups ($n = 1$; 2.9%) were found. Across the 27 controlled studies, different practice activities of CGs were found that need to be considered for interpreting intervention effects (see in detail Supplement III). For example, most CGs practiced according to different approaches compared to the IG ($n = 17$) or participated in their regular ("usual care") practice ($n = 4$). Another three studies compared the interventions to non-active CGs. Only three cases were identified, in which different practice or coaching methods as well as usual care or non-active CGs were investigated (e.g., Witkowski et al., 2011).

Measurements and statistical analyses

In 19 studies (54.3%) two measurement points were assessed (i.e., mostly pre- and post-test). Twelve studies (34.3%) conducted three, and three studies (11.4%) conducted four measurements (e.g., through intermediate measurements). Only six studies (17.1%) conducted a retention test to assess learning effects. Holt et al. (2012) observed the players' performances during the intervention in every session. Five studies that used systematic in-game observations averaged the performances from different matches as values for the respective measurement point (e.g., Práxedes Pizarro et al., 2017).

For assessing outcome effects, most studies used repeated-measures analyses of variance ($n = 14$, 40%). Four studies (11.4%) used multivariate analyses of variance and three studies (8.6%) applied t-tests. Another eight studies (22.9%) used non-parametric tests

(e.g., U-test and Wilcoxon test). Two studies (5.7%) reported the players' improvements descriptively for each player (Holt et al., 2012; Montesano & Mazzeo, 2019) or used non-clinical versions of magnitude-based inferences (Coutinho et al., 2018; Gaspar et al., 2019).

Intervention characteristics

The intervention duration varied substantially across studies (see *Table 7*). Large differences in the intervention duration in weeks ($M = 11.58$, $SD = 11.63$, $Mdn = 8$, [1, 48]), the number of sessions ($M = 29.41$, $SD = 34.27$, $Mdn = 15$, [1, 144]), as well as the sessions' duration in minutes ($M = 45.00$, $SD = 28.36$, $Mdn = 30$, [10, 120]) were found. Further, the number of sessions per week ranged from one to seven sessions ($M = 2.57$, $SD = 1.24$, $Mdn = 2$). Overall, four studies (11.4%) can be classified as short-, 20 studies (57.1%) as mid-, and 10 studies (28.6%) as long-term interventions. One study could not be categorized due to incomplete descriptions (Montesano & Mazzeo, 2019).

Participant characteristics

In total, 992 participants were investigated in the reviewed studies, consisting of on average 28.34 participants per study ($SD = 17.16$, $Mdn = 20$, [5, 75]). The number of participants per group ranged from four to 30 ($M = 13.52$, $SD = 6.36$, $Mdn = 11.66$).

Most studies investigated male participants ($n = 17$, 48.6%), two studies (5.7%) examined both males and females (Barquero-Ruiz et al., 2021; Raastad et al., 2016) and 16 studies (45.7%) did not specify participants' sex. Whereas four studies (11.4%) investigated adult players and two studies (5.7%) examined both youths and adults, most studies utilized youth soccer players (82.9%, $n = 29$). Thereby, most studies were conducted with participants between the age of 11-15 ($n = 20$).

Twentynine studies reported the performance level of the sample (82.9%; see *Tables 4 and 5*). A wide range of terminologies was found, in some cases corresponding to national league systems. Regional level players (incl. descriptions such as ,moderate level‘) were most frequently examined ($n = 11$, 31.4%), followed by studies with youth academy or national level players ($n = 6$, 17.1%) and local (or ‘low’) level players ($n = 4$; 11.4%). Two studies compared the effects of interventions with players on different performance levels (Harvey et al., 2010; Práxedes, Moreno, et al., 2018). Studies with adult participants investigated players from regional levels (i.e., 5th to 8th divisions). The youth and adult players in Schwab et al.’s (2019) study were recruited from local levels, Haaland and Hoff (2003) investigated competitive players.

Instruments

To assess outcome effects, skill tests were used in 22 studies (62.9%) and systematic observations were applied in 13 studies (37.1%; see in detail Supplement III). No study used both kinds of assessments. The systematic observations occurred in different contexts that included in-game observations during practice ($n = 7$), competition ($n = 5$), or technical drills ($n = 1$). The Game Performance Evaluation Tool (GPET; García López et al., 2013) was most frequently employed for in-game observations ($n = 6$), followed by the Game Performance Assessment Instrument (GPAI; Oslin et al., 1998; $n = 2$), the Creative Behavior Assessment in Team Sports (CBATS; Santos et al., 2017; $n = 2$), and the System of Assessment of Functional Asymmetry of the Lower Limbs in Football (SAFALL-FOOT; Guilherme et al., 2012; $n = 2$). SSGs, ranging from 3v3 to 8v8, were utilized for systematic observations.

Quality in reporting and risk of bias

The results for the assessment of the quality in reporting and risk of bias in individual studies are presented in *Figure 16* (see in detail Supplement II). On average, the score of the Downs & Black Checklist reveals a moderate methodological quality ($M = 55.65\%$, $SD = 12.86\%$, $Mdn = 57.69\%$). There are, however, large differences between studies ranging from 30.77% to 78.57% of the total score (2x low score, 5x good score). Most papers lacked a sufficient report of principal confounders (item 5), only four studies (11.4%) met this criterion. To assess outcome effects, 10 studies (28.6%) used assessments that were not evaluated regarding their reliability (item 20). Moreover, very few studies conducted a priori sample size estimations ($n = 5$, 14.3%), leading to an overall low statistical power.

The TIDieR displays large differences across studies with an average score of 59.11% ($SD = 22.52$, $Mdn = 66.67$, [11.11, 100]). Even the two studies that reached 100% did not differentiate for every single session but provided an overview of the intervention content across sessions (Roberts et al., 2020; Zago et al., 2016). Another 20 studies (57.1%) presented the procedures in a manner that permits the replication of at least parts of interventions. Lastly, 15 studies (42.9%) controlled as to whether the intervention was delivered as intended, but only nine studies reported underlying criteria of observation.

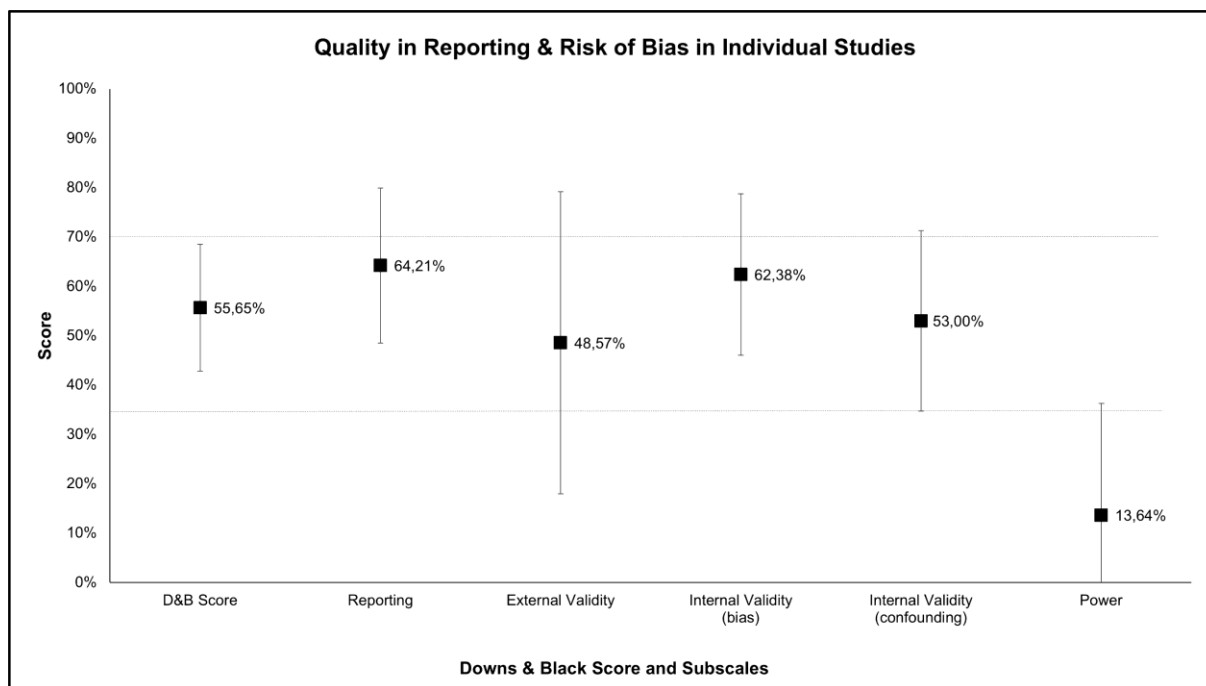


Figure 16. Quality in reporting and risk of bias in individual studies.

Note. D&B Score = Downs & Black score (all items). Results are presented as means with error bars that represent the standard deviation. The dashed lines show thresholds for low ($\leq 35\%$) and high ($\geq 70\%$) scores. It must be considered that the subscales external validity and power were calculated from only three and two items, respectively.

Outcome variables

A list of examined outcome variables is provided in *Table 6*. In total, 150 outcome variables were investigated. However, 123 different variants for operationalization (e.g., different skill tests) and different contexts of assessments (e.g., game formats for systematic observations) lead to a highly heterogeneous conglomeration of outcomes. Moreover, six studies employed overall performance scores which included perceptual-motor and perceptual-cognitive characteristics. Yet, none of these scores were calculated based on variables assessed in comparable contexts or with identical equations.

Table 6. Soccer-specific outcome variables ($n = 150$) from perceptual-motor and perceptual-cognitive skill domains.

Perceptual-motor domain ($n = 105$; 85)	Perceptual-cognitive domain ($n = 45$; 38)
<i>Technical performance (skill tests):</i>	<i>Tactical decision-making (in-game):</i>
Shooting/kicking/striking ($n = 25$; 16)	Decision-making cumulative ($n = 9$; 9)
Dribbling ($n = 19$; 17)	Passing ($n = 5$; 2)
Passing ($n = 15$; 14)	Dribbling ($n = 3$; 2)
Juggling ($n = 8$; 7)	
Ball reception/control ($n = 7$; 6)	<i>Decision-making (skill test):</i>
Turns ($n = 2$; 2)	Goal shooting ($n = 1$; 1)
Awareness ($n = 1$; 1)	
Ball bouncing ($n = 1$; 1)	<i>Defensive tactical behavior (in-game):</i>
Balance with ball ($n = 1$; 1)	Adjust ($n = 2$; 2)
Heading ($n = 1$; 1)	Covers ($n = 2$; 2)
1v1 ($n = 1$; 1)	
Execution time (LSST; $n = 1$; 1)	<i>Creativity (in-game):</i>
	Attempts ($n = 5$; 4)
<i>Technical skill execution (in-game):</i>	Fluency ($n = 5$; 4)
Skill execution cumulative ($n = 8$; 8)	Versatility ($n = 5$; 4)
Passes ($n = 5$; 2)	Fails ($n = 4$; 4)
Dribbles ($n = 4$; 3)	Originality ($n = 4$; 4)
(Goal) shots (2; 2)	
Preferred foot performance ($n = 2$; 1)	
Non-preferred foot performance ($n = 2$; 1)	

Note. Results in brackets represent the n of investigated variables (first number) and the n of different operationalizations (second number). Performance scores that were calculated from both perceptual-motor and -cognitive skill domains ($n = 6$) were not displayed in this table. LSST = Loughborough Shooting Skill Test.

On average, 4.29 ($SD = 3.39$, $Mdn = 4$, [1, 20]) outcome variables were investigated per study. 34 studies (97.2%) assessed perceptual-motor outcomes, such as the players' technical performance in skill tests or in-game technical executions. Eleven studies (31.4%) assessed perceptual-cognitive outcomes, such as the divergent (i.e., creativity) or convergent (i.e., decision-making) tactical performance. Two studies examined tactical behavior in defense (Barquero-Ruiz et al., 2021; Harvey et al., 2010), while all other studies addressed aspects in the attack.

Perceptual-motor outcomes, such as shooting accuracy or dribbling were most often collected via skill tests ($n = 22$ studies). Technical skill execution, assessed with the GPET

or GPAI, was the most frequently examined in-game variable ($n = 8$ studies). Five studies distinguished between different techniques (i.e., in-game passes or dribbles), while others reported cumulative variables.

Decision-making was the most often examined perceptual-cognitive outcome ($n = 9$ studies). Práxedes et al. (2016; 2018a; 2018b; 2019), Práxedes Pizarro et al. (2017), and Roberts et al. (2020) reported whether the decisions occurred in different contexts (i.e., passing, dribbling, or shooting) while others only provided accumulated performance values. Lastly, in-game creativity was examined in two studies (Coutinho et al., 2018; Santos et al., 2018).

Effectiveness of interventions (perspective 3)

Inferences on the effectiveness of interventions can only be drawn from the 27 controlled studies. The main results were narratively synthesized in *Table 7*. A summary of results for studies without a CG is provided in Supplement IV. For the quantitative synthesis of controlled studies, 51 effect sizes (26 significant; 50.98%) for perceptual-motor outcomes and 32 effect sizes (11 significant; 34.38%) for perceptual-cognitive outcomes could be recalculated (see *Table 8*). Given the large differences across studies (e.g., practice activities of CGs) a detailed analysis of individual studies is necessary.

Table 7. Narrative synthesis of the effectiveness of interventions in controlled designs ($n = 27$).

Author (year)	Groups	Intervention duration		Statistical analysis	Outcome variables	Main results
		Sessions (min. p. Session)	Weeks			
Differential Learning (DL; n = 8)						
Bozkurt (2018) ^a	-DL (n = 6) -TL (n = 6)	12 (20)	4	U-Test & Wilcoxon	Skill tests: -passing -dribbling -feet-juggling	No significant differences between groups in technical outcomes were found at pre- or post-test. Thus, neither DL nor TL was found to be more effective for promoting soccer-specific techniques.
Coutinho et al. (2018) ^a	-DL U15 (n = 9) - DL U17 (n = 6) -usual care U15 (n = 9) -usual care U17 (n = 6)	20 (25)	10	Non-clinical magnitude-based inferences	In-game: -technical performance (dribbles, shots, & goals) -creativity (fluency, attempts, & versatility)	In U15, greater improvements after DL compared to TL in all technical variables, fluency, and versatility were found. In U17, DL only achieved greater improvements in shooting, while no effects in further outcomes were found.
Hossner et al. (2016)	-DL (n = 9) -DL & FB (n = 9) -TL (n = 10)	12 (30)	6	Repeated measures ANOVA	Skill-test: -shooting accuracy	No significant interactions between the DL and TL groups, as well as DL with and without feedback groups, were found.
Ozuak & Çağlayan (2019)	-DL (n = 26) -usual care (n = 26)	24 (40-50)	8	U-Test & Wilcoxon	Skill tests: -creative speed test -dribbling -juggling -passing	The DL group achieved significantly greater improvements in creative speed and ball dribbling tests. No significant differences compared to the usual care group were found in juggling and passing.
Santos et al. (2018)	-DL U13 (n = 10) -DL U15 (n = 10) -TL U13 (n = 10) -TL U15 (n = 10)	40 (30)	20	ANCOVA	In-game: -creativity (fails, attempts, fluency, versatility & originality) in passes, dribbles, and shots	DL led to significantly greater effects in few creative components in both ages compared to TL. A decrease in fails in both ages was found. Significant differences were also found in attempts, originality, and most stressed in versatility. More significant and higher effect sizes were found in the U13 age group.
Schöllhorn et al. (2006; study 1)	-DL (n = 8) -TL (n = 8)	12 (20-40)	4	U-test	Skill test: -passing accuracy with non-dominant foot	Significant differences at post-test between groups reveal a greater effectiveness of DL in non-dominant foot passing accuracy compared to TL.

Schöllhorn et al. (2006; study 2)	-DL (n = 8) -TL (n = 8)	12 (25)	6	U-test	Skill test: -shooting accuracy	Significantly greater improvements after DL in shooting accuracy were found. DL also outperformed TL after one-year retention period.
Schöllhorn et al. (2012)	-DL blocked (n = 4) -DL random (n = 4) -TL (n = 4)	8 (25)	4	H-Test	Skill tests: -ball control -shooting accuracy	In the acquisition phase, only the blocked DL achieved greater improvements in goal shooting. At retention-test only the random DL outperformed TL. No differences in ball control were found.
Teaching Games for Understanding (TGfU; n = 2)						
Práxedes et al. (2016)	-TGfU (n = 9) -TL (n = 9)	21 (60)	12	MANOVA	In-game: -decision-making (passing & dribbling) -skill execution (passing & dribbling)	TGfU was found to be significantly more effective than TL in promoting decision-making (passing & dribbling). The only significant difference in the execution variables in favor of TGfU was found for passes.
Sierra-Ríos et al. (2020) ^a	-TGfU (n = 15) -DI (n = 15)	12 (80)	6	MANCOVA	In-game: -decisions (on- and off-the-ball) -executions (on- and off-the-ball)	A significantly greater reduction in the number of unsuccessful on-the-ball executions, a decrease in off-the-ball errors, and more successful off-the-ball actions after TGfU were present. No differences in the successful on-the-ball performance were found.
Non-linear pedagogy (NLP; n = 2)						
Práxedes, Del Villar et al. (2018)	-NLP (n = 10) -TL (n = 9)	14 (60)	7	MANOVA	In-game: -decision-making (passing & dribbling) -skill execution (passing & dribbling)	No significant group x time interaction was found. However, at post-test, the NLP group significantly outperformed the TL group in passing decisions and executions. No differences were found in dribbles.
Roberts et al. (2020)	-NLP (n = 11) -IP group (n = 11)	8 (60)	4	U-Test & Wilcoxon	Skill-test: -strong foot finishing -weak foot finishing -1v1 -decision-making	Significantly greater improvements in the NLP group compared to the IP group were found in 1v1 and decision-making skills. No significant differences were found in the technical shooting proficiency or the execution time.
Effects of technical drill practice (with additional SSGs or coordination training; n = 5)						
Boraczyński et al. (2019) ^a	-PCT (n = 26) -usual care (n = 27) -non-active (n = 22)	n.r. (30 min. add. practice)	12 months	Repeated measures ANOVA	Skill tests (dom. leg): -turning the ball backward -slalom dribbling	Only in the static balance test with a ball, a group x time interaction was found due to greater improvements in the PCT group at

					-static balance with a ball -kicking accuracy	peri- and post-test compared to the usual care group.
Kösal et al. (2020)	-coordination ($n = 15$) -usual care ($n = 15$) -unstructured ($n = 15$)	30 (30 min. add. practice)	10	Repeated measures ANOVA	<i>Skill tests:</i> -dribbling -passing -shooting -ball bouncing -wall volley	The coordination group improved in all variables and fewer within-group effects were found compared to the usual care group. The unstructured practice group did not improve in any variable. However, no interaction effects were reported.
Montesano & Mazzeo (2019)	-add. practice ($n = 9$) -usual care ($n = 9$)	n. r. (60-80)	n. r.	Descriptive analyses	<i>Skill tests:</i> -passing -shooting	Both groups descriptively improved in successful passes and goal shots. Descriptively greater improvements were found after add. practice.
Weigelt et al. (2000)	-intervention ($n = 10$) -non-active ($n = 10$)	28 (10)	4	MANOVA	<i>Skill-tests:</i> -juggling with feet -juggling with knees -ball control strong foot -ball control weak foot	A significant time x group effect due to improvements in knee juggling and ball control with both feet (transfer effect), as well as a trend towards better feet-juggling performance, was found.
Zago et al. (2016) ^a	-intervention ($n = 10$) -control ($n = 10$)	38 (¼ to ½ of the average session time of 98 min)	22	Repeated measures ANOVA	<i>Skill tests:</i> -LSPT -shuttle dribble test -slalom dribble test	A significant time x group interaction was found in the LSPT performance (execution time) due to greater improvements in the IG. No significant interactions in other variables were found.
Practice to reduce lateral asymmetries or improve the non-dominant leg performance ($n = 5$)						
Guilherme et al. (2015a)	Cross-over: -group 1 ($n = 26$) -group 2 ($n = 24$)	48 (20)	16	Repeated measures ANOVA	<i>In-game:</i> -preferred foot performance utilization -non-preferred foot performance utilization	The non-dom. leg practice significantly increased the utilization rate during match-play. The interruption of the additional practice during the retention period partially reversed this effect.
Guilherme et al. (2015b)	-NPL U13 ($n = 12$) -NPL U15 ($n = 11$) -NPL U17 ($n = 12$) -CG U13 ($n = 12$) -CG U15 ($n = 12$) -CG U17 ($n = 12$)	108 (20)	36	Repeated measures ANOVA	<i>In-game:</i> -preferred foot performance utilization -non-preferred foot performance utilization	The experimental practice program led to a significantly greater utilization rate of the non-preferred leg during match-play, while the use of the preferred leg significantly decreased.

Haaland & Hoff (2003) ^a	-intervention ($n = 18$) -usual care ($n = 21$)	n. r. (n. r.)	8	Repeated measures ANOVA	<i>Skill tests:</i> -slalom dribbling -ball control (chest) and volley shooting accuracy -one-touch passing accuracy	Significantly greater improvements in the intervention group compared to the CG in both the dominant and non-dominant legs in dribbling, volley shooting, and one-touch passing variables.
Teixeira et al. (2003)	-12-year PL ($n = n. r.$) -13-year PL ($n = n. r.$) -15-year PL ($n = n. r.$) -12-year NPL ($n = n. r.$) -13-year NPL ($n = n. r.$) -15-year NPL ($n = n. r.$)	80 (45)	16	Repeated measures ANOVA	<i>Skill tests:</i> -speed of dribbling -kicking for accuracy -kicking for force	Only in speed dribbling, the lateral asymmetry was significantly reduced from pre- to post-test in the non-preferred-leg group. In other variables, no significant differences between groups were found due to improvements in both the preferred and non-preferred-leg groups.
Witkowski et al. (2011)	-non-dom-leg ($n = n. r.$) -both legs ($n = n. r.$) -usual care ($n = n. r.$)	144 (n. r.)	12 months	t-tests	<i>Skill tests:</i> -dribbling -ball striking	Both the non-dominant and dominant leg groups achieved greater improvements in technical outcomes compared to the usual care group.
Effects of game-based practice programs ($n = 2$)						
Arslan et al. (2020)	-SSG ($n = 10$) -HIIT ($n = 10$)	10 (10-18)	5	Repeated measures ANOVA	<i>Skill tests:</i> -dribbling speed -zigzag agility with ball	Both groups improved in their technical performance from pre- to post-test. Higher within-group effects were found in the SSG group. No interaction effects were reported.
Radziminski et al. (2013) ^a	-SSG ($n = 9$) -Running ($n = 10$)	16 (90)	8	Repeated measures ANOVA	<i>Skill tests:</i> -juggling -rotation pass -passing -dribbling -heading, -bench passing -shooting accuracy	No significant group x time interaction was found. The performance increased in both the SSG and Running groups.
Practice with modified ball sizes ($n = 2$)						
Bekris et al. (2012)	-competitive ($n = 12$) -20-min ($n = 13$) -30-min ($n = 14$) -control ($n = 15$)	12 (20-30)	n. r.	Repeated measures ANOVA	<i>Skill tests:</i> -passing -juggling -running with the ball	Significantly greater improvements in juggling, running with the ball, and turning in all intervention groups compared to the CG were reported. No effects in passing were found.

					-turning	
Raastad et al. (2016)	-smaller ball ($n = 11$) -larger ball ($n = 11$)	24 (10)	6	Repeated measures ANOVA	<i>Skill tests:</i> -juggling -ball reception	The ball juggling performance of both groups increased from pre- to post-test, but no interaction effect regarding transfer effects was found.
Internal and external focus feedback ($n = 1$)						
Schwab et al. (2019)	-internal adol. ($n = 10$) -internal adult ($n = 18$) -external adol. ($n = 10$) -external adult ($n = 18$)	6 (20)	3	Repeated measures ANOVA	<i>Skill test:</i> -rotational ball velocity -linear ball velocity	External focus feedback led to a significantly greater reduction in the rotational ball velocity from pre- to post and pre- to re-test. No effects on the linear ball velocity were found.

Note. Add. = additional; Adol. = adolescent; DI = Direct Instruction *DL* = Differential Learning; *DL* & FB = Differential Learning & Feedback; HIIT = High-Intensity Interval Training; LSST = Loughborough Shooting Skill Test; TL = Traditional Learning; *TGfU* = Teaching Games for Understanding; NPL = non-preferred leg group; PL = preferred leg; SSG = small-sided games.

^a Further variables, that do not correspond to the perceptual-motor or perceptual-cognitive skill domains (e.g., physiological outcomes), were investigated in the study.

^b Arslan et al. (2020), Kösal et al. (2020), and Witkowski et al. (2011) did not conduct or sufficiently report interaction effects. Thus, the narrative synthesis is limited to the comparison of time effects between groups.

Table 8. Recalculated effect sizes for perceptual-motor and perceptual-cognitive outcomes from controlled designs.

Category (N of studies)	Study design		N of effects		Perceptual-motor domain			Perceptual-cognitive domain		
	UCD	CD	<i>d</i>	<i>d</i> _{ppc2}	N of effects (% sig.)	Median	Range	N of effects (% sig.)	Median	Range
DL (9) ^a	1	8	4	43	21 (33.33%)	0.49	-0.15-2.37	26 (23.08%)	0.45	-0.23-1.92
TGfU (5)	3	2	0	10	6 (66.70%)	1.98	0.45-2.80	4 (100%)	1.89	0.90-2.62
NLP (4) ^b	2	2	2	5	5 (20.00%)	0.58	0.17-1.05	2 (50.00%)	0.83	0.60-1.05
Drill-based (7)	2	5	6	0	6 (50.00 %)	0.73	0.12-1.20	-	-	-
Non-dom. Leg (5) ^c	0	5	10	0	10 (100%)	1.16	0.82-2.91	-	-	-
Game-based (2) ^d	0	2	0	0	-	-	-	-	-	-
Mod. ball sizes (2)	0	2	1	0	1 (0.00%)	0.36	0.36	-	-	-
Instructions (1)	0	1	2	0	2 (50.00%)	0.35	0.11-0.59	-	-	-
Total (35)	8	27	25	58	51 (50.98%)	0.74	-0.15-2.91	32 (34.38%)	0.61	-0.23-2.62

Note. All effect sizes comparing intervention and control groups from pre- to post, but also from pre- to ret-test were included in this overview. CD = controlled designs; UCD = uncontrolled designs. Effect sizes from studies on instructional approaches are provided in the upper half of the table. Effect sizes from studies on specific aspects of practice or coaching are presented below. ^aSchöllhorn et al. (2012) compared random DL, blocked DL, and TL groups. Only the effects for the comparisons of the random and blocked DL groups compared to the TL group, but not for the comparisons of random and blocked DL groups, were considered. ^bPráxedes et al. (2018b) used a multivariate analysis of variance including both the perceptual-motor (i.e., skill execution in passing and dribbling) and perceptual-cognitive outcomes (i.e., decision making in passing and dribbling). The non-significant effect ($d = 1.05$) is once included in the perceptual-motor and perceptual-cognitive domain as no differentiation was possible based on the reported results. ^cGuilherme et al. (2015a; 2015b) reported the effects of the utilization rate for both the dominant and non-dominant leg. As a reduction of lateral asymmetries was intended, the higher utilization rate of the non-dominant leg, but also the lower utilization rate of the dominant leg is displayed as a positive effect. ^dNo effects for game-based studies could be recalculated due to missing data.

Effectiveness of instructional approaches

Differential Learning. Comparisons of *DL* and *TL* led to ambivalent results across studies (see *Table 7*). Most studies assessed the effectiveness in the acquisition phase regarding precision-based technical variables (e.g., shooting accuracy). Only three out of thirteen effects reached significance and, thus, reveal greater effectiveness of *DL* ($Mdn(d) = 0.45$; $-0.15 \leq d \leq 2.37$). Regarding time-based tests (i.e., dribbling speed), Ozuak and Çağlayan (2019) found two significant effects when supplemental *DL* was compared to a usual care CG ($0.49 \leq d \leq 1.22$). Hence, Bozkurt (2018) did not confirm the greater effectiveness of *DL* compared to *TL* in dribbling ($d = 0.11$). Only two studies applied retention tests to assess learning effects in goal shooting precision (Schöllhorn et al., 2006 [study 1]; Schöllhorn et al., 2012). In both studies, significantly greater effects in favor of *DL* were found, although Schöllhorn et al. (2012) only found a statistically relevant retention-effect for random *DL* ($Mdn(d) = 1.14$; $0.64 \leq d \leq 1.97$; two of three significant).

Coutinho et al. (2018) compared *DL*, using SSGs and technical drills, to a non-active group. Non-clinical magnitude-based inferences displayed greater acquisition effects for *DL* in U15 players regarding in-game dribbles and shots, as well as creative components fluency and versatility. In U17, greater effectiveness was only found in the technical shooting performance. Santos et al. (2018) found positive effects in favor of game-based *DL* compared to a game-based CG in few creative components. More significant and slightly higher effects in the U13 ($Mdn(d) = 0.40$; $0 \leq d \leq 1.08$; four of 15 significant) compared to U15 ($Mdn(d) = 0.27$; $-0.08 \leq d \leq 1.91$; two of 15 significant) were found. The largest and most frequent effects were present for versatility in passes and dribbles ($Mdn(d) = 1.05$; $-0.02 \leq d \leq 1.92$; three of four significant). Further, *DL* significantly outperformed *TL*

regarding originality in passes in both ages ($0.45 \leq d \leq 0.68$) and fewer fails in dribbles in U13 ($d = 0.87$; Santos et al., 2018).

To sum up, two studies provide support on the general effectiveness of *DL* in at least a few technical or tactical outcomes (Coutinho et al., 2018; Ozuak & Çağlayan, 2019). Results on the relative effectiveness of *DL* compared to *TL* regarding the promotion of soccer-specific techniques are, however, ambivalent. Yet, no study found significantly greater improvements after *TL*. In terms of creativity, Santos et al. (2018) indicate the potential of *DL* to encourage versatility and originality compared to other game-based models.

Teaching Games for Understanding. The *TGfU* approach was compared to *TL*, primarily including decontextualized drills (Práxedes et al., 2016; Sierra-Ríos et al., 2020). Práxedes et al. (2016) found strong effects in favor of *TGfU* in decision-making for passes and dribbles ($0.90 \leq d \leq 1.40$; two of two significant). A significant effect in the execution variables was present for passes ($d = 1.10$), but not for dribbles ($d = 0.45$). In the study by Sierra-Ríos et al. (2020), *TGfU* outperformed the direct instruction group regarding significantly more successful off-the-ball decisions, and executions ($2.62 \leq d \leq 2.80$; 2 of 2 significant), as well as less unsuccessful actions ($2.37 \leq d \leq 2.48$; 2 of 2 significant). Regarding on-the-ball variables, only significantly fewer inefficient technical actions support the greater effectiveness of *TGfU* ($d = 2.48$), but not more efficient technical executions were found.

Non-linear Pedagogy. Práxedes, Del Villar, et al. (2018) compared *NLP* to *TL* group that prioritized technical components. *NLP* was altogether not significantly more effective

than *TL* ($d = 1.05$).¹² However, at post-test, the *NLP* group significantly outperformed the *TL* group in passing decisions and executions. No significant differences in dribble variables were found. Roberts et al. (2020) compared *NLP* to a practice program based on information-processing theory and found greater improvements after *NLP* in 1v1 ($d = 0.74$) and decision-making skills ($d = 0.60$). No differences occurred in technical variables ($Mdn(d) = 0.44$; $0.17 \leq d \leq 0.58$).

Effectiveness of interventions on specific aspects of practice or coaching

Generally, the low number of effect sizes within this second group, as well as an often limited content-related comparability of studies impede an accumulated report. For game-based interventions, even no effect size could be recalculated.

Sixteen controlled studies investigated multiple aspects of the practice design to promote technical skills. Regarding *technical drill practices (with subsequent SSGs)*, Zago et al. (2016) found that the use of tape-matrix structures as spatio temporal constraints for both, technical drills, and phases of play situations, led to a significantly faster passing execution time compared to a group that practiced without such constraints ($d = 1.05$). No interactions in other precision- or time-based technical outcomes occurred ($Mdn(d) = 0.14$; $0.12 \leq d \leq 0.94$). Weigelt et al. (2000) found a significant interaction of deliberate juggling practice compared to a non-active CG, resulting from improvements in knee-juggling, but also positive transfer effects to ball control performance ($d = 1.20$). Such positive transfer to ball control was not confirmed by Raastad et al. (2016), additionally, no differences occurred in deliberate juggling practice with smaller or larger balls ($d = 0.36$).

¹² Práxedes et al. (2018b) used multivariate statistics and did not report baseline statistics so that only the MANOVA effect, considering both perceptual-motor and perceptual-cognitive outcomes, can be provided.

The *non-dominant leg practice* interventions consistently led to greater effects compared to CGs. Guilherme et al. (2015a, 2015b) found that additional drill-based non-dominant leg practice led to a higher utilization rate in game-based situations compared to non-additional practice CGs ($2.31 \leq d \leq 2.91$; two of two significant). The decrease in the preferred leg utilization rate reveals fewer lateral asymmetries during match-play ($1.40 \leq d \leq 2.31$; two of two significant). Haaland and Hoff (2003) further showed that the predominant use of the non-dominant leg within team practice led to improvements in both the non-dominant ($Mdn(d) = 0.93$; $0.88 \leq d \leq 1.32$; three of three significant) and dominant legs ($Mdn(d) = 0.95$; $0.82 \leq d \leq 0.99$; three of three significant) compared to a usual care CG.

In the only study on *coaches' instructions* (Schwab et al., 2019), external focus feedback led to greater improvements compared to internal focus feedback in the knuckle-ball technique due to a reduction in the rotational ball velocity ($d = 0.59$). No differences were found in the linear ball velocity ($d = 0.11$).

Discussion

Enhancing soccer players' skill acquisition is an essential part of coaches' work that should be supported by evidence-based knowledge to identify the most effective practice and coaching methods. Thirty-five studies were reviewed to pool the growing body of research investigating perceptual-motor and perceptual-cognitive skills as outcomes of interventions anchored in pitch-based settings. Two groups of studies were identified within the present research. In the first group, theory-driven instructional approaches were investigated and compared to non-active CGs or active controls practicing according to differing methodologies. In the second group, specific aspects of the practice design or coaches' instructions were examined, but interventions were often not explicitly

embedded within skill acquisition paradigms. In both groups, methodological differences in terms of the study designs, practice activities of CGs, outcome variables, as well as research quality challenge the comparability of the respective study results. Thus, interpreting the potential of the investigated methodologies requires a detailed discussion of underlying theoretical frameworks, derived principles to practice and coaching, as well as studies' methodological characteristics and limitations.

Theoretical perspectives

Regarding studies on instructional approaches, underlying frameworks of self-organization approaches *DL* (i.e., dynamical systems theory) and *NLP* (i.e., ecological dynamics), as well as corresponding principles for practice and coaching, were clearly stated. Allocating *TGfU* solely based on skill acquisition theory seems inappropriate as it emerged from 'an educative perspective rather than approaching it from purely the field of sports science/skill acquisition' (Harvey et al., 2018, p. 175). In contrast to the underpinnings of IGs' practice, theoretical frameworks of CGs' were only stated in a few studies (e.g., Roberts et al., 2020; Schöllhorn et al., 2006). In many studies on *TGfU* and *NLP*, the respective CG's practice was not explicitly linked to a cognitive, information-processing approach to skill acquisition. Instead, CGs were defined on a practical rather than on a theoretical level by 'prioritizing the technical component' (Práxedes Pizarro et al., 2017, p. 187) while IGs practiced both technical and tactical aspects of play. Similarly, notwithstanding the outlined exceptions, the vast number of studies on specific aspects did not design their interventions based on skill acquisition theory. Thus, many of the reviewed studies only contribute to a practical discussion and do not allow inferences on the explanatory value of skill acquisition theories, and thereto derived methodological conclusions on how to effectively design and deliver practice and coaching.

Practical Implementation

Typically, technical practices following an information-processing viewpoint targeted the development of ‘ideal movement archetypes’ (Schöllhorn et al., 2012, p. 104) mostly through decontextualized drills. When aspiring to tactical objectives, practices were sometimes enriched by subsequent game-based situations to apply the to-be-learned skills in game-realistic contexts. Coaches acted as ‘expert[s] leading participants to a series of pre-determined outcomes’ (Roberts et al., 2020, p. 1456) by using a high number of verbal instructions and demonstrations. However, it was often not clearly outlined if, when, and how the decomposed technical practice was linked to tactical aspects within the sessions’ microstructure and the interventions’ periodization.

Regarding *DL*, a variety of implementations regarding both technically focused drill-based and game-based interventions were utilized. For instance, ‘superfluous exercises’ (Schöllhorn et al., 2006, p. 191) were added to target drills (e.g., additional body movements) or random modifications of SSGs (e.g., equipment or rules) were applied to create noise throughout the learning process. Nevertheless, a hitherto unresolved problem is the lack of metrics for quantifying variability (‘noise’) limiting opportunities for replications and practical recommendations for coaches’ work.

Both *NLP* and *TGfU* interventions primarily include game-based activities and in some cases applied skill practice tasks aiming at a rather natural variability within and between skills. This was mostly achieved through simplified ‘contexts of play’ (Práxedes et al., 2019, p. 335) such as numerical superiority SSGs. These methodological similarities are in line with those outlined in the literature on *TGfU* and the *CLA* that is underpinned by principles of *NLP* (Harvey et al., 2018; Renshaw et al., 2016). Nevertheless, specific differences grounded in the respective theoretical underpinnings were often difficult to

identify. Few studies reported in detail how coaches guided players in *TGfU* in an explicit process through reflective questions (Barquero-Ruiz et al., 2021). Otherwise, more implicit strategies in manipulating constraints to promote ‘strong functional couplings of information and movement’ (Roberts et al., 2020, p. 1456) were described for *NLP* interventions. Yet, the implementation of specific strategies within a defined context, the triggers for their use, as well as the dose were scarcely specified. Such details in the light of the targeted outcomes are, however, particularly important to achieve conceptual clarity and reduce misinterpretations (Cope & Cushion, 2020).

Critical appraisal of methodological study characteristics

The present review faces often outlined methodological challenges in systematic reviews and meta-analyses of intervention research, such as large methodological diversity across studies, outcome variables, and practice activities of CGs (Abad Robles et al., 2020; Silva et al., 2021; Tassignon et al., 2021). Besides that, the quality in reporting and risk of bias, as well as the quality of intervention description largely differed across studies and some general limitations in the present body of research were uncovered. These limitations need to be critically discussed to ensure a careful and reflected interpretation of the interventions’ effectiveness.

Study designs and intervention characteristics

Studies without a CG need to be necessarily excluded from analyses on the effectiveness as the outcomes could be biased by various confounding factors. Even within controlled studies, the research designs varied substantially, limiting the comparability of results. Caution is also required when comparing the effects as different types of CGs were identified (see in detail Supplement III). While comparisons to non-active CGs only allow conclusions on the general effectiveness of interventions, usual-care CGs provide evidence

on whether interventions could improve current practice (Smelt et al., 2010). Attention is advised when CGs mainly practice technical aspects while IGs focus on both technical and tactical content, in particular when both technical and tactical outcomes were assessed through systematic in-game observations. Such comparisons neither allow a theory-led discussion of results, nor enable conclusions on the effectiveness of investigated approaches in relation to other methodologies.

The only studies which allow for conclusions on the relative effectiveness of practice and coaching methods are those that explicitly state theoretical and methodological principles of CGs and by approaching similar practice objectives. However, most studies did not include additional non-active CGs so that improvements in both groups could not be interpreted (e.g., Hossner et al., 2016). Yet, ensuring both sufficient statistical power and including additional no-training CGs could be particularly difficult in applied experimental settings. Nevertheless, in line with Vater et al. (2021), including at least a non-active CG can be seen as the minimum requirement to ensure sufficient quality of evidence. Potentially, randomized crossover designs – as chosen by Roberts et al. (2020) – provide solutions that every player can profit from interventions by simultaneously controlling intervention effects.

Primarily, studies focused on performance changes (i.e., temporary fluctuations in behavior), but not on learning effects (i.e., permanent changes over time; Soderstrom & Bjork, 2015). Such short-time effects may be of great importance within high-performance settings when the goal is to quickly achieve a specific outcome. From a talent development viewpoint, however, developing players' skills systematically would benefit from knowledge on learning effects, thus, requiring the inclusion of retention tests within

intervention designs. Additionally, knowledge about methods resulting in positive transfer to other skills but also from decontextualized to game-realistic settings would provide valuable information on how to effectively prepare players for the dynamic nature of the game.

A further identified concern relates to the scarce description of interventions which limits the potential to replicate the reviewed studies. Besides that, little consideration was dedicated to the intervention adherence and fidelity. Systematic assessments based on specific and outlined criteria of observation provide transparent insights on the intervention delivery (e.g., Práxedes et al., 2019). Especially within the highly dynamic and partly unpredictable pitch-based work, systematic assessments would add valuable information on the interventions' protocol adherence.

Outcome variables and statistical analysis

The multitude of dependent variables illustrates the variety of relevant outcomes even within the perceptual-motor and perceptual-cognitive skill domains. Yet, multiple ways for measuring the same skills underline that there is no consensus regarding standard assessment tools (Williams et al., 2020). Additionally, instruments lacking a scientifically sound investigation of reliability and validity were found. Those results need to be interpreted with caution. Besides outcome-related skill tests, also an increasing number of in-game assessments were applied. These provide higher ecological validity and the opportunity to assess the functional application of practiced skills (for a similar discussion see Koopmann et al., 2020). However, many interfering factors (e.g., performance of other players) need to be controlled. Consequently, combining skill tests and in-game assessments is recommended.

A further prevalent issue was the low statistical power due to small sample sizes. Unsurprisingly given this result – and in line with similar investigations in sports science research (Abt et al., 2020) – only five studies reported a priori sample size estimations. Further, correlations among repeated measures in individual studies were unknown and may have resulted in less precise post hoc power calculations. Besides inferential statistics, two studies used magnitude-based inferences, however, it is widely discussed within sports science whether the use of such parameters is adequate as they are often used to justify small sample sizes (Lohse et al., 2020). Additionally, insufficient reports or interpretations of statistical results, missing interaction effects, or unknown group differences challenged the recalculation and interpretation of effect sizes.

Overall, these limitations reinforced the decision to refrain from a meta-analysis and need to be recognized when interpreting and comparing the effectiveness of interventions. Due to the diverse approaches, many studies must be considered in the light of individual characteristics.

Effectiveness of DL, TGfU, and NLP interventions

A fundamental question arising from theoretical camps is as to whether practice should aim to improve ideal ‘textbook’ techniques or allow exploration for individual solutions. Seven studies on *DL* dealt with this question, but large methodological differences and a low statistical power must be considered.

Only a few significant effects were found that confirm the superiority of *DL* compared to *TL* methods. Nevertheless, no study reported significantly greater effectiveness of *TL* methods, permitting the conclusion that *DL* seems to be at least a viable alternative for practicing technical soccer skills. Supporting this notion, comparisons to non-active CGs provide evidence that *DL* could generally improve performance (e.g., Ozuak & Çağlayan,

2019). Yet, besides two exceptions, the performance was assessed within skill tests. Thus, investigations that *DL* supports ‘more effective and more stable movement patterns’ (Schöllhorn et al., 2012, p. 102) within match-play have been widely neglected so far. Further, the greater effectiveness of *DL* in the retention phase compared to the acquisition phase as found in a meta-analysis by Tassignon et al. (2021) could not be proofed due to the absence of retention tests in most studies.

The two studies on game-based *DL* support its potential to promote divergent tactical behavior in early- to mid-adolescent regional level players (e.g., Santos et al., 2018). Although generalizable conclusions seem premature due to only two game-based studies on divergent tactical outcomes, the results provide support for a developmental framework on promoting creativity in team sports, recommending *DL* as one appropriate method during adolescence (Santos et al., 2016).

In contrast to *DL*, studies on *TGfU* and *NLP* consistently aimed at promoting technical and convergent tactical skills (i.e., decision-making). Generally, positive effects regarding the promotion of perceptual-motor and perceptual-cognitive skills indicate the potential of both approaches although only two controlled designs were found. Besides, many studies rather provide evidence on the general effectiveness as targeted practice objectives in IGs (technical and tactical content) and CGs (primarily technical content) seem hardly comparable.

The predominant use of SSGs with numerical superiority led to greater effects in passing variables (e.g., Práxedes, Del Villar, et al., 2018). Consequently, if improvements in dribbling should be targeted, other strategies to simplify game demands are required. As a general result, more significant effects in perceptual-cognitive compared to perceptual-motor variables were found, probably due to the predominant focus on technical skills in

CGs. Further, intervention periods longer than eight sessions as used by Roberts et al. (2020) or greater consideration of the technical elements (e.g., applied technical practice) may achieve greater effectiveness in the perceptual-motor domain.

Effectiveness of interventions focusing on specific aspects of practice or coaching

Providing a clear image of the effectiveness of studies on specific aspects to practice and coaching is challenged as diverse topics within skill acquisition research, practice methods, and technical outcomes were found. Further, most technical outcomes were only investigated through skills tests limiting the inferences which can be drawn for match-play performances. Nevertheless, most studies support the effectiveness of deliberate technical practice although specific study objectives and particularities of applied methods often require individual analyses. Specifically, positive results were reported after technically focused drill-based interventions to promote the technical non-dominant leg performance. Thus, interventions that primarily include TL methods – often applied as supplemental to regular team practice – were found to achieve improvements. Again, none of these studies assessed its impact on match-play performance. Only two studies provide support that drill-based practices over several months can positively impact match-play behavior in terms of a higher utilization rate of the non-dominant leg (Guilherme et al., 2015a, 2015b). In summary, the present research on specific aspects provides first insights on the potential of different practice and coaching methods, but evidence on whether such practices can improve match-play performance is rare.

Limitations of this systematic review

The limitations of the present review mainly relate to three characteristics. *First*, due to large heterogeneity and methodological weaknesses across studies, pooling effect sizes within a meta-analysis to increase the statistical power and precision of effects was not

possible. Besides the limited number of controlled designs on comparable approaches, not all effects could be recalculated due to missing data, as well as unknown interaction effects or group differences. Consequently, inferences on the effectiveness of interventions were limited, they could not be statistically investigated regarding potential moderators (e.g., the intervention duration) and, thus, must be often interpreted in the light of individual study characteristics. Along with this, the extent of potential publication biases could not be statistically assessed. *Second*, strict inclusion criteria were applied to ensure the highest quality of individual studies (e.g., peer-reviewed research). Nevertheless, relevant studies published within different outlets (e.g., book chapters) may have been omitted as a consequence. *Third*, improvements in players' perceptual-motor and perceptual-cognitive skills were chosen from a wide range of potentially relevant outcomes (Nichol et al., 2019). Thus, skill acquisition needs to be considered at the interface of various interrelating elements, such as motivational or physiological attributes.

Future perspectives

The growing number of studies over the past years elucidated the increasing interest and relevance of the topic. To encourage and improve further work, directions and recommendations for future studies are outlined relating to three main features.

First, *higher standards of intervention research* should be applied, especially in terms of sufficiently powered and controlled designs. Although guidelines for intervention research from health science or medicine may need to be translated and adapted for sports coaching research (e.g., O'Cathain et al., 2019), they can be valuable benchmarks for future work. Further, scientifically grounded and clearly outlined hypotheses are required to better understand what interventions aim to achieve. Pre-registrations could improve

the current practice by outlining the study design, hypotheses, statistical analyses, and a priori sample size estimation.

Second, the specific practice objectives of different practice and coaching methods should be critically juxtaposed to conduct *theory-driven intervention research on the relative effectiveness* of approaches (e.g., Gray, 2020). Here, the additional use of non-active or usual care CGs would allow interpreting improvements in different practice groups. The application of instruments with high specificity is recommended to draw sound conclusions on the respective intervention objectives. These can be both outcome-related skill tests, but also representative in-game assessments if potential confounders could be controlled. Additionally to hypothesis testing based on group means, looking at individual development curves would allow specific implications on how different methods impact acquisition and learning in the light of personal characteristics (Anderson et al., 2021).

Third, systematic *monitoring of practice and coaching* would help to better understand and compare the implementation of different approaches. This requires empirically grounded metrics to quantify practice (e.g., variability) and coaching (e.g., instructions). Although proper metrics are scarce, systematic observation instruments can provide valuable data (e.g., Cushion et al., 2012b). Potentially relevant variables may also be adapted from periodization frameworks on skill acquisition (Farrow & Robertson, 2017; Otte et al., 2019). Collaborations with coaches who transfer methodological principles to their ‘real-world’ coaching contexts could show how differently grounded approaches can be applied in different settings. This could specifically profit from mixed-method designs focusing on both the players’ outcomes, but also coaches’ intentions, expectations, and experiences when applying different methodologies.

Practical Implications

The present findings underline the need for coaches to make numerous considerations before deciding for or against a specific practice and coaching methodology. These may include, for example, coaches' reflections on which competencies they aim to improve in their players (i.e., the practice objectives) as well as the situative circumstances in which practice is conducted (e.g., age groups, sport facilities). Within coaches' daily work, but beyond the scope of the present review, these considerations cannot be limited to perceptual-motor and perceptual-cognitive skills, but need to go further (see, for example, Alves et al., 2017 for reasons on the use of SSGs in soccer practice).

Regarding the promotion of outcomes addressing *technical skills*, the available results support that both decomposed, repetition-based approaches as well as self-organization/variability-based approaches implemented within drills or games can lead to improvements depending on how performance is operationalized. These findings challenge the traditional idea that players must learn the 'fundamentals' first (e.g., ball handling) before they can be put into the game context (Newell, 2020). Given the other benefits of self-organization/game-based practice activities (e.g., more opportunities for decision making), this suggests that, at very least, coaches should reduce the amount of decomposed, isolated drills in practice. Here, coaches' key challenge is to find the most supportive integration and periodization of such practices, as well as the optimal degree of self-exploration and variability by considering individuals' requirements and needs.

Regarding *convergent tactical skills* (i.e., decision-making), the present results allow the cautious conclusion that those approaches which provide players' a greater opportunity to self-explore tactical solutions within game-realistic settings provide a better foundation to facilitate convergent tactical thinking. Knowledge of how and to what degree this

process can be most effectively guided through implicit or explicit coaching strategies is still scarce as comparisons of specific strategies are lacking. In terms of players' *divergent tactical behavior*, it seems worthwhile to confront players with highly dynamic and unpredictable match-play situations that encourage flexible adaptations to game demands. Nevertheless, specific recommendations on the most conducive degree of variability and unpredictability cannot be made based on the present knowledge.

Conclusion

The small number of studies investigating similar approaches, heterogeneity across studies and dependent variables, as well as methodological weaknesses, limit the generalizability of results. Although it was possible to outline the potential of different practice and coaching methods regarding a variety of outcomes, most effects need to be critically interpreted in the light of individual study characteristics and weaknesses. Thus, based on the current body knowledge, drawing scientifically sound conclusions on the effectiveness or even superiority of specific approaches would be premature. Rather, the present review aims to encourage further theory-driven and high-quality studies to extend the growing but still limited body of research conducted in applied experimental contexts. Furthermore, the findings must be systematically enriched by coaches' experiential knowledge. This will contribute to a conscious and evidence-based use of the coaches' methodological 'toolbox' for effectively enhancing player learning and performance.

Data availability statement

Further data, as well as the PRISMA checklist, are provided in Supplements I-V. Datasets of the systematic search and the quantitative synthesis can be accessed in the OSF project of this publication (<https://osf.io/85tjg/>).

Disclosure statement

The authors declare that there are no conflicts of interest.

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Supplementary Materials

Supplementary materials for this article are provided in *Appendix 2*.

3.2.2 Practice Design and Coaching to Support Learning in Elite Youth Soccer Players: Recommendations from International Coaches, Coach Educators, and Researchers (Study 2)

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Abstract

Providing optimal learning support is a major challenge within talent development settings. To accomplish this challenge, practitioners' decisions and actions should be informed by a blend of practical experiences and academic knowledge. This study explored experts' recommendations on *how* to facilitate learning in elite adolescent soccer players during practice. Special focus was dedicated to *why* certain practice and coaching approaches were recommended to better understand experts' justifications. Eighteen semi-structured interviews were conducted with international experts representing three complementary groups of expertise (i.e., six of each *soccer coaches*; *coach educators/developers*; and *researchers* in talent development, motor learning, or coaching pedagogy). By employing a reflexive thematic analysis three themes were constructed: (I) Differentiating overarching learning goals to address players' individual needs; (II) Designing purposeful training sessions with the game in mind; and (III) Coaching interventions to support player learning within a group environment. Overall, the experts recommended the complementary use of different practice and coaching strategies to address individual learning needs. While some strategies may be associated with conflicting theoretical paradigms and established pedagogical approaches, the findings inform a purposeful integration of those different approaches in practical work. Therefore, participants' recommendations can be discussed by integrating interdisciplinary theoretical perspectives.

Key Points

- The study's findings highlight the need for a learner-centred differentiation within a game-centred philosophy as key to developing a learning-conducive environment. Specific coaching interventions and practice activities are outlined to moderate individual learning outcomes.

- Overall, immense relevance was ascribed to players' need to collect experiences in challenging, game-representative situations, and their respective engagement as active problem-solvers.
- Some recommended coaching strategies may be associated with conflicting theoretical paradigms and established pedagogical approaches. However, the findings inform a purposeful integration of those different approaches in practical work.

Keywords: competence; learning environment; motor learning; sport coaching; talent development; theory integration

Introduction

The process of talent development in sport is a complex challenge due to the diverse factors impacting the pathways of aspiring athletes (Till & Baker, 2020). On a theoretical level, this process can be described by the *Differentiated Model of Giftedness and Talent* (DMGT; Gagné, 2021). According to Gagné (2021), *talent* evolves if a person with outstanding natural abilities in at least one domain is enabled to systematically develop a high level of *competencies* in a certain field. This developmental process is moderated by intrapersonal (e.g., psychological dispositions) and environmental catalysts (e.g., external support), as well as several chance factors. Pertaining to soccer, environmental measures supporting player development constitute a vibrant area of research, which also addresses moderators that may enhance player learning (e.g., learning-conducive practice design and motivational coaching; Williams et al., 2020).

Learning as a long-term pursuit is defined by ‘relatively permanent changes in comprehension, understanding, and skills of the types that will support long-term retention and transfer’ (Soderstrom & Bjork, 2015, p. 176). From an *action-theoretical viewpoint* (Nitsch & Hackfort, 2016), these learning outcomes result in a soccer *player’s* newly acquired or optimized action competence which enables them to solve distinct *tasks* under certain *environmental* conditions. Consequently, research on strategies supporting player learning in soccer needs to account for both task-related (e.g., soccer-specific demands) and environmental conditions (e.g., motivational climate). Especially in talent development environments, inherent performance expectations may lead to a perception of conflicting goal pursuits when, on one hand, striving to show current capabilities (i.e., immediate observable performance), and on the other hand, expanding current capabilities to reach future potential (i.e., long-term learning). In this regard, it is the coaches’ responsibility to

create optimal conditions for learning, for example, by designing purposeful practice tasks and promoting an optimal motivational climate (Rynne et al., 2019).

In the soccer coaching literature, effective strategies to support player learning have been discussed for decades (e.g., Wade, 1967; Worthington, 1974), and is still a contemporary topic (e.g., O’Sullivan et al., 2021). Providing coaches with reliable and specific recommendations on how to support player learning is difficult given the multitude of factors impacting soccer performance (Williams et al., 2020). The different theoretical positions on how these performance factors may be promoted further challenge the development of such recommendations. At the core of this discussion are the conflicting assumptions of motor skill acquisition and learning (e.g., information-processing vs. self-organization approaches; Anson et al., 2005; Schöllhorn et al., 2022; Whittall et al. 2020a for reviews). Additionally, the development of tactical skills is also discussed with reference to classical learning theories (e.g., behaviorism vs. constructivism; Gréhaigne & Godbout, 1995; Hallé Petiot et al., 2021 for reviews). Generally, these assumptions can underpin the effectiveness of *different pedagogical approaches* used in practice. Yet, the theoretical foundations, distinct differences and similarities in practice, as well as benefits for player learning of these approaches are still debated (e.g., Cope & Cushion, 2020; Harvey et al., 2018; Pill, 2021; Renshaw et al., 2016).

In practice, coaches need to determine the most appropriate strategies based on a multitude of decision parameters, including goal priorities, player and coach characteristics, and the coaching context. To aid their decisions, several theoretical frameworks summarize characteristics of practice activities and coaching behaviours across a range of different dimensions (e.g., Farrow & Robertson, 2017; Hodges & Lohse, 2022; Otte et al.,

2020; Santos et al., 2016). Key dimensions of *practice activities* are, for example, the degree of specificity (i.e., extent to which motor- and sensory-related parameters reflect competitive demands; Farrow & Robertson, 2017) and representativeness (i.e., amount of competition-like affordances provided within the practice design; Pinder et al., 2011). However, systematic methods for the assessment of such dimensions in soccer practice are missing.

Hodges and Lohse (2022) further propose that the challenge of a practice task is critical and recommend a moderate to high functional (i.e., individual-related) difficulty to facilitate learning. In this regard, both the cognitive demands and the variability within and across skills represent potential dimensions for scaling challenges. Moreover, player learning is also related to *coaches' behaviours* in practice, for example, pertaining to the provision of external information (e.g., different types of instruction; O'Connor et al., 2021a; Pill & SueSee, 2021) or the manipulation of task constraints (Otte et al., 2020). Coaches' respective methodological decisions relate to their underpinning assumptions and goals, for example, as to whether learning processes should occur implicitly (i.e., without awareness and no or minimal increase in reportable knowledge) or explicitly (i.e., with generated reportable knowledge and working memory involvement; Kleynen et al., 2014).

To enrich practitioners' professional expertise in dealing with such decisions, academic endeavours on practice and coaching methods are intended to unravel strategies for optimal leaning support. From a soccer-specific perspective, different research designs have been used to aid this pursuit. For example, conceptual frameworks have been used to link theoretical assumptions on learning to distinct recommendations for coaching practice (e.g., ecological dynamics and the constraints-led approach [CLA], Renshaw et

al., 2019; for practical examples in soccer O'Sullivan et al., 2021). However, the actual effects of coaching practices drawn from those frameworks on player learning are still unknown. Growing research on the effectiveness of different approaches to soccer coaching within intervention designs highlights their general effectiveness (e.g., *Teaching Games for Understanding* [TGfU; Bunker & Thorpe, 1982]; *non-linear pedagogy* [NLP; Chow, 2013]; *Differential Learning* [DL; Schöllhorn, 1999]), but most studies are affected by methodological shortcomings (Bergmann et al., 2021a). In addition, the validity of most findings for soccer talent development is questionable as studies with high-performing individuals are rare. Consequently, drawing empirically-sound recommendations for effective learning support in aspiring soccer players seems premature.

Practitioners' solutions for dealing with the challenge of optimal learning support in 'real-world' talent development contexts have been monitored within systematic observation research (Cushion et al., 2012a). These studies often uncovered a disconnect between skill acquisition frameworks and the on-pitch reality, which often included many decomposed practice tasks and the players being treated as passive recipients rather than reflexively involved (Cope et al., 2016). However, several positivist-shaped studies only looked at coaches' behavioural data as 'snapshots' instead of considering context-specific justifications underlying coaches' behaviours (Cope et al., 2017). In contrast, in qualitative explorations, practitioners were interviewed regarding strategies they use by also accounting for underlying justifications, intentions, and beliefs (e.g., Price et al., 2020). Some studies additionally collected observational data of coaches' on-pitch work which, however, often revealed discrepancies between coaches' intended and actual behaviour (O'Connor et al., 2017; Partington & Cushion, 2013). One 'epistemological gap' (Partington & Cushion, 2013, p. 381) repeatedly highlighted is, for example, represented

by coaches' intention to allow players' exploration while still prescribing game solutions through explicit instructions.

In summary, questions related to supporting learning in aspiring soccer players were addressed from a variety of perspectives. Nevertheless, the studies' methodological characteristics and the complex field of application often limit practical recommendations thereof. To expand our understanding of optimal learning support, focusing on specific coaching contexts and pursued learning outcomes seems indispensable (i.e., *narrowing the coaching context*). Furthermore, exploring recommendations provided by experts occupying different roles (e.g., coaches, coach educators, researchers) but with complementary expertise on motor learning, skill acquisition and coaching practice (i.e., *considering broad expertise*), can facilitate a better understanding on how to integrate different approaches to sport coaching. Linking recommendations from researchers and practitioners may inform research embedded within different scientific paradigms and forward practical implications for talent development.

Purpose of the study

Based on these considerations, the purpose of the current study was to explore strategies recommended by experts on how to support learning in elite youth soccer players. In this regard, the aim was to examine characteristics of the learning environment and practice tasks, and particularly how coaches should manipulate these components to support players' soccer-specific competence development (purpose 1). This first purpose covers both, *what* strategies are recommended as well as *how* experts would apply them in a talent development context. Additionally, factors impacting methodological decisions are explored for a better understanding of *why* experts would use these strategies (purpose 2). In this regard, it is of interest as to whether recommendations provided by

experts represent the outlined theoretical conflicts and if so, whether these affect coaching practice. Overall, the findings of this study are expected to create a better understanding of the implications that different approaches to practice design and coaching have for coaching soccer players. Given the complex character of sport coaching due to the several moderating factors of player learning (Lyle & Cushion, 2017), pursuing inter-theoretical integration (e.g., learning and motivation) based on experts' justifications may enhance their transferability into applied settings.

As coaching is a specific 'objectives-directed intervention process' (Lyle & Cushion, 2017, p. 48) and player learning is always related to the demands of a particular task in the game (Nitsch & Hackfort, 2016), this study requires focus on specific goals within a certain context. Therefore, experts' recommendations were examined considering competency-based *learning goals* pursued within the German Football Association's [DFB] talent development program. Specifically, these nationwide goals guide player development within 357 DFB competence centers across Germany where the best 4% of the U12 to U15 players are provided with additional practice complementing their club's regular activities (in detail Kelly et al., 2024). In this environment, teams of qualified coaches (at least UEFA B-License) aim to facilitate players' long-term learning. To focus even more on learning, no regular competitive matches between competence centers are played which is thought to reduce the competitive pressure in this elite youth soccer context. The pursued learning outcomes (i.e., competencies) are structured around three game tasks: *scoring goals* ("Players can perform precise goal shots even when under increasing time and opponent pressure."), *creating scoring opportunities* (e.g., "Players can perform properly weighted and directed passes toward the situation-specific best foot of their teammate."), and *keeping ball possession* (e.g., "Players can free themselves from their

opponents and effectively use their body to protect the ball after reception.”; DFB, 2022a).

Methodology

To address the study’s purposes, a qualitative approach situated within a pragmatic paradigm was deemed most suitable. According to a pragmatist philosophy, knowledge is constructed by humans’ interactions with the environment when aiming to solve a situational problem (Hall, 2013). Accordingly, research from a pragmatic philosophical viewpoint is intended to collect actionable knowledge (Morgan, 2014). These assumptions correspond with postulations of action theory (Nitsch & Hackfort, 2016), for example, due to a person’s interaction with task- and environment-related conditions, leading to a context-specificity of actions. Consequently, exploring justifications of experts’ recommendations is deemed vital to gather knowledge as ‘warranted assertions’ (Hall, 2013, p. 18) of how to facilitate player learning (i.e., the problem) in the specific context of talent development (i.e., the environment).

Participants

Guided by preliminary defined inclusion criteria (in detail Supplement I), eighteen purposefully recruited participants belonging to three complementary expert groups of *soccer coaches, coach educators and developers*, as well as *sports science researchers* were interviewed ($n = 6$ resp.). Given natural overlaps across careers, these groups are not entirely disjunct (i.e., without shared characteristics). Yet, participants’ assignment to one of these groups is justified by both their current positions as well as formal and informal qualifications (Table 9). The final sample size was determined throughout the data collection process based on the subjectively experienced amount of novel content

and repetition compared to previous interviews, the intention to cover international perspectives, and pragmatic reasons (e.g., availability of experts; Braun & Clarke, 2021a). Overall, the sample draws on extensive international experience as participants had worked in 22 nations across Africa, North America, Asia, Australia, and Europe (Supplement II).

The six *coaches* (C1-C6) had worked with high-performing U12 to U15 players across various talent development settings for several years. Four experts were head coaches of youth national teams. One participant was the head coach for individualization and player development in a youth academy (YA) certified according to the highest national standards, another occupied a similar role in a national association. The group of *coach educators/developers* (CE1-CE6) included two directors of national coach education programs who had gathered instructional experience across all licensing levels. Two experts gathered their experience from leading C- to A-License coach education programs and further contributed to the programs' conceptualization. The remaining two experts were heads of coach development within high-level YAs and were responsible for practice and coaching concepts at their club. All participants had previously coached youth players for several years, and three were still coaching national or regional selections in a part-time role. The remaining six participants represented internationally established *researchers* (R1-R6) at universities working across the fields of motor learning, skill acquisition, or coaching pedagogy. All researchers had completed their PhD in sports science or sports coaching and held a full-time academic position. They conducted studies related to learning processes of youth soccer players as documented in multiple publications. Three researchers were also soccer coaches or coach developers; all others had at least youth soccer coaching experiences on a voluntary level.

Table 9. Participant characteristics separated by the three expert groups ($n = 6$, respectively).

	Soccer Coaches	Soccer Coach Educators/Developers	Sports Science Researchers
Sex	4x male, 2x female	6x male	4x male, 2x female
Age (y.)	49.1 $\pm$ 14.6	49.1 $\pm$ 11.1	46.5 $\pm$ 14.1
Interview length	1h 46 min. $\pm$ 7 min.	2h $\pm$ 17 min.	1h 47 min. $\pm$ 7 min.
Formal Qualifications			
Coaching Licenses & Qualifications ^a	3x UEFA PRO-level; 3x UEFA A-level; 1x NSCAA advanced diploma; 1x NCCA A-level	4x UEFA PRO-level; 2x UEFA A-level; 1x UEFA technical instructor	2x UEFA A-Level; 1x UEFA C-Level
Academic Qualifications	3x no academic qualifications; 1x Bachelor in sport-related studies; 2x Master or equivalent in sport-related studies	5x Master or equivalent in sport-related studies; 1x Master equivalent in non-sport-related studies	6x PhD (3x full professor; 1 assistant professor; 2x senior lecturer or equivalent)
Informal Qualifications			
Time in current job (y.)	3.1 $\pm$ 2.6	5.1 $\pm$ 4.8	7.2 $\pm$ 6.7
Overall work experience ^b (y.)	29.5 $\pm$ 13.5	26.5 $\pm$ 9.3	20.0 $\pm$ 13.8
Number of countries worked in	3.7 $\pm$ 1.7	2.3 $\pm$ 1.6	1.5 $\pm$ 0.8

Note. Results are presented as means $\pm$ standard deviations. UEFA = Union of European Football Associations; NSCAA = national soccer coaches association of America; NCCA = national coaching certification program in Canada.

^a Only the highest level of qualification is reported. If a participant holds licenses in different disciplines/domains (e.g., coaching and coach education), the highest license in each category is listed. Though not all researchers have a soccer-specific coaching license, they all gained at least some experience in coaching soccer.

^b For coach educators and developers, the experience refers to both their coaching as well as their coach educator and developer career since there was no clear-cut transition for the majority of participants.

Data collection

Upon approval from the ethics committee of the first author's University, eighteen semi-structured 'problem-centred expert interviews' (Döringer, 2021, p. 266) were conducted via Zoom (Zoom Video Communications Inc., 2016) except for one in-person interview. These interviews intended to explore experts' knowledge on optimal learning support in aspiring soccer players by focusing on their technical knowledge, routines, processes, and more implicit, interpretative knowledge (Döringer, 2021). This approach is deemed suitable to explore recommendations on temporary and ongoing processes as well as situational conditions that impact player learning as the shared 'problem' across experts. To collect actionable knowledge from a pragmatic perspective, the interviewer was considered part of the knowledge production process and, thus, required to reflexively react in situ for uncovering situational properties of the experts' statements. To ensure such a dialogic-discursive conversation at 'eye-level' (Pfadenhauer, 2009, p. 95), the main interviewer as *quasi-expert* needed to be familiar with the field (e.g., technical terminology; Bogner & Menz, 2009). Therefore, all interviews were conducted by the first author, a full-time sports science researcher who additionally holds the UEFA A-License and has several years of soccer coaching experience. It should be noted that the interviews were conducted in either German or English depending on participants' preferences. Given the native language of the first author (i.e., German) and to ensure data quality, the second author joined all interviews conducted in English to minimize potential language barriers. While she had no previous soccer coaching experience, she is a qualitative researcher with international experience in Germany, the United Kingdom, and Finland, and additionally works as an applied sport psychologist within coach education and talent development settings.

Before the interview, all participants who were not familiar with the DFB's talent development program watched a video clip illustrating organizational aspects (e.g., practice-to-learn environment, reduced competitive pressure). All eighteen experts watched another video clip introducing the soccer-specific learning goals within that program. Providing the experts with this information beforehand was thought to increase the depth of responses as practical examples would facilitate a better comprehension of the practice recommendations. To further visualize the meanings of experts' verbal statements and allow more in-depth questions, all *practitioners* (i.e., *coaches* and *coach educators/developers*) were asked to prepare exemplary practice tasks which they considered appropriate to target selected competencies. No practical examples were requested from *researchers* as not all had extensive experience in coaching soccer, yet all researchers illustrated their recommendations by verbally referring to specific practical examples.

An interview guide focusing on recommendations on the practice design and coaching was used for all experts who were reminded to respond to questions considering their perspective as a coach, coach educator, or researcher (Supplement III). The interview schedule encompassed four parts: (I) experts' general assumptions on learning within talent environments (e.g., "What are important beliefs, values, and goals that should guide coaching to optimally support learning in elite youth soccer players?"), (II) basic overarching coaching principles ("Can you state basic coaching principles which should guide practice and coaching to optimally pursue the presented learning goals"), (III) the design of practice tasks (e.g., "For what purposes would you use representative practice tasks and when would you recommend using less-representative tasks?"), and (IV) creating conducive learning environments through in-session coaching (e.g., "How and when would you intervene in practice to facilitate learning?"). All interviews were finalized

with a summary and overall reflections. The first and second authors subsequently discussed all conversations in terms of implementation (e.g., follow-up questioning) and content which was further aided by reflective notes of the first author. Two pilot interviews supported familiarization with these procedures and led to slight amendments in the interview guides' structure (e.g., initially greater focus on personal background) and the framing of questions. Finally, all interviews (> 33 hours) were transcribed verbatim for data analysis (for details see *Table 9*).

Data Analysis

A *reflexive thematic analysis* (Braun & Clarke, 2021b) of the data was intended to conceptualize patterns of shared meaning across experts' recommendations. Guided by the six, non-linear evolving phases (cf. Braun & Clarke, 2021b), the first author initially familiarized himself with the data by reading the transcripts carefully and listening to the interviews again (phase 1). Using MAXQDA (Verbi Software, 2021), the first author then identified data units relevant to the research question within each interview (phase 2). An abductive approach to data coding (cf. Braun & Clarke, 2021b, p. 56) was deemed appropriate according to which semantic and latent level codes were organized around *person-* (e.g., 'understanding learning needs'), *environment-* (e.g., 'safe setting for risky gameplay'), and *task-related* characteristics (e.g., 'increasing incentives of desired actions') which shape a learning situation (Nitsch & Hackfort, 2016). Preliminary coding around these three broad concepts helped to structure the relevant data without 'driving' inductive coding itself (cf. Terry, 2021). Associations to theoretical paradigms (e.g., dynamical systems approach; Kelso, 2001) and theoretically informed pedagogical approaches (e.g., *CLA*, Renshaw et al., 2019; *TGfU*, Bunker & Thorpe, 1982) were additionally documented in paraphrased sections and memos. If practical examples were provided as

graphics, these were used to better comprehend and interpret experts' verbal statements. These processes were applied for interviews across expert groups without being initially focused on one domain of expertise

After several rounds of re-reading transcripts and codes, collapsing codes increasingly allowed to develop thematic structures across interviews around common organizing concepts (for a similar approach see Trainor & Bundon, 2021), first within expert groups and afterward across all participants (e.g., person-related: “diagnosing errors in game-play”; environment-related: “intentional use of coaching roles [e.g., ‘facilitator’, ‘instructor’ etc.]”); task-related: “purposeful game-design”). Subsequently, more than thirty rather broad “candidate (tentative) themes” (Trainor & Bundon, 2021, p. 14) were conceptualized in MAXQDA (e.g., ‘Scaling challenge by increasing practice variability’; ‘Building upon phases of implicit learning’; phase 3). These initial themes built the starting point to revise corresponding codes as well as to refine preliminary theme names. Initial, in-depth discussions of preliminary themes and exemplary quotes within the whole research group extended the interpretations of the underlying meaning of experts' recommendations (phase 4). This process also offered several links for a theory-inspired discussion while the authors' different perspectives on the data aimed at reducing narrow interpretations based on personal beliefs as a researcher or a coach. This process enabled the first author to merge themes into a purposeful structure suitable to answer the research questions. Throughout this process, conceptualized sub-themes (e.g., Theme II: “Game-centred activities as session foundation”) were dissolved as these were not perceived as separate organizing concepts with equally weighted, individual importance. Finally, three themes were defined and named (phase 5), and the present report was written (phase 6) supported by quotes from all expert groups to represent the sample's multivocality (Levitt

et al., 2018). During the entire data analysis, the second and third authors (without personal soccer coaching experience) acted as critical friends and continuously encouraged the first author to reflect upon the meaning of the developed codes and preliminary themes. Regular discussions with all authors further facilitated nuanced interpretations (Smith & McGannon, 2018).

Research Quality and Trustworthiness

Several measures to facilitate methodological rigor were applied (Smith & McGannon, 2018). Guided by inclusion criteria (see Supplement I), purposeful *sampling* was approached by reflections within the research group on potential participants to strive for the highest possible, international expertise regarding the study's purposes. The interview depth was further enhanced by the prior contact between the interviewers and participants to increase rapport prior to the interview. Participants' preparatory activities (i.e., watching the video clip illustrating specific learning goals; preparing practical examples) further supported engagement with the interview purposes. Additionally, the first author's *reflexive notes* kept after each interview, including reflections on practical examples, supported interpretations of the data. *Reflexivity* through academic (i.e., theoretical and empirical) and applied analytical lenses (i.e., implications for practice and transfer) was facilitated by the research team's diverse background, including not only experience in sports science research but also as soccer coaches (first, fourth, fifth, and last author), coach educators and developers (second, third, and last author), sport psychology practitioners (second and last author) and the head of the DFB's talent development program (fifth author). To strengthen a *transparent account* of the analysis, verbatim quotes in this report and further statements from all expert groups in Supplement IV

aim to give voice to the multiple perspectives of participants. To further ensure a *trust-worthy* translation of the data collected in German language, all quotes were translated by the second author who is a native speaker of German with excellent English skills, and subsequently discussed with the third author who is a native English speaker. Finally, by adopting a pragmatic research paradigm (Morgan, 2014), we therewith invite readers to engage with the findings and consider their *transferability* if ‘they believe that research overlaps with their own situation and/or can intuitively transfer the findings to their own action’ (Smith, 2018, p. 141).

Findings and Discussion

Throughout the reflexive thematic analyses, three themes were developed (*Table 10*). To facilitate player learning effectively, the experts described the necessity to consider *player-characteristics* throughout the learning process (Theme I), the complementary use of different *practice tasks* (Theme II), and *environmental conditions* represented in coaches’ support (Theme III). More specifically, the first theme encapsulates the need for a learner-centred focus by *differentiating overarching learning goals to address players’ individual needs*. Here, recommendations on how to purposefully translate the overarching learning goals provided by the DFB into individual player outcomes were forwarded by the participants. This was linked to distinct areas in which differentiation can take place during practice. This learner-centred focus is complemented by the principle of *designing purposeful training sessions with the game in mind* presented in the second theme. Within a game-centred philosophy, however, different practice activities were described as beneficial to acknowledge individual player needs. Finally, Theme III outlines recommendations for the intentional use of *coaching interventions to support player learning*

within a group environment on-the-pitch that are discussed according to their intended purposes (e.g., individual learning outcomes).

1. Differentiating overarching learning goals to address players' individual needs

All participants agreed with the competency-based learning goals presented to guide player development within the DFB, yet they occasionally referred to slightly different conceptualizations used across talent development programs (e.g., defining what is the session 'input' vs. what is the 'outcome'). As these competencies were linked to tasks a player should be capable of solving, experts highlighted the need to analyse a player's respective capabilities to determine individual areas for improvement. Aligning with concepts of *diagnostic competencies* (e.g. of teachers; Klug et al., 2013), C2 proposed: 'First, you have to evaluate a player and say: "okay, what does he or she have?" I have to understand strengths and weaknesses, areas for improvement.' Given the progressive nature of learning, observations over longer periods and in different settings were outlined as the main source of information.

Table 10. Overview of the three themes developed and summary of their key messages.

Theme	Key Messages
I. Differentiating overarching learning goals to address players' individual needs	A learner-centred approach was recommended. This was linked to the differentiation of overarching learning goals which were, for example, defined within concepts of player development. Building upon <i>coaches' diagnostic competencies</i> , three areas in which differentiation can take place were identified: (a) the support of widely <i>individual movement patterns</i> in technical skills, (b) purposefully <i>explicating behavioral aspects of play</i> to stimulate players' tactical game understanding and self-reflection, and (c) certain developmental goals (' <i>basics</i> ') representing foundations for exploring the entirety of behavioral options in the game.
II. Designing purposeful training sessions with the game in mind	Purposefully designed practice activities were described by their <i>inherent guidance</i> toward a specific learning outcome required in the game and a <i>demanding functional task difficulty</i> . A <i>game-centred main philosophy</i> was recommended, but the need for a variety of conducive practice activities was outlined to specifically address distinct outcomes. Some of these activities were also justified by their mediating role for learning (e.g., self-efficacy). Overall, these practice activities corresponded to <i>principles of representative learning design</i> , engaging and variable <i>drill-based activities</i> , and intentionally designed <i>free play</i> .
III. Coaching interventions to support player learning within a group environment	The intentional use of specific <i>coaching interventions</i> was related to the coach's <i>reflection on practice design</i> and <i>player behavior</i> to intervene either by modifying practice activities or by verbally guiding the players. To keep player learning implicit, yet provide guidance toward specific learning outcomes, modifying <i>task constraints</i> was a prevalent recommendation. Additionally, involving players in <i>guided reflections</i> on tactical principles, but also <i>directive instructions and feedback</i> to direct players' focus on specific aspects of play were recommended to purposefully and selectively make learning more explicit.

To facilitate a *learner-centred approach*, the experts recommended to differentiate within overarching learning goals paying respect to the needs of each individual. R4 explicitly recommended to define only ‘one overarching objective for a session which may have two or three individual outcomes sitting below that’. To support a focused analysis of players’ learning needs and, thus, differentiation in pursued outcomes, CE2 recommended:

Try to be specific in your training objective. The more specific you are, the clearer it is for the players. The clearer it is for you as a coach, to know what you are looking for. [...] What do you have in your mind when you’re observing? You’re looking for very specific behaviour. For me, in an effective training session, you should see a change of behaviour in the players, meaning that the session had an impact on what they are doing. If you have a too general topic, it’s very difficult to assess it. (CE2)

These individual learning outcomes were related to players’ capabilities to practically solve game situations, as well as to their context-specific understanding of optimal game solutions. This was thought to consolidate competent gameplay in the long-term:

I want them to come away with a better ability to do something but with the understanding of why they are doing it and how. Only then it’s real learning. If they just repeat something because you have told them to and they can do it, it’s a blunt tool. [...] They can do it, but perhaps not in context. So, it is understanding, not knowing. (CE3)

Building upon this assumption, both players’ technical skill execution and their game understanding were outlined as relevant domains in which differentiation can take place.

Relating to players’ technical skill execution, experts generally advocated *individual movement patterns*, often by explicitly rejecting the notion of ideal ‘textbook’ techniques.

For example, R3 places importance on a skill's functionality saying, 'players need technical skills to optimally solve game situations, what it looks like is almost irrelevant.' Further, CE5 emphasized the need to consider interpersonal differences: 'My point of gravity is low; your point of gravity is high. That has a huge impact on how I shield the ball. So, no ideal execution, they need to find their best ways of executing.' Additionally, intra-individual movement variations were legitimized by an individual's efficient skill execution under different conditions (e.g., game situations; pitch surface). Nevertheless, while still agreeing that technical execution 'is completely individual and free', C5 stated that 'there a few things that are the same for everyone.' R6 similarly emphasized 'that the idea of an individualized technique is true to an extent, but there are patterns and strategies that do seem to work better than others.' Thus, from the experts' statements, it became evident that individual movement patterns should fall within boundaries of a skill's functional variability by referring to both external (e.g., hitting point of the ball) and internal, movement-related aspects (e.g., ankle stiffness when shooting the ball).

Overall, participants' understanding seemed to correspond with notions advocating self-organized skill learning (cf. Anson et al., 2005), even though not in its purest sense. The experts' statements about the need for individual, yet also functional movement patterns correspond to dynamical systems viewpoints, especially the idea of attractors as 'fixed points in which all initial conditions converge to some stable rest state' (Kelso, 2001, p. 13845). However, the often simultaneously held belief of (more or less consistent) functional movement characteristics across individuals also reveals some parallels to ideas of movement-invariant features typical for information-processing perspectives (e.g., Schmidt, 1975; Anson et al., 2005 for a review). Even though self-organization and infor-

mation-processing approaches represent distinct paradigms on motor control and learning, experts' argumentation showed links to both theoretical viewpoints, thus, underlining certain trade-offs that may be required within practical work. While the interviewed experts could be placed in different positions between these paradigms, the majority of experts welcomed different movement patterns of one skill as well as individual solutions to complete a task. However, to differentiate appropriately, the experts elucidated the need for coaches to identify what is functional for each individual case: 'That's the quality of the coach to see, he [the player] does not execute the skill typically. He may need a cue to improve, but if he still solves the situation with his technique appropriately, I would keep him there' (C3). To accomplish this challenge, the need to amalgamate experience and professional knowledge about movement-related characteristics of soccer skills was described.

Another domain mentioned by participants which required differentiation pertained to the development outcome of players' tactical game understanding. Here, the experts agreed upon the usefulness of making selected behavioural aspects of gameplay explicit. Yet, they highlighted challenges associated with determining the optimal *degree to which behavioural aspects should be made explicit* by considering individual player attributes (e.g., cognitive development, personality traits, etc.). CE6 said: 'Some players need more knowledge; others are more intuitive. They have this intuitive competence, and my claim is to address all player types optimally.' In this regard, experts' statements parallel notions in the literature regarding the benefits of either implicit or explicit learning processes (Kleynen et al., 2014). This conflict became especially potent when discussing the need, on one hand, to facilitate players' capability to develop versatile and original (i.e.,

divergent) game solutions, while also needing to support tactical principle-related game understanding more explicitly.

Implicitly made experiences are a kind of foundation, but purely implicit learning wouldn't work anymore in these age groups. [...] I am now talking about accentuated, tactical goals. I would – and you can call it as you like – kind of reflect upon or organize their experiences. For instance, I would reflect on better or worse options, and try to avoid a certain negligence towards other possible solutions or aspects of play among players. (R1)

Overall, participants' accounts widely corresponded with the developmental framework on tactical creativity in youth players forwarded by Santos et al. (2016). This model recommends addressing tactical learning in early adolescence by diverse, implicit game experiences, that were carefully enhanced by convergent thinking on situational game principles.

As guiding principles in terms of an individually differentiated approach to increasing explicit understanding over time, CE4 acknowledged the importance of taking a player's developmental phase into account, explaining that 'before the age of 12, you don't need to know anything. Just create situations where they feel completely free. Later, I want them to start knowing what they are actually doing and why.' Experts expanded on this by recommending introducing simple tactical principles step by step. This is promoted by purposefully and selectively explaining 'certain decisions that they can make within [tactical] principles' (C1). Using the terminology of Almond (2015), developing an *understanding of the game* (e.g., tactical principles) was connected by the experts to players' *understanding in the game* (e.g., better in-situ decision-making; responsiveness to changes in the game). Further, this was related to players' opportunities for self-reflection which were

described as a critical component of soccer-specific competence. For example, R5 stated that explicit game understanding ‘encourages players to self-reflect. Maybe they’ll talk to each other about it, maybe they’ll think about it at home’.

Lastly, another domain in which differentiation was deemed necessary pertains to certain developmental goals, often termed as *basics*. Irrespective of an expert’s positioning regarding self-organized learning, the call for developing players’ basics was related to different areas. In particular, the experts emphasized the relevance of developing foundational technical skills (e.g., fundamental two-footedness), tactical behaviours (e.g., open body positioning), and habits for successful gameplay (e.g., quick transitioning):

The presented learning goals are correct, that’s a philosophy. But for me, the key is to break it down [...]. They need to have a good first touch. They need to be able to dribble. Another basic for me is transitioning. Yes, I teach the players that if they lose the ball, they must do something to get it back. (C6).

Though principally important for all players, differentiation toward these ‘basics’ was perceived as mandatory: ‘It’s age-dependent and individually different. The lower the expertise, the more engagement on these things is necessary’ (CE6). While the term ‘basics’ was less prominent in the group of researchers, they still argued, for example, ‘we have to ensure that the technical skills they require – that means that they can be successful in the game – develop’ (R4), thus, highlighting the limiting impact of missing basics implicitly. Coaches and coach educators, however, explicitly stated how missing basics could limit player learning, for example, by restricting players to explore the entirety of behavioural options in challenging game situations. That is, justification for developing such basic skills partly questions purely self-organized understandings of learning, as

players were described to omit game situations or the use of skills as long as ‘low perceived controllability of the situation’ (Nitsch & Hackfort, 2016, p. 19) is given.

II. Designing purposeful training sessions with the game in mind

Building upon specific session objectives (i.e., Theme I), the experts generally recommended purposefully designed practice activities that frequently stress distinct *outcomes as required in the competitive game environment* and provide *inherent guidance toward players’ task mastery*.

One of the most important things for me is that coaches are creative and think about what the final result should be. Don’t just go to Google, find an exercise, and say: “Okay, we’re going to do this!” [...] Always ask yourself the question: “What does it mean for my players in my situation, and how do I tweak this exercise so that it’s meaningful given the learning goals you were talking about?” (CE5)

As another general recommendation, the experts called for practice tasks which required players’ investment: ‘You have to create practice activities that are challenging yet also manageable. [...] Players should be able to succeed a few times, but it can’t be too easy so they’re not actually learning anything.’ (C1). Treading this fine line on an individual level offers links to the challenge-point framework in which a demanding functional task difficulty is described as most effective in already skilled individuals (Hodges & Lohse, 2021). Consequently, coaches should consider how to adjust the complexity of a practice task to account for a learner’s competence level. Even better, coaches may create situations in which players ‘need to self-determine their current performance level and can individually adjust the difficulty’ (R3) to also address their senses of competence and autonomy. This could ensure sufficient challenge required for player learning while also balancing the ‘motivational costs’ (Hodges & Lohse, 2022, p. 754).

Regarding the practice design, the participants consistently emphasized the need for ‘a chest of tools’ (CE3) to adequately address individual learning needs. R4 argued: ‘I really encourage coach development related to understanding benefits and trade-offs of certain practices regarding what they’re trying to achieve. No practice is the golden bullet.’ Nevertheless, accounting for this generally shared assumption, more specific guiding principles on purposefully designing practice in a talent development context were provided.

Fundamentally, the experts deemed a *game-centred*¹³ *philosophy* as most conducive to learning and would dedicate plenty of practice time to it. ‘Give the players what they want! That’s my philosophy. Players want to play soccer, and I want to facilitate specific outcomes with it’ (C5). To apply this philosophy purposefully, strategies to constrain and simplify the games according to the session objective were driven by the notion of keeping the specificity as high as possible (cf. Farrow & Robertson, 2017). R5 specified the challenge that ‘representative practice can only be simplified to a certain extent before it no longer becomes representative [...], but I would still search for simplification that retains perception-action couplings.’ The experts highlighted that this can be achieved through small-sided games where space, time, and rules were scaled. Regarding the rules, keeping the logic of the game instead of restricting players in an unrepresentative fashion was one overarching premise to guide player behaviour. C4 criticizes: ‘Coaches often invent rules that do not exist in soccer’. Though this seems difficult to realize if spe-

¹³ The terms *game-centred* (e.g., Almond, 2015) and *game-based* (e.g., Pill, 2021) were often interchangeably used in the literature. *Game-centred* seem to better reflect the idea that purposefully designed and constrained (i.e., ‘exaggerated’) games build the session foundation, but potentially be supplemented by further, less-representative practice activities to purposefully stress specific outcomes.

cific learning goals were pursued, the statement sensitizes weighing up the use of constraints by being aware that they potentially cause unnatural behaviour in any other domain of play. The recommendation for designing games with specific outcomes while keeping the logic of the game intact reflects notions in the literature decades ago (e.g., keeping realism; cf. Worthington, 1974, p. 161). Echoing Pill (2021), it corresponds with game-centred approaches aiming for discovery learning (e.g., constitutive primary, and operational secondary rules; cf. Almond, 2015, p. 21) and also applications of approaches striving for self-organized skill learning (e.g., constrained, yet representative situations; cf. O’Sullivan, 2021, p. 1281). C3 illustrates the progressive developmental process of games:

I start developing games from the session goal. This leads me to how I design the field. Narrow and long or wider and shorter? Based on the field, I develop the rules – maybe I need zones – and, finally, this process results in a specific focus of coaching.

To accomplish this game-centred philosophy, practice activities widely aligning with principles of *representative learning design* (Pinder et al., 2011) but without playing an open game were highlighted. These aimed to strengthen the focus on specific, yet simplified game situations through repeated confrontation with a specific technical-tactical game task to be solved. In this regard, ‘decreasing choices is always a way of simplifying’ (R6) a practice task which can be further supported by implementing additional constraints to stimulate players’ search for desired behaviours (e.g., handicapping defenders to stimulate 1v1 of attacking players). Still ensuring a game-like dynamic, CE4 offered ‘only 1, 2, or 3 options. So, [CE4] would still create situations with decision-making, but decisions are going to be more binary or easier.’ Prominent examples were waves practices (e.g.,

2v1) in which players repeatedly engage in specific situations and were guided toward solutions related to one phase of play.

Moreover, *technical drill practices* were thought to be beneficial to address movement-related aspects of skills in an individualized fashion. C1 specifies by using an example: ‘longer balls or chip balls – youth players have a hard time doing that. I agree to start isolated but you can’t expect all is going to get better in the game. You have to progress that.’ Also, the contribution of drills was often described as a mediator for learning as ‘you feel these technical repetitions give you a certain feeling of security in the game’ (C3). This mediating role was further justified by players’ perceived range of available options that prospectively encouraged the use of demanding skills in game-representative situations:

We also use [drills] to calibrate our capabilities. This is important because the decisions you make during a game are based on your action capabilities. You never decide to give a long pass to the number seven if you’re right back, if you know you can’t get there even if this player is completely free [...] When players feel good about their long pass, they are more likely to do it in a certain scenario where it would be beneficial for them. (R5)

The experts’ justification for the benefit of drill-based activities somewhat parallels the perception of affordances depending on the interrelation of individual action capabilities and environmental information (i.e., Gibson, 1979) which is prominently referred to in the ecological dynamics coaching literature (e.g., Chow, 2013; Renshaw et al., 2019). However, often derived implications like incorporating ‘representativeness [...] and the maintenance of pertinent information-movement couplings’ (Chow, 2013, p. 473) as principles of a *NLP* partly contrast experts’ reasonings on the benefits of decomposed,

drill-based practices in that they broaden the range of opportunities to act in a game situation. If the intended technical improvements primarily aim to enhance a learner's experiences in the game, the argument can also be linked to constructivist viewpoints on tactical learning (i.e., technical 'capabilities' allowing for in-game experiences, thus, serving the assimilation of a wide range of possible decisions; cf. Hallé-Petiot et al., 2021, p. 5). Overall, these potential compatibilities with different theories and their validity for explaining the effects of drill-based practices need to be discussed in the light of the different outcomes which may be pursued.

Notwithstanding these theoretical connections, technical drill practices were perceived as beneficial if certain methodological principles were considered. Generally, drills were described as practice activities stressing the frequent application of technical skills decoupled from decision-making and sometimes even from game-representative perceptual demands. Yet, driven by the claim to develop functional technical skills, movement replication in a constant fashion was predominantly rejected which is similarly emphasized, yet differently pronounced and justified by motor learning models (Schöllhorn et al., 2022 for a review):

There are benefits from drills, but it shouldn't be 20 minutes of the same thing and I am a big proponent of bringing in variable practice conditions. If you want to support learning, there needs to be some difficulty and challenge in what you're doing. (R6)

Practical examples provided underlined this recommendation of inducing within-skill variability across technical repetitions, for example, through drill-activities in which skills were practiced throughout a moving situation.

Finally, phases of *free play* were recommended for every session, justified by their vital contribution to divergent gameplay (i.e., creativity), the self-regulated development of

game intelligence, and the functional application of technical skills. Several experts linked free play ‘to the ideas of street soccer’ (R3) assuming that ‘the game is the teacher’ (C2). However, this statement should not inadvertently lead to the assumption that any game could equally contribute to specific learning goals. Rather, the experts recommended to develop ‘inherently engaging’ (C4) and ‘intelligent games that guide children to gather experiences’ (R1) related to the session objective and, thus, do not require any coach intervention. Based on their experience, several experts emphasized that creating minimally restricted and prescribed free play is a particular challenge for some coaches as ‘[they] were socialized that they think coaching requires to instruct a lot’ (CE2). This is similarly reflected in empirical studies highlighting a disconnect between intention and practice leading to ‘overcoaching’ (O’Connor et al., 2017, p. 657). In this regard, the experts described the specific value of free play also for coaches as they could intentionally observe players to gain a variety of impressions which is required to elaborate on individualized goals and support.

Ultimately, while acknowledging the general benefit of different practice activities, the relevance of a purposeful connection within the *session’s microstructure* was highlighted and several approaches were mentioned (e.g., confidence-competence-confidence; whole-part-whole). Yet, instead of recommending one preferred solution, the participants generally agreed on the need to be flexible and to adjust one’s session design to the pursued outcomes so that ‘the overarching goal becomes clear to everyone’ (C6). However, this decision on the microstructure links back to Theme 1 and the outlined challenge for coaches to initiate learning (more) implicitly or (more) explicitly. This is reflected by experts’ recommendations on session introductions that parallel *associative* and *problem-based* approaches (cf. educational literature; Jonassen & Hung, 2012;

Jozefowicz, 2012). Associative session introductions, potentially supported by visual tools (e.g., video clips), aimed at creating a link between the session objective and something already learned, experienced, or known to initially increase the player's recognition and awareness. Here, CE2 explains the intention to shift players' focus toward certain skills or game situations, but 'without telling them "These are the details you have to focus on!"' Instead, players were expected to 'discover this during the session' (CE2). Problem-oriented introductions were perceived to facilitate a physical exploration of rather unknown technical or tactical problems. Experiences collected could subsequently be made the subject of reflection:

For me, an optimal session does not start with me verbally explaining: "Today, we practice scoring goals." It rather starts with a situation where the problem of scoring goals is very relevant. This allows me to start the sessions actively but leads to a specific problem. To achieve this, I let them play to confront them with this problem; it must become their problem – not because I am telling them, because it is their problem. And if they then say: "we don't get through it – what should we do now?" they have a shared goal which can be the starting point to work out potential solutions together. (R3)

Overall, building upon a specific objective, the use of different – presumingly even contradictory – practice activities may be joint together within a thoughtfully comprised microstructure of a session. Guided by a game-centred philosophy, coaches may support distinct learning outcomes via a range of different activities. While making use of the benefits of diverse practice activities it is important, that coaches also need to be engaged in regular self-reflection to be(come) aware of the activities' potential disadvantages for learning.

III. Coaching interventions to support player learning within a group environment

Corresponding to the ‘chest of tools’ outlined in Theme II, a *spectrum of coaching interventions* was perceived necessary to offer individualized learning support, echoing coaching styles presented in the literature (e.g., Otte et al., 2020; Pill & SueSee, 2021). CE3 highlighted: ‘The magic is developing the individual within the team environment. That’s the art of coaching.’

As a foundation for individualized support (i.e., optimal intervention), coaches were encouraged to reflect on both, the practice design and player behaviour to address players’ individual learning needs appropriately. C5 justified the need for *reflection on practice design* by emphasizing that ‘it doesn’t make sense to start coaching [the player] if you need to intervene all the time because the setup is not good, or they can’t execute it in a certain way.’ To determine the adequacy of the practice design, sufficient involvement of players in intended actions and optimal functional task difficulty (cf. Challenge Point Framework; Hodges & Lohse, 2022), were described as central foci of reflection. Additionally, experts aimed to provide players with time to familiarize themselves with a practice task and allow exploring it without being primed by coach-induced solutions. Mainly related to coaches’ actional diagnostic competence (i.e., linking gathered information and deciding on a specific intervention; cf. Klug et al., 2013, p. 39), the need for *reflection on player behaviour* was reasoned to identify distinct learning needs on-the-pitch and, thus, to decide on potential interventions:

Prepare yourself well but also remain flexible all the time, and don’t try to deliver anything written on paper. Listen to what you feel about the situation and how it develops. Don’t say: “I have these learning goals and bring them on the pitch today.” Quite often, less is more.

When ‘analyz[ing] player behaviour in the sense of a precise diagnosis’ (C4), ‘the most important thing is to understand the causes: Why is the player doing this now?’ (R1). C3 specified: ‘We observe why a player got stuck: Was it a bad decision? Was it a perceptual problem? Was it a technical problem? How can we improve it? Sometimes it’s even a coordinative problem.’ Addressing these reflections, the experts recommended ‘watching the players when the ball is somewhere else’ (CE4) and always considering ‘the coach’s different viewpoint at a game situation compared to the players on the pitch’ (C6).

To enhance coaches’ distinct focus when reflecting and facilitate individualized intervention a collaborative ‘coaching in a team’ approach in which *clear coaching roles* were defined was consistently recommended:

I’m always amazed. I’ve seen sessions with six coaches around the field. I always wonder what all the coaches are doing here. When the objective is to develop individual players, you need to pay attention to individual players and every coach should have a role [...]. So, I would say here [points on a player in a video clip] there should be a coach talking to him about the way he attacks, or just give him a high five because he scored a tremendous goal, he had a tremendous action. (CE5)

Achieving role clarity was described as largely built upon thoughtful pre-session planning and exchange in the team of coaches to deliver appropriate individual support (e.g., optimal coach positioning). Different solutions were described and C1 explained a prevalent approach in which ‘one coach has more responsibility for the overarching practice activity, whereas the others very much focus on individual feedback’.

Overall, it was stated that all coaching strategies leading to inactivity of the players should be used sparsely. Keeping this claim in mind, *modifying task constraints* to inherently guide players toward their pursued learning goals was stated as an important strategy. This required coaches to identify practice situations in which ‘apart from words, the conditions and rules of the game can be varied through different “adjusting screws” which stimulate player solutions’ (R1). The experts argued that by modifying task constraints players would be encouraged to use skills which they would otherwise not use in unconstrained game situations. Illustrated by CE1’s coaching principle: ‘the game is holy’, recommended interventions widely aligned with the strategies described for purposeful task design (see Theme II) aiming for minimal prescriptions, for example, by modifying field dimensions and increasing the incentive of desired actions. At this point, experts’ argumentation seems most related to a *CLA* and *NLP* viewpoint given the assumption that ‘learners do not need to engage in significant amounts of “cognitive processing” before they can discover and explore a performance solution’ (Renshaw et al., 2016, p. 469).

The experts’ statements allow the interpretation that cognitive processing may not be necessary *before* discovery and exploration, they instead even highlighted how this may hinder learning (see Theme I). Yet, experts oftentimes recommended the purposeful use of *guided player reflection* embedded *within* practices to facilitate players’ game understanding, thus, relating to improving tactical decision-making (cf. Almond, 2015). As such, it was recommended to initiate reflective thoughts, for example, by ‘asking a question that makes players think about game solutions’ (C5), and thus, to make ‘bigger goals and principles’ (C1) explicit. The contribution to player learning was linked to the potential transfer of explicated tactical solutions across similar situations. CE5 elaborated:

It's like, we let them play, and we think they learn. Of course, they will learn, but when you reflect on what you do at certain moments if you're able to explain it. It's more about reflection with the players about what you do at this moment. What are the choices you can make?

At this point, greater connections to game-centred approaches associated with constructivist viewpoints became apparent (e.g., *TGfU*; Harvey et al., 2018; see also Gréhaigne & Godbout, 1995). Accordingly, the integration of learners' subjective experiences was described as critical, for example, by using guided reflections as *one* strategy to facilitate 'intelligent performers in a game' (Almond, 2015, p. 17). To achieve this, R5 stated to actively engage each player and eliciting individual responses: 'When I want to open opportunities to act in the game, it's important to ask a question to notice what perspectives they have. What do they see? That's the initial process to get to the root of this issue.' These recommendations partly contrast with findings on top-level youth soccer coaches' questioning practices, revealing the use of questions aiming to result in immediate and desired responses (cf. Cope et al., 2016). If reflections should lead to clearly defined principles of play, the experts in the present study similarly recommended 'to ask open questions and – that's the fine art of coaching – to develop a fundus of solutions whose pros and cons were developed by the players' (CE6). Consequently, the experts emphasized the importance of providing opportunities for players to use divergent, higher-order thinking. This generally implied asking open questions (O'Connor et al., 2021a).

According to the study participants, best-case scenarios only required one stimulating question addressing a collectively repeated error or positive examples so that 'your role as a coach is to listen and try to confirm, try to build, try to summarize with their words,

with their sentences. [...] And if you can make the summary with these elements from their answers – perfect.’ (CE2). Nevertheless, as guided reflections address players’ game understanding in an explicit fashion, experts urged coaches to use it selectively to also keep gameplay fluid. ‘I try to embed reflections into recovery breaks or when we change activities. I only focus on a few relevant aspects that are still in their minds, and I strive to involve the whole group, but still being brief’ (C3).

Furthermore, *direct instructions and feedback* were highlighted as beneficial coaching tools and several experts explicitly differentiated those strategies from being autocratic or commanding: ‘The coach as an instructor is often associated with the coach as somebody who shouts at players a lot. That’s just bad coaching.’ (R4). Thus, echoing recent discussions (Cope & Cushion, 2020), the experts’ perspectives challenged some purely negative connotations in the literature in which direct instructions’ disempowering character is described. Instead, the experts perceived direct instruction as supportive, if only small behavioural changes can lead to immediate better performance. C6 explains: ‘There are a few premises that must be fulfilled. Sometimes it’d be most helpful to just stop the game and tell the player: ‘Look, you cannot receive the ball here. You’re not helping your teammate at the moment. If you move out of the back from your opponent, you’ll get the ball.’ Additionally, it was recommended to support players in particularly high-pressure situations: ‘If I see they are too stressed within the game, then I will give them more help’ (CE1). The experts also described crisp instructions as critical to affirm players’ behavioural changes in-situ. Even if these changes are not observed in immediately better gameplay, it was perceived important to encourage players exploration of solutions within demanding game solutions. Thus, such affirmation (e.g., by praise) was

deemed vital for reinforcing both, ‘what they [players] can and what they did’ (CE1; i.e., their efforts).

From an outcome-related perspective, experts’ examples of the beneficial character of direct instruction are mainly related to tactical behaviour (i.e., better decisions). The participants described the benefits of crisp instructions or cues that could direct players’ attention toward already acquired tactical aspects in-situ, yet, without interrupting the activity. Nevertheless, it was advised to avoid ‘PlayStation coaching’ (C5) in terms of steering a player marionette-like to the preferred solution when in possession of the ball. Instead, instructing or cueing when players were off-the-ball was deemed more effective. However, R1 generally proposed:

I would use it sparsely and especially not introduce a practice task by providing solutions as it will prevent a wide perception of the situation. When children have collected several experiences, there is no reason to not structure these experiences by telling the players what they should focus on.

Regarding technical skills, some experts advised directing a player’s focus on obvious non-functional technical movement characteristics if the same issue consistently occurred and represented an obvious limiting factor within gameplay (see ‘self-organization’ in Theme I). CE1 said: ‘If one player, for example, always hits the ball too far front or back – the player may just need this detailed feedback to improve.’ This assumption seems to conflict with considerations from an ecological dynamics viewpoint on skill learning as it may ‘curtail and hinder intrinsic feedback system functioning during self-organized exploration for functional movement solutions’ (Otte et al., 2020, p. 6). Simulating feedback to a player, R4 generally agreed on the necessity to address such technical errors but similarly illustrated this dilemma: ‘I think I would not address an error in

detail, I may just give the player a little cue to improve rather than saying “regarding the technique, you always showed this or that obvious movement error.”’ Generally, echoing considerations in the literature supporting self-organized learning (e.g., Renshaw et al., 2019, pp. 63-65), there was a shared assumption among experts to be aware of potential (negative) consequences when using directive coaching too frequently when aiming to support technical skill learning. However, this recommendation is not reflected by empirical findings revealing its too widespread use in youth soccer practices (Ford et al., 2010).

To summarise, experts’ reasonings on the need for several coaching tools were mainly related to the variety of outcomes required for competent gameplay. In this regard, adjusting practice tasks to create optimal situations for learning was described as the foundation for both technical and tactical skill learning. Especially for the latter outcome, the experts highlighted the contribution of explicit learning by making use of coaching strategies that selectively stimulate players’ thoughts, thus, contributing to their game understanding.

Conclusion

The findings provide insights from experts in elite youth soccer coaching and integrate the different perspectives of coaches, coach educators/developers, and researchers. Grounding the study in established learning goals and specifying the coaching context (i.e., DFB talent development program) ensured a common basis for all experts from which they could provide focused practical recommendations. The three presented themes address person-, task-, and environmental characteristics which were highlighted as relevant for coaches to consider when designing practice. However, coaches should be aware that these characteristics are not independent, but rather need to be

adjusted in a way that they complement another to create optimal situations for learning. Specifically, experts linked the importance of a *learner-centred differentiation* to a *game-centred main philosophy*, which was however complemented by various ‘practice tools’. To support learning effectively, *specific coaching interventions* were also discussed regarding the need to moderate individual learning outcomes on the pitch.

Overall, the present study sheds light on the benefits of different practice activities and coaching interventions for talent development. However, a certain dilemma appeared from the interrelatedness of technical and tactical skills underlying competent action in soccer as nuanced, but practically relevant differences in how these outcomes can be best developed were described. Regarding *technical skills*, the experts widely plead for self-organized, implicit learning processes (Anson et al., 2005). Yet, most experts did not support a self-organized understanding in its purest form, thus, highlighting the fluent transitions of implications derived from distinct theoretical positions in practical work.

From a practice design perspective, it was consistently stated that game-representative activities are inevitably needed for the development of efficient and functional technical skills (in particular under psychological and physical pressure). While the effectiveness of small-sided games for technical skill learning is supported by intervention research, some studies also show that drill-based activities can lead to technical improvements, especially if performance is assessed in isolated skill tests (Bergmann et al., 2021a). In this regard, the experts emphasized the potential to enrich technical skill learning through properly designed drills if purposefully embedded into the session’s microstructure. The recommended practical strategies represent a contemporary understanding of technically focused drills that go beyond ‘traditional’ views of constant practice targeting

prescribed movements which could be hardly harmonized with claims for engaging activities, the need for within-skill variability, and optimal challenges.

Regarding *tactical skills*, the experts advocated for focusing on the promotion of implicit learning, which is purposefully supplemented by more explicit, principle-related approaches addressing players' game understanding (Almond, 2015; Santos et al., 2016). As both technical and tactical outcomes were often simultaneously emphasized in game-representative practices, the complementarity of different pedagogical approaches and their distinct features was uncovered even though they were grounded in partly different epistemological and contextual roots (Harvey et al., 2018; Renshaw et al., 2016).

From a theoretical viewpoint, connections to ecological dynamics-driven approaches were found in claims that self-organized learning mainly appears within purposefully constrained, representative situations (O'Sullivan et al., 2021). As the experts would mainly make use of small-sided games constrained toward distinct learning outcomes, the practical implications revealed substantial overlaps with game-centred approaches (Pill, 2021 for a discussion). A potential difference between these approaches appeared from the general claim to guide players' discovery learning by addressing their explicit game understanding. As this should be based upon players' subjective experiences and solutions, it seems closely aligned with discovery-based approaches, associated with constructivist viewpoints (Hallé Petiot et al., 2021). However, a thoughtful and dosed use of respective strategies was similarly emphasized by weighing up the benefits and disadvantages for long-term learning in already high-performing youth players. This may contrast the practical application of certain approaches in educational contexts from which they originally emerged (in detail Harvey et al., 2018).

Overall, the effectiveness of recommended strategies seems closely related to supportive talent development environments that constitute a vital foundation for learning support. For instance, immense relevance was ascribed to players' need to collect experiences in challenging situations and their respective engagement as active problem-solvers. As talent development environments are commonly characterised by selection procedures (Williams et al., 2020), they inherit a certain performance pressure. Therefore, it seems crucial to actively shape a practice environment that stimulates players to gather a variety of experiences and encourages players' willingness to take risks. In this regard, coaches should differentiate between immediate performance and long-term learning (Soderstrom & Bjork, 2015), and to understand mistakes are an inevitable consequence of players' risk-taking. This links to characteristics of functional talent environments (e.g., need-supportive coaching, psychological safety; Hauser et al., 2022) and their compatibility with coaching strategies to facilitate widely self-organized learning (Theme I) and to identify optimal 'functional' challenges (Theme II). Such compatibilities can strengthen the theoretical foundation of coaching research and practice and provide impetus to construct coherent networks for theory integration (Gigerenzer, 2017).

From the perspective of coach education, the findings mirror the need for flexible and purposeful use of different coaching strategies. Yet, beyond just adding tools to the repertoire, the findings underline the relevance to equip coaches with expedient strategies for *reflection-in-action* (e.g., task design, player behaviour) to determine immediate coaching interventions and *reflection-on-action* (e.g., atmosphere building, session planning) to facilitate players long-term development (for a heuristic see Downham &

Cushion, 2024). The findings may further inform coaching guidelines for talent development, for example, regarding the complementary use of different approaches to practice and coaching to facilitate specific outcomes.

Nevertheless, the outlined recommendations on practice and coaching are far from being all-encompassing and do not imply that other approaches cannot be conducive to learning. In addition, transferring the strategies into specific contexts requires the consideration of unique circumstances, potentially different learning goals, and other barriers to coaching and learning. Furthermore, interpreting experts' statements was sometimes challenging due to inconsistencies regarding the aim to facilitate either implicit or explicit *learning* and how different *intervention strategies* were described to be more explicit or implicit in nature. This becomes even more complex when considering that different verbal and non-verbal coaching interventions can promote either form of learning depending on their use (Kleynen et al., 2014).

For future coaching research, the findings can be strengthened by considering multiple perspectives related to, for example, person characteristics (e.g., skill-level, motivation), practice tasks (e.g., high vs. low representativeness), and environmental circumstances (e.g., learning vs. performance context). Additionally, the consideration of players' subjectively perceived benefits of different approaches could provide further impetus for more specific practical implications and may enhance our understanding of an individualized use thereof.

Declaration of competing interest

The authors report there are no competing interests to declare.

Supplementary Materials

Supplementary materials for this article are provided in *Appendix 3*.

3.2.3 Fostering Learning-Supportive Coaching in a Nationwide Talent Development Program: Mixed-Methods Evaluation of a Research-Informed Soccer Coach Education Initiative (Study 3)

This chapter contains the manuscript accepted for publication in *Physical Education and Sport Pedagogy* on 27 July 2025. The full reference of the published article is:

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Abstract

Background: In talent development environments (TDEs), supporting youth athletes' long-term development is a core responsibility of coaches. A key element of TDEs is the use of coaching strategies that effectively facilitate learning processes. Research-informed coach education programs (CEPs), which blend experiences of practitioners with research findings, can serve as a valuable medium to optimize coaches' learning support. However, CEPs that have been systematically implemented into large-scale TDEs remain scarce, as does the evaluation of such initiatives.

Purpose: Building on a participatory research approach, this study aimed to develop, implement, and evaluate a research-informed CEP designed to foster learning-supportive coaching within Germany's nationwide soccer talent development program.

CEP Content and Implementation: The CEP included theoretical knowledge and empirical findings on effective learning support, as well as specific recommendations for coaching elite youth soccer players. A multiplier approach to coach education enabled the nationwide implementation of the CEP across seven regions ($N = 229$ coaches). The multipliers, coach coordinators employed in the DFB talent development program, were trained to deliver the CEP.

Methods: The mixed-methods evaluation, guided by the Context-Input-Process-Product model, integrated perspectives from both multipliers and coaches. A quantitative online survey assessed participants' satisfaction with the CEP ($n = 8$ multipliers; $n = 145$ coaches). In subsequent qualitative interviews ($n = 7$ multipliers; $n = 14$ coaches), their experiences, including potential outcomes, were explored in greater depth. Descriptive statistics were used to analyze the survey data, and a Template Analysis was conducted across all interviews.

Results: Participants perceived the CEP as beneficial in enhancing coaches' learning support. Reported outcomes included, for example, research-informed self-reflection, greater awareness of learning-supportive coaching, and the intention to apply the recommended strategies. Nevertheless, areas for further improvement were identified, such as enhancing the appeal of CEP materials, enabling multipliers to better tailor the program for their target audience, and incorporating elements that support coaches' long-term development. Additionally, some coaches reported difficulties in applying the recommended coaching strategies, particularly when aligning them to players' individual learning needs.

Discussion and Conclusion: This study emphasizes the critical importance of striking the right balance between sufficient scientific input and manageable complexity in CEPs. It also highlights the need for didactical methods that foster reflexivity among coaches. In large-scale initiatives, it is particularly important to align a systematic approach to talent development (e.g., transferring consistent coaching principles) with contextual adjustments to meet coaches' developmental needs. This is best accomplished through close collaboration of researchers and practitioners in designing and implementing research-informed CEPs.

Keywords: Coach Development; Competence; Football; Intervention; Participatory Research; Practice-Transfer

Introduction

Sport coaches are crucial for enhancing a variety of outcomes in athletes (International Council for Coaching Excellence, 2012). Different coaching contexts, however, impose specific challenges upon coaches linked to the promotion of different performance factors, consideration of athletes' characteristics, and available resources (Lyle & Cushion, 2017). One specific context is the *Talent Development Environment* (TDE), which is characterized by complex processes aimed at identifying individuals with promising athletic potential and providing them with optimal long-term developmental support (Höner et al., 2023). The *Differentiated Model of Giftedness and Talent* (DMGT; Gagné, 2021) defines the overarching objective of the talent development process as the acquisition of sport-specific competencies – that is, learning. Besides individual athlete characteristics and chance factors, the DMGT emphasizes the moderating role of the environment in the development process. In this regard, one challenge within TDEs lies in the tension between fostering sustained athlete development and the inherent pressure of (de-)selection procedures (Williams et al., 2020).

Coaches are required to navigate these demands by establishing functional TDE features (Hauser et al., 2022). In relation to competence acquisition, the learning support provided by coaches plays a crucial role. Therefore, *learning-supportive coaching* aims to foster the development of sport-specific competencies in athletes and constitutes one key aspect of coaching effectiveness in TDEs (Bergmann et al., 2025a). To assist coaches in this endeavour, their practical experience and contextual insights should be complemented by research findings (Williams & Hodges, 2023). Consequently, there is a need for targeted initiatives that support coaches in facilitating athlete learning by integrating practitioners' experience and knowledge based on current research.

To complement formal qualification programs (e.g., coaching licenses, university degrees), this knowledge is often made available to practitioners via research-informed coach education programs (CEPs). These programs aim to enhance coaches' professional knowledge and, through interaction with inter- and intrapersonal knowledge, further develop their coaching competence (Côté & Gilbert, 2009). According to Stodter and Cushion (2017), CEP inputs traverse a double-loop filter process before being integrated into, adapted for, or rejected from one's coaching practice: Initially, the *individual, cognitive filter* is represented by coaches' beliefs, knowledge, and practice which shape the perspective on matching or mismatching new experiences. The subsequent *contextual filter* verifies whether the coaching context allows for the practical integration of learnings. This filter was found to overrule the individual filter even though learnings aligned with coaches' knowledge and beliefs (Stodter & Cushion, 2019).

These theoretical assumptions have implications for *learner-centred coach education* (Paquette & Trudel, 2018). Specifically, CEPs should facilitate engagement with coaches' beliefs and experiences while being tailored to specific contextual demands and responsibilities they face. For instance, this can be achieved through didactical methods that encourage practitioners' reflexive engagement (e.g., problem-based workshops; Ciampolini et al., 2019; Wang et al., 2023). To further address the challenge of transferring research findings via CEPs, Lyle (2018) recommended involving practitioners in both, the design of practically relevant research studies and the processes of translating and synthesizing these findings to meet the needs of the target audience.

In soccer TDEs, opportunities for research-informed CEPs are facilitated by a growing body of talent research (Williams et al., 2020). For instance, workshops with youth soccer coaches encouraged them to allocate more time on game-based activities (Andrew et al.,

2022; Jones et al., 2024), to use a greater proportion of instructions to create an external focus of attention (Andrew et al. 2024b), and to optimize their questioning strategies (Raya-Castellano et al. 2024; Partington et al. 2015). Beyond the studies situated within single clubs, Wachsmuth et al. (2022) introduced a *multiplier approach* to coach education aimed at promoting motivational coaching within a nationwide talent development program. This approach involves trained multipliers who are responsible for implementing centrally developed CEPs in ‘larger coaching cohorts within a distinct organizational setting’ (ibid., p. 3). The evaluation indicated that such a multiplier approach holds potential for gaining coaches’ buy-in, for transferring and applying research-informed knowledge into practice, and thus for encouraging behavioural changes within larger coaching populations.

Yet, such large-scale CEPs that systematically transfer research knowledge into broader TDEs remain rare. Additionally, to better understand the contribution of these initiatives to talent development, it remains to be explored *whether, how, and why* any transfer and application into coaching practice has occurred as previous studies on individual implementation cases have often focused on selected coach outcomes or the experiences of coach educators. Consequently, qualitative evaluations aimed at gaining a better understanding of the processes and circumstances that foster research-practice transfer are warranted (Jones et al. 2024). These evaluations should integrate the perspectives of both the receivers’ (i.e., coaches) and facilitators’ (i.e., coach educators).

Research Context and Study Purpose

This study aimed to evaluate a research-informed CEP developed to educate approximately 1,300 soccer coaches working for the nationwide talent development program of

the German Football Association (DFB). These coaches are responsible for approximately 14,000 players aged U12 to U15 (Kelly et al., 2024) who participate in one weekly practice session across 350 regional Base Camps (BCs). Guided by nationwide learning goals, these sessions are intended to complement players' promotion in home clubs by exclusively focusing on their long-term learning. The involved coaches acquired at least an UEFA B-License and are supervised by 29 regional coach coordinators. One of the coordinators' main tasks is to further educate and develop BCs coaches within their respective region. In this role, the coordinators acted as multipliers to implement a CEP designed to foster learning-supportive coaching. By disseminating their knowledge to coaches in their region, they aimed to create a ripple effect that would expand the reach and impact of their own training. This study presents the *evaluation* of this CEP by integrating the perspectives of multipliers (i.e., delivering coordinators) and participating coaches. The study specifically sought to evaluate the CEP's contextualized implementation, the relevance of the provided content for coaching practice, the suitability of the didactical methods, and the outcomes experienced by practitioners.

Methods

This study was underpinned by pragmatism assuming that knowledge is created from humans' interaction with the environment when aiming to solve a situational problem (Hall, 2013). In this study, the problem addressed is the transfer of research findings into a nationwide TDE to foster coaches' learning support for their players.

Participatory Research approach

To effectively address the interface between science and practice, a *participatory research approach* (Vaughn & Jacquez, 2020) guided the development, implementation, and evaluation of the research-informed CEP. This approach facilitated a collaborative

process of knowledge production between researchers and practitioners within a broader research project (Bergmann et al., 2021a; 2024a). To this end, the research group involved talent and coaching researchers (authors 1, 2, 4, and 6), a DFB coach coordinator (A⁺-License; author 3), and the head of the program (PRO-License; author 5). All researchers were familiar with the implementation context, including Author 1, who is a UEFA A-Licensed BC coach.

Coach Education Program: Development and Implementation

Complementing players' promotion within their home clubs, it is a core responsibility of BC coaches to designing additional weekly practice sessions that foster players' long-term learning (DFB, 2022a). Consequently, the CEP focus on *learning-supportive coaching* was jointly decided by the program head and all coach coordinators. For the development of the CEP, authors 3 and 4 summarized existing materials on the nationwide learning goals and established coaching guidelines. The researchers conducted a systematic review synthesizing knowledge from field-based intervention studies that investigated the effectiveness of coaching approaches (Bergmann et al., 2021a). Furthermore, a study exploring experts' recommendations about how to support learning in elite youth soccer was conducted (Bergmann et al., 2025a). Applied and scientific insights were critically discussed across multiple meetings involving all authors to identify the most relevant content. The practitioners further contributed to the CEP by providing practical examples to illustrate implications from the scientific input for coaching practice.

Module-based structure and content

The CEP is structured around five 'learning modules' (Supplement I). Despite the intended storyline (*Figure 17*), all modules may also be used as standalone learning inputs,

meaning that familiarity with previous content is not required. This was expected to increase flexibility when tailoring the CEP for regional implementation across a nationwide talent development program. Further advanced self-paced content is available at an online platform (Modules 3.1-4.2).

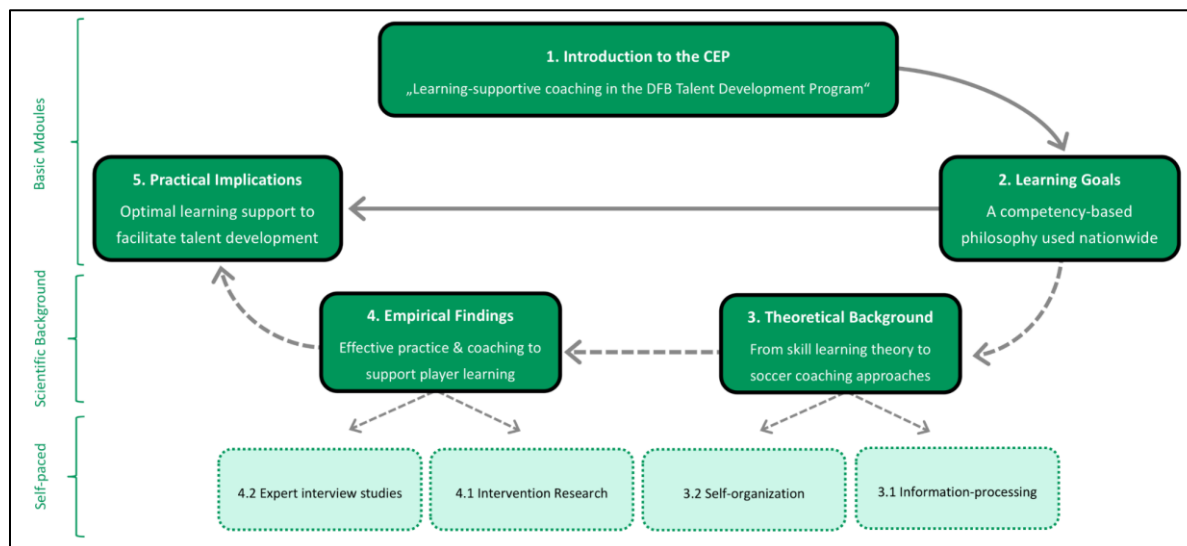


Figure 17. Overview of the CEP structured around learning modules.

The CEP’s research-informed nature is evident in the *theoretical background* (Module 3), presenting both information-processing and self-organization paradigms¹⁴ focusing on the paradigms’ strengths and weaknesses in explaining the mechanisms of coaching strategies. This knowledge was deemed essential to guide informed decisions on how to support player learning. Further, Module 4 presents available *empirical findings* on the effectiveness of these approaches in fostering learning in soccer. Finally, *coaching implications* were presented in Module 5 as ‘10 principles for optimal learning support’ (Figure 18).

¹⁴ The term ‘self-organization’ was chosen (instead of ‘dynamical systems’) to avoid overly complex terminology and to epitomize processes occurring within the player in contrast to ‘information-processing’.

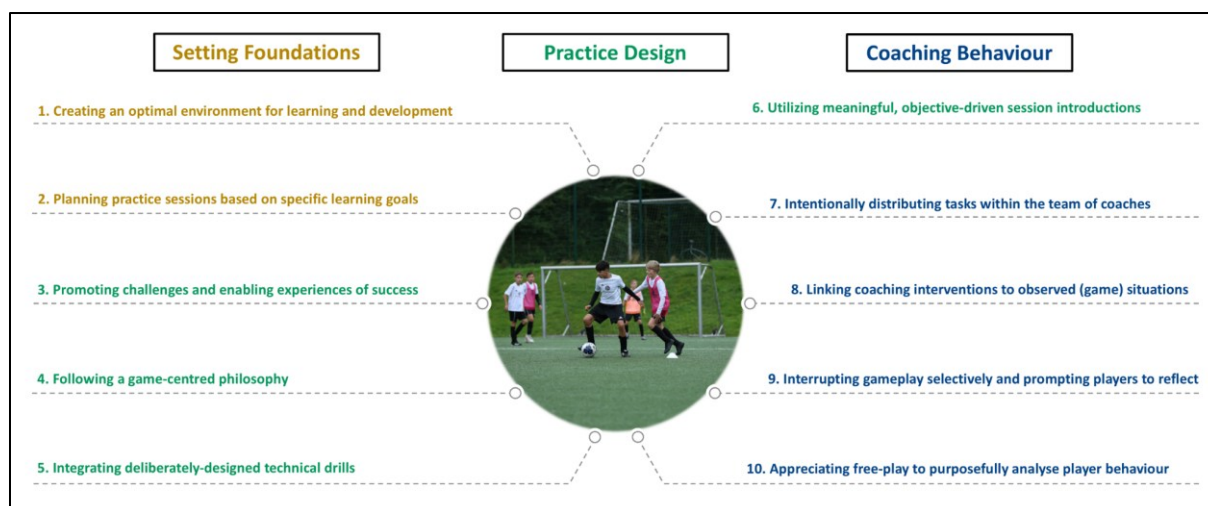


Figure 18. Practical coaching implications presented as “10 principles for optimal learning support” as part of Module 5 of the CEP.

Recommendations for didactical methods to coach education

A guide for multipliers was developed outlining exemplary strategies to deliver each module to coaches (Supplement I). These included problem-based methods as well as ‘on-pitch’ phases (Ciampolini et al., 2019). The content across all modules was illustrated by practical examples. To make the content more relatable to participants, two fictional coaches were presented who embodied stereotypical representatives of an information-processing (‘Coach Martin’) and self-organization approach (‘Coach Jona’). Video clips of practice sequences and verbal coach statements were provided to effectively communicate the practical relevance of respective paradigms.

Contextually-tailored implementation via multiplier approach

Four steps were taken to facilitate the coach coordinators’ (i.e., multipliers) CEP implementation: *First*, all multipliers were provided with virtual presentations of the ‘basic modules’ 1, 2, and 5. *Second*, the theoretical and empirical background modules were presented in-person by authors 1 and 6, at which point all multipliers had the opportunity to provide feedback. *Third*, online refresher meetings addressed the program content and implementation methods. *Fourth*, at least one individual meeting was held with each

multiplier and author 1 to tailor the CEP to the regional cohort of coaches and their specific contextual circumstances.

Subsequently, the multipliers implemented parts of or the entire CEP into regularly held *in-person workshops* lasting at least two half days with one overnight stay at local sport schools. The use of *blended learning* alongside intended to facilitate coaches' extended engagement with the resources supported by encouragement to participate in self-paced learning.

Coach Education Program Evaluation

The evaluation was guided by the Context-Input-Process-Product (CIPP) model using a retrospective, summative approach (Stufflebeam & Coryn, 2014). An *explanatory two-phase sequential mixed-methods design* (Creswell & Creswell, 2018) was employed, combining (i) an online survey assessing multipliers' and coaches' satisfaction with the in-person workshop and (ii) subsequent interviews to explore their experiences in greater depth. Thus, this multi-perspective evaluation examined the suitability of the CEP to transfer scientific knowledge into the *context*, and if the *input* was perceived as meaningful for optimizing coaches' learning support. Furthermore, it explored the *processes* relating to program implementation, which *products* were perceived, and if practitioners encountered any barriers that limited the application of recommended coaching strategies.

Participants

A total of 229 coaches participated in one of seven regional implementations of the CEP included in this evaluation (approx. 25% of implementations nationwide). These were chosen to gather data from a realistic depiction of practitioners within the nationwide program (e.g., various sizes of regions; locations across the country; *Table 11*). The online

survey was completed voluntarily by 153 individuals ($n = 8$ multipliers¹⁵; $n = 145$ coaches, 63% response rate). Of these participants, seven multipliers (M1-M7) and 14 coaches (C1-C14) participated in subsequent interviews. All processes of this study were approved by the first authors' university's ethics department.

Quantitative Evaluation

Data Collection. The day after joining the in-person workshop, all coaches were invited to participate in an online survey (Unipark Software). They were asked to answer four questions addressing *personal information* (i.e., age, sex, coaching license/experience), eight items on the program *input* (e.g., theoretical presentations), six items on its implementation (*process*; e.g., didactical methods), and eight items on the perceived outcomes (*product*; e.g., gained knowledge). The multipliers also participated in an online survey with similar items on input- and product-related features. The six items on *processes*, however, assessed multipliers' satisfaction with their training to implement the CEP.

All items were rated on a 6-point Likert-type scale. Satisfaction with the input and processes was rated from 'very good' (6) to 'very bad' (1). Participants' agreement with statements on *products* were rated from 'totally agree' (6) to 'not agree at all' (1). If participants felt unable to reply to an item, they could choose 'can't say (anymore)'. Participants had the option to provide their email address if they were interested in a follow-up interview.

Statistical Analysis. Descriptive statistics were calculated in SPSS (version 27.0; IBM Corp., Armonk, NY).

¹⁵ One implementation was led by two multipliers in collaboration who both participated in the online survey ($n_{survey} = 8$), but only one was interviewed ($n_{interview} = 7$).

Table 11. *Participant characteristics of multipliers and coaches separated for quantitative and qualitative evaluations.*

Quantitative Evaluation (n = 153)			
		Multipliers	Coaches
<i>n</i>		8 [#]	145
Age [y.]	<i>M ± SD</i>	43.6 ± 6.4	45.4 ± 11.5
Sex	Male	8 (100%)	139 (96%)
	Female	-	4 (3%)
	not reported	-	2 (1%)
License	A ⁺ or Pro	2 (25%)	2 (1%)
	A	6 (75%)	28 (19%)
	Elite Youth or B ⁺	-	73 (51%)
	B	-	38 (26%)
	other*	-	4 (3%)
Experience in TD program [y.]	<i>M ± SD</i>	12.9 ± 8.3	8.2 ± 6.7
Qualitative Evaluation (n = 21)			
<i>n</i>		7	14
Age [y.]	<i>M ± SD</i>	42.3 ± 7.1	45.6 ± 10.7
Sex	Male	7 (100%)	14 (100%)
License	A ⁺ or Pro	2 (29%)	-
	A	5 (71%)	3 (21%)
	Elite Youth or B ⁺	-	10 (72%)
	B	-	1 (7%)
Experience in TD program [y.]	<i>M ± SD</i>	11.5 ± 9	7.4 ± 5.6
Academic Background	Yes	6 (86%)	7 (50%)
	No	1 (14%)	7 (50%)
Interview duration [hrs:min]	<i>M ± SD</i>	01:07 ± 00:17	00:56 ± 00:13
	Σ	07:52	13:04

Note. hrs. = hours; min. = minutes; TD = talent development; y. = years; Σ = total duration of all interviews in each group. [#]One implementation was led by two multipliers in collaboration who both participated in the online survey, but only one was interviewed. *The category “other” includes four C-licensed coaches that hold further qualifications (e.g., goalkeeping coaches), allowing them to be employed at a BC.

Qualitative Evaluation

Data Collection. Three to four weeks after the in-person workshop, semi-structured *multiplier interviews* were led by the second author who did not partake in the multiplier training to facilitate the multipliers' openness and criticality. The *coach interviews* were conducted by the first author five to seven weeks after the in-person workshop, allowing coaches the opportunity to apply the CEP content in practice before the interview. The *interview guides* (Supplement II) were structured around the CIPP-model including open questions on contextual circumstances, the quality of materials, and experiences during the CEP implementation. Additionally, the multiplier interviews explored the training they had received. Finally, product-related questions targeted the perceived outcomes (e.g., behavioural changes) and barriers encountered when applying elements of the CEP into practice. Furthermore, the interviewer examined the quantitative ratings to identify particularly high or low scores, which were then explored in more detail during the interviews.

Data Analysis. A *Template Analysis* (TA; Brooks et al., 2015) was utilized to analyse the transcribed interview data. The first author developed an *a priori template* structured around the CIPP-dimensions (Supplement III). The subsequent analytical process was guided by six steps (Brooks et al. 2015): Initially, the first author familiarized himself with the data (step 1). Then, six interviews were coded both deductively (template guided) and inductively in MAXQDA (VERBI Software, 2021; step 2). Furthermore, the averaged quantitative ratings were purposefully considered during the qualitative analysis to enrich the interpretation and to explore potential underlying reasons for particularly high or low ratings. Added codes were clustered around meaningful concepts (e.g., 'appealing materials'; step 3). This deductive-inductive coding template (step 4) was then applied to an-

other subset of nine interviews (King, 2012). Author 1 discussed added codes and exemplary quotes with authors 2 and 3 as critical friends (Smith and McGannon 2018; step 5). After being applied to the remaining nine interviews, the template was deemed appropriate as it successfully captured all relevant data (step 6; King & Brooks, 2017). Supported by participant quotes, the first author summarized the themes' essence, which was then reviewed by all authors. These measures aimed to facilitate *credibility* of this study by providing a *transparent account* of the data analysis and *sufficient evidence* illustrating the respective findings (Smith & McGannon, 2018). Quotes from both, the multipliers and coaches were used to represent the samples *multivocality*.

Results

The findings are introduced through an integrative theme on systemic constraints, identified as fundamentally shaping coach education across all initiatives within the talent development program. Subsequent findings focus specifically on the CEP for learning-supportive coaching, organized according to the CIPP components (*Figure 19*). The qualitative findings are complemented by quantitative data on inputs, processes, and outcomes (*Figure 20a-d*).

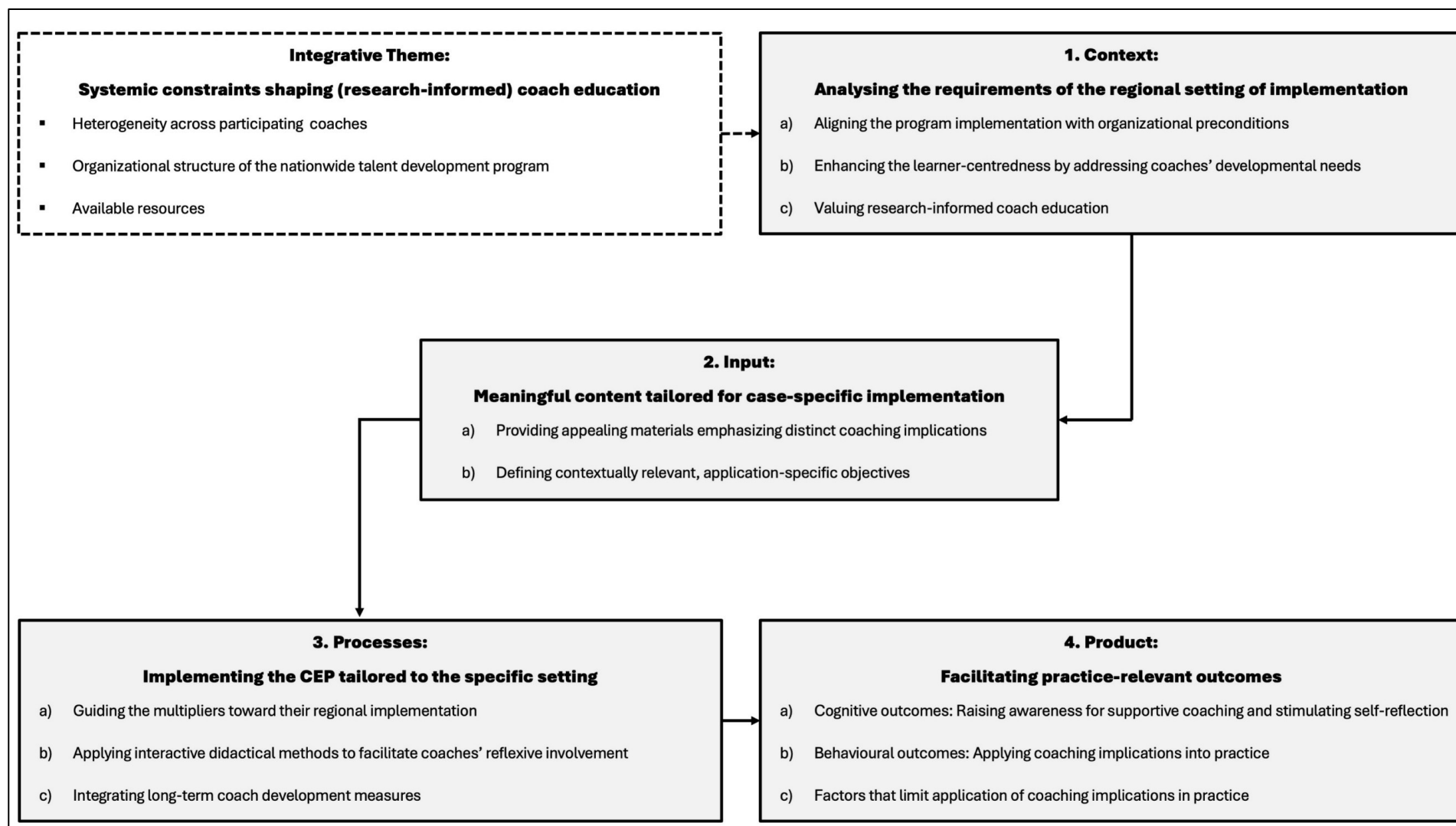


Figure 19. Thematic structure developed based on the Template Analysis of the qualitative interviews and organized around the Context-Input-Process-Product evaluation model.

Integrative Theme: Systemic Constraints Shaping Research-Informed Coach Education

The participants (i.e., multipliers and coaches) referred to characteristics of the talent development program that affect any coach education initiative within this setting. These systemic constraints pertained to the *heterogeneity across coaches*, especially their previous knowledge and educational background. This shaped how they interacted with research-informed inputs, making it essential ‘to deliver content in a simple way to those coaches without an academic background’ (C9). Furthermore, though coaches’ participation in these CEPs is not mandatory, it is rewarded with certification credits required to extend coaching licenses. Consequently, while most coaches participated regularly, they differed in their motives for doing so: ‘Some coaches visit the workshops to renew their license and not because they want to learn something. This sometimes limits the workshop’s flow’ (C11). Such motivational differences affected the overall learning atmosphere, limiting the potential to fully leverage the program’s systemic strength: coaches’ ‘comparably high level of competence’ (C2). This shared perception highlights the importance of creating meaningful links between research-informed content and coaches’ experiences to enhance the contextual relevance of the CEP.

The *organizational structure of the talent development program* – particularly the multipliers’ responsibility for a regional cohort of coaches – was perceived as a valuable resource for supporting coaches’ long-term development. However, not all coaches equally embraced these development opportunities beyond the CEP’s in-person workshop, prompting some multipliers to focus their efforts on those who demonstrated openness:

I strive for a closely connected and intense coach development. [...] [Many coaches] want to develop, they are motivated and interested. Some others rather say “I know that already. Are there any new things?” I dedicate my resources particularly to coaches who are eager to develop.

The *available resources* to implement CEPs represented another systemic constraint. The time for coach education is rather limited, since coaches are employed on a honorary basis. This typically allows for only one or two in-person workshops per year (lasting for 1.5 days), and additional blended learning. During the in-person workshops, however, multipliers need to address several topics which was perceived as inhibiting sustainable learning. ‘It’s always the problem of these workshops: How high can the transfer be after some weeks? There are so many organizational topics that take up a lot of time’ (C3). Therefore, especially the coaches criticized: ‘The time was too short. It’s so important to deal with it to promote our players even better’ (C6). Nevertheless, some participants highlighted these initiatives as a unique advantage: ‘I believe these regular in-person workshops are incredibly important. [...] I enjoy being a BC coach because you touch upon many topics within the DFB’ (C5). Overall, these findings suggest that resources should be strategically leveraged to maximize the CEP’s impact, for example, through differentiated content and self-paced learning opportunities for particularly motivated coaches.

1. Context: Analysing the Requirements of the Regional Setting of Implementation

Participants highlighted how regional contextual requirements influenced the implementation of the CEP on learning-supportive coaching. Understanding these requirements supported the *alignment of the program implementation with the organizational preconditions* in different regions (1a) and helped to identify strategies that *enhanced learner-*

centredness by focusing on coaches' developmental needs (1b). In addition, participants' widespread openness for the initiative was facilitated by generally *valuing research-informed coach education* (1c).

1a. Aligning the program implementation with organizational preconditions

Participants emphasized the role of direct exchange during in-person workshops as a key contributor to the CEP's effectiveness. This was particularly attributed to the opportunity to demonstrate on-pitch how theoretical inputs translate into practical coaching. Referring to the facilitative setting, M3 noted: 'The organizational and learning conditions were great.' In addition to the general perception that the available time for the CEP was too short, participants reported regional differences in time allocation, with some regions able to devote only about half of the in-person time explicitly for learning-supportive coaching. Nevertheless, even this comparatively short in-person time was seen as valuable: 'It allows for a much deeper exchange across coaches. It supports that coaches know each other much better and that they dare to engage and discuss to a greater extent during the workshop' (C9). Regarding the topic specifically, the absence of youth players in some regions required coaches to step in as 'players' during practical sessions. This was perceived as a barrier to creating authentic and realistic coaching scenarios. As C11 noted: 'I think everybody would agree that the behaviour of other coaches is different to those of 13- or 14-year-old players.'

1b. Enhancing the learner-centredness by addressing coaches' developmental needs

These organizational differences across regions highlighted the importance of tailoring the CEP, ensuring the specific needs of each regional cohort were effectively addressed. Generally, participants' responses reflected developmental needs closely aligned with

the CEP's practical recommendations (*Figure 18*), such as designing game-centred activities that target specific learning goals and using 'hands-off' interventions to support players in achieving them. Nevertheless, the multipliers and coaches differed in the extent to which they perceived a need to develop new practice activities to achieve the intended outcomes of the CEP. C3 explained a prevalent viewpoint among coaches: 'I look on the internet, there's so much knowledge available. I think that reinventing something new on a blank paper does not represent our reality anymore.' This perspective appears to conflict with the multipliers' view that incorporating such tasks into the CEP facilitates coaches' critical reflection on the alignment between practice activities and learning goals.

I aim to enable my coaches to ask themselves: "The players have these strengths and areas for improvement. This is why I use these practice activities to make that player better." This sounds trivial, but this is one of the biggest challenges. The coaches often apply something they saw on the internet without reflecting on these things. (M5)

Accordingly, while the multipliers emphasized the value of these activities for developing coaches' competence to design practice aligned with specific learning goals, many coaches expected ready-made solutions to optimize the developmental support for their players. This at times led to discrepancies in how the purpose of CEP activities was understood.

Consistently, the participants stressed the need to enhance their use of 'hands-off' coaching strategies suggesting this as a valuable focus area for the CEP.

How do I achieve detailed coaching using this implicit approach? That's fascinating and I'd much appreciate greater support. [...] When do I ask a question to the entire group? When do I coach the players or let them just experience the situation? (C13).

1c. Valuing research-informed coach education

Another contextual precondition to facilitate coaches' development regarding these needs was a widespread interest in research-informed inputs: 'I believe this [research] knowledge is important because it's a kind of fundament you need. Based on this, every coach needs to find a solution to approach different players' (C8). Yet, the areas of interest and the depth perceived as relevant differed among coaches. This represented a contextual nuance important to analyse by the multipliers when implementing the CEP in their region. C13 stated:

It's not because I don't have a background in sports science, I am not interested in that. [...] I'm interested in how one learns technical skills and find it exciting what different approaches exist. For instance, I found the interview study quite interesting.

While agreeing that 'a certain background is helpful', C11 was one coach who said they would not 'necessarily need this scientific background. [...] I'm not so passionate about coaching that I'm really interested in the scientific background if I can deliver on the pitch.' The multipliers seemed to partly align with C11's notion assuming that 'a deep theoretical background may only be relevant for those coaches who are interested' (M6).

2. Input: Meaningful Content Tailored for Case-Specific Implementation

Alongside a genuine care for the research foundation of the CEP, participants highlighted the need for *appealing materials emphasizing distinct coaching implications* (2a). These

materials formed the basis for *contextually relevant, application-specific objectives* (2b). Participants' quantitative scores were integrated into the qualitative findings (*Figure 20a*).

2a. Providing appealing materials emphasizing distinct coaching implications

Participants emphasized the general relevance of the CEP materials for improving coaching practice, a finding supported by the quantitative ratings (e.g., 'program materials'). Yet, the overall amount of materials made them difficult to manage: 'When you see the whole presentation you get smashed. It's commendable, but too much' (M3). Moreover, despite a shared perception of the materials as meaningful and appealing, some participants found certain parts overly complex, reflected in a trend toward the lowest quantitative ratings ('complexity of the content'). This apparent contradiction primarily related to parts of the CEP which delved too deeply into theory. C11 noted: 'The connection to practice was always there, [...] but the wording in the theoretical parts was quite scientific, and a bit too much for me at that moment.'

The quantitative ratings on 'videos and animations' demonstrate an overall satisfaction, but the authenticity of video-recorded coaching situations was sometimes called into question: 'The videos sometimes seemed a bit staged. The content was good, but it could be delivered in a more relaxed manner' (C8). Thus, enhancing the realism of these videos could increase their appeal and support the theory-practice transfer. Regarding content, participants suggested that the videos could be improved by better addressing coaches' developmental need for strategies that facilitate player learning on-pitch (Theme 1b). M3 'thought about recording practice and then asking the coaches on-pitch how they would guide a situation in a specific direction'.

2b. Defining contextually relevant, application-specific objectives

In line with the intended flexibility, all multipliers tailored the CEP to their specific regional circumstances (Theme 1a). Overall, three foci across implementations were observed: (I.) using a game-centred philosophy to address distinct learning goals (M1, M3, M4), (II.) purposefully connecting game-representative and further practice activities in the session's microstructure (M2, M6, M7), and (III.) using coaching strategies intentionally to moderate individual learning outcomes (M5). All multipliers further aimed for connections between the CEP and current topics in the DFB to support sustainable coach learning and to emphasize overlaps across initiatives. Many participants noted that the CEP provides a foundation for the recently introduced *Practice Philosophy Germany*:

It's quite important in the context of Practice Philosophy Germany. That we approach a game-centred philosophy. [...] But it's central to purposefully select the game that I don't need a lot of words. (C8)

Echoing the CEP's concept, all implementations aimed to stimulate coaches' research-informed reflection of the benefits and trade-offs of coaching approaches. Yet, the focus was seemingly set on coaching implications and less on the theories themselves at the cost of a nuanced engagement with the mechanisms underpinning learning. This is reflected in coaches' frequent references to the fictional coaches used to illustrate the theories' practical consequences.

I have a close connection to Jona's [self-organization] approach. [...] This does not mean the coaches are not allowed to use other approaches, especially for individualized practice. [...] Many coaches follow the Martin [information-processing] approach and that's not reprehensible, but the amount should be much lower (M6).

Consequently, while the provision of recommended coaching strategies can enhance coaches' learning support, their differentiated use – grounded in research-informed understanding of the underlying mechanisms of player learning – appeared to be less effectively emphasized.

3. Process: Implementing the Coach Education Program Tailored to the Specific

Setting

Participants further highlighted several processes that contributed to successfully preparing and carrying out the CEP's implementation. The multipliers considered close *guidance toward their regional implementation* as crucial (3a; Figure 20b). During the in-person workshop of the CEP, the participants particularly highlighted the benefits of *interactive didactical methods that facilitate coaches' reflexive involvement* (3b; Figure 20c). They also recommended placing greater emphasis on enhancing coaches' engagement and creating authentic links to practice through *long-term coach development measures* (3c).

3a. Guiding the multipliers for their regional implementation

The multipliers' self-perceived competence to deliver a research-informed CEP varied. While all desired guidance for implementing the CEP, the extent and timing of the required support differed depending on how informative the provided resources were perceived (e.g., presentations, in-person training). The quantitative ratings of the content and organization of the in-person training indicate general satisfaction but were noticeably lower compared to more individualized measures. This aligns with criticism of the in-person training voiced in the interviews, especially regarding limited focus on the program implementation rather than on the (scientific) content: 'The first presentation was very theoretical. I engaged with the materials as soon as I knew when I was going to apply

it' (M1). To improve these processes, the multipliers recommended to 'conduct the workshop including the on-pitch phases with us representing the coaches, because everybody gets an impression about how to apply it' (M4).

The multipliers emphasized the vital contribution of subsequent guidance by the research team as reflected in the close to optimal scores for the 'individual training' and 'researcher's competence'. The multipliers described how their applied viewpoints complemented the scientific perspective of academic team members, highlighting the close collaboration which allowed the team's strengths to successfully merge:

I had to listen to the recorded presentations again. I needed to prepare myself, and you experience in which parts you feel more secure and in which not [...] Especially [author 1] really helped me at end of the day, because he is the expert in this topic (M7).

3b. Applying interactive didactical methods to facilitate coaches' reflexive involvement

The participants attributed the successful program implementation to the use of effective didactical methods, with quantitative scores between 'good' and 'very good' across all items. Particularly, methods that encouraged coaches' reflexive involvement, such as group-based tasks or guided discussions, were highly valued. Building on the coaches' substantial experiences (Theme 1), C2 commented: 'The exchange – guided by a great question – is indispensable, because you can discuss with many coaches at a very high level.' The CEP's concept and materials facilitated such interactions, for example, the conflicting theoretical viewpoints on skill learning illustrated by two fictional coaches:

I liked the fact that they were sort of debating. You automatically take a position or start to involve yourself into this discussion [...] Controversy is always good, and the depth of thinking is also enhanced (C3).

The effectiveness of these didactic methods was, however, closely tied to active multiplier guidance. C6 stated ‘it’s so important that the discussion is moderated, that it doesn’t get out of hand, because we coaches have strong opinions.’ The participants further noted that group-based tasks were most beneficial when structured with specific, transparent objectives. Furthermore, the coaches’ appreciated ‘on-pitch’ phases in which practical examples were presented and discussed. Critical feedback received during these phases was also experienced as beneficial to advance coaches’ awareness about how their coaching practices align with their intentions: ‘Comparing the intended with actual coaching behaviour – Let’s say you want to coach like Jona, that’s your goal. But you get feedback that you’re more like Martin even if you don’t what it’ (C5). These phases were perceived as most effective when complemented by the ‘excellent feedback’ (C1) provided by the multiplier, a perception also reflected in near-optimal ratings for the ‘multiplier’s competence’.

3c. Integrating long-term coach development measures

Participants highlighted the need to integrate measures for coaches’ long-term development to extend the learning time and strengthening connections between the CEP and coaching practice. Participants described how blended learning prompted meaningful self-reflection ahead of the in-person workshop. In five out of seven implementations, the multipliers provided their coaches with an introductory video (Module 1) that contrasted different coaching approaches, combined with reflective questions designed to stimulate coaches to think critically about their own beliefs and coaching behaviors. This also facilitated a smooth transition to on-pitch phases during the in-person workshop: ‘We could meet directly on the pitch, as we had received the videos beforehand as preparation’ (C10). In contrast, ‘receiving documentations from colleagues hasn’t worked that

well, but it's important to make it more sustainable' (C8). This was attributed to a lack of obligation or shared commitment, which in turn hindered the integration of practical examples into coaching practice.

Another key contributor to coaches' long-term development was regular visits of the multipliers at the BCs. These visits were highlighted as an effective way to address the limitations of in-person workshops, including the challenge of creating authentic coaching situations (Theme 1a) and the desire for expert feedback (Theme 3b). However, some coaches recommended creating even stronger connections to the CEP:

If [the multiplier] comes to watch our practice and gives us feedback, that's always helpful [...]. However, if there are some specifics from the last workshop, you could address these inputs even more and emphasize that he wants to see them. (C4)

4. Product: Facilitating Practice-Relevant Outcomes

After completing the CEP, participants described cognitive outcomes relating to the *awareness raised for supportive coaching and stimulated self-reflection* (4a) and behavioural outcomes relating to *the application of coaching implications into practice* (4b; Figure 20d). Yet, *factors that limit the application of coaching implications* were also noted (4c).

4a. Cognitive outcomes: raising awareness for supportive coaching and stimulating self-reflection

The quantitative scores reflect participants' average satisfaction with the cognitive outcomes of the in-person workshop (e.g., 'knowledge gained'), although the ratings reveal considerable variation among coaches within the sample. The interviews emphasized mixed perceptions with regards to having learned something 'new' and rather indicate outcomes of refreshing or deepening existing knowledge.

All in all, I haven't learned much new, but definitely in some details and guiding principles. [...] You also realise that you want to coach in a certain way, but if you reflect on your coaching practice, you are sometimes far away from that. (C13)

M6 confirmed this perspective and reflected on dilemmas arising from the CEP's tailored concept, noting the lack of a shared single outcome: 'It may be a general question if overarching outcomes were pursued or if the goal is to deliver little pieces to each coach'. Supporting the overall agreement on the CEP's 'contribution to talent development', some coaches perceived these 'little pieces' as important in encouraging their self-reflection. 'I thought about practice from a slightly different direction. I have an overarching learning goal, and each practice activity should contribute to it. I also tried to think more detailed about how I can address learning goals within a game' (C2). The relevance of this learning outcome is supported by M1:

It's more important to shape coaches' senses and emphasize relevant details rather than delivering brand-new things [...]. Raising their awareness will already contribute to their coaching and, thus, to talent development (M1).

C5 confirmed this assumption: 'These aspects that encouraged me to think and self-reflect about coaching were particularly important [...], this is a relevant learning outcome'. Thus, participants identified relevant cognitive outcomes, for example, a more pedagogically aware use of game-centred activities that facilitate players' exploration while remaining aligned with specific learning goals.

4b. Behavioural outcomes: Applying coaching implications into practice

The quantitative scores indicate a genuine intention to 'apply the content' in practice. Some coaches viewed the CEP as an affirmation as they were already implementing

many of the proposed strategies. Others described behavioural changes which is exemplified by M1 who experienced ‘the best feedback what you can get on the CEP: I visited some of the coaches at their BC and they applied some practice activities we developed together’. While this does not necessarily indicate a more goal-directed use, C1’s statement indicated such an effect: ‘After the CEP, I tried to achieve that my practice activities are better constrained to address specific learning goals, and I don’t need a lot of words’. Other coaches described to ‘have often practiced too closed and isolated, but we have shifted somewhat to a much greater ratio of games’ (C4).

Behavioural changes linked how coaches intervene, and guide player learning were less prominent in participants’ reports. C6 represented an exception:

I somewhat observed the game more consciously. I tried to be more hands-off to give the players the time they need to correct themselves. I only sometimes instructed verbally. [...] Before the CEP, I may have interrupted to an earlier point to instruct.

This statement illustrates a deliberate shift toward more mindful observation of player behaviour and more intentional use of strategies to foster self-organised player learning.

4c. Factors that limit the application of coaching implications in practice

The participants also described factors they experienced as limiting the application of coaching implication in practice. One factor was the need for meticulous session planning:

Even though we are a team of coaches, we often plan practice activities on our own. Sometimes, our practice activities during a session seem somewhat thrown together which is a critical aspect (C2).

Furthermore, some coaches experienced difficulties to connect a game-centred philosophy and individual learning support: ‘Concerning the individualisation across players, we have our deficits. [...] On one hand, we really want to practice game-centred. On the other hand, we have to individualise. It’s a balancing act that I can’t always manage’ (C9). Consequently,

several coaches choose more isolated activities as these lead to the situations they want to coach. Even though I work almost exclusively with constrained games, it is often difficult for me to create sufficiently detailed situations (C13).

A prevalent reason was that for following the proposed coaching implications, ‘coaches need to understand the game and the session objective in a much more detailed way’ (M4). Several coaches argued in the same direction:

We are coaching too eagerly and pick out simple coaching points. I am pretty sure that we often do not sufficiently understand the situation [...] I see much potential regarding the reduction of coaching trivial things verbally. As a basis, we need to be able to sufficiently analyse these situations (C5).

This was particularly related to ‘strategies to identify errors in the players’ movements and skills. Such input is lacking somewhat. We are often talking about the big topics, but these small details sometimes come too short’ (C11).

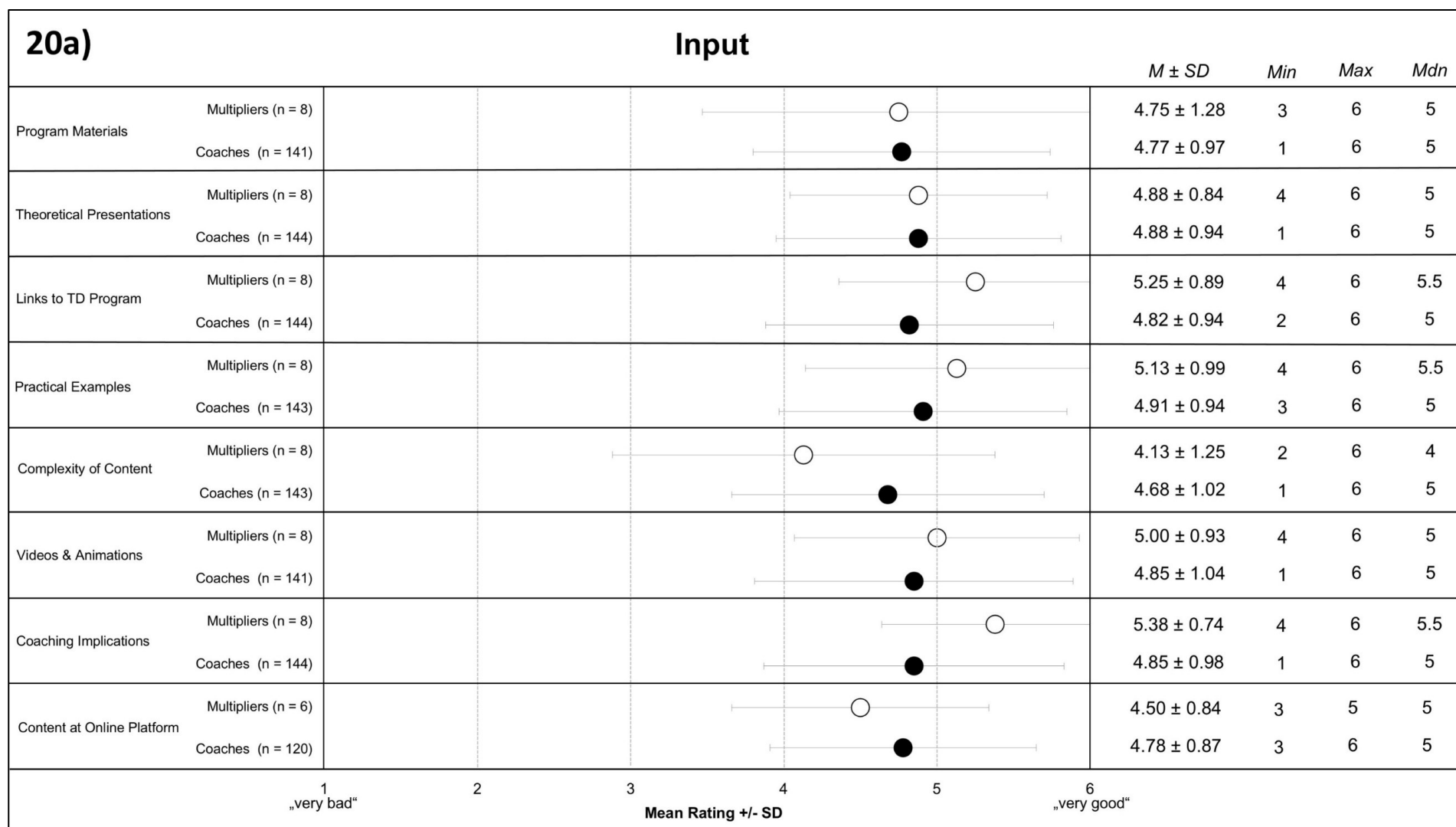


Figure 20. Quantitative results from the survey on the CEP's input (20a), processes (20b & 20c), and products (20d).

Figure 20a-d. continued

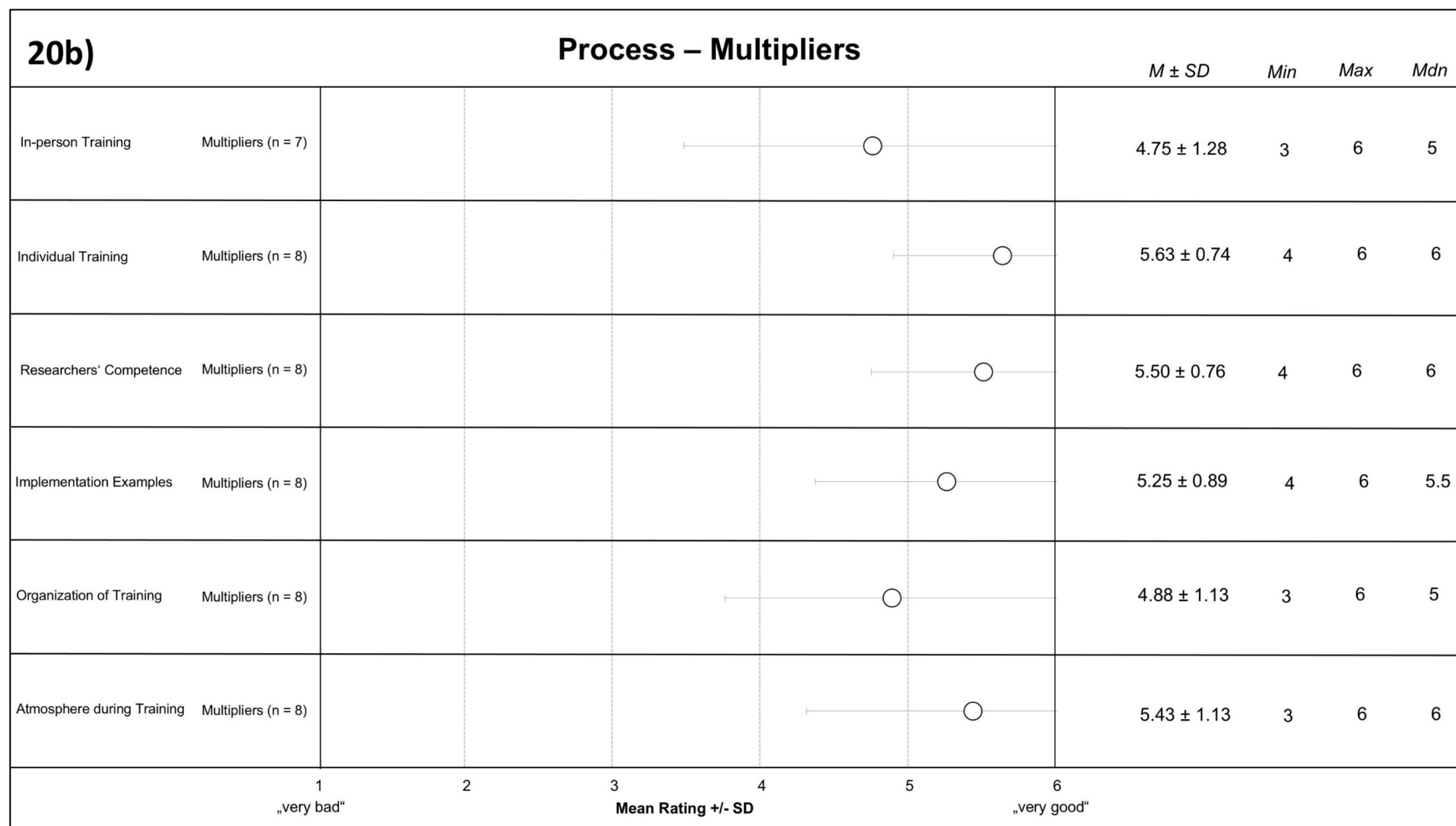


Figure 20a-d. continued

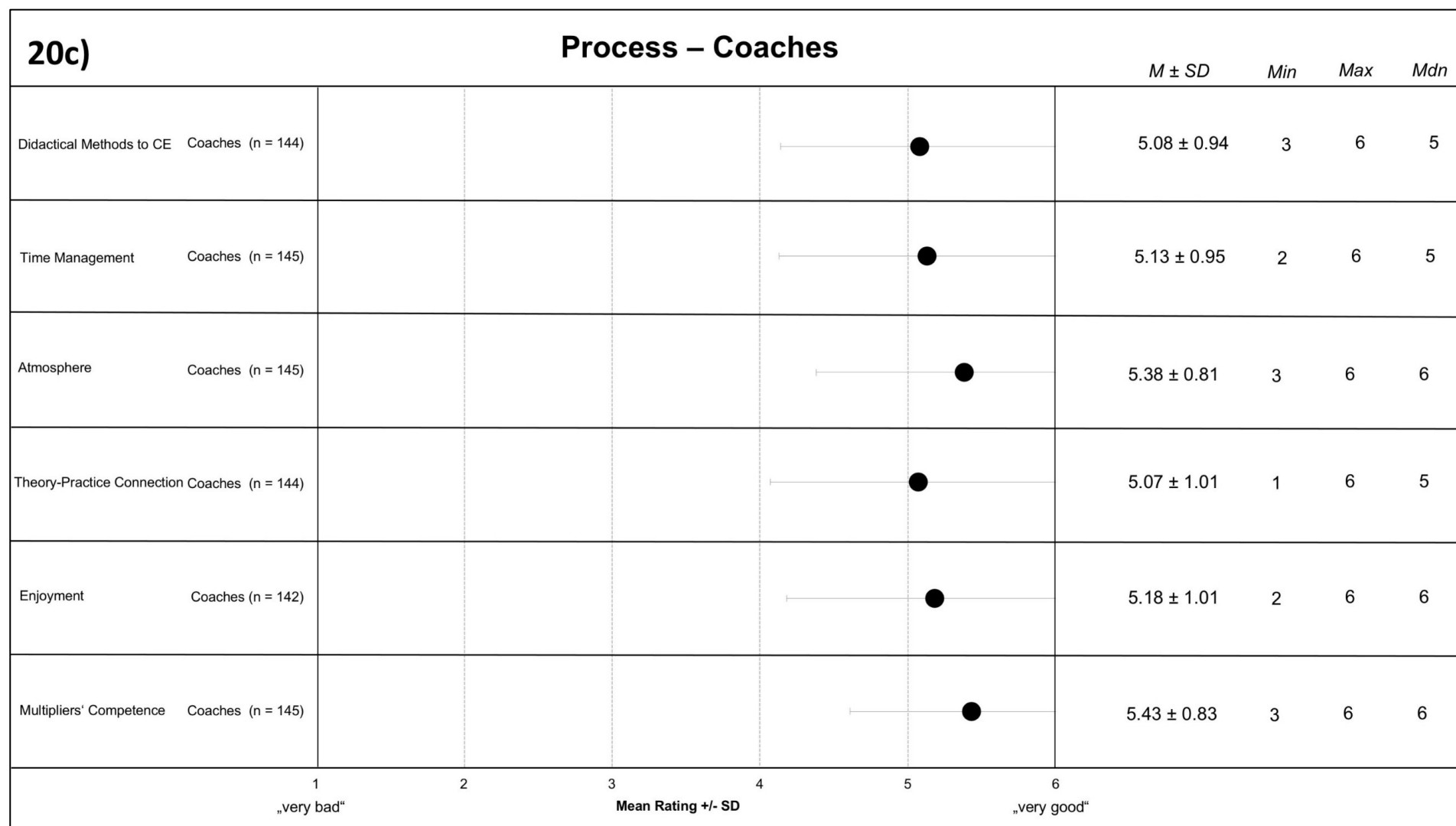
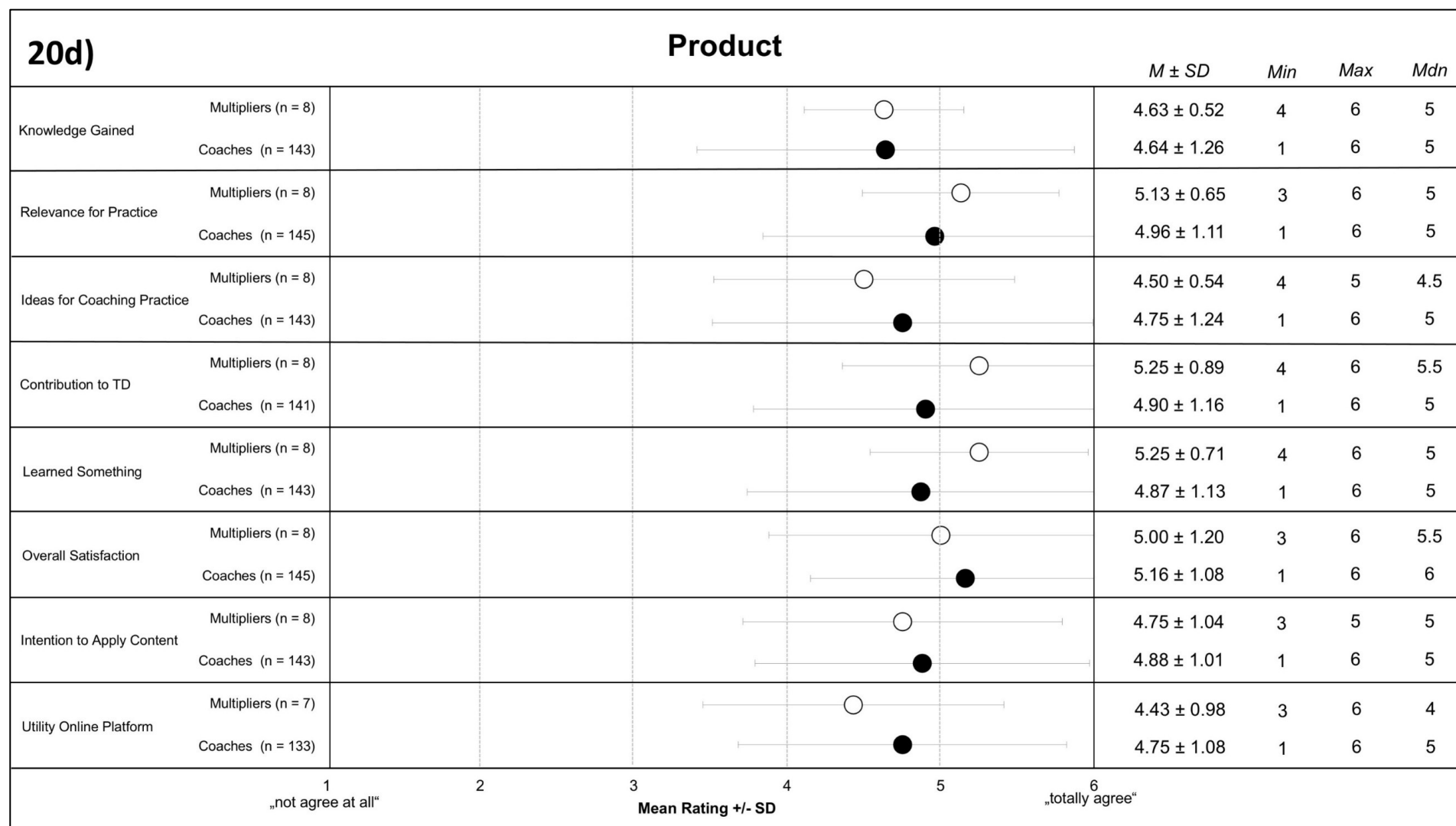


Figure 20a-d. continued



Discussion

The research-informed CEP was perceived as a meaningful contributor to fostering learning-supportive coaching in a nationwide talent development program. Focusing on a specific soccer TDE (*context*), the findings enhance our understanding of how research-informed content (*input*), effective didactical methods (*process*), and both outcomes (*product*) and limiting factors interact. These findings offer implications for successfully integrating research-informed coach education into large-scale TDEs.

Various systemic and contextual factors were identified that both facilitated (e.g., nationwide structures) and hindered effective coach education (e.g., limited resources, coaches' heterogeneity; Lyle & Cushion, 2017). To address these factors, the program employed a module-based structure designed to provide multipliers with the flexibility and customization necessary to enhance learner-centredness (Paquette & Trudel, 2018). While the findings further support the *suitability of the multiplier approach* for transferring research knowledge to larger cohorts of coaches (Wachsmuth et al., 2022), they also reinforce the need to account for the differences in multipliers' self-perceived competence to deliver CEPs. Some multipliers felt overwhelmed by the volume of materials, and adequate familiarization often occurred only after individual training. This may have restricted multipliers' nuanced engagement with the CEP and limited their ability to fully leverage the conceptual flexibility the approach offered. These findings point to the need for multiplier training that emphasizes selective content usage and provides earlier guidance on appropriate didactic methods to effectively implement the CEP.

While participants valued a scientific foundation in their coaching, determining the right balance between *sufficient scientific input and manageable complexity* proved challenging. Thus, the multipliers often condensed the theoretical and empirical parts with the

aim of emphasizing practical coaching implications. While this likely fostered behavioural changes (e.g., increased use of games), it also created tension with the program goal of deepening coaches' understanding of how the underlying mechanisms of skill learning can justify the effectiveness of different coaching strategies. This highlights the importance of dedicating even greater effort to translating and synthesizing scientific content for the target audience (Lyle, 2018). Previous studies have placed even greater emphasis on how scientific literature can be synthesized into 'context-specific lay language' (Andrew et al., 2024b, p. 5) through a multi-step process of co-production. At the same time, open questions remain about the extent to which simplification is feasible without compromising scientific integrity – for instance, when oversimplifying skill learning theories into comparisons between drill- and game-based approaches (cf. Bergmann et al., 2021a, p. 19).

This study further supports the widely acknowledged importance of didactical methods that foster interaction and reflective engagement among practitioners (Ciampolini et al., 2019; Wang et al., 2023). Beyond enhancing coaches' motivation and buy-in, such meaningful exchange is crucial for helping coaches comprehend how the CEP's input relates to their own practice (Paquette & Trudel, 2018). Yet, the findings illustrate that the goal-directed integration of reflective elements, practical on-pitch phases, and the delivery of research-informed content requires careful integration. A noteworthy strategy for encouraging self-reflection and purposeful interaction among practitioners (e.g., debating viewpoints) was the use of fictional narratives featuring relatable characters who embodied two distinct positions on coaching. By contrasting theoretical perspectives on skill learning, rather than presenting a single position, this strategy recognized the diverse beliefs among participating coaches. Yet, some participants expressed a need for further

guidance during interactive activities and more expert feedback related to coaching practice (Ciampolini et al., 2019). This underscores the importance of preparing multipliers to both value coaches' input and provide effective guidance toward achieving the intended CEP outcomes, an effort that requires strong interpersonal skills (Wang et al., 2023).

All participants reported experiencing *cognitive and/or behavioural outcomes* at an individual level but noted the absence of a shared outcome. This may reflect the trade-off of the tailored approach designed to address individual needs among coaches in different regions, and the short duration of the intervention. Achieving sustainable behavioural change through CEPs likely requires ongoing efforts beyond in-person workshops, particularly long-term coach development measures thoughtfully integrated into coaching practice. Prior research has reported measurable changes in coaching behaviour resulting from CEPs, though often based on small samples that allowed for more individualised support in real-world settings (Andrew et al., 2022, 2024b; Raya-Castellano et al., 2024). Such measures may be especially relevant for strategies identified as difficult to implement authentically in workshop settings, such as 'hands-off' coaching strategies aimed at guiding player learning. To address this, the organizational structure of the talent development program (e.g., regional coach coordinators) could be used more strategically to link CEPs with long-term development efforts, including expert feedback and peer reflection (Partington et al., 2015; Raya-Castellano et al., 2024).

The application of recommended coaching strategies was restricted by different *limiting factors*. While the recommendations closely aligned with practitioners' beliefs and a genuine intent to transfer knowledge was evident (individual filter), challenges arose in applying certain strategies within their coaching reality (contextual filter; Stodter & Cushion, 2017). While some of these limiting factors reflect common challenges in game-based

coaching (e.g., session planning; Kinnerk et al., 2018), others are more specific to TDEs. While the effectiveness of game-centred activities in achieving specific outcomes is supported by previous research (Bergmann et al., 2021a), this study highlights the need for clearer guidance on how games can be aligned with the contextual requirement of addressing players' individual learning needs. A related issue concerns coaches' challenges in observing and analysing player behaviour in sufficient detail. These *diagnostic competencies* are not only essential for making in-situ decisions about appropriate coaching interventions, but also for purposefully adapting practice activities (Bergmann et al., 2025a). Evaluating the learning needs of players in TDEs with relatively homogeneous groups requires coaches to recognize subtle nuances highlighting the need to place greater emphasis on this analytical process within CEPs. Beyond the influence of coaches' experiences, intentions, and beliefs (Stodter & Cushion, 2019), these findings emphasize that behavioural change largely depends on coaches' competencies to effectively implement recommended strategies in real-world contexts.

Limitations

The multiplier approach addressed the need for systematic, multi-regional initiatives to coach education, but the tailored approach limited the comparability across regional implementations (i.e., intervention fidelity). Implementing the CEP within established, nationwide structures enhanced the contextual applicability and mitigated issues related to the 'scalability' of initiatives when used outside of the research context (Andrew et al., 2024b). Nonetheless, this 'realistic' setting only offered a comparatively short learning time. From a methodological perspective, incorporating the views of coaches and multipliers adds on previous research, though exploring the experiences of the coached players could have provided further insights.

Conclusion

The participants perceived the CEP as meaningful for already experienced and qualified coaches. The program's strengths, along with the identified areas for improvement offer guidance for future large-scale CEPs which can be summarized around four key recommendations: *First*, enabling and encouraging the multipliers even more to implement the research-informed content selectively and in suitable formats for their target audience. This can be, *second*, facilitated by further refining the scientific input in even closer collaboration with practitioners, thereby ensuring simplification without compromising the integrity of the content. *Third*, incorporating more nuanced assessments of individual needs among coaches to better prepare them for effectively applying practical implications. *Fourth*, integrating measures that support coaches' long-term development within authentic coaching environments. Overall, future large-scale initiatives should aim to balance a systematic approach to talent development – such as transferring consistent coaching principles and building a shared knowledge base – with contextual adaptations to meet coaches' specific needs. In this regard, certain individual characteristics (e.g., diagnostic competencies) were identified as limiting the application of coaching implications. Therefore, future research should dedicate greater attention to identifying essential competencies coaches need for successful application of these strategies.

Declaration of Competing Interest

The authors report there are no competing interests to declare.

Data Availability Statement

Datasets used in this study will be provided upon reasonable request.

Supplementary Materials

Supplementary materials for this article are provided in *Appendix 4*.

3.2.4 Synthesis of Findings and Implications for Using Formative Assessments to Facilitate Player Learning

The objective of Research Focus I was to investigate the contribution of coaching strategies to foster youth soccer players' action competence in TDEs. To generate complementary insights, this objective was addressed through three individual studies, each employing different study designs and research methods. A literature review of intervention studies was conducted to consolidate existing evidence on the effectiveness of various practice and coaching approaches with respect to perceptual-motor and perceptual-cognitive outcomes (Study 1). In addition, a qualitative interview study involving highly experienced international coaches, coach educators, and researchers explored learning-conducive strategies aimed at promoting specific competency-based learning goals (Study 2). Building on these findings, a research-informed CEP designed to foster learning-supportive coaching was developed, implemented, and evaluated within the *DFB Talent Development Program* (Study 3). This study also explored to what extent the derived coaching implications aligned with coaches' intentions and beliefs, and whether they were able to implement them within their coaching practice at DFB BCs.

This CEP is intentionally described as 'research-informed' to emphasize that the coaching recommendations are grounded in existing scientific knowledge. At the same time, this more cautious phrasing – compared to terms like 'evidence-based' – highlights the still inconclusive empirical foundation for these recommendations. Among other aspects, this inconclusiveness arises from the overall low to moderate quality of intervention research, open questions regarding how to effectively combine different coaching strategies, and methodological limitations of individual studies presented in this work. As a result, there remains a need to build consensus on effective coaching principles in soccer TDEs by integrating both the available research and the expertise of experienced

practitioners (see in detail Study 3). Furthermore, it is essential to avoid presenting these principle in a prescriptive or recipe-like manner, as the qualitative findings from Studies 2 and 3 highlighted a variety of decision-making parameters that coaches must weigh up when deciding upon effective coaching strategies. Therefore, practitioners should be further educated not only in the application of these strategies, but also in the theoretical rationales that support them. This facilitates an informed and differentiated application of coaching strategies in practice, a perspective supported by Kearney et al. (2024, p. 4):

An improvement in coaching practice (and athlete experience) could be achieved by reaching consensus on a set of base guiding principles for coaches [...] These principles must be based on an accurate understanding of contemporary theories from each approach, while also acknowledging that different coaching strategies may be effective as a result of different underlying mechanisms.

Before synthesizing the findings across studies, it is essential to briefly reflect on the different research methods employed. Such reflection is important for fostering an awareness of the distinct types of insight generated by combining quantitative intervention studies (as pooled in the systematic review) with qualitative expert interviews, both of which are well-established approaches in coaching research for understanding the contribution of coaching strategies (Nelson et al., 2025). This multi-method approach was intended to juxtapose two complementary perspectives: On the one hand, the intervention studies aimed to generate insights on the effectiveness of coaching approaches by controlling for confounding variables within field-based (quasi-)experimental designs. On the other hand, the qualitative expert interviews emphasized reflexivity in the knowledge-generation process, allowing space for individual perspectives as well as interpretations by the involved researchers and practitioners. This methodological approach not only supports the development of targeted, context-specific practical recommendations, but

also contributes to a deeper understanding of the reasoning and theoretical justifications underlying expert practices.

In the context of *quantitative intervention research*, a limitation is that only a small number of these studies were carried out in TDEs. This raises concerns about the generalizability of many findings to highly skilled players, as performance level is likely to moderate the effectiveness of interventions (Manninen et al., 2025). Another general concern relates to the need of interpreting effect sizes in relation to the respective control conditions. This poses a particular challenge in field-based learning environments, where identifying equivalent control groups (e.g., in terms of skill level) and designing purposeful active control conditions is difficult (Bobrownicki et al., 2022). This is reflected in the heterogeneity of control group designs, which poses challenges when comparing studies with ‘usual care’ conditions with those employing alternative coaching approaches as controls. A notable example is the randomized crossover trial by Roberts et al. (2020) which compared interventions based on information-processing and ecological dynamics theories in a YA. The cross-over design targeted common challenges associated with conducting intervention research within high performance setting, as it allowed control group participants to also receive the intervention. The findings presented in Study 1 are also subject to considerable statistical uncertainty. The relatively low statistical power of many included studies reflects a well-documented issue in sports science (Abt et al., 2020; Mesquida et al., 2023) and, more specifically, in motor learning research (Lohse et al., 2016). This uncertainty, combined with the likely presence of publication bias, raises fundamental methodological concerns. Accordingly, it is essential to avoid attributing an unwarranted level of precision to the reported effect sizes, as many studies lack the statistical sensitivity required to support robust conclusions (cf. Bergmann & Höner, 2021d).

Regarding the *qualitative interview study*, several methodological considerations warrant a cautious interpretation of the findings. Previous research has highlighted discrepancies between practitioners' interview statements and their actual coaching behavior (O'Connor et al., 2017; Partington & Cushion, 2013). Thus, despite the considerable expertise of participants, their recommendations may represent idealized 'best-case scenarios' (Raabe et al., 2020). Moreover, expert responses may have been influenced by the interview context itself. For example, some participants explicitly rejected coaching approaches based on high levels of (constant) movement repetition. However, this rejection may not necessarily indicate practical disagreement, but rather awareness of prevailing academic critiques of such practices (Cowin et al., 2022; Gray, 2020; 2025; Renshaw et al., 2019; Schöllhorn et al., 2022). This seems particularly plausible given that, in addition to the interviewed researchers, more than half of the participating coaches and coach educators held academic degrees in sports science. Such a background may give rise to a form of circular reasoning, where practitioners internalize dominant scientific narratives, even if their actual beliefs or behaviors in practice diverge from them.

While keeping these methodological limitations in mind, the combination of both studies yielded actionable implications for learning-supportive coaching in soccer TDEs. The systematic review demonstrated that a variety of approaches show general effectiveness, often supported by substantial effect sizes (Study 1). These findings were further reinforced through the experts interviewed in Study 2 who linked specific coaching strategies to competency-based learning goals. Consistent with previous research, the findings underscore the importance of developing a 'toolkit' of strategies that enable practitioners to implement goal-directed practice activities and coaching behaviors (cf. Mosston & Ashworth, 2008, p. 5; Price et al., 2019, p. 126). In this regard, considerable empirical

support exists for the contribution of a *game-centered coaching philosophy* which aligns with widespread recommendations advocating the use of SSGs to foster soccer-specific competencies (e.g., Bell, 2021; Brinkschröder, 2020; O'Connor et al., 2021b; O'Sullivan et al., 2021; Pill, 2021; Wade, 1967; Wein, 2004; Wolf, 2024; Worthington, 1974). Findings from both intervention research and expert recommendations suggest that the predominant use of practice activities with high specificity is not only essential for enhancing decision-making skills but also plays a critical role in developing technical skills that remain effective under physical and psychological pressure. Given that the interplay of performance factors relating to motor and cognitive competence areas forms a core element action competence in soccer (Hohmann & Brack, 1983; Höner, 2012), effectively supporting their development in complex learning situations is particularly warranted.

Beyond this overarching recommendation, the findings across studies also point to more specific strategies for optimizing coaches' learning support. In particular, they highlight the effectiveness of practice activities that *inherently guide players toward specific learning goals*. While these activities can, but do not necessarily have to be SSGs, they should aim to create game-representative situations that exaggerate specific actions relevant to the intended learning outcomes. This idea of stimulating certain player actions, while similarly adjusting the demands of the situation according to a players' current action capabilities is well illustrated by the valence-competence interrelation (Nitsch, 2004; Nitsch & Hackfort, 2016; in transfer to soccer cf. Höner, 2012a, pp. 22-23). By modifying task and environmental constraints, learning situations should generate high valence for those actions critical to the learning goal (e.g., through incentives/rewards), while also matching the learner's competence level. This alignment increases the likelihood that

players will engage in, rather than avoid, the target actions, thereby enabling practice tasks to address the nuanced needs of already competent players in TDEs.

Several examples of how the competence-valence interrelation, actively influenced by coaches, can lead to different player outcomes were found in intervention studies examining the concepts of *NLP* and *TGfU*. The SSGs used in these interventions often involved numerical superiority, which reduced the challenge associated with passing. In many studies, additional incentives were included (e.g., bonus points for a certain number of passes) further increasing the valence for passing actions. As a result from this manipulation of the valence-competence interrelation, these studies reported improvements in players' passing skills, while the effects on dribbling skills were either absent or considerably lower (e.g., Práxedes et al., 2016; 2018a). If the development of dribbling is prioritized, the findings highlight the relevance of designing game-representative situations that encourage the players to dribble by providing incentives, while necessarily also including further task modifications that create an optimal level of challenge. This tension highlights the need for coaching strategies that not only elicit the desired actions but also present learners with an optimal level of challenge (Hodges & Lohse, 2022). However, this implication partly conflicts with a tendency found in Study 3 and supported by previous research, namely that coaches often reduce the complexity of practice activities if they aim to address specific skills in their players (Partington & Cushion, 2013; Williams & Hodges, 2005).

Beyond supporting the particular contribution of a game-centred main philosophy, the Studies 1-3 also provide insights into the complementary value of different practice activities. However, the findings indicate that their contribution for learning depends largely on their purposeful combination within the session's microstructure. Specifically, the

systematic review indicates that interventions incorporating isolated drills – that is, low-complexity practice activities that address specific technical skills – can lead to improvements in isolated skill tests. While none of these studies directly assessed the impact of drills on in-game skill execution, some reported positive influences on game behaviour, particularly through enhanced application of the technical skills practiced in isolation (Guilherme et al., 2015a, 2015b). These findings are consistent with insights from the expert interviews in Study 2, in which the use of drills was justified based on their potential to encourage the players to apply these technical skills in game-representative situations, which are considered essential for learning. This interpretation also resonates with findings from other sports, where learners expressed a ‘desire for technique’ and experienced the use of drills as beneficial (e.g., Körner et al., 2021).

These findings emphasize that framing the debate as ‘either’ (game-based) ‘or’ (drill-based) is overly simplistic, particularly in light of well-established arguments that both approaches can contribute to learning when being thoughtfully combined (e.g., Roth, 2005b). Instead, greater attention should be paid to the movement variability generated within low-complexity practice activities, a topic intensively discussed in the literature (e.g., Cowin et al., 2022; Gray, 2020; Schöllhorn et al., 2022). In Study 2, most experts described drill-based activities as particularly effective in soccer TDEs when designed to foster within-skill variability across technical repetitions, for example, by executing skills in dynamic or moving situations. Consequently, although the task complexity in such practice activities is deliberately kept low to focus on specific skill outcomes, this does not similarly imply a high level of standardization (cf. Roth, 2005b, p. 299). This view diverges from traditional understandings of drill-based practice in terms of both isolated skill practice and constant movement replication (Ford et al., 2010). Rather, the findings

reflect a contemporary perspective aligned with broader calls for engaging and (cognitively) challenging tasks. Additionally, the interviewees recommended to purposefully align drills with overarching learning goals. This approach is consistent with coaching approaches that emphasize meaningful connections between SSGs and targeted drills within a session (e.g., *TGfU*; Bunker & Thorpe, 1982; *TGA*; Mitchell et al., 2015).

A critical factor in guiding learning processes is *coaches' behavior* during training sessions. Otte et al. (2020) distinguished coaching behaviors that either focus on modifying task constraints or providing learners with information (e.g., feedback). As an overarching result, the studies emphasize the fundamental importance of coaches purposefully constraining and adapting practice activities in ways that inherently guide learners toward desired outcomes through task design itself. Consequently, designing effective learning situations requires that coaches possess the practical tools to modify key constraints in a manner that promotes targeted player behaviors through the practice task itself (in detail Clemente et al., 2021a).

With regard to the provision of information, the findings reveal an important distinction between technical and tactical skill development. In the case of *technical skills*, the studies highlight the value of creating conditions that foster self-organized, implicit learning, enabling players to develop technical proficiency through their active application across learning situations. However, insights from Study 2 suggest that directive feedback can be useful when addressing non-functional movement patterns in technical skills. Such feedback may be particularly effective in less complex practice activities, where players are better able to process the information and concentrate on refining specific technical elements, with a primary emphasis on improving functional skill execution. Regarding

tactical skill development, findings across the studies emphasize the importance of promoting both implicit and explicit learning. While implicit learning through game experiences is considered essential for incidental decision-making, the results suggest that supplementing these experiences with explicit, principle-based reflection can further enhance players' game understanding (see Almond, 2015; Gréhaigne et al., 2005; Santos et al., 2016). Consequently, this may support their intentional decision-making by enabling players to identify and interpret recurring tactical patterns (e.g., Höner, 2012).

These findings offer empirical support for the instructional principle 'implicit before explicit learning', which advocates allowing players to first gather experiences in purposefully-designed learning situations before engaging in explicit reflection and tactical reasoning about solutions to solve them effectively (Pietzonka & Hohmann, 2020; Roth, 2005c). A key strategy for fostering game understanding is the use of purposeful questioning by coaches (O'Connor et al., 2021a; Raya Castellano et al., 2022). The experts' recommendations also aligned with the literature, emphasizing that questioning techniques should not merely aim to elicit predetermined responses, but should instead encourage meaningful reflective engagement (Cope et al., 2016). However, since guided reflection targets players' explicit learning processes, interviewed experts also advised using this approach selectively to avoid diminishing the benefits of implicit learning.

These and further findings across the Studies 1 and 2 formed the foundation for developing a set of '*ten principles for optimal learning support*' presented in Study 3. These principles were co-created with practitioners from the *DFB Talent Development Program* through a participatory approach. Consistent with the perspectives of the practitioners involved, the findings challenge binary debates that promote a single, universally applicable coaching approach in soccer TDEs (see also Bobrownicki et al., 2023; Collins et al.,

2023; Cope & Cushion, 2020; Kearney et al., 2024; Willimczik, 2013). Instead, they underscore the importance of contextual adaptability, emphasizing that the selection of practice activities and coaching strategies should be guided by their relevance to specific learning goals. This view aligns with the idea of a ‘chest of tools’ required to effectively address individual learning needs (e.g., Mosston & Ashworth, 2008; Pill, 2021; Price et al., 2021). At the same time, it is important to avoid the misconception that ‘anything works’ equally well in a specific coaching context. The developed guiding principles provide targeted recommendations, highlighting the need for the deliberate use of coaching strategies to optimize learning support in soccer TDEs.

As a *preliminary conclusion*, Research Focus I has consolidated a substantial body of knowledge regarding the effectiveness of coaching strategies in soccer TDEs. Despite the acknowledged methodological limitations, the scientific knowledge has grown in recent years, with various approaches receiving empirical support. Moreover, the practical implications derived from Studies 1 and 2 closely aligned with the beliefs of practitioners within the *DFB Talent Development Program* as identified in Study 3. This alignment not only reinforces the practical relevance of the identified principles but also provides a strong foundation for their application within the research context of this dissertation. However, the evaluation of the research-informed CEP revealed that some coaches experienced challenges in applying these strategies in practice. Among other factors, these challenges relate to the need for coaches to conduct detailed analyses of each player’s strengths and weaknesses as a prerequisite for implementing strategies tailored to specific learning outcomes. This highlights the importance of coaches being able to identify and respond to players’ learning needs within dynamic and unpredictable learning envi-

ronments. As noted in Studies 2 and 3, these processes reveal connections to the concept of diagnostic competencies and their crucial role in enabling differentiation across learners and adaptive teaching/coaching (Klug et al., 2013; Reuker & Schicklinski, 2024). These challenges echo earlier findings from the *DFB Talent Development Program*, where coaches were surveyed about their perceived levels of education and developmental needs (Schreiner et al., 2018). While overall education levels were rated positively, coaches reported lower confidence in the areas of talent identification and guiding learning processes. They also noted difficulties in designing game-based activities that effectively address specific learning objectives (cf. *ibid.*, p. 28). Although this evaluation was conducted several years ago, its findings remain highly relevant, as they correspond with those of Study 3. Similar challenges are also documented in the international coaching literature, particularly regarding the application of game-centered activities that are aligned with specific learning goals, as well as the use of ‘hands-off’ coaching strategies (Kinnerk et al., 2018; O’Connor et al., 2021a; Richardson et al., 2024). Thus, improving the learning support in TDEs is not only a matter of identifying effective strategies – it also depends on whether coaches possess the competencies required to implement them effectively in practice.

To support coaches in effectively guiding player learning, the *DFB Talent Development Program* employs both objective and subjective assessments. The data is intended to be also used in a formative way to enhance the developmental support offered to players at DFB BCs (DFB, 2022b). Aligned with the concept of *assessment for learning* (Zeng et al., 2018), one overarching aim of these instruments is to provide coaches’ with meaningful information that can be integrated into their work. In particular, the competency-based coach ratings were introduced in response to the challenges identified by Schreiner et al.

(2018), as they might assist practitioners in systematically evaluating players' strengths and weaknesses as a basis for targeted learning support. These ratings cover motor, cognitive, and psychosocial competence areas (see *Chapter 2.2.4*). A test manual offers concrete descriptions and practice-relevant examples, aiming to enhance coaches' understanding of these competencies and to facilitate their systemation evaluation in practice. This intention of using these assessments to support talent development leads into the central objective of Research Focus II. Current empirical knowledge on the combined contribution of objective and subjective assessments is limited to a single study involving male outfield players (Höner et al., 2021). Therefore, Studies 4 and 5 aim to generate a deeper scientific understanding of the strengths and limitations of the existing assessment methods and their combined use by evaluating their predictive validity with female players and GKs. If the promising yet ambivalent findings regarding the complementary contribution of objective and subjective assessments are confirmed, the studies could provide a foundation for developing concrete strategies to even better integrate these tools into talent development practices. In addition, Studies 6 and 7 introduce a novel GK-specific objective test instrument designed to complement the existing assessment approach. This newly developed test battery aims to support evaluations within the *DFB Talent Development Program* by combining objective and subjective assessments aligned with position-specific talent predictors of GKs.

The findings on the instruments' psychometric properties and the resulting opportunities to support different processes in soccer TDEs will be synthesized in *Chapter 3.3.4*. Given the scope of this dissertation, the general discussion in *Chapter 4* will place particular emphasis on the instruments' potential to function as learning-oriented assessments, and especially on their contribution as assessments for learning.

3.3 Research Focus II: Learning-Oriented Assessment

3.3.1 *Multidimensional Performance Assessments in U15 Female Soccer: The Predictive Validity for Different Selection Levels in U17 and Success in Adulthood (Study 4)*

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Abstract

Female players have largely been neglected in soccer-specific talent research. Particularly prospective studies examining the predictive validity of multidimensional performance factors for different selection levels—especially players' success in adulthood—remain scarce. This prospective cohort study investigated the predictive validity of multidimensional performance factors for the future success of U15 female players ($N = 264$) participating in the German Football Association's Talent Development program. All players' kicking, tactical, and psychosocial skills, as well as endurance capacity were evaluated subjectively. They also completed five objective motor tests (sprint, agility [CODS], dribbling, ball control, juggling). Players' future success was based on their selection for the U17 Bundesliga (43.6% selection rate), U17 Youth National Team (6.4%), and Women's Bundesliga (i.e., professional level in adulthood; 6.1%). Univariate analyses examined performance differences in each predictor between selected and non-selected players. Multivariate analyses determined whether objective predictors, subjective predictors, or a combination thereof offered the best prediction. Univariate results indicate predictive validity of both assessments, revealing a trend toward larger effect sizes for higher selection levels and differences in predictor relevance. Multivariate models showed that adding subjective to objective predictors lead to an increase in explained variance for participation in the U17 Bundesliga (Nagelkerke's $R^2 = 16\%$) and Women's Bundesliga (31%), but not U17 Youth National Team (18%). Sprint performance reached significance across models, while the sole significant subjective predictor was tactical skills regarding participation in the Women's Bundesliga. Overall, the findings support the practical value of both assessments, which can likely be increased further via more distinct coach ratings.

Keywords: football; talent diagnostics; talent identification and development; prognostic relevance; skills

Summary:

- The findings support the consideration of multidimensional performance factors in the context of talent identification and development in elite female soccer.
- The combination of subjective and objective assessments can enhance the predictive power regarding U15 players' future success in late adolescence and adulthood.
- Although objective assessments were particularly suitable for evaluating distinct (motor) predictors, the contribution of subjective coach ratings may be improved through more nuanced evaluations of theoretically distinct competence areas.

Introduction

Talent identification and development (TID) research is a continuously growing area of scholarship with investigations of multifaceted topics across a variety of sports (Baker et al., 2020; Barraclough et al., 2022). Yet, one meaningful limitation of the existing empirical evidence is the underrepresentation of female athletes in study samples—a disparity referred to as the *gender data gap in talent development* (Curran et al., 2019). TID research in soccer is no exception to this trend (Murr et al., 2018a; 2018b; Okholm Kryger et al., 2021; Williams et al., 2020; Wrang et al., 2021) which is surprising given not only the worldwide increase in participation rates among girls and women, but also the popularity of professional women’s soccer tournaments over recent decades (Dunn, 2016; Fédération Internationale de Football Association [FIFA]; 2021b).

To further support this ongoing rise in participation, popularity, and professionalization, FIFA (2018) launched the “Women’s Football Strategy” and encouraged all national football associations to enhance developmental programs for female soccer, including those aimed at optimizing TID (e.g., empowering girls to get involved, modernizing infrastructures, increasing the number of qualified female coaches). While improvements are reflected in a 24% increase in the number of active women and girls playing football since 2019 (i.e., 16.6 million in 2023; FIFA, 2023a, p. 8), implementation of elite talent pathways, and reformed competitive league systems, these processes are far from being completed (see also FIFA, 2023b).

That said, research exploring the identification and development of talent in female youth players can help refine such processes and, in turn, advance the professionalization of women’s soccer. A crucial factor in supporting practitioners in TID processes is the avail-

ability of empirical insight into performance factors that reveal *predictive power for players' future success* (Höner et al., 2023). Based on a systematic review of prospective studies, Williams et al. (2020) proposed a multidimensional model of talent predictors in soccer, encompassing physical, skill-related, psychological, and sociological characteristics. However, 93% ($n = 25$) included studies in this review focused on male players.

The generalizability of findings on male players to female soccer remains uncertain. One factor contributing to this uncertainty is the developmental differences between sexes, such as the earlier average maturation in girls compared to boys (e.g., Malina et al., 2017). Additionally, there are notable differences between the TID systems for male and female players. For instance, despite rising participation rates among girls in recent years, the number of participants in organized soccer remains significantly lower than their male counterparts, resulting in a smaller overall talent pool (Emmonds et al., 2024; Valenti et al., 2021). One consequence is that many girls participate in mixed gender teams during childhood and early adolescence before transitioning to female teams (Andrew et al., 2024a; McEwan et al., 2024). This structure creates challenges for practitioners when evaluating female players' talent within male-dominated training groups where a reference group of same-aged female peers may be lacking. Furthermore, in some countries (e.g., Germany), female players directly transition from Under-17 (U17) to U20 or even adult teams, whereas male players typically pass through U18/U19 and sometimes even U21 squads before reaching the adult level. In combination, such developmental and structural differences may not only affect the predictive validity of performance factors across developmental stages but also influence methodological decisions in designing prospective talent research.

Specifically, the criterion variables that are used to define future success and the prognostic periods that are utilized to evaluate them are common moderators of the predictive power of performance factors (Bergkamp et al., 2019). According to recent literature reviews by Emmonds et al. (2024) and Randell et al. (2021), the predictive validity of talent assessments in female soccer has only been investigated in three prospective studies. These studies offer initial evidence on the predictive validity of objectively assessed technical, physical, and physiological predictors in female players. Höner et al. (2019), demonstrated the five-year prognostic relevance (U12 to U17) of sprint, agility (CODS), dribbling, and ball control tests for the selection into a regional association and youth national team with moderate to large effect sizes within the German Football Association's (Deutscher Fußball-Bund [DFB]) TID program. Sprint and dribbling tests further discriminated with a moderate effect size between future youth national team players and individuals who were selected for regional association squads. Based on a longitudinal design within the same TID program, Leyhr et al. (2020) demonstrated that sprint, agility (CODS), dribbling, ball control, and shooting tests had a predictive value for players' participation in the first adult division in Germany. Yet, the longitudinal development of performance factors did not significantly predict players' adult performance level. Lastly, Datson et al. (2020) analyzed the predictive validity of sprint, countermovement jump, and high-intensity endurance performance tests of female players (12.7-15.3 years old) participating in English Elite Performance Camps. Only the high-intensity endurance capacity was found to predict players' participation in competitive international squads in the age groups U17 to U20.

The overall limited number of such prospective studies highlights the general need to further address the gender data gap in talent research (Curran et al., 2019). In this effort, it

seems especially important to address the lack of prospective studies that adopt a *multidimensional approach* (i.e., incorporating a wide range of potential talent predictors; Emmonds et al., 2024). This has been shown to be particularly predictive in male youth soccer when combining objective motor tests with subjective coach ratings (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a). However, the predictive validity of subjective coach ratings, and consequently their contribution to a multidimensional approach in female youth soccer, remain largely unexplored (Emmonds et al., 2024). Furthermore, the predictive validity of talent assessments is typically moderated by the *selection levels* considered (e.g., due to the ratio of players categorized as successful and non-successful) as well as the length of the *prognostic period* (Bergkamp et al., 2019). Consequently, there is a particular need for studies examining the predictive validity of multidimensional approaches across various career stages in female youth soccer (i.e., incorporating different selection levels), and involving examinations regarding the highest performance level in adulthood.

The Present Study

To address these gaps, this prospective cohort study aimed to analyze the predictive validity of subjective coach ratings and objective motor tests for female youth soccer players' future success at different selection levels and prognostic periods. The research was conducted within the nationwide German TID program in which the girls participate in one practice session per week at one of the 350 nationwide DFB base camps (BCs; "competence centers"; Kelly et al., 2024) to supplement their promotion in home clubs. Girls' participation at one of the BCs within the TID program begins at U12 and concludes after the U15. Players within the program participate in annual objective and subjective assessments allowing for the consideration of multidimensional talent predictors (Höner

et al., 2021). The current study was designed to evaluate the predictive validity of players' test performances during their final year of the program (i.e., U15) which represents a critical developmental trajectory in their soccer careers. Players' performance levels achieved in the U17 age group (i.e., over a two-year period)—their final year in youth soccer in Germany before transitioning to adult teams—along with their performance levels achieved in adulthood were used as criterion variables. More specifically, the research aimed to address the following two research objectives: *First*, examine the univariate predictive validity of each subjectively and objectively assessed performance factor concerning the different criterion variables (objective 1). *Second*, analyze the multivariate predictive validity by evaluating if combining both assessments increases the predictive validity (objective 2).

Method

Sample

The sample of this prospective cohort study consisted of $N = 264$ female U15 players ($M_{\text{age}} = 14.0$ years, $SD_{\text{age}} = 0.9$) participating in the DFB TID program. These girls are among the top 2% of female football players in their respective age groups across Germany. They train in mixed-gender groups alongside their male counterparts, who are among the top 4% of players in their age group. Participants took part in subjective and objective assessments in the 2015/16 (birth cohort 2001), 2016/17 (2002), or 2017/18 seasons (2003). Players' legal guardian/next of kin provided written informed consent for the collection and scientific use of the data before entering the program. The first author's university's ethics department approved the use of the data for this study.

Measures

Subjective Coach Ratings

The subjective assessments of the players were conducted by BC coaches holding at least a UEFA B coaching license. These ratings were implemented in the 2015/2016 season to facilitate a detailed and systematic evaluation of players' competencies in solving specific game situations (DFB, 2022b). Beyond talent identification, a key objective of the individual assessment is to guide practice design and inform other coaching decisions (e.g., differentiated learning goals; Bergmann et al., 2025a; Ford & Coughlan, 2020). Accordingly, the ratings contribute to optimized talent development by complementing the insights derived from isolated motor tests. To ensure uniformity in the evaluations, coaches were provided with a detailed manual that explained each aspect of performance being assessed (DFB, 2022b). In total, the coaches subjectively rated players' performance across 14 characteristics: three items related to *kicking skills*¹⁶ (i.e., kicking the ball with the dominant and non-dominant leg, heading), one item related to *endurance*, seven items related to *tactical skills* (i.e., behavior in offensive and defensive situations before, during, and after ball-related actions, as well as game intelligence), and three items related to *psychosocial skills* (i.e., motivational, volitional, and social skills). Items related to kicking skills, endurance, and tactical skills were each evaluated by coaches with reference to players' age group using a four-point rating scale: "below-average BC level" (0); "average BC level" (1); "level of the extended squad for regional association

¹⁶ This translation is based on the German term *Stoßtechniken*, which encompasses a range of techniques involving one ball contact. In collaboration with native speakers, we carefully searched for an appropriate English equivalent and ultimately chose 'kicking skills' to reflect the inclusion of all techniques involving hitting the ball. For example, it also covers passing skills, which are not considered 'striking' techniques in a narrower sense.

team” (2); or “level of core team for the regional association team” (3). Regarding psychosocial skills, coaches were asked to evaluate their players by using the scale: “below average level” (0); “average level (1); “high level” (2); or “very high level” (3). Reliabilities in terms of internal consistency (Cronbach’s α) for tactical skills ($\alpha = .92$) and psychosocial skills ($\alpha = .90$) were excellent, while kicking skills showed at least satisfying values ($\alpha = .79$). These values widely corresponded with evaluations involving male players (Höner et al., 2021). Therefore, single scores for each of the three skills (i.e., kicking, tactical, and psychosocial) were computed for further analyses, along with endurance which consisted of a single item.

Objective motor diagnostic

To complement coaches’ subjective evaluations with objective information, the results of a motor test battery assessing speed abilities and technical skills were also utilized (DFB, 2022b). In addition to supporting the identification of particularly talented players, the detailed individual test results are intended to foster talent development through personalized training recommendations (Höner et al., 2020). Furthermore, the objective and standardized nature of the test allows for monitoring the progression of talent predictors over time (Leyhr et al., 2018). The assessment consisted of five individual tests: *sprint* (i.e., time to complete a 20m linear sprint), *agility* in terms of change of direction speed (CODS; i.e., time to complete a slalom course without a ball), *dribbling* (i.e., time to complete a slalom course with a ball), *ball control* (i.e., time needed to play six passes alternately to two opposing locations with at least two ball contacts), and ball *juggling* (i.e., ability to juggle the ball alternately with the left and right foot through as many subsections of a figure eight-course as possible without ground contact). The execution times of the sprint, agility (CODS), and dribbling tests were measured using light barriers (Brower

TC Timing, Draper, USA). The execution time of the ball control test was measured with hand-stopped chronographs. Each test was performed twice, and the best result was included for subsequent analyses. Players were given a recovery period of at least 60 seconds between each test trial. The motor tests demonstrated good psychometric properties in terms of reliability, factorial validity, and predictive validity, as confirmed in several samples of both male (e.g., Höner et al., 2015; Höner et al., 2017) and female elite youth soccer players (Höner et al., 2019; Leyhr et al., 2020).

Criterion variables

Players' future success was operationalized through three typical career trajectories in female soccer. First, it was determined if participants who were tested in U15 made the official roster for a team competing in the German *Women's U17 Bundesliga* two seasons after data collection. This league was implemented in 2012 to optimize development pathways for the most talented female players in Germany. In the considered seasons (2017/18 to 2019/20), this league was divided into three regional conferences, serving as one possible final step before entering professional Women's soccer. The second criterion variable considering the same two-year prognostic period was selection for the German *U17 Youth National Team*, which represents the highest possible selection level a player in that age class can achieve. Third, players' future success in adulthood was defined by participation in the *Women's Bundesliga* (seasons 2017/2018 to 2023/2024), which represents the highest performance level in Germany. For all three selection levels, only players who made an official match appearance were classified as "selected", while all others were categorized as "non-selected". Across these three distinct selection levels within the German TID pathway, it was possible that players in the study sample meet more than one criterion. These three criterion variables also allow to evaluate the

potential influence of the different selection levels and prognostic periods on the assessment's predictive validity. *Table 12* presents the selection rates as well as the overlaps of players within the respective sub-samples.

Table 12. *Numbers of selected players, selection rates and the overlaps of the sub-samples that fulfill the different criterion variables (N = 264).*

Criterion	<i>n</i> (selection rate)	Overlaps with other criterion variables
U17 Bundesliga	115 (43.6%)	U17 Youth National Team: <i>n</i> = 15 Women's Bundesliga: <i>n</i> = 14
U17 Youth National Team	17 (6.4%)	Women's Bundesliga: <i>n</i> = 9
Women's Bundesliga	16 (6.1%)	-

Statistical Analyses

Statistical analyses were performed utilizing IBM SPSS (version 28), with a significance level set at $\alpha = .05$. To check the data requirements for subsequent analyses, it was examined whether potential confounders reported in previous research—namely differences across included birth cohorts and relative age effects (Elferink-Gemser et al., 2012; Leyhr et al., 2021)—influenced the predictive power. Specifically, separate two-way ANOVAs for each performance factor and future selection level were used to test potential interaction effects with birth cohort (i.e., 2001-2003) and birth quarter. As no significant interaction effects were found for birth cohort ($F(2, 258) \leq 2.78, p \geq .06$) or relative age ($F(3, 256) \leq 2.51, p \geq .06$) at any of the future selection levels, these variables were not considered further as covariates. Furthermore, as statistical power is a critical concern in prospective talent research (Bergkamp et al., 2019), post hoc sensitivity analyses were conducted to account for the distribution of the total sample ($N = 264$) across the three criterion variables. The minimum detectable population effect size for

differences between two groups (Cohen's d) with predefined parameters ($\alpha = 0.05$, $1 - \beta = 0.80$, two-tailed) was calculated using G*Power (version 3.1.9.7; Faul et al., 2007). The analyses had sufficient sensitivity to detect small to moderate effect sizes for the prediction of players' participation in the U17 Bundesliga ($d \geq 0.31$), and moderate effect sizes for the criteria U17 Youth National Teams ($d \geq 0.71$) and Women's Bundesliga ($d \geq 0.73$).

To analyze the *univariate predictive validity* (objective 1) of each subjectively and objectively assessed predictor, independent-sample t -tests were conducted to investigate mean differences between participants of different selection levels. These were classified by Cohen's d (computed as the mean difference divided by the pooled standard deviation) including the respective 95% confidence intervals and were presented irrespective of their significance given the restricted sensitivity of statistical analyses.

The data requirements to investigate the *multivariate predictive validity* (objective 2) were evaluated through bivariate correlations among predictors. Correlations ranged from $r = .02$ ($p = .70$) for sprint and ball control to $r = .79$ ($p < .001$) for subjectively rated kicking skills and tactical skills. Variance Inflation Factors (VIFs) across predictors were all below 4.17, demonstrating no serious multicollinearity (Akinwande et al., 2015). Therefore, a logistic regression approach was chosen similar to that used by Höner et al. (2021) who evaluated the same assessments in a male sample from the same TID program. Three logistic regression models for each of the three criterion variables were computed in which the binary criterion variable was predicted by subjectively (model 1), objectively (model 2), and a combination of subjectively and objectively assessed performance factors (model 3). Specifically, the independent variables for model 1 comprised the four

subjectively rated performance factors, while model 2 included the five objective motor tests. Model 3 included all those nine assessed performance factors. Overall model fit was assessed using the likelihood ratio chi-squared test and Nagelkerke's R^2 . Regression coefficients and the odds ratio coefficients e^b (including their 95% confidence intervals) were calculated to assess the player's relative chances to achieve a respective selection level, depending on the considered predictors. To facilitate comparisons of the effect sizes across predictors, the odds ratio coefficients e^b were additionally adjusted to the standard deviations of the respective predictor. Thus, the resulting $(e^b)^{SD}$ represents the relative change of the likelihood of achieving a respective selection level by a one standard deviation increase within the considered predictor. Effect sizes for both the univariate and multivariate analyses were consistently reported in a positive direction, regardless of whether the variable was negatively (i.e., lower times indicate higher performance) or positively coded (i.e., more points indicate higher performance), that is better test performance resulted in higher chances of selection.

Results

Univariate predictive validity of subjective and objective assessments (objective 1)

The results of the univariate predictive validity for subjectively and objectively assessed predictors are displayed in *Table 13* and *Figure 21*. Regarding the *subjective coach ratings*, significant differences between future U17 Bundesliga players and the remaining sample were found for all predictors (each $p < .01$) with small to moderate effect sizes ($Mdn(d) = 0.47$; $0.40 \leq d \leq 0.50$). For selection into the U17 Youth National Team, small to moderate effect sizes were observed ($Mdn(d) = 0.44$; $0.30 \leq d \leq 0.57$) with significant differences in endurance ($p < .001$) and tactical skills ($p < .001$), but non-significant differences in kicking ($p = .23$) and psychosocial skills ($p = .18$). Future Women's Bundesliga

players outperformed the remaining sample with small to large effect sizes ($Mdn(d) = 0.63$; $0.29 \leq d \leq 0.95$). While non-significant differences for endurance ($p = .07$) and psychosocial skills ($p = .25$) were found, significant differences for kicking skills and tactical skills (each $p < .001$) occurred. These ratings of kicking ($d = 0.79$) and tactical skills ($d = 0.95$) in predicting players' participation in the Women's Bundesliga yielded the highest effect sizes across all subjectively rated attributes and criterion variables, while the remaining subjective variables all had comparable small to moderate effect sizes ($0.29 \leq d \leq 0.57$; *Figure 21*).

All *objective motor tests*, except for agility (CODS) ($p = .31$), significantly predicted players' participation in the U17 Bundesliga (each $p < .05$) with small effect sizes ($Mdn(d) = 0.30$; $0.13 \leq d \leq 0.46$). For players' selection into the U17 Youth National Team, small to moderate effect sizes were observed ($Mdn(d) = 0.60$; $0.17 \leq d \leq 0.76$) with significant differences in sprint ($p < .05$), ball control ($p < .01$), and juggling ($p < .01$). Regarding players' selection into a Women's Bundesliga team, effect sizes ranged from small to large ($Mdn(d) = 0.68$; $0.18 \leq d \leq 0.86$) with significant differences among all motor tests (each $p < .05$), except for agility (CODS) ($p = .48$). When comparing the relevance across the three criterion variables (see *Figure 21*), ball control and juggling revealed particular relevance for selection into the U17 Youth National Team and the Women's Bundesliga. Similarly, but to a lower extent, the predictive validity for the sprint test seemed to increase by selection levels from U17 Bundesliga to U17 Youth National Team and to the Women's Bundesliga. The agility (CODS) test did not predict any future performance level. Dribbling consistently showed moderate relevance to predict all future performance levels

Table 13. Test results for subjectively (in italics) and objectively evaluated performance factors of U15 players ($N = 264$) based on the criterion variables of having participated in an official match in the U17 Bundesliga ($n = 115$; 43.6% selection rate), the U17 Youth National Team ($n = 17$; 6.4%), and the Women's Bundesliga ($n = 16$; 6.1%).

Performance factor	Future performance level	U17 Bundesliga		U17 Youth National Team		Women's Bundesliga	
		$M \pm SD$	$t (df)$	$M \pm SD$	$t (df)$	$M \pm SD$	$t (df)$
			Cohen's d (95% CI)		Cohen's d (95% CI)		Cohen's d (95% CI)
<i>Kicking skills</i>	Selected	1.63 $\pm$ 0.56	3.25 (262)	1.67 $\pm$ 0.49	1.20 (262)	1.92 $\pm$ 0.46	3.08 (262)
	Non-selected	1.42 $\pm$ 0.53	0.40** (0.16; 0.65)	1.50 $\pm$ 0.56	0.30 (-0.19; 0.79)	1.49 $\pm$ 0.55	0.79** (0.28; 1.30)
<i>Endurance</i>	Selected	2.20 $\pm$ 0.70	4.02 (262)	2.35 $\pm$ 0.61	2.11 (262)	2.31 $\pm$ 0.79	1.80 (262)
	Non-selected	1.86 $\pm$ 0.67	0.50*** (0.25; 0.74)	1.98 $\pm$ 0.70	0.53* (0.03; 1.02)	1.99 $\pm$ 0.69	0.46 (-0.04; 0.97)
<i>Tactical skills</i>	Selected	1.90 $\pm$ 0.58	3.99 (262)	2.06 $\pm$ 0.53	2.28 (262)	2.27 $\pm$ 0.54	3.71 (262)
	Non-selected	1.61 $\pm$ 0.59	0.49*** (0.25; 0.74)	1.72 $\pm$ 0.60	0.57* (0.08; 1.06)	1.70 $\pm$ 0.59	0.95** (0.44; 1.46)
<i>Psychosocial skills</i>	Selected	2.20 $\pm$ 0.64	3.52 (262)	2.25 $\pm$ 0.66	1.36 (262)	2.23 $\pm$ 0.69	1.16 (262)
	Non-selected	1.92 $\pm$ 0.67	0.44** (0.19; 0.68)	2.03 $\pm$ 0.67	0.34 (-0.15; 0.83)	2.03 $\pm$ 0.67	0.29 (-0.21; 0.80)
Sprint (20m) [#]	Selected	3.44 $\pm$ 0.17	2.92 (262)	3.39 $\pm$ 0.16	2.40 (262)	3.38 $\pm$ 0.16	2.63 (262)
	Non-selected	3.50 $\pm$ 0.15	0.36*** (0.12; 0.61)	3.48 $\pm$ 0.16	0.60* (0.11; 1.09)	3.48 $\pm$ 0.16	0.68** (0.17; 1.18)

STUDY 4

Agility (CODS) [#]	Selected	8.22 ± 0.37	1.01 (262)	8.19 ± 0.33	0.69 (262)	8.18 ± 0.37	0.70 (262)
	Non-selected	8.27 ± 0.36	0.13 (-0.12; 0.37)	8.25 ± 0.37	0.17 (-0.32; 0.66)	8.25 ± 0.36	0.18 (-0.32; 0.69)
Dribbling [#]	Selected	10.76 ± 0.65	3.73 (262)	10.66 ± 0.71	1.69 (262)	10.60 ± 0.56	2.04 (262)
	Non-selected	11.06 ± 0.65	0.46*** (0.22; 0.71)	10.94 ± 0.66	0.42 (-0.07; 0.91)	10.95 ± 0.67	0.52* (0.02; 1.03)
Ball control [#]	Selected	9.37 ± 1.25	2.48 (262)	8.68 ± 0.89	3.03 (262)	8.70 ± 0.87	2.89 (262)
	Non-selected	9.76 ± 1.31	0.31* (0.06; 0.55)	9.65 ± 1.30	0.76** (0.26; 1.25)	9.65 ± 1.30	0.74** (0.23; 1.25)
Juggling	Selected	7.76 ± 5.98	2.03 (218.44)	10.47 ± 7.05	2.15 (17.245)	11.31 ± 5.04	3.36 (262)
	Non-selected	6.36 ± 4.93	0.26* (0.01; 0.50)	6.72 ± 5.25	0.70** (0.20 1.19)	6.69 ± 5.36	0.86** (0.35; 1.37)

Note. [#]These variables are negatively coded (i.e., a lower value represents a higher performance). A positive d value displays a better test result for the selected players regardless of whether the considered variable was negatively or positively coded. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

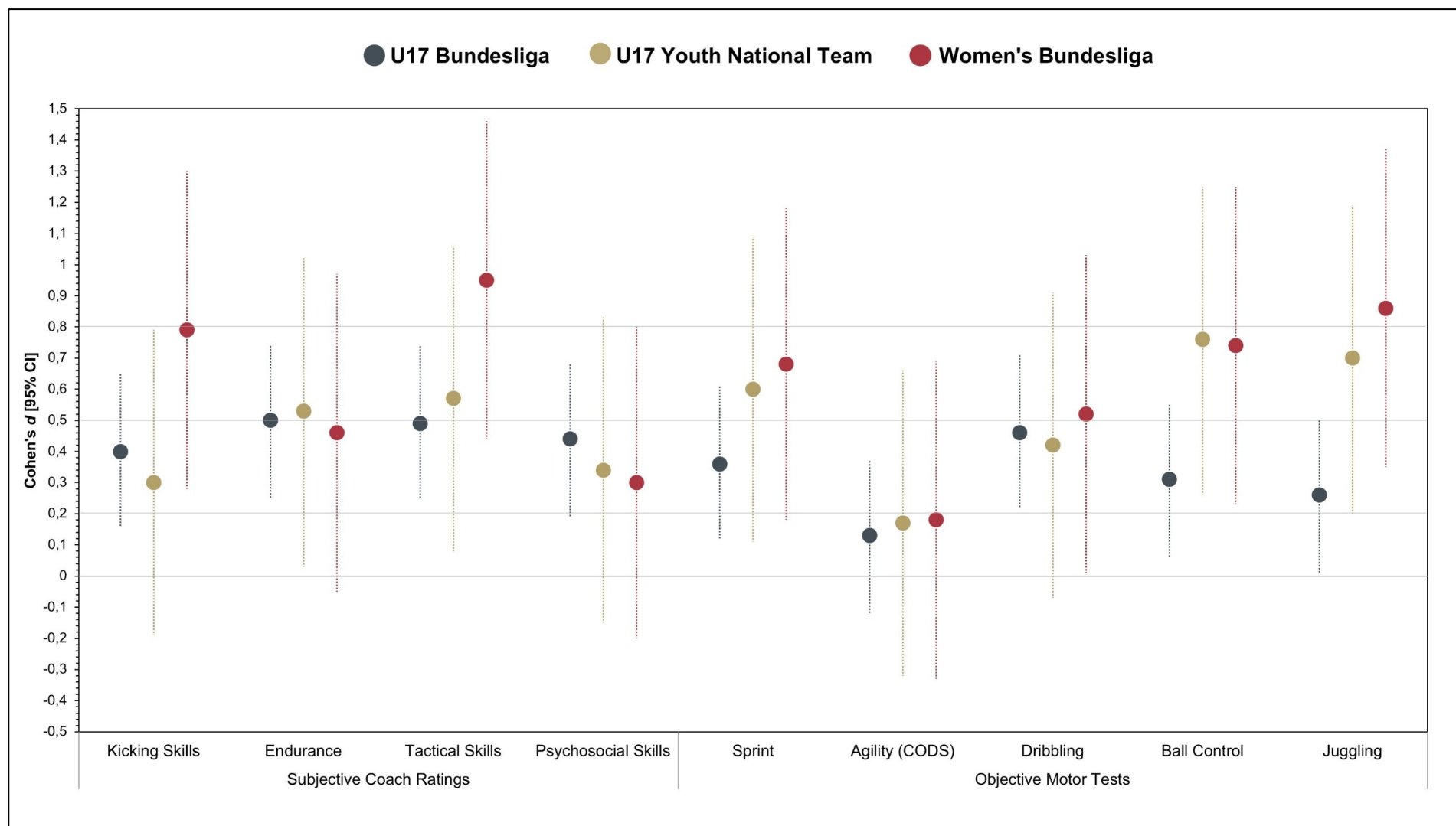


Figure 21. Superior performance in terms of Cohen's d and respective 95% CIs of future selected players among the three criterion variables.

Multivariate predictive validity of the multidimensional assessment (objective 2)

The overall fits of the subjective multivariate assessment model (model 1) were significantly better compared to the null model in predicting players' participation in the U17 Bundesliga and the Women's Bundesliga ($18.11 \leq \chi^2(4) \leq 18.48$, each $p < .001$; $.09 \leq \text{Nagelkerke's } R^2 \leq .18$), but not for predicting selection to the U17 Youth National Team ($\chi^2(4) \leq 7.174$, $p = .13$). The overall fits of the objective assessment models (model 2) were significantly better compared to the null model regarding all three selection levels ($18.30 \leq \chi^2(4) \leq 20.21$, each $p < .01$; $.11 \leq \text{Nagelkerke's } R^2 \leq .21$). The explained variance across the three selection levels was slightly higher for the objective compared to the subjective assessment (i.e., U17 Bundesliga: 11% vs. 9%, U17 Youth National Team: 18% vs. 7%, Women's Bundesliga: 20% vs. 18%).

Hierarchical regressions further revealed that adding the subjective predictors (model 1) to the objective predictors (model 2) led to a significant increase in explained variance for predicting players' participation in the U17 Bundesliga ($\Delta\chi^2(3) = 11.47$, $p < .01$, $\Delta\text{Nagelkerke's } R^2 = .05$) and the Women's Bundesliga ($\Delta\chi^2(3) = 11.48$, $p < .01$, $\Delta\text{Nagelkerke's } R^2 = .11$). Consequently, the combined subjective and objective model (model 3) demonstrated the highest predictive power for these selection levels. For predicting the U17 Youth National Team selection, the combined model 3 did not lead to a significant increase in the explained variance ($\Delta\chi^2(3) = 3.11$, $p = .38$, $\Delta\text{Nagelkerke's } R^2 = .03$) highlighting the objective assessment model 2 as the best-fitting model. These final models are presented in *Table 14* and reveal a trend toward a higher explained variance for higher selection levels (i.e., U17 Bundesliga: 16%, U17 Youth National Team: 18%, Women's Bundesliga: 31%).

Table 14 further provides information on the significance of each predictor within these best-fitting logistic regression models (details for all other models are presented in Supplements I–III). To predict players’ participation in the U17 Bundesliga, only the sprint test reached significance ($p < .05$) and revealed a $(e^b)^{SD} = 1.43$ times higher relative selection chances by a one standard deviation ($SD = 0.16$ sec.) increase in performance. In the objective model predicting U17 Youth National Team selection, both ball control $((e^b)^{SD} = 2.74)$ and sprint $((e^b)^{SD} = 1.80)$ significantly contributed to the model (each $p < .05$). For the criterion Women’s Bundesliga, both subjectively rated tactical skills $((e^b)^{SD} = 4.21)$ and sprint $((e^b)^{SD} = 2.03)$ were significant (each $p < .05$).

Table 14. Logistic regression results for the prediction of players future success (final models) based on the criterion variables of having participated in an official match in the U17 Bundesliga (model 3), U17 Youth National Team (model 2), and Women's Bundesliga (model 3).

Age Group	Omnibus-Tests			Predictor	Logistic regression coefficients				(e ^b) ^{SD(#)}
	χ^2 (df)	p	Nagelkerke R ²		b	Wald	p	e ^b [95%-CI]	
U17 Bundesliga	33.70 (9)	< .001	0.16	Constant	8.16	-	-	-	-
				Sprint	-2.26	5.3	< .05	0.11 [0.02; 0.72]	1.43
				Dribbling	-0.49	3.84	0.05	0.62 [0.38; 1.00]	-
				Ball control	-0.19	2.56	0.11	0.82 [0.65; 1.04]	-
				Agility (CODS)	0.61	2.09	0.15	1.84 [0.80; 4.21]	-
				<i>Endurance</i>	0.38	1.61	0.2	1.46 [0.81; 2.64]	-
				<i>Psychosocial skills</i>	0.25	0.7	0.4	1.28 [0.72; 2.27]	-
				Juggling	-0.01	0.1	0.75	0.99 [0.94; 1.05]	-
				<i>Tactical skills</i>	0.12	0.07	0.79	1.13 [0.47; 2.68]	-
				<i>Kicking skills</i>	0.07	0.03	0.87	1.07 [0.49; 2.33]	-
U17 Youth National Team	18.30 (5)	< .01	0.18	Constant	14.38	-	-	-	-
				Ball control	-0.78	5.57	< .05	0.46 [0.24; 0.88]	2.74
				Sprint	-3.70	3.86	< .05	0.03 [0.00; 0.99]	1.8
				Juggling	0.05	0.89	0.35	1.05 [0.95; 1.16]	-
				Agility (CODS)	0.39	0.23	0.64	1.48 [0.30; 7.36]	-
				Dribbling	-0.08	0.02	0.88	0.92 [0.33; 2.55]	-
Women's Bundesliga	31.70 (9)	< .001	0.31	Constant	13.7	-	-	-	-

Tactical skills	2.39	5.12	< .05	10.92 [1.38; 86.57]	4.21
Sprint	-4.49	4.86	< .05	0.01 [0.00; 0.61]	2.03
Ball control	-0.70	3.44	0.06	0.50 [0.24; 1.04]	-
Psychosocial skills	-1.12	2.4	0.12	0.33 [0.08; 1.35]	-
Juggling	0.05	0.83	0.36	1.05 [0.94; 1.18]	-
Endurance	-0.44	0.48	0.49	0.64 [0.18; 2.25]	-
Agility (CODS)	0.39	0.19	0.66	1.48 [0.26; 8.52]	-
Kicking skills	0.29	0.12	0.73	1.34 [0.25; 7.15]	-
Dribbling	-0.03	0.01	0.96	0.97 [0.29; 3.21]	-

Note. Predictors were ordered by increasing values with regard to the Wald statistic. [#] In order to facilitate comparisons for effect sizes of individual predictors, the odds ratio coefficients e^b were additionally adjusted to the standard deviations. The resulting $(e^b)^{SD}$ represent the relative change of the likelihood for being selected by a one standard deviation increase within the considered predictor. For negatively coded predictors, the adjusted odds ratios were inverted and displayed as $(e^b)^{-SD}$.

Discussion

This study is among the first prospective investigations of talent predictors in female soccer (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019). The findings indicate the predictive validity of a multidimensional assessment used with a comparably large sample of U15 players. Specifically, the findings confirm that subjective coach ratings and objective motor tests have predictive power for players' future success over a two-year period (i.e., to U17) as well as into adulthood (i.e., professional level). Nevertheless, differences in the predictive relevance across predictors were identified, and the multivariate evaluation showed limited incremental validity of the different performance factors. These findings should be discussed in light of the characteristics of the *subjective and objective assessment methods* (Höner et al., 2021), as well as potential moderating effects of the different criterion variables in terms of the *selection levels* and *prognostic periods*.

The three criterion variables showed varying success rates of selected players. The U17 Women's Bundesliga serves as a comparably less selective criterion while the U17 Youth National Team and the Women's Bundesliga represent the highest levels of achievement. Here, evaluating players' participation in the U17 Women's Bundesliga is a novel criterion for TID research and the selection rate of 43% in this study is notably high in comparison to previous prospective talent research (Datson et al., 2020; Dugdale et al., 2021). This higher selection rate might be explained by the fact that to be selected for a DFB BC all players in the sample were assumed to have sufficient talent to participate in training sessions with the top 4% of boys in the U15 age group (Kelly et al., 2024) and, therefore, possess comparably high-performance capability. Selection into the U17 Youth National

Team and the Women's Bundesliga represent the highest levels of achievement, reflecting much lower selection rates. It is noteworthy that Höner et al. (2019) previously reported a higher selection rate of 14.2% of U12 female players in the same TID program into the U17 Youth National Team. However, this might relate to the different birth cohorts, age groups (i.e., U12 instead of U15) and the resulting different prognostic period (five years instead of two). The selection rate for future Women's Bundesliga players in this study (6.1%) aligns closely with findings from a longitudinal study on U12 to U15 female players by Leyhr et al. (2020; 6.2%).

The *relevance of individual predictors* based on univariate group-based comparisons (objective 1) showed some discrepancies that warrant discussion considering the different assessment methods used. The subjectively assessed predictors consistently showed small to moderate effect sizes across variables for predicting future participation in the Women's Bundesliga, with only two notable exceptions: kicking skills ($d = 0.79$) and tactical skills ($d = 0.95$). Corresponding to the findings in male youth soccer (Höner et al., 2021), the results confirm that the subjectively rated performance factors reveal predictive validity also in female youth soccer. Furthermore, the relevance of subjectively rated endurance capacity corresponds to Datson et al. (2020), who identified the objectively assessed high-intensity endurance capacity as a predictor for the selection into competitive U17-U20 squads in England. It should be noted that the present study used a subjective single-item rating to assess this predictor, whereas Datson et al. (2020) employed objective tests. While objective endurance data provides more detailed insights, the subjective approach within the DFB TID program seems to offer a valuable complement for the identification and development of talent due to the efficiency and pragmatism of the assessment.

The predictive power of objectively assessed predictors demonstrated greater differences, ranging from negligible to large effect sizes. The sprint performance showed consistent relevance across all criterion variables with a trend toward greater effect sizes at higher selection levels. This consistent relevance aligns with previous findings highlighting linear sprinting performance as a critical predictor for future success (for reviews Murre et al., 2018b; Williams et al., 2020). Agility (CODS), as another purely speed-based test, showed non-significant and negligible effect sizes across all future performance levels which appears to contradict findings by Höner et al. (2019) who reported moderate effects when comparing female youth national team players and non-selected players ($d = 0.67$). However, this apparent inconsistency may be explained by methodological differences between the two studies and, in particular, their respective study samples. That is, while Höner et al. (2019) investigated U12 players, the ongoing deselection processes for the U15 participants in the current sample may have led to a more homogeneous performance level. The dribbling test showed similar relevance across selection levels with slightly lower effect sizes compared to Höner et al. (2019) who identified dribbling as the most predictive test. The predictive power of the dribbling test is likely due to the fact that the test captures both speed abilities and technical skills (Höner et al., 2017), each of which has shown prognostic relevance when considered independently (Williams et al., 2020). Players' ball control performance showed considerable predictive power for the highly selective groups widely aligning with previous studies ($d = 0.55$; Höner et al., 2019; $d = 0.50$; Leyhr et al., 2020). Regarding juggling, the present study is the first that evaluated this technical skill test with female players, and support its predictive validity for all selection levels, but especially for the youth national team and the Women's Bundesliga.

Overall, the consistent predictive power of the test battery coupled with the feasibility of its utilization highlights its value in identifying and developing female soccer talent.

The *multivariate predictive validity* of the assessments was also confirmed (objective 2), with the best-fitting models explaining considerable amounts of variance. Consequently, the study adds on previous research with male players that combining subjective and objective assessments can increase the predictive power (Höner et al., 2021; Sieghartsleitner et al., 2019a). Nevertheless, the findings also highlight certain limitations of the assessments with only a limited number of predictors reaching significance in these models. Despite notable effect sizes, these results indicate restricted incremental validity and noticeable differences in the relevance of individual performance factors. Specifically, sprint performance significantly contributed to prediction across all selection levels ($1.43 \leq (e^b)^{SD} \leq 2.03$). To predict the selection for the U17 youth national team, ball control performance further contributed to model 2 ($(e^b)^{SD} = 2.74$), but adding subjective predictors did not significantly improve the model (only) for this selection level. Only regarding players' participation in the Women's Bundesliga, subjectively rated tactical skills significantly contributed to the prediction with the highest effect size across all predictors ($(e^b)^{SD} = 4.21$). Although this emphasizes generally high predictive power of coach ratings, this similarly suggests limited additional value from other variables. Although this issue was already noted in previous research with male players (Höner et al., 2021), it appears more pronounced in this female sample.

Subjective ratings can, in principle, offer valuable advantages, such as incorporating long-term observations and in-game behavior (Lath et al., 2021; Roberts et al., 2019a). However, three specific factors may have affected the accuracy of the judgments in the present study. First, all players were part of an already high-performing, pre-selected

group. This may have amplified the “restriction of range of talent” issue (Bergkamp et al., 2019), making it harder to differentiate between players in this homogenous group. This echoes previous research showing subjective ratings as less sensitive compared to objective assessments, especially when aiming to discriminate between players at rather comparable performance levels (Dugdale et al., 2020). Second, the ratings can be further affected by reference group effects that can occur when people’s characteristics are evaluated within salient reference groups (Rothenbusch et al., 2016; Schild et al., 2018). Girls in the present study were observed and rated within a high-performing male-dominated training group, which is not uncommon in female soccer TID (Andrew et al., 2024a; McEwan et al., 2024). Yet, this seems particularly challenging for the coaches as players need to be rated with reference to individuals of same age and sex. As only few girls compete at each BC, lacking reference to other talented girls can challenge coaches in judging players accurately. Third, it is important to highlight that coaches at BCs who conducted the subjective ratings have commonly more experience in working with male youth players. Therefore, potential gender-specific differences (e.g., different talent pathways, talent pool size, maturational processes) may have led to less accurate ratings. Consequently, the findings underscore the necessity to further educate coaches, especially their ability to make more selective observations for more distinct ratings of individual performance factors. Similarly, increasing awareness of (gender-specific) biases and strategies to mitigate them could improve the predictive validity of subjective assessments. To complement such engagement within coach education initiatives, a critical practical implication may be to encourage BC coaches to actively become involved with female-specific talent development measures (e.g., regional association tournaments),

as this can both foster a deeper understanding of the players' actual reference group and promote more nuanced and engaged interaction with the female talent pathway.

Limitations

While providing valuable insight into the predictive validity of a multidimensional assessment in female soccer, this study is not without limitations. Given the highly selective sample of U17 youth national team and Women's Bundesliga players, the sensitivity of statistical analyses addressing these criterion variables only allowed for detecting moderate effect sizes. Additionally, it should be noted that the findings of prospective studies are always tied to the structures of the respective talent development system which influence potential talent pathways and, consequently, the selection of criterion variables. While female talent pathways tend to be more diverse than those of boys (Andrew et al., 2024a), the DFB talent development program—particularly the mixed-gender promotion of highly talented girls alongside boys at BCs—may represent a unique feature that limits the generalizability of the findings to other contexts. Furthermore, controlling for different talent pathways in Germany next to the U17 Bundesliga (e.g., early participation in U20 female teams of professional clubs) was not possible. However, given the small number of players who did not participate in the U17 Bundesliga but made it to the youth national team ($n = 2$; 12%) or the Women's Bundesliga in adulthood ($n = 2$; 13%), this likely had a minimal impact on the findings. In addition, the Women's U17 Bundesliga organized in regional conferences has been further reformed since the season 2024/25 in terms of a championship for female teams in combination to participation in regional male soccer leagues. In addition, it was not possible to control for playing position in U15 as the DFB TID program widely follows a position-independent promotion (Kelly et al., 2024). Lastly,

a potential influence of players' biological maturation on the test performance as indicated by previous research (Datson et al., 2020) was not considered. That said, future talent research with female players, should investigate whether a) the biological maturity status already influenced players selection into the program (i.e., the amount of bias in the study sample), b) if it has an impact on players' success in the future, and c) potentially moderates the predictive validity of talent assessments.

Conclusion

This study is within the first to demonstrate the predictive validity of subjective coach ratings and objective motor tests, offering a multidimensional approach to TID in U15 female soccer. The findings highlight the contribution of combining these assessments in practice and emphasize the relevance to considering different talent predictors. A trend toward more predictive power for higher selection levels was observed, suggesting a moderating effect of selection levels and prognostic periods over two years (i.e., U17) and into adulthood. Additionally, the study uncovered specific insights relevant to TID research in female players. For instance, while coach ratings were generally predictive, conducting distinct evaluations for specific predictors proved challenging. Therefore, to further enhance TID for female players, it is crucial to educate practitioners on these nuances. More broadly, future TID research should focus on the developmental contexts in which female players are promoted. As shown in this and further studies (Andrew et al., 2024a; McEwan et al., 2024), many future professional players trained and competed in mixed-gender settings. Hence, it is vital to investigate whether girls who trained in mixed-gender environments differed in their likelihood of reaching the professional level compared to those who trained in female-specific environments.

Declaration of competing interest

The authors report there are no competing interests to declare.

Data Availability Statement

All datasets used in this study will be provided upon reasonable request.

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Supplementary Materials

Supplementary materials for this article are provided in *Appendix 5*.

3.3.2 “Don’t Forget the Number 1 in Soccer Talent Research!” – Predictive Validity of Objectively Tested Motor Attributes and Subjectively Rated Position-Specific Skills in Elite Youth Goalkeepers (Study 5)

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Abstract

In the ever-growing body of evidence on relevant talent predictors in soccer, goalkeepers (GKs) remain vastly underrepresented. Therefore, this large-scale prospective study was designed to investigate the predictive validity of objectively tested motor attributes and subjectively rated position-specific skills on GKs' selection into a youth academy (YA) three seasons after data collection. GKs across four age groups (U12-U15; $N = 3,431$) who are part of German Football Association's talent development program completed five motor tests assessing general speed abilities and position-independent technical skills. GK-specific technical and tactical skills, and GKs' overall performance level, were subjectively assessed via coach ratings. Univariate analyses performed separately for each age group confirmed the predictive validity of the motor tests ($Mdn(d) = 0.35$), evaluations of GK-specific skills ($Mdn(d) = 0.68$), and ratings of GKs' overall performance level ($Mdn(\Phi) = 0.21$). Multivariate analyses demonstrated that considering all predictors in combination revealed explanatory power for a YA selection ($.13 \leq \text{Nagelkerke's } R^2 \leq .22$), with at least one significant objective and subjective predictor. Yet, except for participants in U14, only one GK-specific predictor reached significance indicating limiting additional explanatory power from other subjectively rated variables. Overall, the findings indicate benefits from the combined consideration of position-independent and GK-specific attributes as predictors of goalkeeping talent.

Keywords: football, talent development, talent identification, multidimensional assessment, motor test, coach rating

Introduction

Understanding talent in sports is a complex process that requires consideration of various performance characteristics of young athletes (Buekers et al., 2015; Höner et al., 2023). There is a growing body of talent identification and development (TID) research in soccer which has helped to establish a model of potential physical, sociological, psychological, and skill-related talent predictors. However, the current empirical evidence about talent predictors is almost exclusively based on research with outfield players (Murr et al., 2018a; Verbeek et al., 2023, Williams et al., 2020). Even a consensus study on position-specific talent predictors in soccer deliberately excluded goalkeepers (GKs), which was justified by the unique nature of the position and its distinct talent pathway (Roberts et al., 2019b). Thus, this specific position group is vastly underrepresented in TID research (Vahia & Kelly, 2024), despite common agreement on GKs immense relevance to a soccer team's success—epitomized by the number 1 on the jersey. To address this research gap, the current study examined talent predictors in GKs.

The limited available research on soccer GKs has largely focused on specific demands related to their playing position (for reviews see Otte et al., 2023; West, 2018). Previous studies have highlighted the relevance of multidimensional performance factors to master GKs' three core game tasks: goal defense, space defense, and attacking game. Specifically, there are several GK-specific technical (e.g., catching and diving) and tactical skills (e.g., optimal positioning) as well as physical (e.g., speed and explosive actions) and mental attributes (e.g., bravery and confidence) that GKs need to develop to perform optimally (Otte et al., 2023; West, 2018). Further studies have investigated expertise-related differences which have primarily focused on anthropometric, physiological, and physical characteristics as well as comparisons between GKs and outfielders (for a

review see White et al., 2018). One of the main findings in that research is that late-adolescent and adult GKs were, on average, taller and heavier than outfielders who, in turn, performed better in multiple performance-related assessments (e.g., endurance, sprint). Although these findings provide some helpful information for the optimization of GK-specific practices (e.g., Bastias et al., 2024; Otte et al., 2020), they fail to specify the predictors that are relevant to identifying goalkeeping talent at different developmental stages indicating the need for prospective study designs.

However, research on talent predictors in soccer generally faces methodological challenges (Barracough et al., 2022; Bergkamp et al., 2019), some of which appear even more difficult to address in GK-specific studies. There is common agreement on the need for *multidimensional approaches*, considering performance factors from different disciplines to enhance the explanatory power for players' future success (Verbeek et al., 2023; Williams et al., 2020). A key challenge, beyond identifying the most relevant predictors, lies in selecting appropriate methods for their assessment. A variety of isolated motor tests to evaluate soccer-specific skills (e.g., dribbling, passing, ball control) have demonstrated predictive validity (Williams et al., 2020 for a review). While these tests are reliable and practically feasible for assessing individual predictors, they often fail to capture the complexity of the game. To address this limitation, it is desirable to integrate less commonly available, but more representative measures that may provide higher predictive power (for a discussion see Bergkamp et al., 2019; den Hartigh et al., 2018). In previous research with outfielders, considering a variety of talent predictor within multidimensional approaches were realized by purposefully combining isolated motor tests and coach ratings that can incorporate an evaluation of players' in-game behavior (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a). In addition to considering

a variety of performance factors in combination, *holistic views* on a person's talent are recommended to grasp the complexity in practical decision making (Charbonnet & Conzelmann, 2023). This comprised predictions about an individual's future success based on a comprehensive set of performance factors (Sieghartsleitner et al., 2019a) and/or the *instinct of expert practitioners* (Roberts et al., 2019a).

To evaluate the predictive power of either individual performance factors or holistic accounts of talent empirically, adequate *criterion variables* to operationalize future success are needed (Bergkamp et al., 2019). In the available talent research, criterion variables are often represented by categorical or ordinal variables, to distinguish between players of different performance levels (Williams et al., 2020). Notably, outfield players can increase their chances of selection by transitioning into the positional role that best fits their strengths at different developmental stages. In contrast, GKs typically do not change their playing position throughout their careers. This distinction is further amplified by the significantly larger pool of outfield players compared to GKs, which not only increases variability in positional pathways but also reinforces the importance of specialized TID strategies for GKs. Lastly, pre-selected samples cause a restriction in the range of talent which stresses the need for study designs with high sensitivity to allow for the detection of relationships between talent predictors and criterion variables (Ackerman, 2014). Thus, given a comparably small population of GKs in soccer squads, designing sufficiently *powered studies* potentially represents another demanding challenge for GK-specific talent research (Vahia & Kelly, 2024).

Difficulties to navigate these challenges are indicated by the extremely small number of studies in which talent predictors have been evaluated among youth soccer GKs. For ex-

ample, Gil et al. (2014) investigated the relevance of anthropometrics, biological maturity, and physiological test performances with a small sample of GKs ($N = 14$) aged nine to ten years. The four selected GKs for the youth teams of a professional youth club showed descriptively greater anthropometrics (e.g., body height), had a taller predicted adult height, were closer to their maturity offset, and performed better in a physiological test battery (e.g., countermovement jump) compared to their non-selected counterparts. In addition, there is a dearth of studies on the relevance of GK-specific technical and tactical skills as talent predictors (Vahia & Kelly, 2024). This gap may be due to the limited number of instruments that have been scientifically evaluated to objectively measure GK-specific skills. The few GK-specific instruments available aimed to measure complex defensive actions by combining reaction tasks with GK-specific diving techniques (Knoop et al., 2013; Rebelo-Gonçalves et al., 2016). However, moderate to strong correlations were found between performance in these GK-specific assessments and both anthropometric and physiological characteristics (e.g., explosive strength), highlighting the influence of these attributes on test outcomes. Furthermore, the complex test set-ups limit the assessments' practical feasibility for being systematically applied with a broad pool of youth GKs.

In summary, there is a lack of empirical knowledge on GK-specific talent predictors due to methodological challenges in designing scientifically sound studies (e.g., small samples) and limited GK-specific skill assessments available. Based on previous findings with outfield players (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a), a feasible approach to evaluate multidimensional talent predictors in GKs is to build upon the benefits of motor tests and coach ratings. Scientifically evaluated *objective motor tests* allow for the assessment of general physical attributes (e.g., speed

abilities; West, 2018; White et al., 2018) and position-independent technical skills a GK requires for the attacking game (e.g., passing and ball control; Otte et al., 2023). Given the lack of adequate objective assessments for highly specialized GK-specific technical and tactical skills, these performance factors may be best evaluated via systematically conducted *subjective coach ratings*. Another benefit of the ‘coach’s eye’ is to consider a multitude of potential predictors within *holistic ratings* of GKs’ talent that also allow experts to integrate their instincts and practical experience (Lath et al., 2021; Roberts et al., 2019a).

The present study

The present study was conducted within the German Football Association’s (Deutscher Fußball-Bund [DFB]) TID program. Across 350 regional Base Camps (BCs; “competence centers”), outfield players and GKs in the age groups U12 to participate in a weekly practice session that is provided by teams of DFB BC coaches in addition to players’ practice sessions at their home clubs. These sessions exclusively focus on promoting players’ long-term development (in detail DFB, 2022a; Kelly et al., 2024). As part of the TID program, both GKs and outfielders participate in nationwide objective and subjective assessments to evaluate talent predictors. The objective assessment, which measures speed abilities and position-independent technical skills through five motor tests (Höner et al., 2015), has been used since the TID program’s inception. This established, standardized, and practically feasible test battery is applied to both outfield players and GKs. However, its test demands appear to align more closely with the soccer-specific profiles of outfield players than those of GKs. To address this limitation, and in close collaboration with the TID program’s scientific support, additional systematic coach ratings were implemented by the DFB in the season 2015/2016. These ratings place greater emphasis

on outfielder-specific and GK-specific talent predictors. Specifically, they assess GK-specific technical and tactical skills and include a holistic coach rating of GKs' overall performance level. While the objective motor assessment and subjective coach ratings have demonstrated predictive validity for outfielders (e.g., Höner et al., 2017; Leyhr et al., 2018; Höner et al., 2021), both of them have not been evaluated with GKs.

Therefore, this prospective cohort study aimed to investigate the predictive validity of (a) objectively tested general speed abilities and position-independent technical skills, and (b) subjectively rated position-specific skills and overall performance level for GKs' future success. A univariate evaluation was used to examine the predictive validity of each assessed position-independent and -specific attribute (*objective I*), whereas a multivariate perspective allowed for an investigation of each individual performance factor's predictive validity when considering all predictors in combination (*objective II*).

Method

Sample

The sample consisted of $N = 3,431$ male GKs ($M_{\text{age}} 12.69 \pm 1.04$ years) in the age groups U12 ($n = 1,594$), U13 ($n = 929$), U14 ($n = 576$), and U15 ($n = 332$). All GKs were members of one of the 350 BCs of the DFB's TID program. They were assessed during four seasons between 2015/2016 and 2018/2019 (i.e., birth cohorts 2001-04, 2002-05, 2003-06, and 2004-07).

Before entering the TID program, written informed consent for the recording and scientific use of each GK's data was provided by a legal guardian/next of kin. All GKs participated voluntarily in the assessments. DFB staff members conducted both the motor test and

performed the subjective evaluations. The DFB provided the processed data to the authors for this study. The use of the data in this manner was approved by the authors' university's ethics department.

Measures

Objectively assessed position-independent motor attributes

The utilized test battery consists of five individual motor tests (DFB, 2022b; Höner et al., 2015): *sprint* time (i.e., time to complete a 20m linear sprint), *agility* related to change of direction speed (CODS; i.e., time to complete a slalom course without a ball), *dribbling* (time to complete a slalom course with a ball), *ball control* (i.e., time needed to play six passes alternately to two opposing locations with at least two ball contacts), and *ball juggling* (i.e., ability to juggle the ball alternately with the left and right foot through as many subsections of a figure eight-course without ground contact). Juggling performance is represented by the points accumulated for successfully completing each subsection of the course while juggling the ball. The execution times of the sprint, agility, and dribbling tests were measured using light gates (Brower Timing Systems, Draper, USA) and recorded to the nearest hundredth of a second. The execution time of the ball control test was measured with hand-stopped chronographs, also recorded to the nearest hundredth of a second.

Each test was performed twice, and the best result was included in subsequent analyses. Sufficient recovery before performing the motor tests is ensured by a break of at least one minute between test trials. All procedures and a detailed explanation of all tests are described in the publicly available test manual (DFB, 2022b) and the psychometric properties for outfielders are reported by Höner et al. (2015). A confirmatory factor analysis confirmed the two-factorial structure found in outfielders for the current sample of GKs

($\chi^2(3) = 62.38$, $p < .001$, $RMSEA$ (90%-CI) = .08 (.06; .09), $CFI = .98$, $TLI = .93$, $SRMR = 0.02$).

Sprint and agility loaded on the first factor, representing speed abilities, while ball control and juggling loaded on the second factor representing technical skills. Dribbling showed substantial loading on both factors, indicating an association with both speed abilities and technical skills. The internal consistencies of GKs' two test trials were slightly lower compared to outfielders. Across the four age groups, excellent internal consistencies were found for speed-based tests sprint ($.87 \leq \alpha \leq .93$) and agility ($.83 \leq \alpha \leq .92$). Lower values were found for juggling ($.66 \leq \alpha \leq .77$), dribbling ($.37 \leq \alpha \leq .54$), and ball control ($.57 \leq \alpha \leq .58$).

Subjectively assessed position-specific performance factors

Coaches at the BCs, holding at least a UEFA B-License, subjectively evaluated the GKs' position-specific technical and tactical skills (in detail *Table 15*). These items were developed by GK experts of the DFB in close collaboration with members of the scientific support staff at Tübingen University (DFB, 2022b for the detailed manual). To facilitate a common understanding of the items, coaches were educated by DFB staff members, and the manual was distributed to the coaches before implementing the subjective evaluation (in detail Höner et al., 2021). Furthermore, these coaches also participate regularly in further coach education within the DFB TID program. While topics relating to TID in GKs are regularly included, they tend to receive relatively less emphasis compared to outfielder-specific topics. Although the employment of a formally qualified GK coach (i.e., holding a GK-coach license or certification) is intended at each BC, this cannot be guaranteed across all BCs in the nationwide TID program.

The coaches rate the GK-specific performance factors based on their observations during the weekly practice session at each BC. *GK-specific technical skills* were assessed via

four items that focus on both defensive aspects but also game-opening skills. Three items addressing *GK-specific tactical skills* only relate to defensive game situations. In addition, the subjective performance evaluation comprised a holistic rating of GKs' *overall performance level*. Coaches were asked to rate their overall impression, allowing them to consider other criteria of their own choice.

Each item was rated by the coaches on a four-point rating scale in relation to the participant's respective age group based on their observations within the weekly training sessions (i.e., U12-U15): "below-average BC level" (0); "average BC level" (1); "level of the extended squad for regional association (RA) team" (2); or "level of core team for the RA team" (3). Grounding on sufficient to good internal consistencies for GK-specific technical ($.83 \leq \alpha \leq .84$) and tactical skills ($.72 \leq \alpha \leq .78$), the average scores for all items across both skill domains were used for data analyses.

Table 15. *Subjectively assessed performance factors serving as potential predictors of goalkeepers' future success.*

Performance Factor (# items)	Items for subjective evaluation of goalkeepers' performance factors
GK-specific technical skills (4)	– Techniques from a standing position (e.g., get behind the ball when catching) – Diving (e.g., initiate movements quickly with the leg closest to the ball) – Defending crosses (e.g., powerful take off by swinging the arms up) – Offensive gameplay (e.g., roll out the ball/pass with the inside of the foot)
GK-specific tactical skills (2)	– Positioning in the goal (e.g., adjust the own position in the goal to ball location) – Defensive 1v1 situations (e.g., advance as close as possible towards the attacker)
Overall performance level (1)	– Holistic rating of current performance

Note. Detailed explanation of each performance factor and items are provided in the manual (DFB, 2022b). Both the outfielders and GKs were additionally evaluated regarding their psychosocial skills. These ratings were not considered in the present study because they represent further general (i.e., position-independent) characteristics.

Criterion of goalkeepers' future success

Operationalizing an individual's future success requires appropriate criterion variables that align with the talent development system (Bergkamp et al., 2019). In Germany, the transition from the *talent development stage* (i.e., U12 to U15) to the *elite promotion stage* (i.e., U16 to U19) and especially the selection into a YA during or after participating in the DFB's TID program marks an important transition (Kelly et al., 2024; Wachsmuth et al., 2024). As this criterion is also feasible for the use in a large-scale study, the selection for a YA three seasons after data collection was applied to operationalize GKs' future success. BC coaches, who conducted subjective evaluations within the DFB TID program, were formally not allowed to be employed at a YA in the corresponding age groups simultaneously. Furthermore, considering that YA selection typically involves judgments by various experts (e.g., head coaches, GK coaches, scouts), it can nearly be ruled out that the same person both rated the GKs subjectively at the BC and made the final decision on their YA selection.

In the present study, GKs were categorized as *selected* ($n = 249$; 7.3%) if they joined a German YA in the 2018/19, 2019/20, 2020/21, or 2021/22 season. This ensured a consistent prognostic period of three seasons for all GKs included in the present sample. Former BC GKs who were not selected for any German YA in the respective seasons were defined as *non-selected* ($n = 3,182$; 92.7 %).

Statistical Analyses

Statistical analyses were processed utilizing IBM SPSS (version 28) and Mplus (version 8.2.; Muthén & Muthén, 2017). As coaches' subjective evaluations were conducted with regard to the respective age group (i.e., U12, U13, U14, and U15), all statistical analyses

were conducted for each age group separately. The data was collected over the four seasons from 2015/2016 to 2018/2019 leading to different birth cohorts in the sample (2001-2004, 2002-2005, 2003-2006, and 2004-2007). To check whether this confounded the analysis of performance across selection levels, two-way ANOVAs for each performance factor were conducted to test potential interaction effects between future success and season of data collection (*future success x season*). No significant interactions were found for any of the variables ($F(3; 3,423) \leq 1.98, p \geq .115$) and, therefore, data from all seasons were accumulated for each age group (U12-U15) to provide robust results regarding the predictors' prognostic relevance. If a GK participated in more than one season, only the data from the first assessment were included for analysis. Another potential confounder of the analyses on the predictive validity is the relative age effect (RAE) commonly present in soccer TID programs (e.g., Leyhr et al., 2021). As two-way ANOVAs for each performance factor showed no significant interaction effects between GKs' future success and birth quarter (*future success x birth quarter*; $F(3; 3,423) \leq 1.34, p \geq .261$), relative age was not considered further as a potential covariate. Since some variables did not follow a normal distribution, additional non-parametric analyses were conducted, consistently confirming the non-significant interaction effects.

In prospective talent studies, test power is a critical issue (Bergkamp et al., 2019) because the investigated variables' variance within each age group of the preselected samples and, consequently, the expected statistical effect sizes may be limited (restriction of range of talent; Ackerman, 2014). Accordingly, post-hoc sensitivity analyses were performed for each of the four age groups to determine the size of a possibly detected population effect for differences between two groups (Cohen's d) utilizing G*Power (version 3.1.9.7; Faul et al., 2007) and predetermined parameters ($\alpha = 0.05, 1 - \beta = 0.80$, two-

tailed). The analyses were sensitive enough to detect small effect sizes in the U12 ($d \geq 0.27$), U13 ($d \geq 0.34$), and U14 ($d \geq 0.45$) as well as moderate effect sizes in the U15 ($d \geq 0.66$). All effect sizes displayed in this study were set positive if the selected GKs achieved better test results.

In the univariate evaluation of the predictive validity (*objective 1*), differences between future selected and non-selected GKs across all assessed individual predictors were examined via independent-samples t-tests. Cohen's d – computed as the mean difference divided by the pooled standard deviation – served as the effect size that can be classified as small ($0.2 \leq d < 0.5$), medium ($0.5 \leq d < 0.8$), and large ($d \geq 0.8$; Cohen, 1992). To investigate the univariate predictive validity of the holistic coach rating of GKs' current performance level, non-parametric Mann-Whitney U-tests were used, and Phi (Φ) served as the effect size classified as small ($0.1 \leq \Phi \leq 0.3$), medium ($0.3 \leq \Phi \leq 0.5$), and large ($\Phi \geq 0.5$; Cohen, 1992).

To check the data requirements for the predictors' multivariate evaluation (*objective 2*), bivariate correlations among predictors ranging from $r = -.02$ (sprint and juggling in U13) to $.80$ (GK-specific technical and tactical skills in U15) were observed (for details see Supplement Ia-d). Although some considerable correlations were found, *Variance Inflation Factors (VIF)* were all ≤ 3.2 , indicating no serious multicollinearity (Akinwande, et al., 2015). Logistic regression models were applied using the likelihood ratio chi-squared test and Nagelkerke's R^2 as overall model fits. Regression coefficients and the odds ratios e^b (including 95% CI) served as indicators for each predictor. All subjectively and objectively assessed performance factors served as the predictors within logistic regression models (enter method) to predict the criterion variable (selected vs. non-selected for YA).

To evaluate the predictive validity of the assessments and the contribution of each predictor, optimal cut-off values were determined for each performance factor. This was based on receiver operating characteristic (ROC) analyses and the corresponding area under the curve (AUC). Initially, optimal cut-off values for each variable and age group were estimated using two established approaches, namely *Youden's J* and the *closest to (0, 1)* criterion (in detail Rota & Antolini, 2014). A preference for one approach was determined based on the practical meaning of the results. While both approaches produced identical results for most variables in this study, the *closest to (0, 1)* criterion tended to assign a slightly higher weighting to sensitivity in certain cases where small discrepancies occurred. This justified the use of the *(0, 1) criterion* in the present study, as the higher weighting to sensitivity aligns with the structure of the DFB TID program, which aims to promote a relatively broad pool of players and GKs within the U12 to U15 age groups. Based on these cut-off values, each GK was categorized as “talented” (1) or “not talented” (0) because of a better or worse test performance than the cut-off in each objectively tested or subjectively rated predictor. Besides adding information about optimal cut-offs across performance factors, these binary-coded variables enabled the comparison of odds ratios across predictors within logistic regression models.

Table 16 presents the results of the ROC analyses and the optimal cut-off values for each variable and age group. Additionally, the number of GKs' who were categorized as “talented” and “not talented” as well as selected and non-selected for a YA is displayed. Considering the optimal cut-off values across motor tests, the need for better performance in higher age groups illustrates performance development in these predictors. On the other side, as all subjective coach ratings were conducted with reference to the corresponding age groups, no such systematic developments can be observed with optimal

cut-off values ranging from 1.75 to 2.25 for GK-specific technical and tactical skills. The optimal cut-off in the holistic rating of GKs' current performance was the value 1.5 in all age groups thus separating GKs rated as performing 'below average or average BC level' and the 'extended or core RA teams'.

Results

Univariate evaluation (objective 1)

Table 17 presents the results of the univariate evaluation on the predictive validity of all objectively tested motor attributes and subjectively rated GK-specific skills. Overall, the coach ratings of GK-specific technical and tactical skills ($Mdn(d) = 0.66$; $0.24 \leq d \leq 1.07$) demonstrated higher predictive power (i.e., higher effect sizes) than the motor tests assessing speed abilities and position-independent technical skills ($Mdn(d) = 0.34$; $0.26 \leq d \leq 0.87$). Regarding the *objectively tested motor attributes*, the 20m linear sprint revealed the highest predictive power across all age groups ($Mdn(d) = 0.54$, $0.34 \leq d \leq 0.87$), with only one non-significant difference in U15 ($p = .150$). Dribbling showed a slightly lower predictive power ($Mdn(d) = 0.41$, $0.26 \leq d \leq 0.56$) and discriminated significantly between selected and non-selected GKs (except for U14; $p = .104$). The three remaining motor tests juggling ($Mdn(d) = 0.34$), agility ($Mdn(d) = 0.32$), and ball control ($Mdn(d) = 0.31$) were of comparable relevance with small median effect sizes. In the agility test, a significant difference between selected and non-selected GKs was present in all age groups except for U14. The ball control and juggling tests only discriminated significantly between selected and non-selected GKs in the two youngest age groups U12 and U13. The subjective coach ratings of *GK-specific technical and tactical skills* showed across all age groups significantly higher skill levels in selected than non-selected GKs with mod-

erate to large effect sizes. The highest median effect size occurred for GK-specific technical skills ($Mdn(d) = 0.74$; $0.56 \leq d \leq 1.07$). Except for U12, the effect sizes for GK-specific tactical skills were slightly lower ($Mdn(d) = 0.65$; $0.53 \leq d \leq 0.86$). For the *holistic ratings for GKs' current performance*, non-parametric U-tests revealed significantly better ratings in selected than non-selected GKs across all age groups (*Table 18*) with small effect sizes ($Mdn(\Phi) = 0.21$; $0.14 \leq \Phi \leq 0.27$).

Multivariate evaluation (objective 2)

The overall fits of the logistic regression models were significantly better compared to the null model (*Table 19*). That is, the binary-coded predictor variables significantly predicted the binary outcome variable (selected vs. non-selected) with the explained variance ranging from 13% in U12 to 22% in U14.

Regarding the *relevance of individual predictors*, at least one objectively tested position-independent and one subjectively rated position-specific predictor significantly contributed to the model across age groups. Considering the motor tests, the 20m sprint reached significance in U12, U13, and U14 with $e^b = 1.74$ (U12) to $e^b = 4.39$ (U13) relatively higher chances for YA selection if a GK sprinted faster than the cut-off. Dribbling as a position-independent technical skill only significantly contributed to the model in U12 ($e^b = 1.67$). In U15, ball control ($e^b = 3.84$) was the only significant position-independent predictor. Regarding subjectively assessed position-specific predictors, the holistic rating of GKs' current performance reached significance in U12 ($e^b = 3.29$), U13 ($e^b = 5.17$), and U14 ($e^b = 3.42$). In U14, GK-specific tactical skills ($e^b = 2.88$) also significantly contributed to the model. In U15, the only significant predictor was GK-specific technical skills ($e^b = 3.81$).

Table 16. Results of the Receiver Operating Characteristics (ROC) analyses to estimate optimal cut-off points in each performance factor and age group as well as the number of GKs categorized as “talented” (1) and “not talented” (0) as well as selected (s) and non-selected (ns) for a YA.

Performance factor	Categorization based on test results	U12				U13				U14				U15			
		cut-off	n		AUC [95% CI]	cut-off	n		AUC [95% CI]	cut-off	n		AUC [95% CI]	cut-off	n		AUC [95% CI]
			s	ns			s	ns			s	ns			s	ns	
Sprint (20m) [#]	1	3.72	69	577	.64***	3.55	50	246	.75***	3.41	26	173	.70***	3.36	14	164	.60
	0		46	902	[.58; .69]		24	609	[.70; .81]		15	362	[.61; .77]		5	149	[.48; .72]
Agility (CODS) [#]	1	8.58	64	561	.60***	8.40	38	316	.59*	8.37	27	233	.59	8.12	14	174	.66*
	0		51	918	[.55; .66]		36	539	[.52; .65]		14	302	[.50; .67]		5	139	[.53; .79]
Dribbling [#]	1	12.02	80	707	.62***	11.14	33	253	.60**	11.14	20	221	.56	10.96	13	127	.65*
	0		35	772	[.57; .67]		41	602	[.54; .67]		21	314	[.47; .65]		6	186	[.51; .78]
Ball control [#]	1	10.44	64	565	.60***	9.82	37	314	.57	9.58	24	218	.58	9.32	15	144	.61
	0		51	914	[.55; .66]		37	541	[.50; .64]		17	317	[.49; .66]		4	169	[.49; .73]
Juggling	1	0.70	41	390	.57**	1.50	42	365	.61**	3.50	20	159	.60*	4.50	9	103	.58
	0		74	1089	[.51; .63]		32	490	[.55; .68]		21	376	[.50; .69]		10	210	[.44; .71]
GK-specific Technical Skills	1	1.38	84	712	.57***	1.38	53	354	.71***	1.88	27	165	.77***	2.13	9	64	.68**
	0		31	767	[.51; .63]		21	501	[.65; .77]		14	370	[.70; .84]		10	249	[.55; .81]
GK-specific Tactical skills	1	1.75	80	597	.68***	1.75	51	422	.67***	2.25	23	95	.73***	1.75	13	182	.62
	0		35	882	[.63; .73]		23	433	[.60; .74]		18	440	[.65; .81]		6	131	[.48; .76]
Current PL (holistic)	1	1.50	90	637	.69***	1.50	63	414	.73***	1.50	36	265	.77***	1.50	15	186	.66*
	0		25	842	[.65; .74]		11	441	[.67; .78]		5	270	[.70; .85]		4	127	[.52; .80]

Note. [#] In these variables, a lower test value (i.e., time in seconds) indicates better performance; A GK was categorized as talented if his performance was better than the optimal cut-off value (coded as 1) and categorized as not talented (coded 0) when his performance was below the cut-off value. Therefore, the crosstab presents the true-positives (i.e., categorized as talented and selected; upper left corner), false-negatives (i.e., categorized as not talented and selected; lower left corner), false-positives (categorized as talented and non-selected; upper right corner), and true-negatives (categorized as not talented and non-selected; lower right corner). AUC = area under the curve; Overall PL (holistic) = holistic rating of current performance; s = selected; ns = non-selected * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 17. *Test results for objectively and subjectively (printed in italics) assessed performance factors of selected and non-selected GKs separated by age groups (U12-U15, N = 3431).*

Performance factor	Future performance level (after 3 seasons)	M ± SD				t (df) Cohen's d* (95% CI)			
		U12	U13	U14	U15	U12	U13	U14	U15
Sprint (20m) [#]	Selected (N)	115 (7.2%)	74 (8.0%)	41 (7.1%)	19 (5.7%)				
	Non-selected (N)	1479 (92.8%)	855 (92.0%)	535 (92.9%)	313 (94.3%)				
	Selected	3.68 ± 0.19	3.48 ± 0.16	3.38 ± 0.16	3.29 ± 0.15	4.67 (1592) 0.45*** (0.26; 0.64)	7.16 (927) 0.87*** (0.63; 1.11)	3.89 (574) 0.63*** (0.31; 0.95)	1.44 (330) 0.34 (-0.12; 0.81)
	Non-selected	3.76 ± 0.19	3.65 ± 0.20	3.50 ± 0.20	3.35 ± 0.18				
Agility (CODS) [#]	Selected	8.58 ± 0.46	8.43 ± 0.37	8.31 ± 0.37	8.07 ± 0.41	3.52 (1592) 0.34*** (0.15; 0.53)	2.47 (927) 0.30* (0.06; 0.54)	1.85 (574) 0.30 (-0.20; 0.62)	2.48 (330) 0.59* (0.12; 1.05)
	Non-selected	8.73 ± 0.44	8.57 ± 0.44	8.44 ± 0.44	8.32 ± 0.43				
Dribbling [#]	Selected	11.65 ± 0.75	11.28 ± 0.78	11.15 ± 0.64	10.74 ± 0.75	5.17 (146,63) 0.40*** (0.21; 0.59)	3.50 (927) 0.42*** (0.19; 0.66)	1.63 (574) 0.26 (-0.05; 0.58)	2.35 (330) 0.56* (0.09; 1.02)
	Non-selected	12.03 ± 0.99	11.66 ± 0.91	11.36 ± 0.78	11.17 ± 0.76				
Ball control [#]	Selected	10.55 ± 1.38	10.06 ± 1.27	9.66 ± 1.05	9.22 ± 1.34	3.65 (1592) 0.35*** (0.16; 0.54)	2.13 (927) 0.26* (0.02; 0.50)	1.72 (574) 0.28 (-0.04; 0.60)	1.40 (330) 0.33 (-0.13; 0.80)
	Non-selected	11.08 ± 1.50	10.41 ± 1.38	10.03 ± 1.36	9.67 ± 1.34				
Juggling	Selected	1.83 ± 2.15	3.27 ± 3.80	4.54 ± 3.94	6.37 ± 6.81	2.54 (125,88) 0.29* (0.11; 0.49)	2.35(80,10) 0.37* (0.13; 0.60)	1.92 (574) 0.31 (-0.01; 0.63)	1.79 (330) 0.42 (-0.04; 0.89)
	Non-selected	1.30 ± 1.74	2.21 ± 2.82	3.38 ± 3.70	4.42 ± 4.47				

<i>GK-specific Technical skills</i>	Selected	1.73 ± 0.55	1.99 ± 0.57	2.21 ± 0.54	2.09 ± 0.61	5.81 (1592) 0.56*** (0.37; 0.75)	6.42 (927) 0.78*** (0.54; 1.02)	6.58 (574) 1.07*** (0.74; 1.39)	2.93 (330) 0.69** (0.23; 1.16)
	Non-selected	1.39 ± 0.62	1.52 ± 0.60	1.59 ± 0.59	1.67 ± 0.60				
<i>GK-specific Tactical skills</i>	Selected	1.98 ± 0.59	2.10 ± 0.64	2.24 ± 0.60	2.13 ± 0.70	7.11 (136.84) 0.63*** (0.44; 0.82)	5.43 (927) 0.66*** (0.42; 0.90)	5.29 (574) 0.86*** (0.54; 1.18)	2.25 (330) 0.53* (0.07; 1.0)
	Non-selected	1.57 ± 0.66	1.69 ± 0.62	1.71 ± 0.63	1.80 ± 0.62				

Note. [#]In these variables, a lower test value (i.e., time in seconds) indicates better performance. *A positive d value displays better test performance for the selected players regardless of a higher or lower test value indicates better performance. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 18. Univariate comparisons (non-parametric U-tests) of selected and non-selected GKs' holistic rating of their current performance level.

Rating	Future performance level (after 3 seasons)	Age Groups				Z Φ			
		U12 (n = 1594)	U13 (n = 929)	U14 (n = 576)	U15 (n = 332)	U12	U13	U14	U15
<i>Overall PL (holistic)</i>	Mean rank of selected GKs	514.85	272	142.21	117.39	7.513	7.057	6.396	2.507
	Mean rank non-selected GKs	819.48	481.70	299.71	169.48	.19***	.23***	.27***	.14*

Note. GKs' overall performance was rated on a four-point rating scale in relation to the participant's respective age group (i.e., U12-U15); A lower rank is associated with higher performance, while a higher rank represents lower performance; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 19. Logistic regression results for the prediction of GKs' future success (selected for a YA three seasons later) and relevance of general technical skills and speed abilities, as well as GK-specific skills (printed in *italics*).

Age	Omnibus test			Predictor	Logistic regression coefficients			
Group	χ^2 (df)	<i>p</i>	Nagelkerke <i>R</i> ²		<i>b</i>	<i>Wald</i>	<i>p</i>	<i>e</i> ^b (95% CI)
U12	82.71 (8)	< 0.001	0.13	Constant	-4.23	-	-	-
				<i>Current PL (holistic)</i>	1.19	11.86	< .001	3.29 (1.67; 6.46)
				Sprint (20m)	0.55	6.59	0.01	1.74 (1.14; 2.64)
				Dribbling	0.51	5.16	0.02	1.67 (1.07; 2.60)
				<i>GK-specific tactical skills</i>	0.49	2.99	0.08	1.63 (0.94; 2.83)
				Ball control	0.32	2.40	0.12	1.38 (0.92; 2.08)
				Agility (CODS)	0.20	0.87	0.35	1.22 (0.80; 1.87)
				<i>GK-specific technical skills</i>	-0.28	0.78	0.38	0.76 (0.41; 1.41)
				Juggling	0.05	0.06	0.81	1.05 (0.69; 1.60)
U13	82.78 (8)	< 0.001	0.20	Constant	-4.55	-	-	-
				Sprint (20m)	1.48	28.95	< .001	4.39 (2.56; 7.53)
				<i>Current PL (holistic)</i>	1.64	14.64	< .001	5.17 (2.22; 12.04)
				<i>GK-specific tactical skills</i>	-0.60	2.97	0.09	0.55 (0.28; 1.09)
				<i>GK-specific technical skills</i>	0.47	1.86	0.17	1.60 (0.81; 3.14)
				Juggling	0.35	1.79	0.18	1.42 (0.85; 2.39)
				Dribbling	0.29	1.08	0.30	1.34 (0.77; 2.32)
				Ball control	0.24	0.82	0.37	1.27 (0.75; 2.15)
				Agility (CODS)	-0.08	0.09	0.77	0.92 (0.53; 1.59)

U14	53.55 (8)	< 0.001	0.22	Constant	-4.98	-	-	-
				<i>GK-specific tactical skills</i>	1.06	6.95	0.01	2.88 (1.13; 6.32)
				Sprint (20m)	0.84	5.18	0.02	2.31 (1.12; 4.74)
				<i>Current PL (holistic)</i>	1.23	4.63	0.03	3.42 (1.12; 10.45)
				Agility (CODS)	0.70	3.07	0.08	2.00 (0.92; 4.36)
				Juggling	0.57	2.48	0.12	1.77 (0.87; 3.62)
				Ball control	0.50	1.95	0.16	1.65 (0.82; 3.35)
				Dribbling	-0.41	1.16	0.28	0.66 (0.31; 1.40)
				<i>GK-specific technical skills</i>	0.16	0.14	0.71	1.18 (0.50; 2.78)
U15	22.46 (8)	0.004	0.18	Constant	-5.14	-	-	-
				<i>GK-specific technical skills</i>	1.34	5.13	0.02	3.81 (1.20; 12.11)
				Ball control	1.34	4.97	0.03	3.83 (1.18; 12.50)
				Agility (CODS)	0.78	1.92	0.17	2.18 (0.72; 6.56)
				<i>GK-specific tactical skills</i>	-0.66	0.85	0.36	0.52 (0.13; 2.09)
				Dribbling	0.53	0.85	0.36	1.70 (0.55; 5.22)
				Sprint (20m)	0.51	0.74	0.39	1.66 (0.53; 5.07)
				<i>Current PL (holistic)</i>	0.55	0.85	0.36	0.52 (0.13; 2.09)
				Juggling	0.26	0.27	0.60	1.30 (0.48; 3.51)

Note. Current PL (holistic) = holistic rating of current performance; The predictors were ordered based on the Wald statistic.

Discussion

In the current study, a mid-term prognostic period lasting three seasons was considered to evaluate the predictive validity of objectively tested motor attributes and subjectively rated position-specific skills in pre-selected U12 to U15 soccer GKs. The findings indicate that both, objectively assessed motor attributes, and subjectively rated position-specific skills reveal predictive power for GKs' future success represented by a YA selection. Besides GKs' sprint performance, ratings of GK-specific skills showed the highest predictive validity in the univariate evaluation. Therefore, consistent with empirical studies involving soccer outfielders (e.g., Dugdale et al., 2020; Höner et al., 2021), the present results support calls for the combined use of objective and subjective assessments providing a multidimensional perspective on youth GKs' talent. The multivariate evaluation allowed for a comparison of the predictors' relevance after dichotomization based on optimal cut-off values. Across age groups, these models revealed predictive power for GKs' future success with at least one significant objectively and subjectively assessed predictor. Yet, the holistic rating of GKs' current performance level was the only significant subjectively rated predictor in U12 and U13, and GK-specific technical or tactical skills reached significance in the older age groups. Consequently, although the position-specific coach ratings should offer different views on the goalkeeping talent, their combined consideration reveals limited additional explanatory power.

In general, the reported effect sizes support the conclusions of systematic reviews suggesting that talent assessments lack sufficient sensitivity to justify individual selection decisions (Murr et al., 2018a; Williams et al., 2020). This applies to both objective motor tests and subjective coach ratings. The considerable number of false positives and false

negatives (*Table 16*) indicates that the ‘optimal’ cut-off for each variable merely represents the best possible balance between sensitivity and specificity. This should not be misinterpreted as providing an optimal assignment for practical decision-making and highlights the crucial importance of combining multiple sources of information when (de-)selecting individual GKs. Furthermore, the practical purpose of assessments should be viewed as twofold: not only to support talent identification, but also to provide a scientific foundation for talent development by integrating individual test results into applied practice (in detail DFB, 2022b).

There are limited opportunities to discuss these findings in light of previous research as—to the authors’ knowledge—there is only one other prospective study with GKs which was focused on anthropometric, maturity-related, and physiological attributes (Gil et al., 2014). Yet, comparing some findings to previous research with outfielders is possible. This generally requires nuanced consideration of relevant study characteristics, especially the selection rates of GKs (i.e., 5.7% in U15 to 8.0% in U13). These were similar to those reported for outfielders in a study on the predictive validity of the same assessments, criterion variable, and prognostic period (4.7% in U15 to 9.7% in U13; Höner et al., 2021). The relatively lower selection rates in the U15 can be explained by a potentially earlier selection of highly talented individuals (for a more in-depth discussion, see Ford et al., 2020). Another reason is that after tracing U15 GKs over three seasons (i.e., until the U18 age group), they already participate in the U19 YA squads because the German talent pathway promotes U18 and U19 players in the same teams (Kelly et al., 2024). Thus, individuals of two birth cohorts compete against each other, of which all U15 GKs included in the present study belonged to the younger cohort. Besides differences due to

the smaller sample size in the U15 (e.g., lower sensitivity of statistical analyses), this may have caused some deviations compared to younger age groups.

The univariate evaluation (*objective 1*) revealed effect sizes for the motor test battery assessing technical skills and speed abilities ($Mdn(d) = 0.35$; $0.26 \leq d \leq 0.87$) that were almost similar to those found for outfielders ($Mdn(d) = 0.41$; $0.22 \leq d \leq 0.73$; Höner et al., 2021). The linear sprint possessed the highest relevance in both outfielders and GKs emphasizing the fundamental and position-independent importance of speed abilities in soccer (Murr et al., 2018b; Williams et al., 2020). A lower predictive power with small effect sizes was found across ball control, juggling, and agility tests, whereas dribbling was of greater relevance potentially because it relates to both speed abilities and technical skills (Höner et al., 2015). Passing and ball control were previously highlighted as relevant technical skills for GKs' game opening (Otte et al., 2023; West, 2018), so the relatively low relevance of the ball control test may seem somewhat surprising. This finding may be explained by the test demands (i.e., six passes alternately to two opposing locations which requires a quick 180-degree turn; DFB, 2022b) which may not optimally reflect these technical skills as typically required in GKs' game-opening situations.

The higher median effect sizes found for subjectively rated GK-specific skills compared to the position-independent motor attributes might be explained by higher predictive validity of predictors closely related to game demands (den Hartigh et al., 2018), and/or the subjective approach chosen (Sieghartsleitner et al., 2019a). A study with outfielders in the German TID program using the same assessments also reported higher effect sizes for the coach ratings indicating a generally higher predictive power of the coach ratings when being considered on a univariate level (Höner et al., 2021). Specifically, the moderate to large effect sizes found for GK-specific technical and tactical skills ($Mdn(d) = 0.68$;

$0.53 \leq d \leq 1.07$) were similar to those found for kicking skills and tactical skills in outfielders ($Mdn(d) = 0.75$; $0.61 \leq d \leq 0.85$; Höner et al., 2021). The present findings underline the strong relevance of technical skills for GKs but—due to the predictive validity of GK-specific tactical skills—also highlight the value of considering additional skill domains.

The rating of *GKs' overall performance level* addresses claims for holistic views on talent (Charbonnet & Conzelmann, 2023). Although the use of a single item is a 'pragmatic' solution, it represents the only entirely holistic approach aiming to complement the multi-dimensional approach based on a variety of individual predictors. The confirmed predictive validity supports the use of assessments that allow coaches some flexibility to integrate their practical senses, intuition, and experiences (Bar-Eli et al., 2024, Buekers et al., 2015; Lath et al., 2021; Roberts et al., 2019a). While previous researchers reported by far the highest effect size for single-item assessed in-game performance (Sieghartsleitner et al., 2019a), the significant univariate effect sizes for the holistic rating in this study were small. This finding may indicate that the four-point Likert scale used for the holistic rating did not discriminate optimally between selected and non-selected GKs. This conclusion is further supported by the metric scores for GK-specific skills which reached moderate to large effect sizes in the univariate evaluation, whereas the holistic rating generally demonstrated higher predictive validity than the ratings for technical and tactical skills in the multivariate evaluation.

The multivariate evaluation (*objective 2*) showed that considering all predictors in combination explains considerable amounts of variance for a later YA selection across all age groups ($.13 \leq \text{Nagelkerke's } R^2 \leq .22$). However, findings about the relevance of individual predictors hint at relevant properties of the assessments used. Specifically, the univariate evaluation identified sprint and dribbling as being the most predictive motor tests, but

their shared variance with speed abilities (Höner et al., 2015) resulted in (except for U12) only one predictor significantly contributing to the model. While the univariate evaluation indicated the substantial relevance of GK-specific skills, only the holistic rating of GKs' current performance level (except for U15) was most relevant for the prediction in multivariate models. Therefore, the coach ratings are highly predictive ($2.88 \leq e^b \leq 5.17$), but seemingly general judgments of a GK's talent. This limited additional explanatory power across coach ratings of specific skills somewhat reflects findings in outfielders (Höner et al., 2021), and further corresponds with findings from various sports, revealing inconsistencies in coaches' understanding of theoretically distinct skill domains (e.g., Roberts et al., 2019a). On the one hand, this finding empirically supports the advantages of holistic ratings, such as considering various predictors and integrating coaches' instinct. On the other hand, it highlights possible limitations of subjective evaluations, as less differentiated ratings across distinct skill domains diminish the potential to effectively integrate test results into practical work. This is particularly problematic, as both assessments are intended to contribute not only to talent identification but also to the development of GKs, for example, by providing relevant information to support individualized skill practice.

From a GK-specific perspective, however, coach ratings are the only feasible approach to assess GK-specific skills in large-scale study given the limitations of objective assessments available (e.g., complex set-ups; Knoop et al., 2013; Rebelo-Gonçalves et al., 2016). In addition to integrating experts' experience and practical sense (Lath et al., 2021), coach ratings allow for more ecologically valid evaluation of GKs' capabilities to efficiently apply these highly specialized skills in the game (den Hartigh et al., 2018 on the contribution of game-representative talent assessments). Consequently, it is relevant to

better understand why coach ratings seem to differentiate less between different GK-specific skill domains (*Table 19*). One possible reason is cognitive biases in coaches' judgments such as the halo effect which is the tendency for impressions/judgments in one area to indirectly (i.e., from global impressions to traits) or directly (i.e., from traits to traits) affect impressions/judgments in other areas (Gräf & Unkelbach, 2016; Thorndike, 1920). Halo effects could have occurred in the current study with coaches' more general impressions (e.g., holistic rating) influencing individual predictors. Another reason may relate to coaches' less differentiated understanding about the nuanced differences among highly specialized GK-specific skills as not all coaches participated in GK-specific coach education programs and/or competed as GKs in their active careers.

The presented findings provide impetus to facilitate coaches' competence in evaluating GKs both holistically, considering their overall performance, and specifically, focusing on distinct predictors. This is also relevant for enabling the use of these assessments as talent development tools, particularly in translating findings into individual recommendations for GK-specific skill practices (Bastias et al., 2024; Otte et al., 2019; Otte et al., 2023). This aligns with the idea that assessments can contribute to understanding an individual's strengths and weaknesses as a basis for differentiated practice and coaching (Ford & Coughlan, 2020), a concept also known as 'assessments for learning' (for a review Zeng et al., 2018). To facilitate their effective application in this field, coaches' further education should focus on enhancing diagnostic competencies. This could include, among other areas, coaches' understanding of the specific characteristics of GKs-specific skills, as outlined and exemplified in the manual (DFB, 2022b). This can fundament further interventions relating to coaches' awareness of potential biases in their observations and how these can be minimized (e.g., independent observation by different

coaches). Furthermore, integrating a variety of perspectives in holistic ratings or observing specific performance factors selectively may benefit from purposefully chosen situations for observation (e.g., isolated exercises vs. complex game situations; for examples about how to design and constrain GK-specific practices see Bastias et al., 2024). Therefore, it may be worth considering if assisting coaches regarding optimal practice activities for observing GK-specific skills can lead to more accurate judgments. A potential approach to aid their predictor-specific ratings could represent so-called ‘game-test situations’ (e.g., Memmert, 2010). These ensure frequent involvement in game-representative situations constrained to stress specific competencies (e.g., positioning in the goal based on shots from different angles).¹⁷ Beyond assessing whether the predictive validity of coach ratings can be improved through these strategies, an important consideration is the inter-rater reliability among different coaches evaluating the same individuals (for a discussion Bergkamp et al., 2022).

Limitations

Because there is only a single “number 1” compared to 10 outfield players per game, conducting sufficiently powered studies with GKs is a vital challenge (Vahia & Kelly, 2024). Although a powerful sample of selected GKs was investigated in the present study, one limitation is the lower sensitivity of statistical analyses in U15 that only allowed for the detection of moderate effect sizes. Especially for position-independent motor tests with smaller effect sizes, this still limits robust inferences on their significance as talent pre-

¹⁷ Potential examples can be found within the ‘Practice Philosophy Germany’ which presents a variety of con-strained small-sided games. For instance, GKs’ positioning in the goal (i.e., a GK-specific tactical skill) is particularly emphasized in the following example (see 29:00-30:50): <https://www.youtube.com/watch?v=YWGZXHKSO-I>. GKs need to quickly adjust their position in the goal when the floating player next to the pitch receives the ball and can either cross it or take a shot on goal.

dictors and complicates comparisons with younger age groups. While a potential influence of relative age on the predictive validity was investigated within the present study, a limitation represents the lack of consideration of maturation-related variables. Especially given the reported relevance of elite GKs' body height in previous studies (White et al., 2018), parameters relating to biological maturation (e.g., age at peak height velocity) would have been worth considering. This would also allow the evaluation of a potentially confounding influence on coaches' judgments (Fuhre et al., 2022).

Future Perspectives

Future GK-specific talent research could potentially benefit from more sophisticated GK-specific assessments. For instance, biomechanical analysis of GK-specific diving techniques showed laterality effects (Spratford et al., 2009) which, however, seem to lose their effect in elite adult GKs (Ibrahim et al., 2019). Accordingly, this would encourage separate coach ratings of GK-specific technical skills performed to the left and right side, quite similar like ratings of outfielders' kicking skills performed with the dominant and non-dominant foot (DFB, 2022b). Furthermore, objective assessments of purposefully chosen generic attributes assumed to underpin GKs' development could be of interest in the early phases of talent development (e.g., coordination; Bergmann et al., 2024b; Elleray, 2021). Furthermore, the common challenge of finding adequate criterion variables to assess GKs' future success could be addressed by incorporating additional measures that reflect a GK's in-game performance rather than merely a selection decision (Bergkamp et al., 2019). While such approaches fulfill the demand of representative criteria for performance assessment, it should be noted that such measures are rare for both outfield players and GKs. Lastly, there is not a single TID study with female GKs

(Vahia & Kelly, 2024) which represents a meaningful gap that should be addressed to support the increasing popularity and professionalization of female soccer (FIFA, 2023b).

Conclusion

The present study contributed to the scarce empirical knowledge on the predictive validity of talent predictors in GKs. Considering a mid-term prognostic period, it was the first prospective design to evaluate the relevance of a multidimensional approach for elite youth soccer GKs' future success. When considering each predictor on a univariate level, the study revealed the predictive validity of objectively assessed position-independent performance factors, subjectively rated GK-specific skills, and the holistic rating of GKs' current performance level. At this univariate level, a tendency toward higher predictive power of coach ratings evaluating GK-specific skills compared to most position-independent motor tests was identified, except for the similar high relevance of the linear sprint. When all predictors were considered in combination, a considerable amount of variance could be explained, with at least one predictor from each assessment significantly contributing to the prediction. However, in addition to at least one objective motor test, only one subjective coach rating significantly contributed to the model in three out of four age groups. Beyond the general benefit of combining objective and subjective assessments, this suggests that, within a multidimensional approach, the predictive validity of the different predictors was limited due to intercorrelations. These findings underscore the importance of enhancing coaches' diagnostic competencies to provide more distinct evaluations of GK-specific skills. Such improvements are essential not only for refining talent identification processes but also for leveraging these evaluations to inform talent development practices, including individualized training and coaching tailored to

GK-specific skills. Overall, these findings highlight the contribution considering both position-independent and GK-specific predictors, achieved through a purposeful combination of motor tests and coach ratings. Nevertheless, it needs to be emphasized that both assessments were by far not sensitive enough to legitimize decisions on an individual level, such as (de-)selections.

Declaration of competing interest

The authors report there are no competing interests to declare.

Data Availability Statement

All Datasets used in this study will be provided upon reasonable request.

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Supplementary Materials

Supplementary materials for this article are provided in *Appendix 6*.

3.3.3 Development and Evaluation of a Motor Coordination Assessment for Youth Football Goalkeepers (Studies 6 & 7)

Study 6 of this dissertation presents the initial scientific evaluation of a novel GK-specific motor coordination assessment. The corresponding manuscript, written in German, is presented in *Appendix 7*:

Bergmann, F., Danner, J., Schultz, F., Pollmann, D., & Höner, O. (2021b). Talentdiagnostik von Fußballtorhütern. Entwicklung und Evaluation eines sensomotorischen Koordinationstests [Talent Assessment in Soccer Goalkeepers. Development and Evaluation of a Motor Coordination Test]. *Leistungssport*, 51(1), 50-55.

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Bergmann, F., Schultz, F., Fransen, J., & Höner, O. (2024a). Evaluation of a Goalkeeper-Specific Motor Coordination Assessment in Youth Football. *Science and Medicine in Football*. <https://doi.org/10.1080/24733938.2024.2429486>

Abstract

Talent identification and development (TID) in football can be enhanced through objective assessments of talent predictors. Yet, available instruments rarely consider the unique demands of goalkeepers (GKs). During early phases of talent development, considering a GK's giftedness relating to, for example, different abilities (e.g., motor coordination), can complement views on highly specialized GK-specific attributes (e.g., technical skills). Therefore, this study aimed to evaluate a GK-specific motor coordination assessment to support TID in football at early developmental phases. Six tests were designed to assess ball control relevant to GKs. Their content and face validity were confirmed by independent experts ($N = 8$). The assessment was evaluated with GKs selected for the German Football Association's TID program (U12-U15; $N = 120$). This study examined the assessment's test-retest reliability and agreement, the structural validity, and the concurrent validity. The overall test score demonstrated good test-retest reliability, although some individual tests showed lower coefficients. Additionally, limited agreement between repeated measurements due to considerable measurement error as well as issues with the structural validity of the test battery were identified. Nevertheless, the findings support the assessment's concurrent validity as higher-rated (i.e., more talented) GKs outperformed lower-rated individuals. Yet, the test battery's diagnostic accuracy is not high enough to justify individual decisions for talent selection. Overall, these findings support the consideration of motor coordination as a talent predictor in youth GKs and emphasize the assessment's potential to enhance coaches' evaluations. The identified psychometric weaknesses in some individual tests provide impetus to further optimize the test battery.

Keywords: Talent Assessment; Predictors; Test Development; Playing Position; Soccer

Introduction

The goalkeeper (GK) plays a crucial role for a football team's success and should therefore receive concerted attention along the talent pathway (Vahia & Kelly, 2024). Recent literature reviews on GK-specific game demands emphasize the need for multidimensional ability- and skill-related attributes such as quickness, power, as well as several GK-specific technical and tactical skills (Otte et al., 2023; West, 2018). This empirical knowledge about the demands imposed upon GKs in the game contributes to a sophisticated understanding of the determinants required for high-level performance. However, this body of research hardly informs about the attributes which should be considered as *predictors of goalkeeping talent* at a young age. Given this limited knowledge about talent predictors in GKs, current talent identification and development (TID) practices remain largely a product of the expertise and experience of practitioners (Vahia & Kelly, 2024). This paucity of research evidence alongside the fact that well-established practical approaches to identifying and developing talented GKs remain under-researched, severely limits our understanding of how these processes can be optimized.

This limited understanding opposes trends regarding the growing empirical insights on talent in sports in general (Baker et al., 2020; for a review) and in football more specifically (Williams et al., 2020; for a review). In football, these studies have informed sport practice pertaining to, for example, the consideration of several prognostically relevant talent predictors in outfield players. In this regard, research demonstrates higher predictive power of football-specific compared to general motor attributes in youth players already selected (Sieghartsleitner et al., 2019b). Furthermore, different studies report the best predictions if subjective ratings by practitioners were combined with objective assessments (e.g., motor tests; Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a).

Yet, the available research also emphasizes the need to consider talent predictors in the light of different developmental phases given a variety of mediating and moderating factors (e.g., training history; access to high-quality coaching; Williams et al., 2020).

The relevance of accounting for developmental phases is also emphasized by the *Differentiated Model of Giftedness and Talent (DMGT)* (Gagné, 2021). According to the *DMGT*, a person's (innate) *giftedness* refers to the possession of exceptional abilities (e.g., coordination) which are relevant for a certain field (e.g., goalkeeping). These abilities form the foundation for the development of *talent*, characterized by a person's systematically developed, extraordinary competencies (see also Preckel et al., 2020).¹⁸ Consequently, in early developmental phases, talent assessments may not only focus on highly specialized, sport-specific attributes, whose development is largely related to the training history (Vandorpe et al., 2012). The additional consideration of abilities as indicators of a GK's giftedness and, thus, the potential to develop high levels of GK-specific competencies can add valuable information.

Talent research on the football goalkeeper

The relatively scarce talent research focusing on GKs is, for example, due to the far lower number of GKs compared to outfield players in football squads. For this reason, GKs were seemingly often deliberately excluded or omitted in previous talent research (Vahia & Kelly, 2024). One exception presents the study by Gil et al. (2014), who examined talent predictors in GKs and observed that nine- to ten-year-old GKs were more likely to be selected when being taller and performing better in generic, physical tests (e.g., jump tests). Another study by Höner et al. (2025) demonstrated that position-independent motor tests

¹⁸ Preckel et al. (2020) use the term *aptitude* that relates to, for example, general and domain-specific abilities.

assessing technical skills (e.g., passing, and ball control) and speed abilities (e.g., linear-sprint) had predictive power for selection into a German youth academy (YA) three years after the assessment for a sample of pre-selected GKs aged U12 to U15. In this study, however, additionally conducted subjective coach ratings of GK-specific technical and tactical skills showed even higher predictive power in univariate analyses. Yet, multivariate analyses indicated that these coach ratings discriminated less between distinct GK-specific technical and tactical skill domains. Thus, the subjective ratings represented accurate, but seemingly general judgments of a GK's talent. These findings hint at the contribution of objective motor tests for more differentiated assessments of specific talent predictors (Höner et al., 2021 for a discussion).

These studies further concluded that TID could be optimized if objective assessments would better account for GK-specific demands. Such objective tools become even more relevant if no GK-experts were available for subjective ratings, and for generating reference values that allow for a systematic comparison of GKs' talent in large-scale TID programs. There are, however, only a few scientifically evaluated *GK-specific assessments* available in the literature. Performance in these assessments was often related to both GK-specific technical skills (e.g., diving) and physical attributes (e.g., jump performance; Knoop et al., 2013; Rebelo-Gonçalves et al., 2016). Even though scientific evaluations with (late) adolescent GKs underline the assessments' concurrent validity in these age groups, their predictive validity in early developmental phases is unknown and the test performance seems highly associated with GKs' anthropometrics and maturation. Another challenge with these assessments in practice is their comparably complex test setups, which limit their practical feasibility.

Consequently, there is a lack of objective and practically feasible assessments of talent predictors suitable to support GKs' TID in early developmental phases. At these early time points, also considering abilities that underpin GK-specific developmental processes seem relevant (Gagné, 2021; Preckel et al., 2020). These attributes could indicate a youth GK's potential to develop high levels of GK-specific competence when being systematically promoted within TID programs (e.g., position-specific practice; coaching by GK experts etc.).

Motor coordination as a potential talent predictor in youth sports

The applied and academic literature on football GKs highlights that motor coordination is one relevant ability, and further identifies domain-specific attributes related to coordination (e.g., 'ball handling'; 'eye-hand coordination'; Busch, 2017; Elleray, 2021; Otte et al., 2023). The relevance of motor coordination as a predictor of talent is further supported by empirical studies across various sports, which describe it as one indicator of an individual's potential for sport-specific skill development (Pion et al., 2015a; Pion et al., 2015b; Rommers et al., 2019; Vandorpe et al., 2012). Therefore, assessments of motor coordination may reveal the potential to support GKs' talent identification in practice.

In the scientific literature, manifold theories and taxonomies on motor abilities have been proposed (e.g., general motor ability vs. specificity hypotheses; Haibach et al., 2018; Hands, 2018). At present, multidimensional conceptualizations of motor abilities, one of which is motor coordination, seem most accepted (in detail, e.g., Lämmle et al., 2010). Motor coordination relates to the patterning of head, body, or limb motions relative to the patterning of environmental objects and events (Turvey, 1990; Magill & Anderson, 2021). Utesch and Bardid (2019) describe motor coordination as an underlying mechanism of motor competence and, thus, fundamental for goal-directed movements.

This variety of phenomenological and empirical concepts also led to several factorial structures of motor coordination assessments (e.g., Lämmle et al., 2010). These assessments can broadly be categorized by the types of motor tasks they use, which are based on either static environments (e.g., jumping sideways over a line; Kiphard & Schilling, 2007) or dynamic environments (e.g., controlling a ball; Faber et al., 2015). Particularly in dynamic environments, participants need to continuously adjust their movements based on environmental information (e.g., ball movements) to optimally solve a motor task. This categorization shows parallels to assessments of higher-order constructs like general motor competence, often represented by latent factors termed *locomotion* and *object control* (Aadland et al., 2022; gross motor function and ball control, Faber et al., 2015; self-movement and object-movement, Herrmann & Seelig, 2017; locomotor and ball skills, Garn & Webster, 2021).

Despite the use of such test batteries within a deficit-oriented approach (e.g., detecting motor coordination issues; Coppens et al., 2021; Fransen et al., 2014), there is some evidence from studies conducted in different sports that motor coordination assessments can support the detection and identification of sporting talent. A review by O'Brien-Smith et al. (2019) indicates that the “Körper Koordinationstest für Kinder” (KTK; Kiphard & Schilling, 2007), which is based on motor tasks in static environments, can explain part of the variance between youth athletes competing at different performance levels across sporting domains. Furthermore, a cross-sectional study indicated the concurrent validity of ball-related tests (i.e., motor tasks in dynamic environments) in table tennis (Faber et al., 2014).

In prospective study designs, it has been found that test items of the KTK relating to maintaining balance possess predictive power for child gymnasts' participation in an elite talent pathway two years after the assessment (Vandorpe et al., 2012). Similarly, Deprez et al. (2014) confirmed the two-year predictive validity of the KTK test items “jumping sideways”, “moving sideways”, and “balancing backward” in early to mid-adolescent Belgian soccer players. Two further studies partially confirmed the predictive validity of ball-related “eye-hand coordination” and “ball skills” tests in table tennis players below the age of eleven (Faber et al., 2016; 2023). A longitudinal study further demonstrated that coordination tests with and without ball were among the best predictors in identifying handball talent (Matthys et al., 2013).

In summary, previous research indicates that assessments of motor coordination can aid the detection and identification of sport-specific talent, especially when applied during the early developmental phases. However, most studies similarly emphasize the importance of considering specific aspects of motor coordination, taking into account the unique demands of each sport.

Development of a GK-specific motor coordination assessment

Accounting for football GKs' highly specialized positional demands, Bergmann et al. (2020) presented a GK-specific motor coordination assessment that was developed based on a co-design involving practitioners and researchers. Specifically, an expert panel, consisting of GK experts working for the German Football Association's (DFB) TID program (i.e., full-time practitioners with several years of experience) and full-time researchers providing scientific support for the program, developed the assessment through a five-step process (in detail Supplement I): Initially, the experts inductively developed a test battery (step 1). A first pilot study (step 2) demonstrated good to very good

procedural objectivity ($.90 \leq r_{xy} \leq .99$) and moderate to good test-retest reliability ($.66 \leq r_{xy} \leq .89$). In a subsequent pilot study evaluating the concurrent validity (step 3), it was found that the individual tests demonstrated diagnostic power in distinguishing between pre-selected GKs who were rated as having different levels of talent by experts ($.10 \leq \eta_p^2 \leq .22$). Despite these promising findings found within the two pilot studies (i.e., steps 2 & 3; Bergmann et al., 2020), practical experience when conducting the assessment and statistical results encouraged the expert panel to further optimize the test battery (e.g., practical feasibility, test demands; step 4). Finally, these further developed tests underwent an independent expert rating that demonstrated the test battery's content and face validity, as well as the practical feasibility (step 5; in detail Supplement I). The six test items finally included in the test battery are presented in *Table 20* (Bergmann et al., 2024c).

Table 20. Overview of the six individual tests included to the test battery (for the detailed test manual, see Bergmann et al., 2024b).

	1. Juggling-Ball-Change (JBC)	2. Double-Ball-Bouncing (DBB)
		
Equipment	Adhesive tape (alternative: hall line) Two juggling balls in different shades/colours (70 g, 62 mm) Smartphone/tablet as stopwatch (with three-second countdown)	2 age-appropriate footballs 8 cones (alternative: basketball center circle) Adhesive tape Stopwatch
Set-up	The goalkeeper stands behind an indoor boundary line (alternative: tape line) and holds one juggling ball in each hand, which are different in colour.	The goalkeeper stands in the centre of a circle (diameter: 3.6 metres). The starting point at the center of the circle is marked by a 1-meter-long strip of adhesive tape.
Procedure	The goalkeeper throws the juggling balls from a shoulder-width arm position simultaneously from one hand to the other. A pre-determined ball (colour-coded) is always thrown over the other ball.	The goalkeeper initiates the test independently by simultaneously bouncing both balls on the indoor floor. His task is to bounce the balls above his own waist level using the same hand for each ball, without securing them or leaving the circle.
Familiarization	4 throws	4x simultaneous bouncing
Duration	2 attempts à 30 seconds	2 attempts, which end as soon as at least one ball can no longer be controlled, are secured or after max. 45 seconds
Rating	1 point is awarded if both balls are caught All points scored during the 30-second test period are summed	1 point if both bounced balls are touched again above the goalkeeper's waist with the respective bouncing hand All points scored during the test period are summed
Errors Patterns & Consequences	If at least one ball is dropped, no point is awarded for the throw. The test continues. If the goalkeeper maintains an arm position narrower than shoulder-width, indicated by the verbal cue from the test supervisor ("shoulder!") no points are awarded. The test continues.	At least one ball can no longer be controlled (attempt ends). At least one ball is secured (e.g., pressed against the body). The goalkeeper or a ball touches the ground outside the circle. At least one ball bounced below the hip (no point, test continues).

Table 20. *continued*

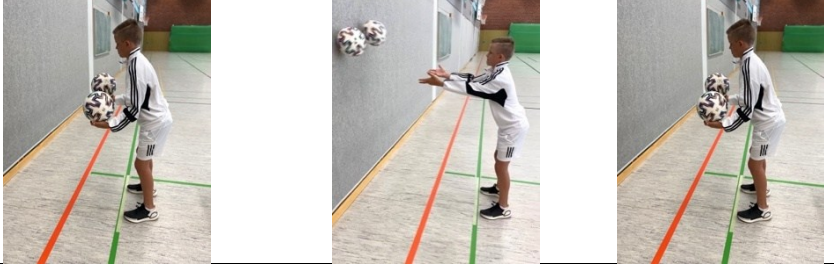
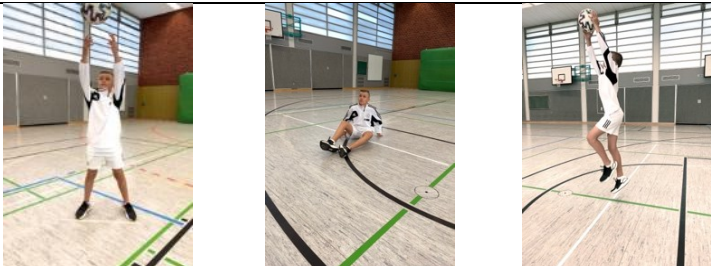
3. Ball-Wall-Rebounder - one Ball (BWR I)		Ball-Wall-Rebounder - two Balls (BWR II)	
			
Equipment	Adhesive tape Ruler or measuring tape At least 4 age-appropriate footballs 1 vaulting box or similar equipment for spare balls Smartphone/tablet as stopwatch (with three-second countdown)		Adhesive tape Ruler or measuring tape At least 6 age-appropriate footballs 1 vaulting box or similar equipment for spare balls Smartphone/tablet as stopwatch (with three-second countdown)
Set-up	The marking line is adhered to the floor, parallel to the indoor wall, with a distance of 1.4 metres.		The marking line is adhered to the floor, parallel to the indoor wall, with a distance of 1.2 metres.
Procedure	The goalkeeper throws a football using both hands from below the elbows against the indoor wall and catches it with both hands above his own elbows. This sequence is repeated as many times as possible within the testing time.		The goalkeeper simultaneously throws two footballs against the indoor wall and catches them with the same hand. This sequence is repeated as many times as possible within the testing time.
Familiarization	4 throws		4 throws
Duration	2 attempts à 20 seconds		2 attempts à 30 seconds
Rating	1 point is awarded if the ball is thrown below the elbows and caught above the elbows All points scored during the 20-second test period are summed		1 point is awarded if both balls are caught All points scored during the 30-second test period are summed
Errors Patterns & Consequences	The ball is dropped (no point for the throw, the test continues) The goalkeeper crosses the marking line when throwing or catching (no point for the throw, the test continues)		At least one ball is dropped (no point for the throw, the test continues) The goalkeeper crosses the marking line when throwing or catching (no point for the throw, the test continues)

Table 20. *continued*

5. Throwing-Sitting-Catching (TSC)		6. Bouncing-Turning-Catching (BTC)	
			
Equipment	Adhesive tape (alternatively indoor line) 1 age-appropriate footballs At least 15 x 15 metres of free indoor space		Adhesive tape 1 age-appropriate football Smartphone/tablet as a stopwatch (with three-second countdown)
Set-up	A free hall area of at least 15x15 metres is required. On one side of this area, an indoor line (alternative: line of adhesive tape) is marked as the starting position.		A strip of adhesive tape line (length: 1 meter) is adhered to the indoor floor. At each end of the line, a strip of adhesive tape measuring 50cm is marked at a right angle to the line.
Procedure	The goalkeeper throws a football into the air using both hands, quickly sits down on the indoor floor, stands back up, and catches the ball as high in the air as possible. After each throw, the goalkeeper has time to recover before starting the next throw. The quality of each attempt is assessed using a four-point scale.		The goalkeeper bounces the ball in front of him on the indoor floor, rotates 360 degrees around his own axis and attempts to catch the ball in the starting position (i.e. standing with his feet to the right and left of the marking line). Then, he performs the same sequence with a 360-degree rotation to the other side and repeats this as many times as possible.
Familiarization	2 throws		four trials (2x rotation to each side)
Duration	1 round á 5 throws (the points of the 5 throws are summed)		2 attempts à 15 seconds
Rating	The ball is not caught or caught while still sitting down (0 points) ... caught below the chin while standing (1 point) ... caught above the chin while standing (2 points) ... caught above the head in a jump (3 points)		1 point is awarded if the goalkeeper catches the ball after the turn back in the starting position. All points scored in the 15-second test period are summed
Errors Patterns & Consequences	Goalkeeper did not touch the hall floor when sitting (no point) Ball touches indoor ceiling (repetition of throw)		Goalkeeper is not in starting position when catching the ball Goalkeeper turns to the wrong side (no point, test continues) Goalkeeper loses the ball or falls down (no point, test continues)

The present study

The present study aimed to evaluate the motor coordination assessment designed to support TID in youth football GKs. The evaluation was conducted at both a global level (i.e., the overall test performance) and with respect to each test item. These processes followed the consensus-based standards for the selection of health status measurement instruments (COSMIN), particularly guidelines for evaluating an instrument's measurement properties (Mokkink et al., 2010a; Mokkink et al., 2020). Guided by the COSMIN taxonomy on instrument's measurement properties (Mokkink et al., 2010b), this study pursues three objectives addressing the assessment's reliability (objective 1) and validity (objectives 2 & 3):

1. Assessing the test battery's *internal consistency*, *test-retest-reliability* (i.e., 'relative reliability'), and *agreement* across repeated measurements (i.e., 'absolute reliability') to estimate the degree of measurement error in the test data.
2. Exploring the *structural validity* of the test battery to identify potentially underlying dimensions as the theoretical construct of motor coordination is inconsistently defined, assessed, and discussed in the literature.
3. Evaluating the *concurrent validity* in terms of the assessment's accuracy in identifying goalkeeping talent which is essential to support TID in practice.

Methods

Sample

To evaluate the psychometric properties of the test battery, male U12 to U15 GKs were tested ($N = 120$; in detail *Table 21*). All GKs were selected for a base camp (BC; "competence center") of the DFB TID program located in two different regional football associations, namely *Fußball- und Leichtathletik Verband Westfalen* ("Westphalia"; $n = 69$; 25 different BCs) and *Württembergischer Fußballverband* ("Württemberg"; $n = 51$; 17 different BCs). At these BCs, approximately the best 4% of GKs in their respective age were

offered one additional practice session per week complementing their regular clubs' activities (Kelly et al., 2024). Both regions are split up within the DFB's TID program into two 'coordination areas', each supervised by a full-time coach coordinator. The decision to assess GKs from these two regions was justified, as they were represented by four comparably large coordination areas (between 11 and 16 BCs), thus contributing to achieving large sample sizes given the commonly low number of GKs at each BC. Additionally, the two coordination areas in each region prepare their players for one regional association squad, further enhancing the comparability of these two regions (see also 'criterion variable'). As the data were collected at two different time points in Westphalia (June 2022; Season 2021/2022) and Württemberg (October 2022; Season 2022/2023), two different birth cohorts were assessed (Westphalia: 2007-2010; Württemberg: 2008-2011). However, no significant difference in the sub-samples' age was found ($t(118) = 1.697, p = .53$) so that these two time points had no consequences for the statistical analyses.

Before entering the DFB TID program, written informed consent for the recording and scientific use of each individual's data was provided by a legal guardian/next of kin. The first author's university's ethics department approved the use of the data for this study.

Table 21. *Sample characteristics separated by the four investigated age groups and two different regions.*

Total Sample				Westphalia				Württemberg			
<i>N</i>	Age (yrs.)	Height (cm)	Weight (kg)	<i>n</i>	Age (yrs.)	Height (cm)	Weight (kg)	<i>n</i>	Age (yrs.)	Height (cm)	Weight (kg)
120	12.93 ± 1.20	162.93 ± 11.67	50.32 ± 12.06	69	13.12 ± 1.13	164.72 ± 10.77	52.38 ± 11.61	51	12.65 ± 1.21	160.49 ± 12.47	47.53 ± 12.22
42	11.70 ± 0.41	154.04 ± 8.12	42.16 ± 7.36	25	11.95 ± 0.32	156.20 ± 7.46	44.55 ± 6.94	17	11.34 ± 0.21	150.87 ± 8.02	38.66 ± 6.69
34	12.72 ± 0.41	160.63 ± 8.79	47.51 ± 8.29	19	12.97 ± 0.27	162.46 ± 6.14	49.62 ± 5.96	15	12.39 ± 0.31	158.31 ± 11.11	44.85 ± 10.32
21	13.84 ± 0.43	171.36 ± 8.81	56.70 ± 8.72	15	14.05 ± 0.29	174.34 ± 6.66	59.69 ± 7.55	6	13.29 ± 0.11	163.90 ± 9.66	49.21 ± 7.09
23	14.61 ± 0.42	174.84 ± 7.12	63.45 ± 12.38	10	14.95 ± 0.32	175.91 ± 8.77	66.25 ± 15.70	13	14.36 ± 0.29	174.02 ± 5.79	61.46 ± 9.24

Data Collection

The data collection was embedded into GK-specific training camps of the DFB, including sufficient recovery breaks. Guided by the detailed test manual (Bergmann et al., 2024c; for an overview of all individual tests see *Table 20*), research assistants, trained and supervised by a member of the research team, conducted all data collection. Before participating in the assessment, all participants filled out a one-page questionnaire covering questions on personal information (e.g., name, date of birth), training history (e.g., GK experience), and their current club. Additionally, anthropometric data were assessed. Weight was measured with calibrated scales (Seca 813 electronic flat scale) to the nearest 0.1 kg and height was measured to the nearest 0.1 cm with a fixed stadiometer (Seca 213 portable stadiometer).

All GKs completed the whole test battery twice (i.e., test-retest design) with a recovery break in between. The tests were conducted in a fixed circle during both the test (T1) and retest (T2) to ensure a comparable time between both measurement points. With an average completion time of approx. 45 min. for the entire assessment per group, ensuring sufficient and equally comparable recovery, the test-retest interval for the same test was approx. 60 minutes.

Across all tests six tests included in the test battery, the number of points collected represents the metric test outcome. Similar to previous studies using ball-related tests (Faber et al., 2015), the best out of two attempts was considered for analyses except for the TSC in which the sum of points out of five trials represents the test outcome. A familiarization phase before each test should ensure participants' comprehension, but least affect their baseline performance (i.e., a person's initial performance level on a given task; Baltes, 1987).

Criterion Variable

All tested GKs were assigned into three groups by expert GK-coaches who were not involved in the motor testing. They assigned GKs to *group A* who possess sufficient talent to be considered for selection into a regional association squad, representing the next higher selection level in the German TID program. *Group B* includes GKs who were appraised to be among the top 4% of GKs in their respective age cohort and were hence considered to possess sufficient talent to remain at their BC. *Group C* includes GKs who were considered to possess little talent and hence their deselection from the program should be contemplated. The coach rating was conducted after GKs participated in training camps that serve as measures for GK-specific promotion. This procedure is commonly used in the TID program to evaluate GK's talent. Thus, it was deemed the most appropriate criterion variable to evaluate the assessment's validity.

Given previous findings (Gil et al., 2014), a potential influence in the coach rating based on GKs' age or anthropometric characteristics was checked. No significant differences between the talent groups regarding GKs' age, height, or weight were present ($0.149 \leq F(2, 117) \leq 1.341; p \geq .273$). Thus, a potential bias by these parameters can be precluded.

Statistical Analysis

To evaluate the assessment's psychometric properties on a global level, a score that includes performance in each test with an equal weight was calculated for both T1 and T2. This score is represented by the mean out of all Z-transformed individual test performances.

Reliability (Objective 1)

Following Mokkink et al. (2010b), three domains of reliability were evaluated to estimate the degree of measurement error in the data. These are represented by the assessment's

internal consistency, the test-retest reliability ('relative reliability'), and the agreement ('absolute reliability'; Atkinson & Nevill, 1998; de Vet et al., 2006).

To display the assessment's *internal consistency*, Cronbach's α for all individual tests at T1 and T2 was calculated (Tavakol & Dennick, 2011). It was also evaluated if Cronbach's α differed if one test was deleted from the calculation.

To assess the *test-retest reliability*, Pearson's correlation coefficient (r_{xy}) between test performances at T1 and T2 was computed for the total sample.¹⁹ As the sample's heterogeneity could affect the reliability (de Vet et al., 2006), partial correlations controlled for the age groups (r_{xy-age}) and the two regions of data collection ($r_{xy-region}$) were calculated. As these regions similarly represent the two included birth cohorts, no additional control for cohort effects was required. Reliability coefficients were displayed with their 95% confidence intervals. These were computed via bootstrapping for partial correlations using the *boot* package (Canty & Ripley, 2024). A uniform guideline to interpret reliability coefficients of motor tests is not available as highly dependent on an assessment's practical purpose (Weir, 2005). This is why rather conservative thresholds used in medical contexts were applied that classify coefficients as "poor to moderate" (0.5-0.75), "good" (0.76-0.9), and "acceptable for clinical measures" (>0.9; Portney & Watkins, 2015).

To display the assessment's *agreement*, the standard error of measurement (SEM; Equation 1), smallest detectable change (SDC; Equation 2), and coefficient of variation (CV in %; Equation 3) were evaluated (de Vet et al., 2006; Mokkink et al., 2020). To calculate the

¹⁹ The COSMIN guidelines recommend the *ICC* to evaluate the reliability. The *ICC* in a two-way random model (type consistency) leads to the same results as Pearson's r , if two measurements were considered. Thus, Pearson's r was preferred as it allows to control for covariates due to the sample's heterogeneity.

SEM and SDC for each individual test item, a variable representing the performance difference between T1 and T2 was computed. From this variable, the standard deviation (SD_{diff}) was calculated. To compute the CV, the standard deviation ($SD_{T1,T2}$) and mean ($M_{T1,T2}$) were calculated from each individual's test performances at T1 and T2.

$$SEM = \frac{SD_{diff}}{\sqrt{2}} \quad (1)$$

$$SDC = 1.96 * SD_{diff} \quad (2)$$

$$CV (\%) = \left(\frac{SD_{T1,T2}}{M_{T1,T2}} \right) * 100 \quad (3)$$

To display individual variations and systematic differences between test performances at T1 and T2 graphically, Bland Altman Plots were used with the mean of performances at T1 and T2 on the x-axis and the differences between these measurement points on the y-axis (Bland & Altman, 1999). The mean difference and corresponding 95% limits of agreement (LoA) were computed and marked within the graphs according to Bland and Altman (2003) by using the *Blandr* package (Datta, 2017). Additionally, paired t-tests were used to evaluate significant differences between performances at T1 and T2 (Atkinson & Nevill, 1998). Cohen's *d* served as effect size (Cohen, 1992) calculated as Cohen's d_{av} (Equation 10 in Lakens, 2013).

To investigate the agreement for the score, raw values of individual tests at T2 were Z-transformed by subtracting the respective mean value and dividing by the standard deviation from T1. The score for T2 was calculated by the mean out of all these Z-transformed individual test performances.

Structural Validity (Objective 2)

Due to the inductive test development, exploratory factor analysis (EFA) with the Z-transformed data of all six tests at T1 was performed. While all tests were based upon motor

coordination relating to ball control (i.e., motor tasks in a dynamic environment), this allows the identification of potentially underlying dimensions of the assessment. The number of factors was estimated by the Kaiser-Guttman criterion suggesting to retain as many factors as there are eigenvalues greater ≥ 1 and a scree-test. Oblique promax-rotation for all retained factors served to present the final solution (Thompson, 2004).

To cross-validate the assessment's factorial structure identified at T1, confirmatory factor analysis (CFA) with the data collected at T2 were performed. In these analyses, fixed factor loadings were defined based on the EFA results. As model-fit indicators, the χ^2 -value, root mean square error of approximation (*RMSEA*), and the standardized root mean square residual (*SRMR*), as well as the comparative fit index (*CFI*) and the Tucker-Lewis Index (*TLI*) were considered. Acceptable model-fit was assumed if the corrected χ^2 -squared values (i.e., divided by the tests degrees of freedom) are ≤ 3.0 , *RMSEA* and *SRMR* $\leq .08$, and *CFI/TLI* $>.90$ (Hu & Bentler, 1999; Marsh et al., 2004).

Concurrent Validity (Objective 3)

To display the assessment's *concurrent validity* – as one domain of criterion validity (Mokkink et al., 2010) – the diagnostic accuracy was evaluated with Receiver Operating Characteristic (ROC) Curves at both T1 and T2 (Mandrekar, 2010). These analyses were conducted regarding two different practical purposes of a talent assessment. First, the identification of GKs with sufficient talent to get promoted at one of the DFB BCs. Therefore, the rating was dichotomized to assess the accuracy in identifying GKs considered worth promoting (i.e., groups A and B) in relation to detecting the least talented GKs (group C). The second practical purpose is the identification of 'elite youth GKs'. Thus, the accuracy in identifying A-rated (i.e., group A) GKs in relation to detecting lower-rated individuals (i.e., group B and C) was investigated. It should be noted that dichotomization removes

some of the data's variance but given the fact that this is how such assessments may be used in practice, such evaluation seems relevant. To control for the age groups and regions of data collection, covariate-adjusted ROCs (AROC) and the respective adjusted area under the curve (AAUC) were calculated using the AROC package (Machado e Costa & Braga, 2020). A significant deviation of the ROC curve from the diagonal (i.e., 45-degree line) and the corresponding AAUC was checked by considering the curves' 95% confidence intervals.

More detailed insights on the concurrent validity were evaluated with analyses of covariance (ANCOVAs) considering the test performance as dependent variable and categorical expert ratings of a GK's talent (i.e., groups A, B, or C) as independent variable. This shows which talent groups differ in their test performance and further allow for comparison of the individual test's diagnostic power. Partial eta squared (η_p^2) served as the effect size to display the assessment's concurrent validity at T1 and T2. Computing ANCOVAs by controlling for both the age groups and the regions of data collection as covariates was chosen given comparably small sample sizes in each age and talent group (Hecksteden et al., 2022). To check the independence of the covariates and the coach rating as the independent variable, chi-squared tests were performed, revealing no significant differences for neither the age groups ($\chi^2(6) = 5.88, p = .44$) nor regions of data collection ($\chi^2(2) = 3.61, p = .17$).

The test power is a critical issue in talent research in general (Bergkamp et al., 2019) and specifically in GK-specific talent research (Vahia & Kelly, 2024). Therefore, sensitivity analyses were performed to determine the size of a possibly detectable effect utilizing G*Power (version 3.1.9.7; Faul et al., 2007) with the predetermined parameters for

ANCOVAs ($\alpha = 0.05$, $1 - \beta = 0.80$, $N = 120$ across three groups, and two covariates). The analyses were sensitive enough to detect a moderate effect size (i.e., $\eta_p^2 = .076$).

Group-based differences were tested for significance via contrasts. To confirm the criterion validity, it was hypothesized that higher-rated GKs outperformed lower-rated GKs (i.e., $A > C$, $A > B$, $B > C$). Based on the covariate-adjusted descriptive statistics, differences between talent groups were displayed as Cohen's d (computed as the mean difference divided by the pooled standard deviation; Cohen, 1992). Effect sizes were provided irrespective of their significance, considering the notable differences in sample sizes across the three groups.

Statistical analyses relating to the agreement, EFAs, and ANCOVAs were processed utilizing IBM SPSS (version 28). CFAs were performed in Mplus (version 8.2; Muthén & Muthén, 2017). Test-retest reliability, Bland Altman, and AROC analyses as well as the data visualization using the ggplot2 package (Wickham, 2016) were computed in R (version 4.2.2; R Core Team, 2022). The alpha level was set at 5% in all analyses.

Results

Reliability (Objective 1)

The test battery demonstrates good *internal consistency* at T1 ($\alpha = .78$) and T2 ($\alpha = .78$). At both measurement points, Cronbach's α differs only marginally when one test is deleted from the calculation ($\Delta\alpha \leq .06$).

The *test-retest reliability* coefficients are presented in *Table 22*. The score shows “good” test-retest reliability for the total sample ($r = .90$). When controlling for age groups, the score's reliability is lower, but still “good” ($r = .80$). The individual tests show “good” (i.e., JBC, BWR II) and “poor to moderate” reliability (i.e., DBB, BWR I, TSC, BTC). When controlling for age groups, the reliability of the JBC is still “good”, the further tests reach “poor

to moderate” coefficients. These age-adjusted coefficients are slightly lower in the JBC, TSC, and BTC ($.02 \leq \Delta r \leq .06$). More pronounced differences compared to the age-unadjusted coefficients are found for the DBB, BWR I, and BWR II ($.13 \leq \Delta r \leq .22$). Partial correlations controlled for the region where the data was collected are in some test marginally lower compared to the unadjusted coefficients ($.00 \leq \Delta r \leq .08$).

Results on the *agreement* across T1 and T2 are displayed in *Table 22* and *Figure 22*. The score is affected by substantial measurement error (SEM = 2.3; SDC = 4.5; CV = 3.77%) and significantly better test performances at T2 are present ($d = 0.75$). All test items show substantial, yet differently pronounced measurement errors ($1.3 \leq \text{SEM} \leq 14.7$, $3.5 \leq \text{SDC} \leq 40.8$; $7\% \leq \text{CV} \leq 45\%$). The DBB reveals the most pronounced measurement error. These differences between the test performances at T1 and T2 are also visible in Bland Altman analyses and plots (*Figure 22*). These further illustrate significantly better test performances at T2 across all individual tests with small to moderate effect sizes ($0.16 \leq d \leq 0.69$). The TSC and BTC demonstrate the least pronounced systematic improvements, but outliers are similarly present.

Table 22. Results on the test-retest reliability ('relative reliability') and agreement ('absolute reliability').

	<i>N</i>	Test-Retest Reliability			Agreement			
		r_{xy} [95% CI]	r_{xy} - Age Group	r_{xy} - Region	SEM [points]	SDC [points]	CV [%]	SMD [Cohen's <i>d</i>]
Score	120	.90*** [.86; .93]	.80*** [.71; .87]	.90*** [.85; .93]	2.3	4.5	3.77 [3.42; 4.13]	0.75*** [0.38; 1.12]
JBC	120	.80*** [.73; .86]	.75*** [.65; .83]	.75*** [.64; .82]	3.5	9.7	15.92 [13.47; 18.37]	0.56*** [0.20; 0.93]
DBB	120	.65*** [.54; .75]	.52*** [.37; .65]	.65*** [.54; .76]	14.7	40.8	44.73 [38.81; 50.66]	0.62*** [0.25; 0.99]
BWR I	120	.71*** [.61; .79]	.49*** [.24; .70]	.73*** [.55; .84]	2.5	6.9	7.27 [6.09; 8.44]	0.69*** [0.32; 1.06]
BWR II	120	.78*** [.70; .84]	.64*** [.53; .74]	.77*** [.70; .84]	1.5	4.1	11.83 [10.23; 13.43]	0.53*** [0.16; 0.89]
TSC	120	.73*** [.63; .80]	.67*** [.55; .77]	.72*** [.60; .80]	1.9	5.2	31.67 [25.38; 37.95]	0.16* [-0.20; 0.55]
BTC	120	.71*** [.61; .79]	.69*** [.60; .78]	.63*** [.50; .74]	1.3	3.5	18.64 [15.45; 21.83]	0.33*** [-0.03; 0.87]

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; JBC = Juggling-Ball-Change; DBB = Double-Ball-Bouncing; BWR I = Ball-Wall-Rebounder - one ball; BWR II = Ball-Wall-Rebounder - two balls; TSC = Throwing-Sitting-Catching; BTC = Bouncing-Turning-Catching; r_{xy} = product-moment correlation coefficient (Pearson); r_{xy} - Age Group = Partial correlation controlled for the age groups U12 to U15; r_{xy} - Region = Partial correlation controlled for the two regions (i.e., Westphalia & Württemberg) in which the data was collected; SDC = Smallest Detectable Change; SEM = Standard Error of Measurement; SMD = Standardized Mean Difference; CV = Coefficient of Variation.

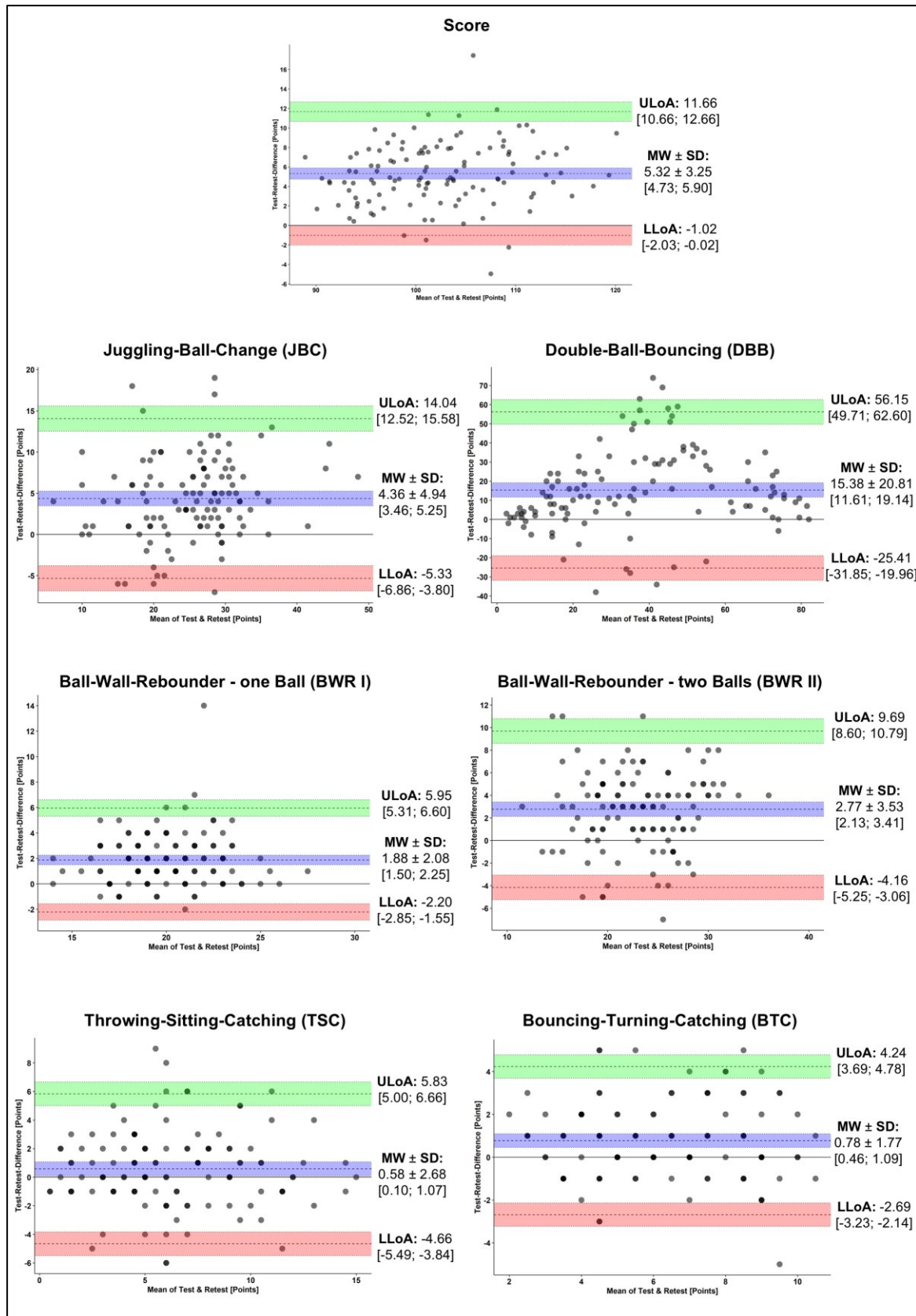


Figure 22. Bland Altman Plots to display differences in performance at the first (T1) and second measurement point (T2) for the score and individual test items.

Note. Green (upper limit of agreement; ULoA) and red (lower limit of agreement; LLoA) lines, as well as their shadings, represent the 95% confidence intervals.

Structural validity (Objective 2)

A significant Bartlett test ($\chi^2(15) = 189.22, p < .001$) and – as indicated by the good internal consistency ($\alpha_{T1} = .78$) – Kaiser-Meyer-Olkin criterion of .80 reveal a sufficient correlation between the six individual tests at T1 to perform an EFA. Kaiser’s criterion and the scree plot (Supplement II) yield empirical justification for a one-factor solution with an Eigenvalue of 2.92 and 49% of explained variance.²⁰ The pattern matrix shows the highest factor loadings for DBB, BWR I, and BWR II ($.67 \leq \lambda \leq .79$) and, thus, communalities between 45% and 62% of explained item variance (Table 23). The three further tests reveal lower, yet still acceptable loadings ($\lambda \geq .47$) with communalities from 22% to 46%.

To cross-validate the one-factor solution proposed by the EFA at T1, a CFA was conducted using the data collected at T2. The cross-validation shows insufficient model-fit with a significant χ^2 -test ($\chi^2(9) = 5.53, p < .001$) and poor model-fit indices *RMSEA* [90%-CI] = .19 [.14; .25], *CFI* = .79, *TLI* = .68, *SRMR* = .09). Thus, the proposed one-factor solution could not be replicated at T2. Yet, all tests reveal substantial factor loadings ($.54 \leq \lambda \leq .82$; all $p < .001$), except for BTC with a lower, though still significant factor loading ($\lambda = .34, p < .001$). Consistent with the factor loadings found in the EFA, DBB, BWR I, and BWR II, show the highest factor loadings ($.62 \leq \lambda \leq .82$).

²⁰ While these findings support a one-factor solution, it should be noted that a two-factor solution reveals an eigenvalue of .989 and 65% explained variance. Thus, the recommendation for a two-factor solution was just below the defined threshold of 1.0.

Table 23. Results of the exploratory factor analysis with the data collected at T1.

	Factors and communality	Factor Loadings						Eigenvalue	Explained variance
		JBC	DBB	BWR I	BWR II	TSC	BTC		
1-Factor solution	Factor 1	.59	.67	.79	.68	.47	.50	2.916	48.61%
	h ²	.34	.45	.62	.46	.22	.25		

Note. JBC = Juggling-Ball-Change; DBB = Double-Ball-Bouncing; BWR I = Ball-Wall-Rebounder - one ball; BWR II = Ball-Wall-Rebounder - two balls; TSC = Throwing-Sitting-Catching; BTC = Bouncing-Turning-Catching.

Concurrent validity (Objective 3)

The overall test performance, as reflected in the score, demonstrates *concurrent validity* for two practical purposes. Regarding the identification of all talented GKs (i.e., groups A and B; sensitivity) in relation to the identification of C-rated GKs (i.e., specificity), AROC analyses demonstrate significant and nearly equivalent diagnostic accuracy at T1 ($AAUC = .68 [.56; .79]$; *Figure 23a*) and T2 ($AAUC = .67 [.56; .78]$; *Figure 23b*). This indicates a 68% (T1) and 67% (T2) chance of correct assignment based on the score.

Regarding the identification of elite youth GKs (i.e., group A; sensitivity) in relation to lower-rated individuals (i.e., groups B and C; specificity), significant diagnostic accuracy is found at T1 ($AAUC = .73 [.57; .87]$; *Figure 23c*) and T2 ($AAUC = .79 [.68; .89]$; *Figure 23d*). This indicates a 73% (T1) and 79% (T2) chance of correct assignment based on the score.

These results generally confirm that the assessment reveals some diagnostic power. More detailed insights on the concurrent validity were evaluated with ANCOVAs by considering the test performance as the dependent variable and the talent groups as the independent variable. Regarding the score, these analyses show significant differences between the talent groups with a large effect size at T1 ($F(2, 115) = 10.30, p < .001, \eta_p^2 = .15$) and with an even slightly higher effect size at T2 ($F(2, 115) = 11.83, p < .001, \eta_p^2 = .17$). Subsequently performed contrasts to compare the test performances across talent groups show significantly better performances of higher rated GKs, thus, supporting the assessment's concurrent validity. The contrasts to compare the talent groups show the largest differences between A-rated and C-rated GKs ($d_{T1} = 1.36; d_{T2} = 1.47$). Lower, but still large effect sizes are found for comparisons of A-rated and B-rated GKs ($d_{T1} = 0.81; d_{T2} = 0.90$). Moderate effect sizes are present for comparisons of B-rated and C-rated GKs ($d_{T1} = 0.56; d_{T2} = 0.58$). These results confirm the assessment's concurrent validity at both

T1 and T2. Yet, the overall slightly higher diagnostic power at T2 suggests better considering data from the second measurement point.

For this second measurement point, findings regarding the concurrent validity of all six individual tests are displayed in *Table 24*. In four out of six individual tests, the ANCOVAs show significant differences between the groups with moderate effect sizes ($.05 \leq \eta_p^2 \leq .12$). Partial eta-squared of the two non-significant models are still moderate but it should be noted that the effect sizes are below the threshold for a detectable effect size when considering the analyses' sensitivity. Across all individual tests, the elite GKs (i.e., group A) significantly outperform the least talented GKs (i.e., group C) with moderate to large effect sizes ($0.65 \leq d \leq 1.23$; *Figure 24*). The comparisons of GKs in groups A and B show two significant differences with moderate to large effect sizes ($0.63 \leq d \leq 0.82$). Two non-significant differences with moderate effect sizes are found ($0.45 \leq d \leq 0.55$) and two further non-significant differences show small effect sizes ($0.22 \leq d \leq 0.32$). The comparisons between B-rated and C-rated GKs show significant differences with small effect sizes in three tests ($0.40 \leq d \leq 0.43$), while the remaining three tests reveal no significant differences with small effect sizes ($0.18 \leq d \leq 0.27$).

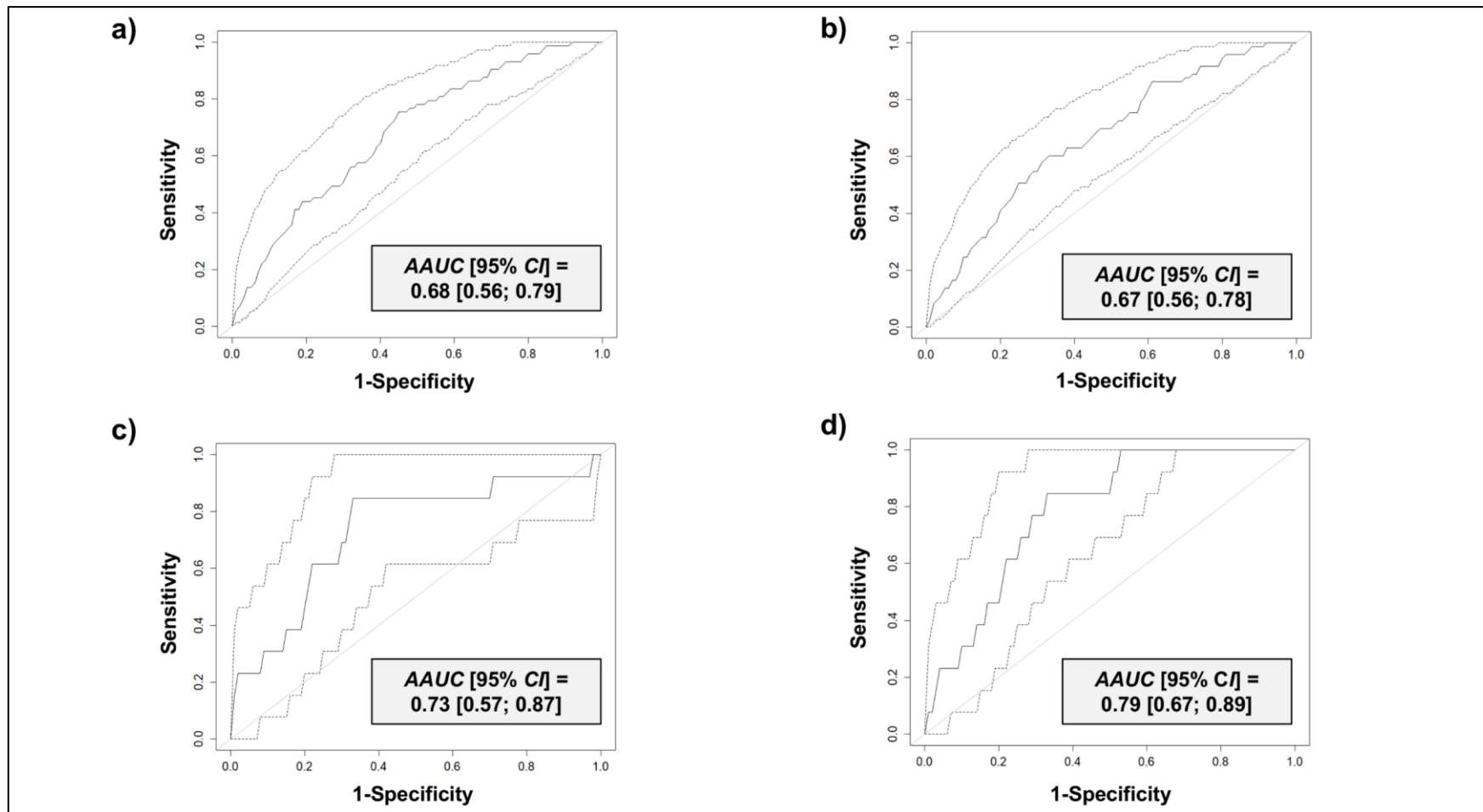


Figure 23a-d. AROC curves displaying the diagnostic accuracy of the score (i.e., the overall test performance).

Note. The analyses were guided by two potential practical purposes of a talent assessment. The first purpose (Figures 23a and 23b for T1 and T2, respectively) is the identification of GKs who are worth promoting in the TID program (i.e., groups A and B) in relation to detecting the least talented GKs (i.e., group C). The second practical purpose (Figures 23c and 23d for T1 and T2, respectively) is the identification of 'elite youth GKs' (i.e., group A) in relation to detecting lower-rated individuals (i.e., group B and C).

Table 24. Results of the ANCOVAs controlled for age groups and regions in which the data was collected and contrasts to compare test performances between three talent groups.

Test	N	$M_{adjusted} \pm SE$ 95% CI [LL; UL]			ANCOVA			Contrasts Cohen's d 95% CI [LL; UL]		
		A (n = 13)	B (n = 60)	C (n = 47)	F(2, 115)	p	η_p^2	A > C	A > B	B > C
Score	120	104.34 $\pm$ 1.23 [101.90; 106.78]	100.36 $\pm$ 0.57 [99.22; 101.49]	97.77 $\pm$ 0.65 [96.48; 99.07]	11.83	<.001	.17***	1.47*** [0.80; 2.14]	0.90** [0.28; 1.52]	0.58** [0.19; 0.97]
JBC	120	30.00 $\pm$ 1.68 [26.69; 33.33]	28.08 $\pm$ 0.78 [26.54; 29.63]	25.48 $\pm$ 0.89 [23.73; 27.24]	3.80	.025	.06*	0.74* [0.11; 1.37]	0.32 [-0.28; 0.92]	0.43* [0.04; 0.82]
DBB	120	57.30 $\pm$ 6.18 [45.07; 69.54]	45.04 $\pm$ 2.87 [39.35 50.73]	40.98 $\pm$ 3.27 [34.49; 47.46]	2.70	.072	.05	0.73* [0.10; 1.36]	0.55 [-0.01; 1.16]	0.18 [-0.20; 0.57]
BWR I	120	22.27 $\pm$ 0.54 [21.19; 23.34]	21.04 $\pm$ 0.25 [20.54; 21.54]	20.51 $\pm$ 0.29 [19.94; 21.08]	4.06	.020	.07**	0.89** [0.25; 1.52]	0.63* [0.03; 1.24]	0.27 [-0.11; 0.65]
BWR II	120	26.10 $\pm$ 1.16 [23.80; 28.39]	25.17 $\pm$ 0.54 [24.10; 26.23]	23.38 $\pm$ 0.61 [22.16; 24.59]	3.28	.041	.05*	0.65* [0.03; 1.28]	0.22 [-0.38; 0.82]	0.43* [0.04; 0.81]
TSC	120	9.46 $\pm$ 0.87 [7.73; 11.19]	6.85 $\pm$ 0.41 [6.05; 7.66]	5.57 $\pm$ 0.46 [4.66; 6.49]	7.87	<.001	.12***	1.23*** [0.58; 1.89]	0.82** [0.21; 1.44]	0.40* [0.02; 0.79]
BTC	120	7.45 $\pm$ 0.51 [6.42; 8.47]	6.61 $\pm$ 0.24 [6.13; 7.09]	6.12 $\pm$ 0.27 [5.59; 6.66]	2.68	.073	.04	0.72* [0.09; 1.35]	0.45 [-0.15; 1.06]	0.26 [-0.20; 0.65]

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; JBC = Juggling-Ball-Change; DBB = Double-Ball-Bouncing; BWR I = Ball-Wall-Rebounder - one ball; BWR II = Ball-Wall-Rebounder - two balls; TSC = Throwing-Sitting-Catching; BTC = Bouncing-Turning-Catching; The age groups (i.e., U12-U15) and the region in which the data was collected (i.e., Westphalia & Württemberg) were included as covariates in the ANCOVAs.

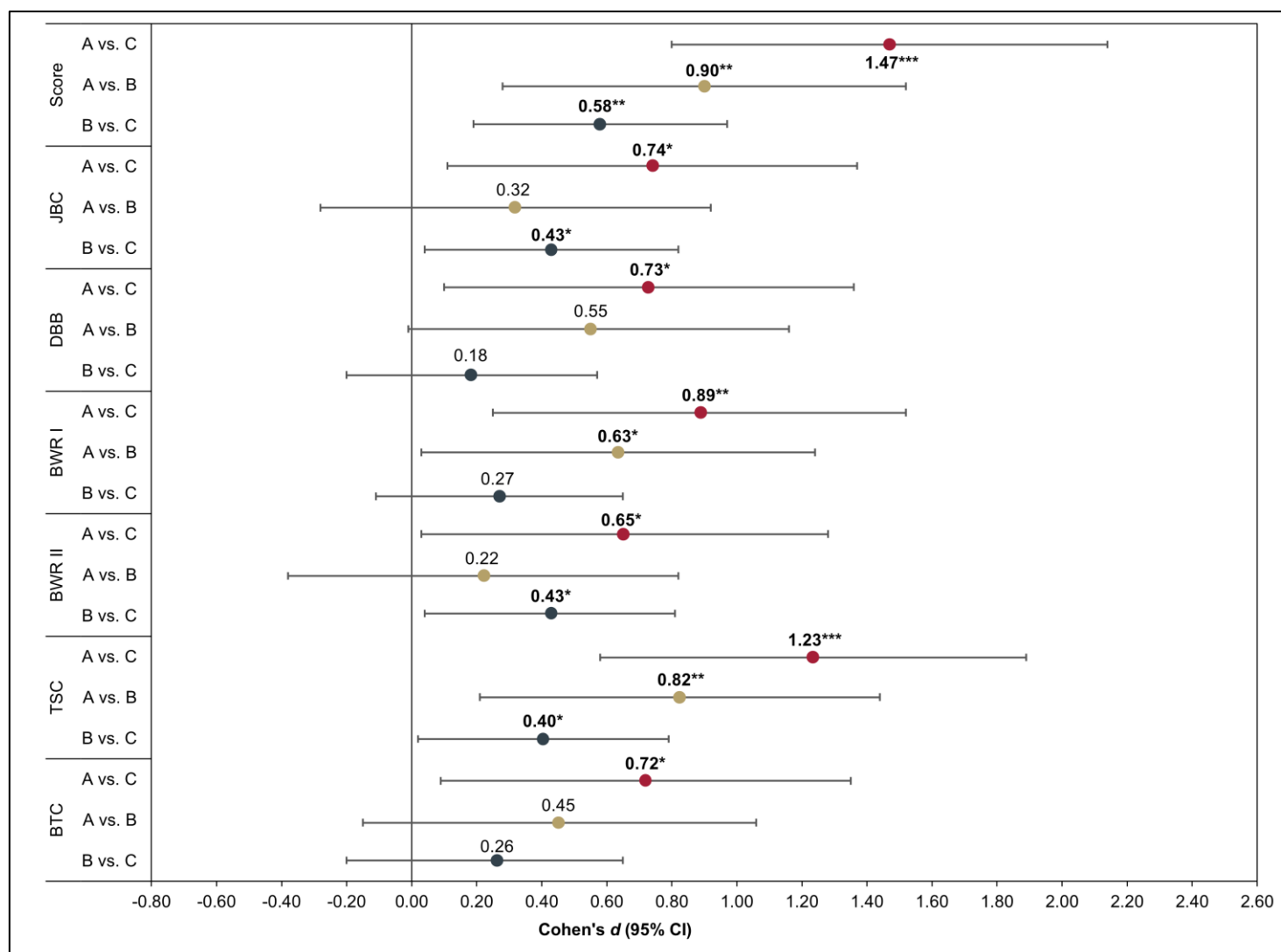


Figure 24. Standardized mean differences to display differences in performance of GKs assigned to three talent groups at T2.

Note. A positive effect size represents better performance of higher-rated GKs. Error bars display the 95% confidence intervals.

Discussion

A GK-specific motor coordination assessment aiming to support TID in football was co-designed by researchers and practitioners assembled into an expert panel. Ratings by experts not involved in the test development demonstrate the test battery's content and face validity, as well as the practical feasibility. Findings on the assessment's psychometric properties reliability (objective 1) and validity (objectives 2 & 3) are ambivalent. The score representing the GKs' overall test performance shows good reliability. Furthermore, the score reveals a practically relevant diagnostic power in identifying the more talented GKs, thus demonstrating concurrent validity. Therefore, corresponding to previous talent research using motor coordination tests across sports (e.g., O'Brien-Smith et al., 2019; Vandorpe et al., 2012), the test battery offers potential to support the identification of goalkeeping talent. Yet, the findings also underline that the assessment's diagnostic accuracy is not sufficient to justify decisions on an individual level (e.g., [de]selections). In addition, the test-retest reliability of some tests is only poor to moderate, and substantial measurement error affects the agreement across repeated measurements. Furthermore, the exploration of the structural validity indicates that the test battery does not represent a uniform construct. Therefore, the findings also uncover different areas where the assessment should be optimized for enhancing its potential to support GKs' talent identification in practice.

Comparing findings on the *reliability* with other studies is difficult due to several factors: i) longer test-retest periods, ii) heterogeneous study samples without the control for covariates (e.g., age, sex), iii) unknown measurement errors, or iv) the absence of reliability coefficients. A comparison of the test-retest reliability for the total sample and a study with table tennis players (7-12 yrs.) is possible that report slightly higher coefficients of

an ‘eye-hand coordination test’ between attempts performed on the same day ($ICC = 0.83$; Faber et al., 2014). Visual analysis indicates less systematic improvements between test attempts, but random errors and outliers are similarly present. Further studies evaluating comparable tests show heterogeneous test-retest reliability coefficients ($.31 \leq ICC \leq .91$; Faber et al., 2015), and some tests similarly reveal limited agreement ($3\% \leq CV \leq 43\%$, Faber et al., 2015; $10\% \leq CV \leq 12\%$, Matthys et al., 2013). Therefore, the presented findings widely correspond with previous research regarding challenges in achieving proper test-retest reliability and especially agreement in ball-related coordination tests.

Considering that the assessment is mainly intended to aid discriminative purposes (i.e., identifying talented individuals among a group of GKs), ‘relative reliability’ (e.g., test-retest-reliability) is principally more relevant than ‘absolute reliability’ (e.g., agreement; de Vet et al., 2006). Nevertheless, if the assessment aims to systematically support talent identification in a large-scale TID program, reducing measurement error is essential to establish reference values for comparing GKs across different regions and birth cohorts. Overcoming this issue may relate to optimizing the testing guidelines. Similar to previous studies (Faber et al., 2015; Matthys et al., 2013; Höner et al., 2015), data close to participants’ *baseline performance* (i.e., the initial performance on a given task; Baltes, 1987) was analyzed given only short familiarization before the actual testing at T1. Yet, ongoing familiarization across attempts led to considerable improvements from T1 to T2 ($0.16 \leq d \leq 0.69$). Thus, it is worthwhile to explore how many attempts are required until a plateau in performance is reached, to potentially consider data with less measurement error, which is also expected to improve the test’s reliability (Weir, 2005).

Regarding the assessment's *structural validity*, a unidimensional structure of the assessment as suggested by the EFA would be coherent with other assessments because all tests assess motor coordination related to ball control (i.e., based on motor tasks in a dynamic environment). In previous research, ball-related motor tests often load on a latent factor termed “object/ball control” or similar (e.g., Faber et al., 2015; Garn & Webster, 2021; Herrmann & Seelig, 2017). However, while these and further assessments include comparable tests to those evaluated in the present study, their underlying constructs often differ (e.g., “motor skills”, “fundamental motor skills”; “motor competence”). This also reflects the variety of taxonomies and theories to classify motor skills and abilities (Hands et al., 2018; Lämmle et al., 2010; Magill & Anderson, 2021), as well as concepts aiming to collectively assess motor performance dispositions as general or basic motor competencies (Fransen et al., 2014; Herrmann & Seelig, 2017). In contrast to these studies, the presented assessment was guided by the assumption that high levels of abilities relevant to a certain field (i.e., goalkeeping) are one of many indicators of a person's potential to develop GK-specific performance attributes. Guided by the GK literature (e.g. Busch, 2017) and the expertise of practitioners, it is assumed that this can be evaluated via purposefully developed motor coordination tests relating to ball control.

Considering the factor loadings of individual tests at T1, the TSC and BTC exhibit lower but still sufficient loadings. This could be explained by more pronounced gross-motor demands (i.e., sitting down, standing up, jumping; turning around) compared to the remaining tests. On a confirmatory level, the TSC again shows a lower factor loading ($\lambda = .54, p < .001$), but especially the BTC ($\lambda = .34, p < .001$) seemed to not fit optimally in the test battery. One reason for the poor model fit found for the replication of the unidimensional structure at T2 can be differently pronounced measurement errors across individual

tests. In this regard, it seems worth noting that the TSC and BTC demonstrate the least systematic improvements from T1 to T2. Again, these findings hint at a potential contribution from optimized testing guidelines aiming to reduce measurement errors that eventually affect the assessment's structural validity.

Given these findings, the score used as a global estimate of the test performance therefore does not represent a uniform theoretical construct. However, this score as a proxy for subjectively rated goalkeeping talent (i.e., the criterion), shows higher diagnostic power in classifying the GKs compared to individual tests, thereby enhancing the *concurrent validity*. This finding aligns with previous talent research which uses scores computed from different (heterogeneous) tests to improve the diagnostic and predictive power (e.g., Höner et al., 2015).

The highest diagnostic accuracy in identifying A-rated GKs and moderate to large group-based mean differences between A- and C-rated GKs indicate that the assessment is more suitable for identifying the most talented individuals. In addition, the somewhat higher effect sizes found at T2 reveal associations with the paradigm of *testing the limits* used in cognitive diagnostics (Baltes et al., 2007). Specifically, more talented GKs outperformed less talented individuals to a greater extent when considering test data closer to a GK's baseline reserve capacity (i.e., the upper range of an individual's performance potential at a given time point, Baltes, 1987). Yet, the available data does not allow for clear conclusions on how close GKs were to their baseline reserve capacity. Therefore, in line with strategies to potentially improve the assessment's test-retest reliability and agreement, a longer time for familiarization, more test attempts, or even practice seem worth evaluating in the future.

Adjusting the testing guidelines toward more attempts is, however, not trivial as other factors could negatively affect the repeated motor test performance (e.g., fatigue, decreasing concentration), or the practical feasibility (e.g., time needed). Therefore, respective adjustments could make it necessary to reduce the overall number of tests. This decision can be facilitated by comparing the effect sizes to identify tests with the highest concurrent validity. In this evaluation and the pilot study (Bergmann et al., 2021b), the TSC shows the highest diagnostic power across all talent groups. On a group-based level, there are significant performance differences in the BWR I between A-rated GKs compared to lower-rated groups, but not between B- and C-rated GKs. The JBC and BWR II discriminate A- and B-rated GKs from group C with almost similar effect sizes. The DBB and BTC fail to reach significance on a group-based level, but the effect sizes are below the threshold of the analyses' sensitivity. As far as adjustments in the testing guidelines do not improve these tests' concurrent validity, if the DBB remains substantially affected by measurement error, and if the BTC still shows a considerably lower factor loading compared to the remaining tests, eliminating these tests from the test battery should be contemplated.

To summarize, this study supports that the GK-specific motor coordination assessment reveals the potential to support talent identification in football. However, the findings also hit at risks if the assessment's psychometric weaknesses and the resulting limitations for practical use are disregarded. Like other assessments established in TID programs across sports (e.g., Faber et al., 2015; Matthys et al., 2013; Sieghartsleitner et al., 2019b; Vandorpe et al., 2012), the limited accuracy in assigning talented individuals underlines that such assessments can only supplement and not substitute experts' subjective judgments. Yet, if the measurement error can be reduced, reference values would

allow for comparison of GKs in the nationwide TID program, which represents a valuable contribution to enrich the coach's eye.

Limitations

Although the sample of youth GKs assessed in this study is large compared to other studies, the sensitivity of analyses was still limited. This limitation is particularly notable due to the pre-selected sample, where small to moderate effect sizes (i.e., below the study's sensitivity) could still be relevant. Additionally, one somewhat expected consequence of the short test-retest period is considerable performance improvements from T1 to T2. Achieving a longer, yet similar test-retest period across GKs was not feasible due to the specific target group so this rather conservative approach was preferred. Furthermore, defining thresholds for coefficients on the measurement error (e.g., CV, LoAs) is difficult due to lacking studies using comparable assessments that further evaluated the amount of 'acceptable' error while still ensuring practically relevant validity. Additionally, ratings from GK-coaches were used to operationalize a GK's talent as the criterion variable for evaluating the concurrent validity of the assessment. This was chosen because experts' judgments are established and often regarded as the most relevant approach for categorizing GKs in terms of their talent in practice. However, it is important to note that objective assessments are intended to enhance and supplement these subjective evaluations (e.g., Höner et al., 2025; Sieghartsleitner et al., 2019a), suggesting that reliance solely on expert ratings may not yield the most accurate method for identifying talent. Lastly, all analyses needed to be conducted across four age groups. While the analyses on the reliability and concurrent validity were controlled for covariates, the exploration of structural validity was based on this age-heterogenous sample.

Future perspectives

Optimizing the assessment's test-retest reliability and agreement similarly like the concurrent validity may be achieved by considering data closer to a GK's *baseline reserve capacity* (Baltes et al., 2007; Weir, 2005). Therefore, future investigations on the time point when a plateau in the test performance occurs in different age and talent groups are required to potentially optimize the testing guidelines. If these modifications do not contribute to some test's psychometric properties, their elimination should be considered. In addition, the test's purposeful weighting (e.g., based on discriminant analyses) could further improve the score's diagnostic accuracy regarding different practical purposes. After a few years, the present data will allow for evaluation of the test battery's *predictive validity* which is one of the most relevant requirements to inform TID. As established and prognostically relevant objective and GK-specific subjective assessments were already used in the DFB TID program (Höner et al., 2025), the *incremental validity* of this new assessment needs to be analyzed.

Finally, considering different processes on the talent pathway (Williams et al., 2020), this study evaluates the assessment's potential to inform the *identification* of talented individuals within a pool of GKs already participating in the DFB TID program. Given the focus on motor coordination as one of many indicators of a GK's giftedness (Gagné, 2021), this assessment could eventually inform the *talent detection* of subjects not yet acting as a GK. This could address individuals already participating as outfielders as well as children not yet playing football.

Declaration of competing interest

The authors report there are no competing interests to declare.

Acknowledgments

We would like to thank the staff of the DFB's Department for Talent Development for productive discussions in several meetings.

Data Availability Statement

The dataset, codes, and outputs (SPSS, Mplus, and R) are publicly available in the open science framework: osf.io/exuhq

Supplementary Materials

Supplementary materials for this article are provided in *Appendix 8*.

3.3.4 Synthesis of Findings on the Possibilities of Assessments to Support Coaches' Work

The objective of Research Focus II was to examine the possibilities of different assessments to evaluate relevant talent predictors in soccer TDEs. While the use of assessments is well-established in the *DFB Talent Development Program*, the combined contribution of objective motor tests and subjective coach ratings has only been evaluated in one study involving male outfield players (Höner et al., 2021). Therefore, Studies 4 and 5 extend this work by evaluating the predictive validity of these assessments with female players and GKs. In doing so, these studies contribute to a deeper understanding of the strengths and limitations of the current instruments, as well as the added value of their combined use. Furthermore, Studies 6 and 7 introduce a novel GK-specific objective test battery, designed to complement the existing assessment approach. Altogether, the findings extend the knowledge base on suitable assessment approaches applicable to evaluate talent predictors in youth soccer. This chapter synthesizes the findings across studies, placing particular emphasis on the instruments' psychometric properties. This provides a foundation for determining their possibilities for supporting different processes in soccer TDEs.

The shared objectives of Studies 4 and 5 were to gain a deeper understanding of relevant talent predictors and to identify scientifically-sound assessment strategies. To date, these topics have been addressed in only a limited number of prospective study designs involving female players (Datson et al., 2020; Höner et al., 2019; Leyhr et al., 2020) and GKs (Gil et al., 2014). Widely consistent with previous research involving male outfield players (Höner et al., 2021), the findings reinforce the predictive validity of the motor test battery designed to evaluate speed abilities and position-independent technical skills as

well as subjective coach ratings across various competence areas. Accordingly, the studies provide further empirical support that various technical and tactical skills, as well as motor abilities – all of which underpin action competence in soccer (Hohmann & Brack, 1983) – serve as relevant talent predictors during early adolescence.

The studies also revealed notable differences compared to earlier research on male outfield players highlighting the essential character of conducting specific research with female players and GKs. These differences may be attributed to conceptual differences between the studies, particularly with regard to the criterion variables used and the performance factors considered. These methodological decisions were made in response to specific characteristics of the population under study and thus warrant careful examination before drawing direct comparisons between the findings. One specific feature of Study 4 involving female players is that it examined the predictive validity of performance factors over a two-year time period and for reaching professional level in adulthood. Among other reasons, this decision was because female talent pathways are often more diverse than those of boys (e.g., mixed-gender vs. female-specific teams; Andrew et al., 2024a), and ongoing reforms in the competitive youth leagues in Germany encouraged a focus on two selection levels in the U17 age group. A notable specific of Study 5 is that the GKs were subjectively evaluated based on position-specific technical and tactical skills. To date, this is the only position-specific evaluation applied to GKs, as the established motor test battery focuses on position-independent technical skills.

A shared characteristic of both study samples is the typical limited number of same-aged female players and GKs participating at each DFB BC. This presents challenges for coaches when conducting subjective evaluations, as developing a nuanced understand-

ing of appropriate reference groups, which serves as a relevant basis for detailed assessments, is far from trivial. Moreover, the methodological decision to employ both univariate and multivariate statistical methods to evaluate the predictive validity is justified by the distinct yet complementary insights each analysis provided. While univariate analyses offer nuanced insights into the relevance of individual predictors and enable detailed comparisons of effect sizes, multivariate analyses allow for conclusions regarding the complementary potential of different assessment approaches. In particular, the multivariate analyses yield important insights into the extent to which objective and subjective assessment complement one another, and whether they provide information that coaches can use in a formative way. As such, findings from these two analytical strategies warrant closer examination to fully understand a) the relevance of specific talent predictors and b) the strengths and limitations of respective assessment methods.

Regarding the relevance of individual predictors, univariate analyses among the *position-independent performance factors* suggest linear sprint ability as a particularly relevant talent predictor. This finding was independent of sex or playing position and reinforces the importance of sprinting speed in early adolescence (for reviews Murr et al., 2018b; Williams et al., 2020). In contrast, agility showed small to moderate effect sizes in the univariate analyses for GKs across age groups, whereas the effect sizes for female players were negligible across all future selection levels. The results concerning objectively assessed technical skills indicate varying levels of relevance depending on the target group and selection level. Regarding female players, ball control and juggling demonstrated strong predictive power for selection into the U17 Youth National Team and the Women's Bundesliga, whereas their relevance for U17 Bundesliga participation was low.

Dribbling showed moderate relevance across all three selection levels, potentially because dribbling performance relies on both speed abilities and technical skills, two domains that still demonstrate predictive power when considered independently (Höner et al., 2015). For GKs, the position-independent motor tests demonstrated relatively consistent moderate predictive validity with the sprint as particular relevant test in the U13 and U14 age groups. As shown in *Figure 25*, the effect sizes observed for GKs were comparable to those for outfield players (Höner et al., 2021). This finding is particularly noteworthy, given that the test battery was originally designed with a primary focus on performance factors underlying the action competence of outfield players.

The predictive validity of *subjective coach ratings* across motor and cognitive competence areas was generally confirmed for both GKs and female players. This provides further support for the value of subjective ratings, which may be attributed to their inherent advantages over motor tests, such as the opportunities to base rating upon long-term observations, consider in-game behavior, and draw on coaches' professional experience (Lath et al., 2021; Roberts et al., 2019a; Sieghartsleitner et al., 2019a). Specifically, the findings for GKs reveal higher median effect sizes for subjective ratings compared to most objective motor tests at the univariate level, with the exception of the similarly high relevance of linear sprint performance. While these findings broadly align with those reported by Höner et al. (2021), they may be further reinforced by the focus on position-specific skills, which highlights a particular strength of this assessment for GKs. Among female players, the coach ratings consistently demonstrated small to moderate effect sizes. Large effect sizes were observed only for subjectively rated kicking and tactical skills as predictors of reaching the Women's Bundesliga (i.e., professional level) in adulthood.

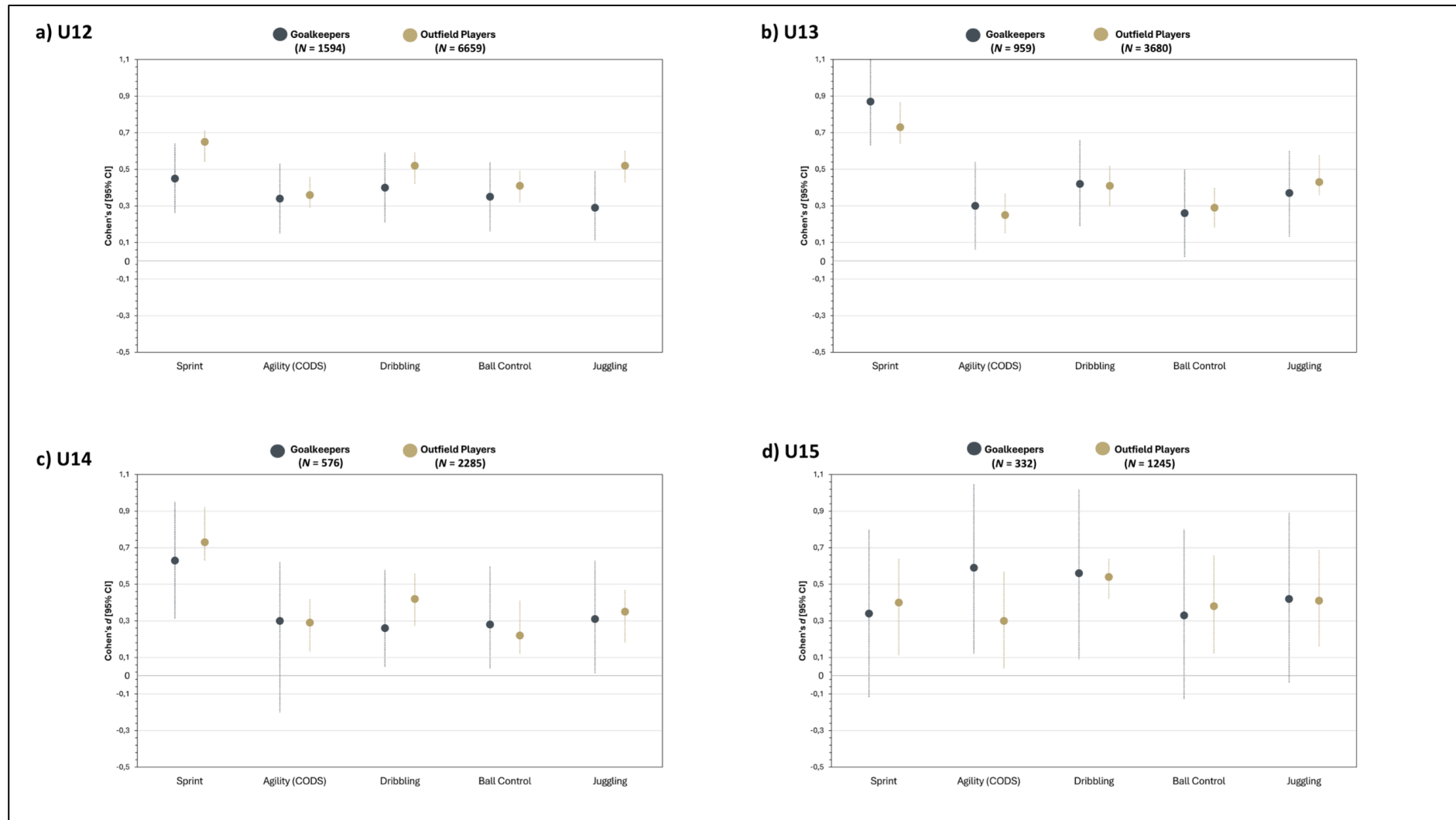


Figure 25. Comparison of effect sizes demonstrating the predictive validity of the objective motor test battery for GKs (as found in Study 5) and outfield players (as reported by Höner et al., 2021 regarding the same criterion variable of a YA selection three years after assessment).

The multivariate analyses offer relevant implications about the strengths and limitations of the different assessment approaches and potential benefits from their combined use. The studies consistently confirmed that combining objective and subjective assessments can increase the overall explanatory power for predicting future success. In principle, these findings provide further support on the complementary value of both assessment methods (Dugdale et al., 2020; Höner et al., 2021; Sieghartsleitner et al., 2019a). At the same time, both studies revealed only limited incremental validity of the individual predictors, in particular among different coach ratings. The fact that coach ratings lost explanatory power in the multivariate analyses is particularly noteworthy, as they are intended to assess a broader spectrum of performance factors across motor, cognitive, and psychosocial competence areas. Yet, a closer examination of the results suggests that although coach ratings are highly predictive, they tend to reflect general judgments of a player's overall talent rather than distinct evaluations of specific attributes within the three competence areas. While this issue had already been observed in previous research with male players (Höner et al., 2021), it appeared even more pronounced in the present studies focusing on female players and GKs.

Within the context of the *DFB Talent Development Program*, this limitation of the coach ratings is particularly relevant, as one goal of their implementation was to support coaches in performing nuanced evaluations and thereby generate information to be used to tailoring their learning support (DFB, 2022b; Schreiner et al., 2018). To serve this purpose effectively, ratings across different competence areas would need to provide more specific insights. Consequently, both the findings involving male players as well as Studies 4 and 5 highlight current limitations in using the test results for such individualized support. Consequently, the contribution of coach ratings as an *assessment for learning*

remains limited. To enhance the potential benefits of these subjective evaluations, a detailed examination of the underlying reasons for less differentiated ratings is required as a relevant basis for developing targeted improvement strategies.

One potential reason lies in biases inherent to subjective evaluations. Specifically, the limitations of coach ratings were even more pronounced Studies 4 and 5 compared to studies involving male youth soccer players. This may be attributed to the specific target groups examined. Given the similarities between the samples of female players and GKs, reference group effects may have made nuanced evaluations particularly challenging. Such effects occur when individuals are assessed relative to a salient reference group (Rothenbusch et al., 2016; Schild et al., 2018). In this context, female players were evaluated within high-performing, male-dominated training groups. While this is not uncommon in soccer TDEs (Andrew et al., 2024a; McEwan et al., 2024), it can complicate accurate assessments with reference to same-aged female players. A similar issue may have arisen with GKs, as it is common for only one or two GKs to be present within the same age group at DFB BCs. This challenge may be further amplified by the need to evaluate highly specialized, GK-specific skills, combined with a limited number of coaches who have firsthand experience as GKs and/or have completed GK-specific coach education. These factors may have limited the extent to which coaches were able to provide differentiated ratings, highlighting the need for targeted support to strengthen their diagnostic competencies. For the target groups of female players and GKs specifically, this includes a more detailed understanding of performance levels among different selection levels (i.e., the reference groups) as well as sophisticated knowledge of the performance factors being assessed and how these are operationalized in practice.

At the same time, the findings across studies underscore the distinct advantages of objective motor tests, as their results are not subject to the same biases and contextual influences that can affect subjective evaluations (see also Dugdale et al., 2020). As a result, integrating *objective assessments of GK-specific talent predictors* offers a promising approach to better address the unique demands of the position (Otte et al., 2023; West, 2018). This is particularly relevant given the current limitations of GK-specific subjective evaluations and the position-independent nature of the existing motor test battery used in the *DFB Talent Development Program*. Furthermore, it would allow for a systematic comparison of GKs across different BCs, which can hardly be achieved through coaches' subjective evaluations, as these are typically limited to a specific regional cohort of GKs. Therefore, a novel GK-specific test battery was developed and evaluated that may complement the two assessments already used. This test battery focuses on domain-specific attributes related to motor coordination, a relevant motor ability for GKs (Busch, 2017; Elleray et al., 2021). The theoretical rationale for this focus is also supported by the *DMGT* (Gagné, 2021) which posits that high levels of domain-relevant abilities form the foundation for the systematic development of specific competencies (see also Preckel et al., 2020).

Studies 6 and 7 confirmed that the newly developed test battery demonstrates some concurrent validity. These findings provide initial support for considering motor coordination as a relevant domain-specific motor ability in youth GKs. However, the results also highlight potential risks if the test's psychometric weaknesses and related practical challenges are not adequately addressed. A key concern is the substantial measurement error observed in the data, which complicates the generation of reliable reference values. One overarching reason for this finding is the use of ball-related test items which are

known to produce higher measurement error compared to tests without a ball (Faber et al., 2021; Höner, 2012b). While the overall test score demonstrates good psychometric properties, some individual items require further refinement. The resulting need to consider the overall performance score, along with the substantial measurement error in some individual tests, suggests that the novel assessment is less suitable for longitudinal evaluation. In addition, opportunities to derive meaningful insights from individual tests are limited. Unlike the established position-independent motor test battery (Höner et al., 2015; Leyhr et al., 2017), these psychometric limitations reduce the potential of the novel test battery to function as assessment for learning, as it may not sufficiently capture nuanced strengths and weaknesses among GKs and their development over time.

Nevertheless, the promising findings regarding the test battery's concurrent validity support its contribution to a GK-specific multidimensional approach to talent identification. Accordingly, the assessment holds value for advancing current practices within the *DFB Talent Development Program*. Based on these findings, the nationwide implementation of the test battery for use at DFB BCs is planned for 2026. This rollout will also enable more specific insights into the test battery's incremental validity and, thus, its complementary potential alongside the assessments currently in use. Moreover, Study 7 proposes targeted strategies to enhance the level of psychometric properties of the test battery, potentially expanding its range of application.

Overall, Research Focus II advanced the empirical understanding of relevant talent predictors in female players and GKs and extend the knowledge on the strengths and limitations of different assessment approaches. The findings across studies can be synthesized along the following six key aspects:

- *First*, the findings reinforce the well-established importance of considering and therefore fostering a broad spectrum of performance factors relating to different competence areas during early adolescence.
- *Second*, performance factors identified as prognostically relevant in male youth soccer also yield predictive power in female players and GKs, although some variations in their relevance were observed.
- *Third*, the additional consideration of position-specific technical and tactical skills in GKs is highly warranted. Moreover, initial evidence supports the added value of evaluating domain-specific abilities such as motor coordination through an objective test battery.
- *Fourth*, a thoughtful combination of objective motor tests and subjective coach ratings can offer a practically feasible assessment strategy to capture the wide range of relevant talent predictors across motor, cognitive, and psychosocial competence areas
- *Fifth*, although all assessments evaluated demonstrated practically-relevant diagnostic/prognostic power, this is by far too limited to justify decision-making at the individual level.
- *Sixth*, one promising area of application in soccer TDEs is the use of these instruments as assessment for learning. However, this potential must be carefully weighed against the specific strengths and limitations of each assessment.

The general discussion will explore in greater depth how assessment data can be integrated into practical coaching. Particular emphasis will be placed on the added value of each approach in the context of learning-oriented assessment (see *Chapter 4.3*). In conjunction with the findings from Research Focus I, this will help clarify the extent to which these assessments can contribute to providing tailored learning support in soccer TDEs.

4. General Discussion

The overarching objective of this dissertation was to generate scientific knowledge on how youth soccer players' action competence can be effectively fostered. The research addressed two interrelated areas, both of which represent core components of soccer TDEs: (1) the provision of effective learning support through practice and coaching, and (2) the role of assessments in providing meaningful information to guide coaches in these processes. Specific research questions were examined across seven individual studies, each thoroughly discussed in relation to relevant theoretical perspectives and existing empirical evidence within the respective manuscripts. Additionally, *Chapters 3.2.4* and *3.3.4* synthesized findings within the two research foci of this dissertation, offering insights across studies. This chapter presents a general discussion of all included studies, aiming to integrate their findings and highlight their collective contribution to optimizing talent development practices in soccer.

This discussion is structured around six key areas: *First*, effective coaching strategies for fostering youth soccer players' action competence are examined within the context of existing scientific knowledge in the field. *Second*, the contribution of these coaching strategies is considered in light of different theoretical perspectives on learning. *Third*, opportunities and limitations of different instruments to function as learning-oriented assessment, particularly as assessments for learning, are discussed. *Fourth*, theoretical perspectives related to the broader soccer TDE are examined to shed light on potential moderating influences on the development of relevant performance factors. *Fifth*, selected findings are translated into implications for further coach education and development. *Sixth*, future research directions at the intersection of talent development and coaching are presented.

4.1 Coaching Strategies for Fostering Action Competence in Youth Soccer

To foster youth soccer players' action competence within TDEs, it is essential to connect scientific insights on relevant talent predictors with coaching strategies that effectively support their development (Höner et al., 2023). Given the interplay of motor (e.g., technical) and cognitive (e.g., tactical) skills in solving game-specific tasks, this work focused on supporting the development of attributes related to both competence areas. Alongside relevant motor abilities (e.g., endurance, speed, coordination) and psychosocial attributes (e.g., volition, motivation) they form fundamental components of action competence in soccer (Hohmann & Brack, 1983; Höner, 2012a). The focus on both competence areas is further supported by prospective studies that have identified a range of technical and tactical skills as relevant talent predictors in early adolescence and therefore support their targeted promotion in this phase of development (Höner et al., 2021; Ivarsson et al., 2020; Murr et al., 2018a; 2018b; Williams et al., 2020).

Insights into how the development of performance factors across the motor and cognitive competence areas can be effectively fostered are provided by soccer-specific intervention research (for a review see Study 1). Across all reviewed studies, moderate median effect sizes were observed in both the motor competence area (51 effect sizes; $Mdn(d) = 0.74$; 51% significant) and the cognitive competence area (32 effect sizes; $Mdn(d) = 0.61$; 34% significant). Although only the half of motor-related effect sizes and roughly one-third of cognitive-related effect sizes reached statistical significance, the evidence of effectiveness was distributed across a variety of coaching approaches. This also applies to the three theoretically grounded approaches *DL*, *TGFU*, and *NLP*. Direct comparisons between these approaches have not yet been conducted in soccer, and the observed effect sizes do not suggest that any single approach is clearly superior. These findings further

highlight the importance of evaluating the effectiveness of practice and coaching strategies in light of contextual factors and the specific learning outcomes being targeted (e.g., Collins et al., 2025; Willimczik, 2013; 2021).

Since the publication of this systematic review in 2021, research interest in the effectiveness of coaching and teaching strategies in team sports has continued to grow. As a result, other research groups have synthesized the available evidence. *Table 25* presents findings from systematic reviews with meta-analyses focusing on outcomes in the motor and cognitive competence areas. In contrast to the quantitative synthesis conducted in Study 1, which exclusively focused on club-level soccer, these meta-analyses pooled effect sizes across different sports and, in some cases, across various contexts (e.g., PE and club settings). Despite this broader scope, their findings largely align with those of Study 1, reinforcing the conclusion that various coaching approaches can be effective.

A closer examination of the pooled intervention effects shows that different GBAs, which have been the primary focus of existing research, can effectively support the development of both technical and tactical skills. However, the vast majority of studies focused exclusively on acquisition-effects, providing little insight into long-term learning outcomes. Moreover, substantial variation in the magnitude of effect sizes is observed across the meta-analyses. Nonetheless, the current body of evidence supports the conclusion that GBAs are effective in promoting outcomes in both the motor and cognitive competence areas. Therefore, the findings partially contradict earlier narrative literature reviews, which had concluded that there was limited evidence for the effectiveness of GBAs in developing technical skills (Kinnerk et al., 2018; Miller, 2015).

Table 25. Overview of systematic reviews with meta-analyses investigating the effectiveness of coaching and teaching methods.

Author	Approach	Context	Outcomes (<i>k</i> = number of included experiments)		
			Motor Competence Area	Cognitive Competence Area	Other
Abad Robles et al. (2020)*	GBAs	Educational settings	Motor Skills (<i>k</i> = 6): <i>d</i> = 0.89 [-0.45; 2.23]	Decision-Making (<i>k</i> = 7): <i>d</i> = 0.89 [0.12; 1.65]	
Clemente et al. (2021b)	GBAs	Team sports	Technical Skills (<i>k</i> = 6): <i>g</i> = 0.59 [0.29; 0.89]		
Manninen et al. (2025) [#]	GBAs	PE and club sport	Motor skills (isolated; <i>k</i> = 16): <i>g</i> = 0.36 [0.14; 0.57] Motor skills (in-game; <i>k</i> = 16): 1.13% [-2.43, 4.68]	Decision-Making (<i>k</i> = 17): 11.41% [4.39, 18.43]	Knowledge (<i>k</i> = 9): <i>g</i> = 0.37 [-0.12; 0.86]
Ortiz et al. (2023) [°]	TGfU	PE and club sport	Technical Skills (<i>k</i> = 3): <i>d</i> = 1.70 [-5.32; 8.73]	Decision-Making (<i>k</i> = 4): <i>d</i> = 5.93 [2.15; 9.71]	
González-Valero et al. (2024)	TGfU	Educational settings		Decision-Making (<i>k</i> = 25): <i>g</i> = 0.72 [0.47; 0.95]	
Tassignon et al. (2021)*	DL	Club sport contexts	Technical Skills (<i>k</i> = 14): <i>d</i> = 0.34 [0.17; 0.51]	Tactical Skills (<i>k</i> = 4): <i>d</i> = 0.20 [-0.03; 0.44]	

Note. GBAs = Game Based Approaches (i.e., umbrella term for various approaches, such as TGfU or the TGA); In line with the reporting in meta-analyses, the table presents effect sizes as either Cohen's *d* or Hedge's *g*.

* The findings from this meta-analysis should be interpreted with caution, as several relevant studies were missing.

[#] For decision-making and motor skill performance measured in game situations, raw mean change differences were computed and presented in percent as they were measured with the same procedures (for details see Manninen et al., 2025, pp. 21-22). The effect sizes were calculated by subtracting the mean change in the control condition from the mean change in the intervention condition and dividing the difference by the pooled standard deviation of the pre- and post-test.

[°] The effect size reported in Ortiz et al. (2023) is extremely large and should be interpreted with caution. In addition, the authors did not include several interventions that would have met their inclusion criteria.

* The meta-analysis included studies from various contexts, such as club sport, university sport, and rehabilitation. As the authors conducted sub-group meta-analyses, only the effect sizes reported for "sport contexts" are reported in this table.

In addition to providing insights into practice design, findings of this work, along with the meta-analyses presented in *Table 25*, contribute to a deeper understanding of the impact of different coach behaviors on player outcomes. Consistent with the intervention research reviewed in Study 1 (e.g., Práxedes et al., 2016; Sierra-Rios et al., 2020) and findings of Study 2, Manninen et al. (2025, p. 26) concluded:

[T]he instructional focus and aims (e.g. via questioning and planned progressions) in GBAs also prioritize cognitive understanding, recognition, and tactical awareness during gameplay. This type of instruction may contribute to improved decision-making throughout games. Therefore, GBAs possibly facilitated enhanced decision-making through a combination of context-specific motor skill development and explicit instructional strategies targeting cognitive processes.

Interpreting the contribution of practice and coaching strategies to outcomes in both motor and cognitive competence areas requires careful consideration of two key aspects: First, while some studies assessed players' in-game performance using systematic observation, none of the soccer-specific studies conducted additional evaluations using isolated skill tests (for a recently published exception, see Deuker et al., 2023). As a result, potential effects in isolated motor tests – such as those found in studies on drill-based training (e.g., Kösal et al., 2020; Witkowski et al., 2011) – remain unknown. Such assessments would have offered valuable insight into purely technique-related effects, measured independently from other influencing factors in the game (e.g., tactical skills, motor abilities etc.). Second, many meta-analyses did not differentiate between types of control conditions. Most soccer-specific studies demonstrate general intervention effectiveness, often in comparison to non-active controls or groups engaged primarily in isolated practice tasks. However, such control conditions involving primarily isolated activities can hardly be compared to predominantly game-based interventions. This is because they do not represent conceptually opposing approaches if the aim is to develop both motor and cognitive outcomes, which together constitute core elements of action

competence in soccer. Moreover, these control conditions do not accurately reflect the reality of applied practice where game-representative activities often comprise more than half of the session time (O'Connor et al., 2017; Roca & Ford, 2020).

To date, only a limited number of studies have directly compared conceptually opposing approaches that aim to achieve similar learning outcomes. This limits the extent to which conclusions can be drawn about their relative effectiveness. Consequently, existing evidence suggests that various approaches – including *TGfU*, *NLP*, *DL*, several other interventions based on SSGs or drill-based activities, and various coaching interventions – can lead to measurable improvements. However, there remains limited insight into their comparative advantages or disadvantages in fostering youth soccer players' action competence within TDEs.

Although there is a pressing need for more high-quality intervention studies, the growing number of systematic reviews and meta-analyses represents, in principle, a valuable development in the research field. This increase, along with consistent trends in the results, shows parallels to research on the effectiveness of classroom-based teaching methods. More than fifteen years ago, the rising number of meta-analyses prompted Hattie (2009) to synthesize this body of evidence for the school context, resulting in the *Visible Learning Project* (Hattie, 2023, for a methodologically enhanced update). Although based on a much larger evidence base, Hattie (2009; 2023) similarly concluded that a wide range of teaching methods appear to 'work' at least when effectiveness is broadly defined as contributing to any measurable outcome. Another notable similarity between intervention research in sport and education is the occasional reporting of extraordinarily high effect sizes. For example, Ortiz et al. (2023) reported a pooled intervention effect of nearly six standard deviations for the effectiveness of *TGfU* in enhancing decision-making skills

($d = 5.93$ [2.15; 9.71]; *Table 25*). Likewise, individual studies reviewed in Study 1 reported remarkably high effects for drill-based practice targeting the non-dominant leg ($d = 2.91$), *DL* ($d = 2.37$), and *TGfU* ($d = 2.80$). These observations call for critical reflection, as emphasized by Wisniewski et al. (2020, p. 9):

These effect sizes must be classified as gigantic. In an educational context, effect sizes that large are uncommon and much higher than usually expected from any treatment. Following Brand and Bradley (2012), such unusually large effects could even be described as ‘voodoo’ effects.

A crucial insight from Study 1, and supported by Hattie’s (2009; 2023) *Visible Learning Project*, is the need to move beyond the question of whether an approach works in general. Instead, it is essential to develop explanatory frameworks that identify which individual and environmental factors influence its effectiveness in supporting learning. This perspective advocates for a stronger emphasis on comparing conceptually opposing coaching approaches that are, in principle, suitable for use within soccer TDEs and that aim to achieve similar learning outcomes. Moreover, it calls for further investigation into how individual player characteristics may moderate these effects (e.g., skill level). In addition, exploring the justifications and rationales that influence the decision behind the choice for or against a particular coaching approach is crucial. Collectively, this shift in focus involves asking what works best, for whom, under which conditions, and why.

Beyond further intervention research that addresses these aims, qualitative explorations hold complementary value in developing a context-specific understanding of how coaching strategies can support player learning in TDEs (see also Pietzonka & Hohmann, 2020; Price et al., 2020). In particular, such studies can deepen the understanding of why experts perceive certain coaching strategies as effective and how they can be effectively combined in specific contexts. The findings of Study 2 generally support many of the quantitative results, for example, the central importance of a game-centered philosophy

in soccer TDEs. At the same time, the findings emphasize the need to address specific learning goals, as this facilitates purposeful player observation and enables more targeted coaching interventions. A shared implication across studies is therefore the importance of designing practice activities with high specificity, while also adapting them to effectively target specific learning outcomes in players.

Besides this overarching implication, the findings also suggest that practice activities with lower specificity can make a valuable contribution to target distinct learning outcomes. The experts in Study 2 noted several opportunities to reduce the complexity of practice activities while still maintaining motor and cognitive demands (e.g., 2v1 waves practices). Nevertheless, the experts also emphasize the value of drill-based practices in fostering technical skills. This is supported by intervention research showing that drill-based (enrichment) training programs can lead to considerable performance improvements in isolated motor tests ($Mdn(d) = 0.73$). Such practices may be particularly relevant for developing complex technical skills or those that are more difficult to address with sufficient repetition in game-representative situations. As one example, dribbling skills often showed smaller intervention effects in some studies compared to passing skills (e.g., Práxedes et al., 2016). One possible explanation is that passing can be more easily addressed in SGGs (e.g., through numerical superiority), whereas dribbling is less easily elicited in these game-representative settings. This concerns not only the availability of appropriate tools to stimulate specific technical skills during gameplay, but also to players' ability to recognize situations in which complex skills can be applied. Especially for players with lower skill levels, such opportunities may not even be perceived, thereby limiting the potential for skill development in game settings (for a discussion see Study 2).

Consistent with the qualitative study by Gearing and Bridge (2024) in a YA setting, the use of drill-based practice activities was accompanied by the caveat that such activities should be used sparingly and designed according to specific design principles. In particular, the experts in Study 2 recommended inducing within-skill variability across repetitions, for example, by practicing technical skills in movement and designing practice activities that offer a considerable level of challenge. Nonetheless, there are no experimental studies that have investigated the effects of such low-complexity practice activities on actual game performance. This also applies to research comparing drill-based *DL* with low-variability approaches. While existing evidence suggests greater effectiveness of *DL* compared to constant practice activities for sport-specific skill acquisition and long-term learning in motor tests (Tassinon et al., 2021), the current evidence base provides limited guidance on the optimal amount of variability and how it should be progressively increased over time.

Finally, the applied initiative *Practice Philosophy Germany* (DFB, 2023; Wolf, 2024) has gained increasing attention in recent years. Given its aim to provide actionable guidance for practice design and coaching within the *DFB Talent Development Program*, it is particularly relevant to reflect on this initiative in light of the findings presented. According to this initiative, training sessions are structured according to a 15-30-15-30 format (DFB, 2024c, pp. 4-5). The initial 15-minute block consists of a warm-up with soccer-specific coordination tasks. This is followed by two 30-minute segments focusing on SSGs, which are designed using specific constraints such as numerical superiority or inferiority, floating players, additional rules, or variable pitch dimensions. Between these phases, a 15-minute block is allocated to isolated technical drills.

Several practitioners who participated in Study 3 emphasized that the CEP provides a meaningful scientific foundation for the *Practice Philosophy Germany*. This is further supported by the close alignment between many of the coaching recommendations proposed in the CEP and the core principles of the initiative. A clear area of alignment is the strong emphasis on SSGs, which are designed to inherently elicit desired player actions. The initiative also endorses the use of technically focused drills for short durations, clearly subordinated to the SSG-based core components. A potential point of divergence lies in the focus of these technical drills. While the findings of Study 2 highlight the importance of targeting specific learning outcomes throughout the entire session, *Practice Philosophy Germany* suggests that drills do not necessarily align with the skill demands of the SSGs. Furthermore, the role of specific coaching behaviors to guide learning – beyond initiating practice activities and motivating players (DFB, 2024c, p. 18) – remains vague. At its core, the initiative places particular emphasis on players' implicit learning during gameplay and resulting effects on incidental decision-making. The relevance of such implicit learning is clearly supported by the Studies 1 and 2. These studies also demonstrate that coaching behaviors aimed at facilitating intentional decision-making (e.g., through guided reflection on tactical principles) can meaningfully contribute to learning. Accordingly, the presented findings may serve as a scientific foundation for specifying how such coaching interventions can be linked to the practice design principles suggested by the initiative. This also applies to the alignment with the recommendation to target specific learning goals (see Study 2), which has already been addressed by linking practical session examples from the *Practice Philosophy Germany* to the learning goals addressed at DFB BCs (DFB, 2024c).

To summarize, various practice and coaching approaches were identified as potential contributors to the development of motor and cognitive attributes that underpin youth action competence in soccer. In addition to identifying strategies that may effectively support player learning, these findings have been translated into distinct guiding principles for coaching practice, as outlined in the research-informed CEP. Beyond enhancing the understanding of the effectiveness of these strategies, it is important to establish connections to theoretical perspectives on learning. Such theoretically grounded interpretation becomes particularly relevant when the goal is to enable the differentiated application of these strategies within soccer TDEs. In this way, it can support a nuanced understanding of why certain approaches are effective for specific learning outcomes.

4.2 Interpreting Coaching Strategies in Light of Learning Theories

A more comprehensive understanding of effective learning support in soccer TDEs benefits from insights into the underlying mechanisms of coaching strategies. Such insights can be informed by theories of motor control and learning, as well as classical learning theories. Developing explanatory frameworks grounded in selected theories represents as a scientific response to the ‘Why-question’ (cf. Krug et al., 2023, p. 987) – that is, the endeavor to explain why these coaching strategies contribute to learning within particular coaching contexts. Moreover, establishing connections between findings from basic scientific research (e.g., learning paradigms) and field-based studies on the contribution of coaching strategies can respond to the call for interdisciplinarity through theoretical integration (Willimczik, 2003; in press). Yet, explaining learning processes in sport is inherently complex, as reflected in the coexistence of multiple, and sometimes competing, theoretical perspectives (Hallé Petiot et al., 2021; Roberts & Potrac, 2014; Schiebl, 2007;

Schöllhorn et al., 2022; Whittall et al., 2020a; Willimczik, 2021). As demonstrated in *Chapter 4.1*, the development of action competence in soccer can be supported by a variety of coaching strategies. Accordingly, the contribution of this broad array of strategies is likely best understood through the lens of different theoretical perspectives (e.g., Bobrownicki et al., 2023; Harvey & Cope, 2025; Kearney et al., 2024).

Across all studies presented, the research context was kept constant, enabling a focused investigation into the explanatory power of distinct theoretical concepts within soccer TDEs. To support the development of explanatory frameworks for the contribution of coaching strategies, Study 1 aimed to analyze the theoretical underpinnings of the intervention studies. In addition, Study 2 sought to establish links between coaching strategies recommended by experts and different learning theories. This work laid the foundation for one of the central aims of the research-informed CEP: to facilitate coaches' understanding how and why certain coaching strategies can be effective. The underlying assumption was that, beyond offering actionable coaching recommendations, fostering a theoretical understanding of their underlying mechanisms would enable coaches to apply these strategies more purposefully and with greater differentiation.

Regarding the available intervention research, approximately 50% of the interventions were not explicitly designed based on theory, while the other half focused on established theory-driven coaching approaches (e.g., *DL*; *NLP*; *TGfU*). This finding reflects a common feature of research on coaching and learning in sport: the existence of different starting points for intervention development (see also Willimczik, 2003). On the one hand, some interventions emerge from applied settings and are grounded in the experiences of practitioners. Their effectiveness is often assumed based on observed success in practice. This aligns with Höner's (cf. 2008, p. 20) argument for field-based research, which aims

to understand the mechanisms behind strategies already considered effective in real-world contexts. On the other hand, some interventions are explicitly derived from theoretically grounded coaching approaches that inform both practice design and coaching behavior. These interventions aim to investigate the effectiveness of these approaches in youth soccer, thereby testing the theoretical assumptions in this specific context.

The analysis of theory-based intervention studies reveals that direct comparisons between interventions designed according to dynamical systems theory (or the ecological dynamics framework) and those based on information-processing theory are rare (for exceptions, e.g., Schöllhorn et al., 2012; Roberts et al., 2020). In many studies, strategies associated with the information-processing perspective are used as control conditions but are not explicitly linked to this theoretical paradigm. Instead, such strategies are often described using vague and imprecise terms like ‘traditional approaches’ (e.g., Gaspar et al., 2019). A further notable finding was that central concepts derived from an information-processing viewpoint – such as variability-of-practice (e.g., van Merriënboer, 2012) – have neither been considered in the intervention design, nor are they addressed in the discussion. As such, potential compatibilities between information-processing and self-organization approaches at the level of derived practical coaching implications are often overlooked (e.g., the role of variability in the development of technical skills; see also Anson et al., 2005). Moreover, this body of work rarely considers classical learning theories, despite that fact that many coaching approaches are commonly associated with respective paradigms (e.g., *TGfU* and social-constructivism; Harvey et al., 2018). This omission further limits the theoretical explanation of how various interventions lead to acquisition and learning effects in youth soccer players.

Theoretically grounded approaches *TGfU*, *NLP*, and *DL* have each demonstrated effectiveness in club-level soccer, despite being (partially) grounded in distinct theoretical foundations. While all three approaches share a common emphasis on developing players' competence to solve game situations (i.e., guided by a functional understanding), they differ in how they conceptualize cognitive engagement and the construction of knowledge throughout the learning process. In contrast to *TGfU*, both *DL* and *NLP* suggests that effective (motor) learning can occur without cognitive 'processing' (Button et al., 2021; Chow, 2013; Renshaw et al., 2019). *TGfU* emphasizes the development of learners' explicit tactical understanding as a basis for solving game situations. This perspective aligns with Roth's (1989) differentiation between the decision for a particular GMP in a given game situation ('*what-decision*') and the execution of the movement through an appropriate program variant ('*how-decision*'; see also Höner, 2000; Memmert & König, 2020). While this argumentation was grounded by Schmidt's (1975) schema theory, *TGfU*'s dual emphasis on developing cognitive understanding alongside motor skill execution also justifies its associations with classical learning theories (Harvey & Cope, 2025; Harvey et al., 2018). In line with principles from *TGfU*, the experts' in Study 2 argued that selective reflection on appropriate game solutions is essential to facilitate players' intentional decision-making (i.e., '*what-decision*'). At the same time, they acknowledged the particular value of self-organized, implicit learning in the development of technical skills (i.e., '*how-decision*'). With regard to technical skills, the experts' argumentation revealed stronger associations with self-organization approaches. These approaches share a core assumption that appears to stand in contrast to *TGfU*; player learning does not require an explicit understanding of what to do and how to do it, but instead emerges through decentralized self-organization processes (e.g., Button et al., 2021; Chow, 2013).

Despite these differences at the theoretical level, a detailed analysis of the intervention design in Study 1 shows similarities in the practical application of *NLP* and *TGfU*. This suggests that distinct theoretical foundations can lead to comparable practical coaching strategies. Specifically, the heart of interventions following these approaches were purposefully modified SSGs to align with specific session objectives (e.g., Práxedes et al., 2018; Sierra-Rios et al., 2020). In some *TGfU* studies, technically focused drills were integrated between modified games (e.g., Barquero Ruiz et al., 2021). In line with the focus on the development of game understanding, all *TGfU* interventions further included guided reflection phases on key principles of play. As a result, explicit learning was a central feature of these interventions. While the practice designs in *NLP* interventions were similar in structure, they predominantly emphasized implicit, self-organized learning. This is based on the assumption that functional movement solutions emerge through the interaction between the learner and the environment (cf. Renshaw et al., 2016, p. 469). Thus, the primary learning outcomes targeted by each approach represent defining characteristics of their pedagogical intent and encourages for different coaching behaviors.

DL represents a distinct case within this broader category of ‘self-organization approaches’. Grounded in dynamical systems theory (e.g., Kelso, 1995), *DL* interventions differ notably from *TGfU* and *NLP*. This distinction is particularly evident in the aim of *DL* to induce stochastic perturbations through a) the chosen practice activity and b) inherent variations in the learner’s movement patterns (cf. Schöllhorn et al., 2022, p. 16). The theoretical foundations posits that learning results from the system’s continuous adaptations to changing conditions (cf. Schöllhorn, 1999, p. 9). The implementation of *DL* has varied across the reviewed studies, particularly with regard to varying levels of complexity in practice activities. For example, *DL* was applied with a focus on inducing additional

movement variability ('noise') within low-complexity practice activities, targeting technical skill development exclusively (i.e., motor competence area; Bozkurt, 2018; Schöllhorn et al., 2006; 2012). Other studies implemented *DL* in game-based contexts to enhance players' creativity (i.e., cognitive competence area; Coutinho et al., 2018; Santos et al., 2018). While originally illustrated with examples from track and field (Schöllhorn, 1999), this pattern of result suggests a potentially expanding scope for *DL* applications. Yet, two fundamental challenges remain unresolved in the context of soccer coaching: 1) determining the optimal degree of variability as induced by the practice activity for maximum effectiveness, and 2) clarifying whether variability should aim for fully individualized movement solutions for technical skills or guidance toward (partially) predefined movement patterns that mark the functionality of a technical skill (for a discussion see also Gray, 2020, pp. 7-8).

A general observation in the research field is that studies examining the same theoretically grounded coaching approach often exhibit considerable inconsistency in how interventions are implemented. Beyond differences in the practice design, as illustrated by *DL*, this was particularly evident in the implications drawn for coaches' behaviour. For example, Práxedes et al. (cf. 2019, p. 333) evaluated the effectiveness of *NLP* in which coaches were instructed to avoid any explicit verbal instruction. In contrast, Roberts et al. (cf. 2020, p. 1462) examined *NLP* and coaches aimed to minimize instruction and guide learning through the manipulation of task constraints, but verbal instructions focused on technical execution still represented the most frequent coaching behavior. These differences highlight inconsistencies in how the same approach is applied in practice and reinforce criticisms concerning the inconsistent use of terminology within the

ecological dynamics framework and their implications for coaching practice (Bobrow-
icki et al., 2023; Collins et al., 2025; Kennedy & O'Brien, 2024).

In contributing to the research field, a central question is whether theoretically grounded coaching approaches yield conflicting or complementary practical implications for coaching practice. In addressing this question, Study 2 highlighted important distinctions in the explanatory power of different approaches concerning the development of technical and tactical skills. With regard to *technical skills*, the experts' views largely aligned with a self-organization perspective, emphasizing the individuality of movement patterns and the role of exploratory processes in discovering functionally effective solutions (But-
ton et al., 2021; Renshaw et al., 2019). At the same time, many experts also expressed a belief in the existence of (more or less) consistent functional movement patterns in technical skill execution. This view partly reflects the concept of movement invariant features associated with an information-processing perspective (Schmidt, 1975; Schmidt et al., 2019). The coexistence of these perspectives among practitioners is just one of many findings that indicate both self-organization and information-processing theories continue to offer explanatory value in applied coaching contexts and supported their consideration when designing the research-informed CEP presented in Study 3.

Regarding the development of *tactical skills*, the findings contribute to the ongoing debate in the coaching literature surrounding constructivist-informed approaches (e.g., Cope & Cushion, 2020; Harvey et al., 2018). The results underscore the value of coaching strategies often associated with this paradigm, suggesting that guided reflection can support the construction of functional knowledge structures that enhance intentional decision-making. Specifically, the findings highlight the benefits of encouraging players to reflect on different decision-making options during gameplay (Almond, 2015; Bunker &

Thorpe, 1982; Grehaigne et al., 2005; Mitchell et al., 2013). At the same time, they also underscore the importance of implicit learning through game experiences, which facilitates more intuitive decision-making in the game. Taken together, these results emphasize the necessity of differentiating not only between technical and tactical skill learning, but also between distinct outcomes within motor and cognitive competence areas. Furthermore, the findings illustrate the explanatory power of different theoretical perspectives in understanding the underlying mechanisms of coaching approaches.

These findings contribute to a better understanding of the distinct benefits offered by established coaching approaches in soccer TDEs, even when these approaches are grounded in different theoretical paradigms. Yet, an ongoing debate remains unresolved concerning the extent to which these approaches are genuinely aligned with specific learning theories. An example is direct instruction, a strategy identified by experts in Study 2 as beneficial when used purposefully, yet often dismissed in academic coaching literature. Cope and Cushion (2020, p. 1) critically reflect on this debates:

As the prominence of constructivist approaches has grown, a ‘turf war’ is occurring in relation to instructional approaches. Commonly, coaching approaches labelled as direct instruction are disparaged or dismissed [...] Significantly, constructivist-informed and direct instruction approaches are poorly conceptualised in the coaching literature, and it is often unclear what is being described.

These theoretical debates in the coaching literature closely resemble discussions in general education research. For example, Hattie (2009, pp. 204-205) makes a similar point like Cope and Cushion (2020) with a reflection on the perceived (in)compatibility of constructivist teaching and direct instruction:

Every year I present lectures to teacher education students and find that they are already indoctrinated with the mantra ‘constructivism good, direct instruction bad’. When I show them the results of these meta-analyses [suggesting the effectiveness of direct instruction for learning], they are stunned, and they often become angry at having been given an agreed set of truths and commandments against direct instruction. [...]. Direct Instruction has a bad name for the wrong reasons [...].

The debate surrounding direct instruction serves as just one example that highlights a broader implication: the need to critically examine the contributions of various coaching strategies and the explanatory potential of different theoretical perspectives, rather than pursuing a ‘one-size-fits-all’ approach to understanding learning outcomes across diverse domains (Kennedy & O’Brien, 2024; Koester, 2023). From an applied coaching perspective, the focus should shift toward leveraging the insights each theory provides into learning and coaching, rather than only concentrating on their respective limitations.

Taken together, the findings highlight the value of considering different theoretical perspectives to better understand the mechanisms underpinning player learning in soccer TDEs. The fact that no single theory can fully explain all facets of learning, should not be viewed as a falsification of any particular perspective, but rather as a reflection of the inherent limitations each theory entails for specific purposes (cf. Nitsch & Munzert, 1997, p. 140). These insights also had practical implications for the design of the research-informed CEP. Rather than providing a prescriptive, ‘recipe-like’ set of coaching strategies, the CEP was developed to combine practical recommendations with theoretical justifications drawn from different perspectives. The consideration of different paradigms – while emphasizing their incommensurabilities – is justified by the distinct explanatory value each offers for understanding learning processes (Koester, 2023). The CEP evaluation in Study 3 demonstrated that practitioners’ appreciated this contrastive theoretical framing and supported its relevance for applied work. Moreover, the evaluation revealed that coaches within the *DFB Talent Development Program* differ in how closely their practices align with information-processing and self-organization paradigms. Therefore, cultivating a broad understanding of multiple theoretical perspectives can serve as a valua-

ble resource for strengthening coaches' professional knowledge. In combination with inter- and intrapersonal knowledge, such scientifically-informed understanding can build a core foundation of coaching competence (Côté & Gilbert, 2009; Sygusch et al., 2022).

4.3 Opportunities and Limitations of Assessments to Support Player Learning

An essential foundation for effective learning support is a detailed understanding of relevant talent predictors that should be fostered during specific phases of development. As synthesized in *Chapter 3.4.4*, the available evidence is pooled by literature reviews of prospective studies (Murr et al., 2018a; 2018b; Verbeek et al., 2023; Williams et al., 2020) and is further expanded within Studies 4 and 5 for female players and GKs. Another foundation for coaches work is a detailed understanding of each individual's skill and competence levels to tailor the practice design and coaching interventions accordingly (Ford & Coughlan, 2020). However, findings across Research Foci I and II highlight persistent challenges in this process. Specifically, Studies 4 and 5 demonstrate notable multicollinearity among coach ratings across different competence areas, limiting opportunities to derive nuanced implications for coaching practice. Widely in line with these results, many coaches interviewed in Study 3 described difficulties in accurately identifying individual learning needs and in translating this information into tailored strategies for practice design and coaching behavior (see also Schreiner et al., 2018). In soccer TDEs, these challenges may be amplified by the broad range of relevant performance factors which can lead to highly diverse learning needs within the same training group (Williams & Hodges, 2023). Furthermore, the overall high skill level of the players in TDEs demands that coaches are able to detect and respond to subtle performance nuances.

The importance of analyzing a learner's strengths and weaknesses as a basis for tailored support is not unique to soccer TDEs; rather, it represents a fundamental responsibility of instructors in any educational context to adapt their support accordingly. As a result, this broader topic is discussed in the educational literature under the concept of *diagnostic competencies*. This concept not only relates to the collection of learner-related information but also to its interpretation and translation into instructional strategies (Klug et al., 2013; Reuker & Künzell, 2021; Reuker & Schicklinski, 2024). In soccer TDEs, a promising opportunity to support coaches in navigating this complex process lies in the use of systematic assessments of relevant talent predictors. This aligns with the concept of *learning-oriented assessment*, which aims to provide practitioners with meaningful information about a player's skill and competence levels (Carless, 2007; Zeng et al., 2018). When this information is used to differentiate and individualize learning support (i.e., formative assessment), it reflects the principles of *assessments for learning*.

Although the use of assessments in soccer TDEs is well established, their role has primarily been discussed in the context of talent identification and selection (for reviews Murr et al., 2018a, 2018b; Williams et al., 2020). Existing research, along with findings from this dissertation, indicates that these assessments demonstrate sufficient predictive validity to support practitioners' decision-making. While predictive validity is also essential for justifying their use as formative assessments, their specific potential to function as assessments for learning remains underexplored. This gap is also evident in recent systematic reviews on talent development, which do not explicitly address this topic (Dunn et al., 2024; Verbeek et al., 2023). The limited body of research on this topic, combined with findings from Research Focus I indicating the promising potential of formative assessments to address challenges perceived by coaches, provides a strong rationale

for emphasizing this issue within the scope of this dissertation. This particularly relates to insights into the potential of objective and subjective assessments to provide coaches with distinct, yet complementary insights that can inform talent development practices.

With regard to assessment characteristics, there is an ongoing debate about whether the focus should lie on individual predictors or on adopting a holistic view of a player's talent (Charbonnet & Conzelmann, 2023). When the goal is to inform and guide developmental support as *assessment for learning*, a detailed analysis of individual predictors is indispensable. Such analysis of specific predictors enables nuanced insights that can be translated into individualized learning support (Zeng et al., 2018). A comprehensive view of the strengths and limitations of both objective and subjective assessments used in the *DFB Talent Development Program* emerges through multivariate evaluations in Studies 4, 5, and earlier evaluations by Höner et al. (2021). The coach ratings demonstrated limited incremental validity across studies, even when scores were calculated from individual items to represent distinct motor, cognitive, and psychosocial competence areas. This is in line with conclusions drawn in a recent literature review summarizing the strengths and weaknesses of subjective assessments in TDEs (Barracough et al., 2022). Consequently, the findings indicate that the coach ratings currently offer only limited potential for deriving actionable implications for coaches' learning support.

Regarding the position-independent motor tests, partially different results were found. While some intercorrelations were observed across individual tests, they were less pronounced and consistent with the test battery's theoretically grounded factorial structure (Höner et al., 2015). These findings reinforce the advantages of this objective test battery for evaluating distinct predictors and underscore its potential value when integrated into practical coaching contexts (Höner et al., 2020). The identified benefits of motor tests are

also consistent with findings from other studies conducted in TDEs (e.g., Dugdale et al., 2020). At the same time, findings in Studies 6 and 7 on the novel GK-specific motor coordination test battery revealed considerable measurement error as intensively discussed in *Chapter 3.3.4*. This illustrates that the practical applicability of test results to inform coaches' learning support should not be seen solely as a function of the objective assessment method itself. Rather, it depends on the talent predictors being assessed and their underlying constructs (e.g., individual skills or motor abilities), the presence of sufficient psychometric properties, and the way in which results are reported, for example, at the level of overall scores versus individual items.

Furthermore, another perspective that influences the meaningful interpretation and application of test results is the extent to which they can actually capture (elements of) action competence in soccer. This also relates to the representativeness of assessments used which was often found to be low in previous research (Bergkamp et al., 2019). For example, isolated motor tests offer limited insight into how individuals apply technical skills to solve game situations (for a discussion on 'technique' versus 'skill', see Ali, 2011). While numerous isolated motor tests exist, there remains a notable lack of assessment tools for attributes within the cognitive competence area (for a review Zhang et al., 2025).²¹ This gap is also evident in intervention research, where cognitive outcomes (e.g., decision-making) are often assessed through systematic game observations as discussed in Study 1. Although such observational methods offer high representativeness, they often lack practical feasibility for large-scale implementation in TDEs. Furthermore, both motor and cognitive outcomes derived from these assessments are influenced by

²¹ A more detailed discussion of the assessments of cognitive performance factors can be found in the dissertation by Reinhard (2025).

each other, by additional characteristics (e.g., motor abilities), and by external factors (e.g., teammates). These interdependencies complicate the detailed interpretation of assessment results and limit the precision with which they can be used to practice.

In the pursuit of assessing talent predictors across different competence areas, a major challenge lies in identifying suitable assessment tools that efficiently evaluate these predictors. A promising approach involves combining different assessments taking into account their respective strengths and weaknesses at the psychometric level, design features, and practical feasibility for large-scale implementation in TDEs. Given the limitations of isolated motor tests and the scarcity of practically feasible instruments to evaluate cognitive performance factors, the *DFB Talent Development Program* introduced the coach ratings that cover multiple competence areas (DFB, 2022b). As such, this implementation can be viewed as both a pragmatic response to the challenge of designing practically feasible assessments and as an effort to systematically capture how skills are applied in the dynamic and interactive context of the game.

To move forward, it is essential to develop targeted strategies that enhance the practical value of the instruments used within the *DFB Talent Development Program* as assessment for learning. Across studies within Research Focus I, several approaches to improving the objective and subjective methods have been discussed. Therefore, particular attention is given to the subjective coach ratings, as they were implemented with the aim of further contributing to tailored learning support. The desired effects of the coach ratings for talent development can relate to improvements in coaches' observation and evaluation of their players which, in turn, might lead to more individualized learning support. Further positive effects could result from the intentional use of individual test results in coaching practice (e.g., defining individual development goals; Höner et al.,

2020). Respective opportunities would be reinforced by further educating coaches on the underlying constructs of the assessed competencies. This involves strengthening coaches' understanding of how competence areas are operationalized in practice, for example, how they manifest in observable player behaviour during practice (for specific examples see the detailed test manual; DFB, 2022b). Additionally, raising coaches' awareness of potential biases in their evaluations is essential (e.g., halo effects), which might be even more pronounced when evaluating underrepresented target groups within soccer TDEs (e.g., male vs. female players; different positions of play).

Another promising area for improvement involves directly addressing the challenges reported by practitioners in Study 3. These include the lack of effective observational strategies, along with the design of specific game-representative situations suitable to target specific learning outcomes (see also Kinnerk et al., 2018; O'Connor et al., 2021b; Schreiner et al., 2018). One approach could be to provide practical guidance through SSGs that are specifically designed to both fostering and evaluating particular competencies. This alignment is not only essential for improving the coach ratings themselves, but also serves as a crucial foundation for tailored developmental support for players as, for example, proposed by the PACE-model (Dugandzic, 2023). One concrete strategy for advancing assessment practices involves linking purposefully designed SSGs, as presented within the *Practice Philosophy Germany* (DFB, 2024c; Wolf, 2024), to competency-based outcomes defined for evaluation purposes (DFB, 2022b; DFB, 2025). Establishing connections between SSGs and items that capture specific competencies may offer a promising path forward, one that aligns with the concept of *game-test situations* (Memmert, 2010, 2015).

Figure 26 illustrates a concrete example of how constrained SSGs can be used to systematically observe and evaluate competencies within the motor and cognitive competence areas. The items are presented separately for outfield players and GKs, although the proposed SSG offers an appropriate basis for evaluating both positional groups. As such, the SSG ensures frequent involvement of both GKs and outfielders in game-representative situations offering detailed insights into to be evaluated competencies. Consequently, this game-based test situation provides a practically feasible example of how to address the call for action- and situation-specific assessment practices within representative game-environments.

Another important aspect of subjective assessments is the use of a Likert scale (for a discussion Barraclough et al., 2022). This four-point scale is based on reference levels defined within the *DFB Talent Development Program* and includes categories such as *below average*, *average BC level*, and levels corresponding to the *extended* or *core regional association squads* (DFB, 2022b). However, these reference points are subject to annual variation due to the pyramid-like educational structure of German youth soccer (DFB, 2009; see also *Chapter 1.1*). As a result, even if a player demonstrates improvement over the course of a year, they may still be classified within the same *average* category because the overall level of the cohort has risen, resulting in fewer players being placed in the lower categories. That is, the scale serves as a standardized tool for inter-individual comparison, particularly in relation to relevant selection levels along the German talent pathway. While it was designed to offer a nationwide, comparable, and easy-to-interpret assessment tool, it also presents clear limitations when used to monitor intra-individual progress over time (i.e., ‘Evaluation’; Dugandzic, 2023; Ford & Coughlan, 2020).

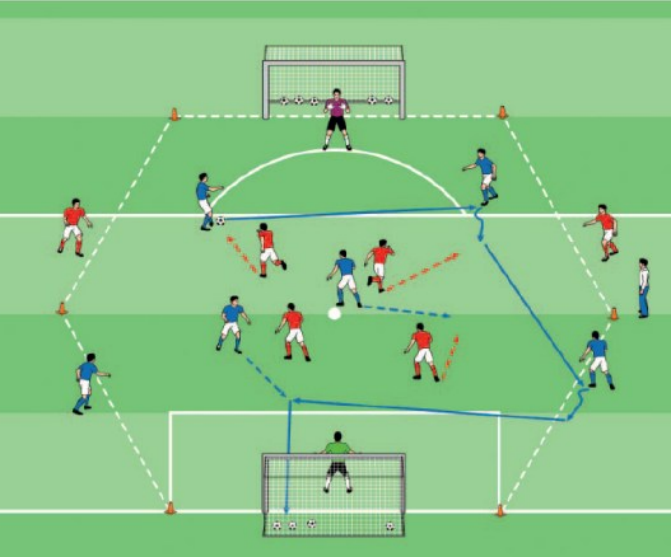
 Organization: • field size: 20x30m. in diamond shape • 2 teams of 6 players + GKs • 2 players of each team positioned diagonally Process: • Scoring is possible with or without involving diagonal players • diagonal players rotate after a set time • Variation: diagonal players are allowed to dribble into the field	Exemplary competency-based coach ratings for outfield players Kicking Skills (separately rated for the dominant and non-dominant foot) BC players can pass/shoot balls at a speed that is appropriate for the situation (e.g. firm passes, but also ability to differentiate when playing). Tactical Skills <i>during</i> ball-related actions BC players can orientate themselves while they are on the ball: e.g. glance away from the ball, see the next playing position. ... decide appropriately: e.g. pass the ball to a teammate, dribble with the ball, shoot the ball at the goal (note: this requires that diagonal players are allowed to dribble and shoot). Exemplary competency-based coach ratings for GKs GK-specific Technical Skills BC GKs can get into a ready position: e.g. feet slightly wider than hip width apart, knees slightly bent, body weight shifted to the balls of the feet, arms bent, palms of the hands facing each other, high body tension, eyes focusing on the ball. GK-Specific Tactical Skills BC GKs can act correctly with passes into the box: e.g. assess whether they can intercept the pass or reposition themselves according to the anticipated follow-up action.

Figure 26. Exemplary connection of an SSG proposed by *Practice Philosophy Germany* (DFB, 2024c, p. 32), allowing for detailed observation and evaluation of selected competencies assessed through subjective coach ratings (for details see DFB, 2022b and Höner et al., 2021).

Finally, another relevant perspective in the context of learning-oriented assessments concerns their potential to promote learning through the assessment process itself – a concept commonly referred to as *assessment as learning* (Carless, 2007). While Studies 6 and 7 on the novel GK-specific assessment examine short-time performance improvement through repeated participation, these improvements are attributable to familiarization with the test design rather than genuine learning effects. Consequently, the studies included in this dissertation did not explicitly address effects related to assessments as learning, but potential contributions may be inferred based on specific characteristics of the assessment approaches. While direct learning effects of position-independent objective motor tests remain unclear, the immediate, accessible, and easy-to-understand test results provided after each trial is likely to foster players' self-reflection and engagement with their own strengths and weaknesses (i.e., indirect effects on learning; for a discussion Murphy et al., 2023). In contrast to discrete occasions when the motor test battery is applied, subjective coach ratings are based on continuous observation during regular training sessions. As such, players' participation in these assessments occurs automatically through their routine involvement in practice, requiring no additional effort. Unlike objective tests, this form of subjective evaluations typically do not provide players with immediate feedback which may limit effects on learning.

Educational research from other domains highlights the benefits of actively involving learners in self-assessment processes as engagement with reference criteria, performance standards, and structured reflection has been shown to positively influence self-directed learning (Carless, 2007; Murphy et al., 2023). In the *DFB Talent Development Program*, these advantages may become increasingly relevant with the introduction of a structured self-evaluation process of all players in the 2023/2024 season. This process

mirrors the coaches' subjective evaluations and presents promising opportunities for future research. The alignment between coach ratings and players' self-evaluation could provide additional insights. Moreover, in light of the reference group effects in coaches' ratings (see Studies 4 and 5) further research should examine the extent to which both coach and player ratings are shaped by the overall performance level at the BC. This performance level could be estimated based on motor test results, such as the percentile rank of the BC.

To summarize, this dissertation has contributed to a deeper understanding of the strengths and limitations of various assessment methods regarding their use as learning-oriented assessments. In particular, the position-independent objective motor tests designed to evaluate distinct predictors were found to offer valuable information that can support coaches in individualizing their learning support. Respective opportunities of the novel GK-specific motor tests are limited, but may be increased as far as modifications can further reduce the measurement error in the test results. Subjective coach ratings, in principle, offer specific advantages, especially in capturing competencies as they emerge in the dynamic game environment. Yet, their contribution as learning-oriented assessment depends on a more differentiated evaluation of predictors associated with distinct competence areas. These findings underscore the importance of further educating and supporting coaches in the effective application of assessment practices. Moreover, the actual contribution of any assessment depends on coaches' competencies to understand and interpret the test results which form the basis for translating them into effective coaching. Therefore, it is crucial to strengthen the integration of assessment-derived information with coaching strategies that have been identified as effective in fostering specific performance factors underpinning action competence in soccer.

4.4 The Foundational Role of the Broader Talent Development Environment

The preceding chapters have focused on learning-supportive coaching and learning-oriented assessment as two core elements of soccer TDEs, aimed at facilitating talent development. However, the extent to which these measures can be successfully implemented and reach their full potential is likely influenced by broader characteristics of the TDE itself. This influence is reflected in the *DMGT* (Gagné, 2021), which emphasized the moderating role of various environmental factors in competence acquisition (see also Preckel et al., 2020). Yet, due to their heuristic nature, the *DMGT* and similar models do not offer specific insights into which environmental factors are most influential in a specific context (e.g., soccer TDEs), nor do they explain the precise mechanisms through which these factors affect the talent development process.

More specific insights into the influence of broader TDE characteristics come from extensive research examining their role in elite youth sport, which has identified a range of both functional and dysfunctional features (for a review, see Hauser et al., 2022).²² Many of these environmental factors also shape the overall learning climate, encompassing the social, emotional, and physical conditions under which competence acquisition takes place (Seif et al., 2012). While a wide range of perspectives is considered in the scientific discourse on soccer TDEs (e.g., within the “TOR Project”; Wachsmuth et al., 2020), this chapter focuses on three closely interrelated factors that are particularly relevant in the context of the proposed coaching recommendations: *psychological safety*, the *motivational climate*, and the *coach-player relationship*. These perspectives have also been addressed in previous work within the *Scientific Support of the DFB Talent Development*

²² A more detailed discussion of the role of the TDE in elite youth sport can be found in the dissertation by Hauser (2025).

Program (e.g., Raabe et al., 2020), thereby enabling connections that may contribute to research-informed coach education in this specific context. A closer examination of these environmental factors in light of the findings presented in this dissertation remains essential, as they (a) demand active engagement from stakeholders within TDEs and (b) warrant greater attention in future research on coaches' learning support in youth soccer. Findings reported in Studies 1 and 2, along with existing research, underscore the contribution of promoting self-organized and implicit player learning in challenging situations (Clemente et al., 2021b; Tassignon et al., 2021). The extent to which players engage with these challenges and seek out personally demanding solutions is likely shaped by the overall learning climate which must be actively cultivated by coaches (cf. Renshaw et al., 2012, p. 91). A key aspect of creating an environment that encourages players to take risks during practice is the promotion of *psychological safety*. This concept refers to a climate in which individuals feel safe to take risks without fearing negative consequences and where mistakes are recognized as a common part of the learning process (for a review, see Vella et al., 2024). Coaches aiming to support player learning should therefore strive to create "a culture where athletes feel comfortable exposing their weaknesses, performing under novel conditions where successes are not guaranteed, and engaging in practice conditions that are challenging" (Hodges & Lohse, 2022, p. 759).

Vella et al. (2024) identify several antecedents of psychological safety in sport, including organizational cultures characterized by clearly defined roles, structured environments, and predictable program designs. However, addressing these characteristics within TDEs presents a complex challenge for practitioners, as learning occurs in systems that simultaneously exert pressure on players through ongoing selection and deselection pro-

cesses (Ford et al., 2020; Williams et al., 2020). Consequently, practitioners must navigate these potentially competing demands by intentionally creating a culture in which players feel sufficiently safe to engage in personally demanding learning situations.

One structural feature of the *DFB Talent Development Program* is the absence of regular competitive matches between BCs, which enables coaches to fully concentrate on creating a ‘practice-to-learn’ environment (DFB, 2022a; Kelly et al., 2024). Moreover, the PACE-model illustrates the program’s emphasis on individualized learning support by assigning specific coaches to individual players, thereby optimizing coach-player matching (see *Chapter 1.1*; Dugandzic, 2023). In addition to enhancing developmental outcomes through more tailored learning support, this approach may also help strengthen positive interpersonal relationships between players and coaches, an important factor in fostering a psychologically safe climate (Vella et al., 2024). These examples reflect the awareness of the importance of encouraging players’ risk-taking for learning and illustrate context-specific initiatives that might contribute to a more psychologically safe climate. However, despite knowledge on the benefits of psychological safety on health, motivation, and long-term sport participation (Hauser et al., 2022), its specific role in supporting learning within soccer TDEs remains underexplored. Future research could therefore investigate if psychological safety moderates learning processes and identify the barriers coaches face when attempting to cultivate such an environment. These barriers are likely rooted in the inherent tension between fostering a safe and supportive learning climate while also managing ongoing performance evaluations and selection decisions.

Another relevant perspective relates to the *motivational climate* as a potential moderator of how learners respond to coaching interventions (Duda et al., 2014). Robinson (2023) conceptualizes the motivational climate as a latent construct reflecting learners’ shared

perceptions at the group level, while individual differences in these perceptions are referred to as ‘micro-climates’. Coaches play a central role in shaping athletes’ perceptions of the motivational climate through intentional motivational support. A key area extensively explored in the sport coaching literature is the promotion of intrinsic, self-determined motivation, which is widely regarded as a critical precondition for effective learning environments (for a review, see Raabe et al., 2019). This includes the use of various need-supportive coaching strategies (i.e., motivational support) aimed at enhancing athletes’ perceptions of autonomy, relatedness, and competence (Ryan & Deci, 2017).

Research on need-supportive coaching conducted within the *DFB Talent Development Program* (Raabe et al., 2020) reveals clear alignments with findings of Study 2 at the level of the coaching implications. One shared recommendation is the provision of optimally challenging tasks, which are not only essential for promoting learning but also for enhancing players’ perceived competence. To implement this effectively, coaches must tailor practice activities to provide individually appropriate levels of challenge for players within the same training group. To make these compatibilities more tangible for coaches, findings from this dissertation were explicitly linked to need-supportive coaching strategies (Raabe et al., 2020; Wachsmuth et al., 2022). One practical recommendation resulting from this integration was presented within the CEP on learning-supportive coaching under the title *Promoting Challenges and Enabling Experiences of Success* (see Figure 18 in Study 3). This recommendation was illustrated through practice activities designed to address specific learning goals while simultaneously enhancing players’ senses of autonomy and competence. A central feature of these activities was the opportunity for players to self-regulate the level of pressure imposed by the defender (e.g., by adjusting their distance), thereby calibrating the level of challenge when receiving the ball.

Another relevant perspective on the motivational climate concerns players' mastery- and ego-involved goal orientations (see Duda, 2004, for details on *Achievement Goal Theory*). Beyond dispositional tendencies, the extent to which an individual adopts mastery- or ego-oriented goals is also influenced by situational and task-specific cues offered within the learning environment, and can therefore be shaped by coaches (cf. *ibid*, 2004, p. 114). A mastery-oriented climate emphasizes individual progress, effort, and skill development, whereas an ego-oriented climate focuses on normative comparisons and competition (Harwood et al., 2015). While inter-individual performance comparison is inherent to TDEs, it remains essential to also cultivate a mastery climate, especially when the overarching aim is to support long-term development. Research conducted within soccer TDEs highlights the importance of implementing practice activities and coaching behaviors that promote a mastery-oriented climate, with the differentiation of learning goals identified as a key strategy (Gjesdal, 2025). This emphasis aligns with findings from Study 2 presenting a theme titled *differentiating overarching learning goals to address players' individual needs*. The importance of differentiation for both motivational and learning outcomes underlines the relevance of further developing coaches' competencies in identifying individual learning needs and responding with targeted coaching interventions.

The relevance of differentiating among players to facilitate both player learning and motivation has also implications for how assessments, discussed in the previous chapter, are utilized within TDEs. Fostering a mastery goal climate involves meaningful choice of performance metrics and the manner in which individual test results are communicated to players. Feedback should provide detailed insights into each player's strengths and areas for improvement, accompanied by personalized recommendations to guide future development (i.e., assessment for learning; Zeng et al., 2018). While comparisons with

peers (e.g., via percentile ranks) can provide useful benchmarks, it is essential that coaches also emphasize individual reference standards when delivering feedback. When players participate in repeated testing, longitudinal development profiles become particularly valuable for monitoring progress over time (Höner et al., 2020). Currently, this is especially feasible with the position-independent motor test battery used in the *DFB Talent Development Program* which enable reliable monitoring of individual development trajectories.

Finally, the *coach-player relationship* is widely recognized as a key factor in facilitating both psychological safety (Vella et al., 2024) and motivational support (Gjesdal, 2025) and constitutes a crucial determinant of coaching effectiveness (Jowett, 2017). A closer examination of the coach-player relationship in the context of learning support is therefore highly warranted, particularly as it likely represents a prerequisite for the successful implementation of coaching approaches identified as contributors to player development in Studies 1 and 2. This is especially relevant for approaches that emphasize meaningful interaction between coaches and players to enhance game understanding (Almond, 2015; Brinkschröder, 2020; Gréhaigne et al., 2005). Therefore, many of the experts interviewed in Study 2 described strong interpersonal relationships as a foundational requirement for coaching strategies that involve high levels of reflective exchange. More specifically, the experts emphasized the importance of players trust in the coach as a crucial foundation, an emphasis consistent with previous findings that identify trust as a mediating factor in coach-player interactions (Juan et al., 2021).

Considering the available research on the effectiveness of coaching approaches, a review of the literature on GBAs found that only two studies explicitly addressed the role of

the coach-player relationship (Kinnerk et al., 2018). Notably, in these studies, the relationship was conceptualized as an outcome rather than a prerequisite of approaches that rely on questioning strategies. While positive effects resulting from questioning-based methods on relationship quality were found, the experts interviewed in Study 2 instead emphasize the foundational role of strong interpersonal relationships in enabling the effective implementation of such strategies to support learning. This perspective – framing the relationship as a precondition or as part of a potentially reciprocal dynamic (Jowett, 2003) – has received little attention in previous research (for an exception, see Evans, 2013). Addressing this gap is particularly relevant given that observational studies in elite youth soccer have shown that coaches often face challenges in achieving sufficient depth in their guided reflection and rarely stimulate critical thinking among players (Cope et al., 2016). A deeper understanding of the conditions under which questioning strategies can be applied effectively in TDEs is therefore essential, with the quality of the coach-player relationship likely being one of several relevant factors.

Taken together, this chapter has discussed psychological safety, the motivational climate, and the coach-player relationship as factors that may influence how players' respond to learning support offered in TDEs. While these perspectives are widely acknowledged within the academic discourse on TDEs in sport, their more specific consideration in the context of fostering youth soccer players' action competence is highly warranted. Accordingly, this chapter has outlined clear associations with empirical findings on both learning-supportive coaching and learning-oriented assessment. These insights may provide valuable guidance for more systematically integrating these perspectives into practice and for ensuring they are given greater consideration in future research on player learning within soccer TDEs.

4.5 Insights for Research-Informed Coach Education and Development

One overarching objective of this dissertation was to generate scientific insights that meaningfully contribute to advancing talent development practices in soccer. In particular, it sought to build on the established line of research within the *Scientific Support of the DFB Talent Development Program* on Coach Development (see *Chapter 1.1*). Beyond addressing practically relevant research questions, two further aspects are relevant to achieving this goal. *First*, it is essential to synthesize and translate research findings into actionable recommendations for coaches (Lyle, 2018). *Second* identifying appropriate formats for transferring this knowledge into real-world coaching environments is crucial (e.g., Wang et al., 2023). Both aspects were addressed within the research-informed CEP on learning-supportive coaching, as presented and evaluated in Study 3. Aiming to transfer scientific knowledge on effective learning support in a TDE, this study also highlights the potential of a multiplier approach to educate broader cohorts of coaches (Wachsmuth et al., 2022). Furthermore, this study underscores the value of participatory research approaches that aim for close collaboration between researchers and practitioners from the selection of relevant topics to the translation of findings into practical recommendations and the CEP implementation itself (Vaughn & Jacquez, 2020).

The findings across studies highlight additional areas for future research-informed coach education and development initiatives. Four key areas are examined at the intersection of insights drawn from the studies:

1. A game-centered approach in the context of individual learning support,
2. ‘hands-off’ coaching interventions to guide player learning,
3. coaches’ diagnostic competencies, and
4. the integration of assessment results to tailor learning support.

While the first two areas have been incorporated into the CEP on learning-supportive coaching, the program evaluation presented in Study 3 identified them as particularly challenging to implement in practice. This underscores the need to address these aspects more effectively in future initiatives. The latter two areas demonstrate strong potential to enhance coaching practices in soccer TDEs and therefore represent valuable topics for future CEPs.

Regarding the *first area*, the evaluation of the CEP revealed a dilemma perceived by some coaches in balancing the goal of providing individualized learning support with the predominant use of game-centered practice activities. As a result, some coaches described to rely on less representative practice activities, which they perceived as better suited to address specific learning goals. These perceived challenges reflect findings from previous research in soccer TDEs (Cushion et al., 2012a; Partington et al., 2014), underscoring the need to place greater emphasis on how to effectively implement a game-centered approach. Specifically, the findings suggest focusing on session planning and the design of games that are tailored to address specific learning goals (O'Connor et al., 2021b).

A relevant foundation for addressing this topic in future initiatives is the high level of self-awareness demonstrated by the coaches who participated in the CEP evaluation. Moreover, these coaches consistently emphasized their belief in the particular importance of a game-centered approach for talent development (i.e., coaches' 'individual filter'; Stodter & Cushion, 2017). The limiting factors therefore appeared to be either a lack of coaching competencies in applying these strategies, contextual constraints that hinder implementation, or a combination of both. Accordingly, future initiatives should focus on addressing these challenges in ways that facilitate meaningful behavioral change in

coaching practice. One promising approach involves demonstrating how the core principles of game-based coaching models can be effectively implemented within soccer TDEs. For instance, key tenets of *TGfU*, such as ‘representation’ and ‘exaggeration’, encourage the creation of complex game situations that elicit specific tactical actions from players (e.g., Harvey et al., 2018; Memmert et al., 2015). In addition, O’Sullivan et al. (2021, p. 1218) provide practical guidance through strategies derived from the *CLA* for modifying environmental and task constraints to guide players toward specific learning outcomes (see also Clemente et al., 2021a). These modifications are structured around four key elements: opponent(s), consequence (e.g., through additional rules), direction of play, and ball. Applying such conceptual frameworks may support coaches in creating greater structure and clarity in their planning and help ensure greater alignment between game-centered activities and specific learning goals.

Previous intervention studies involving elite youth soccer coaches can offer valuable guidance on how to better prepare them to apply the recommended coaching strategies in practice. For example, Andrew et al. (2024b) reported an increased use of game-representative activities among YA coaches followed targeted intervention. These behavioral changes were likely facilitated by video-based feedback provided, which enabled coaches to observe how specific constraints in SSGs influenced players’ actions during gameplay. This external perspective can offer insights that are often difficult to access from the first-person viewpoint of a coach actively leading a session. A resulting practical implication is the importance of supporting meaningful shifts in coaches’ perspectives on their own practice design. Such shifts can enhance both pedagogical and content knowledge, particularly in terms of understanding how to modify tasks to elicit specific

player behaviors. Addressing these areas of knowledge is especially important, as they have been found to influence the effective use of GBAs (Richardson et al., 2024).

The *second area* is closely related to the first, as it concerns the effective use of ‘hands-off’ coaching interventions during sessions. While practitioners participating in the CEP evaluation expressed strong interest in this topic, they also noted that it received comparatively less attention than the design of practice activities and their integration into the microstructure of a session. The relevance of this topic is further supported by empirical evidence from intervention studies suggesting the effectiveness of *NLP* as effective, in which ‘hands-off’ coaching strategies are a fundamental component (e.g., Práxedes et al., 2018a; Roberts et al., 2020). Furthermore, Study 2 of this dissertation clearly identified the use of such strategies as a crucial foundation for inherently guiding players toward specific learning outcomes through the design of practice activities, while maintaining a predominantly implicit learning process. Although the CEP provided recommendations on coaching interventions, a key limitation was the challenge of authentically addressing this topic within the context of large-scale CEP delivery. In particular, it proved difficult to simulate realistic coaching scenarios when coaches either took on the role of players themselves or worked with unfamiliar youth players for the first time during the CEP. To address this issue, participants in Study 3 suggested for future workshops to incorporate video-based examples featuring sequences of practice activities accompanied by brief coach statements explaining their observations and the rationale behind specific interventions. This approach might enhance coaches’ awareness of various intervention strategies and deepen their understanding of when and how to apply them.

Previous case studies have explored how behavioral change in coaching interventions can be effectively supported. A notable example is the case study by Raya-Castellano et

al. (2024), which aimed to support YA coaches identifying teachable moments and refining their questioning strategies. Improvements in coaches' use of questioning – particularly with respect to timing and phrasing – were facilitated through the use of systematic observation data and video-based feedback. Such strategies appear especially valuable, as they can help identify discrepancies between coaches' intended and actual on-field behaviors, as highlighted in previous research (O'Connor et al., 2017; Partington & Cushion, 2013). These studies revealed, for example, limited coach awareness regarding the extent to which they allowed players to self-explore solutions, as well as a tendency toward verbal 'overcoaching'. Implementing systematic observation on a nationwide scale within the *DFB Talent Development Program* is currently not feasible, as existing tools (e.g., Cushion et al., 2012b) are typically limited to small-sample settings. Nevertheless, introducing regular feedback processes either systematically via DFB coach coordinators or through peer feedback from other BC coaches may offer a promising alternative to address this topic more effectively within authentic coaching environments.

The *third area*, coaches' diagnostic competence, was not explicitly addressed in the CEP on learning-supportive coaching. Yet, the need to foster this competence is evident from findings across individual studies in Research Foci I and II, as well as from earlier evaluations within the *DFB Talent Development Program* (Schreiner et al., 2018). This body of research demonstrates that coaches encounter difficulties with conducting detailed assessments of players' current skill and competence levels, particularly when it comes to nuanced analysis across specific areas. Such analysis, and the 'actional diagnostic competencies' allowing to link this information to appropriate coaching strategies (cf. Klug et al., 2013, p. 39), is a relevant prerequisite for effectively supporting player development. To inform the design of relevant CEPs, insights from research in PE contexts may prove

valuable. In these settings, similar challenges have been discussed under concepts such as ‘noticing’ or teachers’ ‘professional view’, referring to the processes of directing selective attention, engaging in knowledge-based reasoning, and making informed pedagogical decisions (Reuker, 2017; Reuker & Schicklinski, 2023). These studies consistently highlight diagnostic competence as a key element of effective learning support, especially in the context of ‘adaptive teaching’ (Reuker & Künzell, 2021).

One promising avenue for enhancing coaches’ diagnostic competence involves optimizing their observational strategies during practice, enabling them to direct their attention more purposefully toward specific player behaviors. The importance of this competence was also emphasized in Study 2 which highlighted, for example, the contribution of role clarity among coaches in improving their selective player observation. Strategies to promote role clarity have already been integrated into DFB BCs through the concept of ‘Coaching in Teams’. This approach includes guidance on how to purposefully distribute tasks and responsibilities among coaching staff, thereby enabling more focused observation and effective intervention (Dugandzic, 2023). In addition, targeted observational strategies and recommendations for optimal practice design may help coaches assess competencies across motor, cognitive, and psychosocial areas in a more nuanced manner. In this context, an action-theoretical framework can support coaches in becoming aware of potential discrepancies between their own subjective perception of a game situation and that of the player (Höner, 2005; 2012a). This shift in perspective may help explain why a player chooses a course of action that differs from what a coach considers optimal. Improving diagnostic competence through these initiatives would not only help coaches better identify individual learning needs during practice, but also enhance the incremental validity of subjective coach ratings across different competence areas.

This leads to the *fourth area*, which concerns how coaches can effectively integrate assessment results into their practical work. Findings on the instruments used within the *DFB Talent Development Program*, particularly in their function as learning-oriented assessments, can support this objective. Despite the known limitations (see *Chapter 4.3*), the meaningful use of test results largely depends on coaches' competence to interpret the data, translate them into practical coaching implications, and provide development-focused feedback to their players (Höner et al., 2020). Although the assessments are well established within this context, coaches may still require additional support in systematically delivering feedback and embedding assessment data into their work with players.

This includes, for example, how coaches define learning goals for their sessions and to what extent they use individual test results for differentiation. One promising context for such application is the use of assessment results during so-called 'individualization phases' at DFB BCs. During these phases, training groups are formed by clustering players with similar developmental goals, using individual test results as a key basis for group assignment. These settings offer a targeted and meaningful opportunity to demonstrate how test data can be integrated into coaching practice. Moreover, individualization phases provide valuable opportunities to actively involve players in collaborative goal-setting processes, encouraging a shift in focus toward individual reference standards. As such, these processes also offer a basis for integrating insights from research on motivational coaching strategies (Gjesdal, 2025; Raabe et al., 2020).

Overall, these four areas represent important directions for future coach education and development. As demonstrated in Study 3, however, scientific insights from coaching research cannot and should not be transferred in a prescriptive way. Therefore, such initiatives must be grounded in sound theoretical foundations that encourage coaches to

critically reflect on the suitability of various strategies and how to apply them meaningfully in their own practice (Downham & Cushion, 2024). In addition, the literature on coach education and development highlights the importance of connecting formal initiatives with ongoing support in coaches' everyday work (Paquette & Trudel, 2018). This reinforces the need to utilize the organizational structures of the *DFB Talent Development Program* more effectively. In particular, greater attention should be given to how coach coordinators can support coaches' long-term development through regular observation and expert feedback. Moreover, encouraging collaboration among coaches working together at BCs (e.g., through peer feedback) represents a promising approach to supporting their professional development within authentic coaching environments.

4.6 Directions for Future Research

The perspectives outlined in the individual studies and the general discussion pave the way for future research directions. Structured around five key areas, the proposed research agenda aims to further strengthen the connection between talent research and coaching research. This endeavour is guided by the overarching goal of gaining a deeper understanding of the processes underlying the development of action competence in youth soccer players and how these processes can be effectively supported.

4.6.1 Improvement of Soccer-Specific Assessments

A crucial foundation for several future research directions is the ongoing improvement of soccer-specific assessments used in TDEs. The need to further enhance the assessments is emphasized throughout the studies within Research Focus II and also supported by the systematic review of interventions in Study 1, which highlight a lack of established and psychometrically sound tools used in soccer (for similar conclusions, see Williams

et al., 2020). The findings presented offer clear avenues for improvement by identifying various strengths and limitations of both objective and subjective assessment methods (see also Höner, 2021). Refining these tools is therefore essential not only to support applied practice within TDEs but also to strengthen methodological rigor in future intervention studies. Although specific strategies for improvement have been discussed in detail within the respective manuscripts, broader implications can be drawn by synthesizing findings across studies.

To enhance the utility of *subjective assessment* (DFB, 2022b), it is essential to facilitate more nuanced evaluations of individual talent predictors. One promising approach involves the use of game-test situations, which aim to combine the advantages of standardized tests with those of subjective evaluations (Memmert, 2015). Future research could examine whether coaches' evaluations in these purposefully designed game scenarios yield more reliable and potentially more predictively valid results compared to evaluations based on regular training observations. With regard to *objective assessments*, findings from the novel GK-specific assessment suggest that strategies to reduce the measurement error (e.g., increasing number of test trials) may improve the test battery's contribution for applied work. A systematic investigation of these strategies could provide deeper insights into how the assessment can facilitate coaches' work in TDEs.

Beyond improving existing methods, a critical gap remains in the availability of an *assessment of action competence* that integrates players' skills, knowledge, and volitional components. Although such instruments have been developed in the context of intervention research in PE (e.g., Volk et al., 2021, 2022), comparable approaches tailored to soccer TDEs are lacking. Existing theoretical frameworks commonly used in school settings (e.g., Weinert, 2001) may provide useful guidance but require adaptation to adequately

reflect the interrelation of competence domains in soccer-specific contexts. Currently, numerous studies use systematic observation tools to evaluate players' overall in-game performance (e.g., García López et al., 2013). Yet, the time-intensive nature of these instruments limits their practical applicability in large-scale TDEs, and the performance factors assessed are often too unspecific to yield meaningful insights in the context of elite youth sports (see Rösch, 2024, for a detailed discussion). Therefore, developing a theoretically grounded, psychometrically sound, and practically feasible soccer-specific competence assessment represents a promising direction for future research.

4.6.2 Mediators and Moderators in the Development of Action Competence

Beyond the practice design and coaching strategies, numerous additional factors influence the development of action competence. A more nuanced understanding of these influences, particularly through moderator analyses in meta-analyses (e.g., skill level of players, sex, intervention duration, and control conditions), has so far only been possible when synthesizing studies across various sports and contexts (e.g., Manninen et al., 2025). However, the continuously growing body of intervention research within club soccer will likely expand these opportunities in the near future.

In addition to evaluating the role of these 'common' moderators in (motor) learning research, *Chapter 4.4* emphasized further environmental factors that are likely to influence competence acquisition and development. Establishing stronger theoretical links between these environmental factors and learning outcomes could provide valuable insights for advancing talent development practices. One particularly relevant area is the interplay between motivational support, players' perceptions of the motivational climate, and the resulting effects on learning outcomes (Robinson, 2023). Additional insights may

be gained by further examining how learning-supportive coaching strategies align with motivational coaching strategies. Preliminary work in this area has been undertaken within the research-informed CEP by exploring conceptual alignment at the level of coaching implications, as presented in Study 3. In addition to enhancing our understanding of how coaching strategies influence players' perceptions of the motivational climate, such integration could contribute to a clearer understanding of both the alignment and potential conflicts among theoretically grounded coaching approaches.

The mediating role of coaching strategies represents another important avenue for research. For example, findings from Study 2 highlight the perceived value of drill-based activities because of their mediating effect on learning. Participants suggested that such activities may enhance players' self-confidence in executing specific techniques, which in turn could support the transfer of these skills to more game-representative situations that are essential for learning. Determining whether such practices exert a direct or indirect influence on learning remains a complex yet promising area of investigation, and their in-depth exploration could contribute to a more comprehensive understanding of the processes shaping player learning in TDEs.

4.6.3 Contextual and Individual Barriers Encountered by Coaches

The evaluation of the research-informed CEP in Study 3 revealed challenges perceived by some coaches when attempting to implement the recommended strategies in practice. While coaches' experiences represented only one facet of the analysis, the findings align with existing literature that highlights various difficulties related to the implementation of game-centered activities, such as the demands of session planning and designing purposeful games (Kinnerk et al., 2018; O'Connor et al., 2020; Richardson et al., 2024).

Coaches also reported challenges in guiding learning processes effectively, including the use of questioning strategies and achieving an appropriate balance between verbal and non-verbal interventions (O'Connor et al., 2021a; Raya-Castellano et al., 2024). A notable limitation of current research is that only a small number of studies have explicitly investigated the challenges coaches face within the specific context of soccer TDEs.

Consequently, in addition to gaining a clearer understanding of the individual competencies required to implement learning-supportive strategies, future research should also examine contextual constraints that may hinder their application. For instance, tensions may arise from the dual role many coaches occupy: supporting long-term player development while simultaneously making decisions about player (de-)selection. Moreover, it is important to investigate whether and how additional features of the TDE can be addressed in the coaching reality to promote an effective learning climate (e.g., psychological safety; see *Chapter 4.4*). Developing a more nuanced understanding of both individual and contextual barriers could provide a valuable foundation for designing future CEPs that are better aligned with the practical realities of coaching in TDEs.

4.6.4 Intervention Research Adhering to High Methodological Standards

Valuable insights for improving coaching practice are expected from intervention research that evaluates the effectiveness of practice activities and coaching strategies while adhering to higher methodological standards. Although meeting such standards poses challenges in field-based settings, guidance can be drawn from established checklists (e.g., Downs & Black, 1998; Hoffmann et al., 2014), which were adapted to the context of soccer coaching in Study 1. Intervention studies comparing different coaching approaches regarding similar learning outcomes could generate valuable insights into their

relative effectiveness. However, implementing such interventions within TDEs remains challenging due to the often dense schedules of participating players. A feasible alternative may involve integrating selected intervention components into only a limited number of weekly training sessions or offering them as ‘enrichment’ programs. Although this approach raises concerns about uncontrolled influences from other sessions, randomized cross-over trials – in which control groups from the same teams receive the intervention at a later stage – represent a promising solution (Roberts et al., 2020). Moreover, cluster-randomized control (or cross-over) trials involving different clubs may help increase statistical power. In such large-scale studies, a key challenge lies in balancing a systematic and controlled intervention protocol with the practical necessity of allowing intervention providers to make adaptations based on their players’ and contextual needs. In this context, it is crucial to systematically evaluate intervention adherence and, ideally, conduct a process evaluation to understand if and why deviations from the protocol occur.

To further enhance the benefits of such interventions, combining them with coach education programs prior to implementation may be particularly effective. This approach can improve both the quality of the intervention and the learning experience for participating coaches. Involving expert practitioners in the intervention design process is also crucial, especially since many coaching approaches are not inherently soccer-specific and may require contextual adaptation to be effectively implemented in TDEs. A participatory research approach that includes expert coaches in the development of the intervention helps ensure that it not only reflects sound pedagogical principles but also meets the practical demands of the target group. For example, such collaboration can help tailor the intervention to the appropriate level of challenge or align it with typical developmental goals, and thereby enhancing its contextual relevance.

4.6.5 Coaches' Diagnostic Competence

Another important avenue for future research involves developing a deeper understanding of coaches' diagnostic competence. Studies across Research Foci I and II revealed that identifying players' strengths and weaknesses, and tailoring coaching interventions accordingly, poses challenges in practice. Future studies should therefore investigate the diagnostic processes coaches use in applied settings, such as their observational strategies. Research in classroom-based teaching has introduced validated theoretical models that structure diagnostic processes into pre-actional phases (e.g., setting diagnostic goals, intentional observation), actional phases (e.g., selecting relevant information, making predictions), and post-actional phases (e.g., providing feedback, planning further development; Klug et al., 2013). Although similar models have been developed or adapted for PE (Reuker & Künzell, 2021), they have not yet been empirically validated. Moreover, it remains unclear to what extent these frameworks require adaptation to conceptualize coaches' diagnostic competence within the context of TDEs, which may differ in terms of learning goals and the performance level of the players involved.

Gaining such a conceptual understanding is essential for designing targeted interventions within coach education and development programs aimed at improving practitioners' diagnostic competence. While previous research has proposed various strategies to be delivered through such interventions (Reuker & Schicklinski, 2024), there is currently limited empirical evidence regarding their effectiveness in practice. Given the complexity of developing such interventions, a valuable first step may be to qualitatively explore the strategies used by expert practitioners (e.g., observational approaches, selective attention, and role clarity among coaches to facilitate detailed player evaluations). Grounded in theoretical models, such exploration should examine how coaches collect and apply

diagnostic information in dynamic training environments, the challenges they encounter, and how their practices can be structured based on existing models of diagnostic competence. This line of research could yield dual benefits: first, by providing insight into diagnostic strategies that may be most effective for coaches working in TDEs, and second, by identifying specific focus areas for the design of interventions aimed at facilitating coaches' diagnostic competence.

5. Conclusion

This dissertation addresses the ongoing debate surrounding optimal support strategies for the development of soccer talent. The *DFB Talent Development Program*, which served as the research context for this work, has played a key role in the development of numerous elite players, including the current captains of the German national teams, Giulia Gwinn and Joshua Kimmich. Both players have publicly emphasized the crucial importance of this program and, in particular, the impact of their youth coaches on their careers. As just two examples among many success stories, their experiences suggest that effective support strategies are already being implemented in practice. Nevertheless, soccer TDEs continue to be characterized by a wide range of, at times conflicting, perspectives and assumptions about what constitutes effective developmental support. In the pursuit of further optimizing talent development practices, this dissertation focuses on two closely related areas: (1) *learning-supportive coaching* and (2) *learning-oriented assessment*. Specifically, the insights generated through seven individual studies contribute to a deeper understanding of how youth soccer players' action competence can be effectively fostered within soccer TDEs.

The findings on *learning-supportive coaching* highlight the complementary benefits of various practice designs and coaching interventions. Although some of these strategies are associated with conflicting theoretical perspectives on learning, their purposeful combination appears to be the most effective way to address the broad range of relevant performance factors in soccer and to respond to players' individual strengths and weaknesses in a nuanced manner. Specific coaching implications were developed through a participatory process involving researchers and expert practitioners, and transferred into the *DFB Talent Development Program* via a research-informed CEP. The implications are

grounded in strong empirical support for the predominant use of practice tasks with high specificity that are suitable for addressing specific learning goals. The complementary value of less representative practice activities to target distinct player outcomes appears to depend on coaches' adherence to key design principles (e.g., providing meaningful challenges, promoting variability). Moreover, their (perceived) contribution depends on their purposeful integration into the microstructure of a session. Given the benefits of self-organized, implicit learning, it is essential that coaches are able to adapt practice tasks so that the activity itself inherently guides players toward the intended learning outcomes. At the same time, there is empirical support for coaching strategies that promote explicit learning processes, particularly in relation to players' tactical game understanding. Overall, these findings contribute to a deeper understanding of how established coaching approaches can support player learning by illustrating how their distinct features can be strategically leveraged to target specific outcomes within soccer TDEs.

The meaningful selection of practice activities and the effective use of coaching interventions likely depend on coaches' competence to integrate multiple sources of information into their decision-making. One relevant piece of information is the current skill and competence levels of their players and how these develop over time, highlighting the potential contribution of *learning-oriented assessments*. The findings presented provide further empirical support for the possibilities of both objective and subjective assessment methods to inform various areas of coaches' work in TDEs. At the same time, they highlight distinct strengths and limitations of the instruments evaluated, particularly regarding their suitability as *assessments for learning*. Beyond their psychometric properties (e.g., reliability, structural validity) – especially their predictive and incremental validity – their contribution to this purpose is shaped by additional factors. These include the specific

talent predictors assessed, the underlying theoretical constructs (e.g., motor abilities or competencies), and the representativeness of the test setting.

The findings across studies reveal areas in which coaches may require additional guidance to enhance the learning support they provide to their players. One key challenge lies in the nuanced evaluation of players' competence levels and the translation of this information into meaningful implications for coaching. Consequently, strengthening coaches' diagnostic competence may represent a relevant area for improving talent development practices. Beyond enabling more tailored learning support, facilitating this competence may also enhance the predictive and incremental validity of coaches' subjective evaluations. Another relevant area relates to aligning seemingly effective coaching strategies with the core objectives and principles of talent development programs. For example, some coaches experienced challenges in adhering to a game-centred main philosophy, while simultaneously addressing specific learning goals and providing individualized learning support. These challenges faced by some coaches also highlight areas in which the complementary value of learning-supportive coaching and learning-oriented assessment can be more effectively harnessed.

Overall, this dissertation provides an empirical contribution to the understanding of how action competence in youth soccer players can be effectively supported. While acknowledging that coaches' learning support represents only one of many interacting components within TDEs, the findings offer practical implications for this specific area of work. At the same time, the inherent complexity of the field, combined with limitations in existing scientific knowledge, makes it difficult to derive universally applicable practical rec-

ommendations. Instead, the findings presented may serve as a valuable point of reference for expert practitioners seeking to develop guiding principles tailored to the specific demands of soccer talent development in particular contexts.

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Appendix 1. Further Publications Related to this Dissertation

Pre-registered PRISMA-Protocol:

Bergmann, F., Gray, R., Wachsmuth, S., & Höner, O. (2020). The influence of practice design and coaching behavior on skill acquisition in soccer: A systematic review protocol (PRISMA-P). *Open Science Framework*. <https://doi.org/10.17605/OSF.IO/NUYZP>

A book chapter presenting talent development program across different countries:

Kelly, A. L., Eveleigh, C., **Bergmann, F.**, Höner, O., Braybook, K. Vahia, D., Finnegan, L., Finn, S., Verbeek, J., Jonker, L., Ferguson, M. P., & Dugdale, J. (2024). International perspectives: Evaluating Male Talent Pathways from Across the Globe. In A. L. Kelly (Ed.), *Talent Identification and Development in Youth Soccer: A Guide for Researchers and Practitioners* (pp. 228-262). Routledge. <https://doi.org/10.4324/9781032232799>

Further journal article (with peer-review):

Leyhr, D., **Bergmann, F.**, Schreiner, R., Mann, D., Dugandzic, D., & Höner, O. (2021) Relative age-related biases in objective and subjective evaluations of performance factors in groups of selected talented youth soccer players. *Frontiers in Sports and Active Living*, 3: 664231 <https://doi.org/10.3389/fspor.2021.664231>

Conference contributions (in chronological order):

Bergmann, F., Wachsmuth, S., Metke, C., Dugandzic, D., O'Connor, D., & Höner, O. (2025, September 16-19). *Evaluation einer Fortbildung zur lernförderlichen Gestaltung des Trainings im DFB-Talentförderprogramm*. 27. dvs-Hochschultag with the conference title "Sportwissenschaft: Vielfalt und Nachhaltigkeit!?", Münster.

Bergmann, F., Wachsmuth, S., Dugandzic, D., Metke, C., & Höner, O. (2024). Mixed-method evaluation of a research-informed coach education program to facilitate effective coaching for soccer talent development. In R. C. R. Davison, E. Tsolakidis, J. L. Thompson, A. Ferrauti, & M. F. Piacentini (Eds.), *29th Annual Congress of the European College of Sport Science from 2. to 5. July in Glasgow, Scotland* (p. 615).

- Bergmann, F.,** Dugandzic, D., Metke, C., Meyer, C., Wachsmuth, S., & Höner, O. (2023). Lernförderliches Training im DFB-Talentförderprogramm: Eine sportwissenschaftlich-informierte Fortbildungsintervention mit Trainer*innen. In C. Heim. & U. Frick (Hrsg.), *„Die Wahrheit liegt auf dem Platz“ – fußballrelevante wissenschaftliche Erkenntnisse und deren Umsetzung in der Trainings- und Wettkampfpraxis“*. 28. Jahrestagung der dvs-Kommission Fußball (S. 41-42). Goethe Universität Frankfurt am Main.
- Bergmann, F.** (2023). Kompetenzförderliche Vermittlungsmethoden und multidimensionale Leistungsdiagnostiken zur Unterstützung der Talententwicklung: Ein Forschungsprogramm im Fußball. In T. Schlesinger, E. Grimmer-Seidensticker, A. Ferrauti, M. Kellmann, C. Thiel, & L. Kullik (Hrsg.), *Leistung steuern. Gesundheit stärken. Entwicklung fördern*. 26. dvs-Hochschultag 2023 in Bochum (S. 433). Feldhaus Edition Czwalina.
- Bergmann, F.,** Schultz, F., Dugandzic, D., Danner, J., & Höner, O. (2023). Evaluation eines Ballkoordinationstests zur Unterstützung der Talententwicklung von Fußballtorhütern. In T. Schlesinger, E. Grimmer-Seidensticker, A. Ferrauti, M. Kellmann, C. Thiel, & L. Kullik (Hrsg.), *Leistung steuern. Gesundheit stärken. Entwicklung fördern*. 26. dvs-Hochschultag 2023 in Bochum (S. 229). Feldhaus Edition Czwalina.
- Bergmann, F.,** Schultz, F., Dugandzic, D., Danner, J., & Höner, O. (2023, May 24-26). *Reliability and validity of a ball-coordination test for talent diagnostics in soccer goalkeepers*. World Congress on Science and Football with the conference title “Enhance Performance Engage Society” (p. 39), Groningen
- Bergmann, F.,** Leyhr, D., Daniel, J., & Höner, O. (2022). *Prognoserelevanz subjektiver Trainerbeurteilungen von torhüterspezifischen Leistungsfaktoren bei der Talentförderung im Fußball*. 12. Sportspielsymposium der Deutschen Vereinigung für Sportwissenschaft with the conference title „Diversität im Sportspiel“, Lüneburg.
- Leyhr, D., **Bergmann, F.,** Dugandzic, D., & Höner, O. (2022, September 22-24). *Trainerauge und/oder motorischer Test? Prognoserelevanz objektiv und subjektiv erfasster Talentprädiktoren im Mädchenfußball*. 12. Sportspielsymposium der Deutschen Vereinigung für Sportwissenschaft with the conference title „Diversität im Sportspiel“, Lüneburg.
- Bergmann, F.,** Wachsmuth, S., Larkin, P. O’Connor, D., & Höner, O. (2022). A qualitative investigation of experts’ practice and coaching strategies to promote soccer-specific competencies in players on a talent pathway. In F. Dela, M. F. Piacentini, J. W. Helge, À. Calvo Lluch, E. Sáez, F. Pareja Blanco, & E. Tsolakidis (Eds.), *17th Annual Congress of the European College of Sport Science from 30 August to 2 September in Sevilla, Spain* (p. 251).

APPENDIX 1: FURTHER RELATED PUBLICATIONS

- Bergmann, F.,** Wachsmuth, S., Dugandzic, D., & Höner, O. (2022, June 16-18). *Vermittlung fußballspezifischer Kompetenzen in der Talentförderung: eine qualitative Studie über Coachingstrategien von Expert*innen*. 54. Jahrestagung der Arbeitsgemeinschaft für Sportpsychologie mit dem Tagungstitel „Ein Gehirn, viel Bewegung“, Münster.
- Bergmann, F.,** Gray, R., Wachsmuth, S., & Höner, O. (2021). A systematic review on the influence of practice designs and coaching behaviors on skill acquisition in soccer. *International Sport Coaching Journal*, 8(SI), 25-26. <https://doi.org/10.1123/iscj.2021-0066>
- Bergmann, F.,** Kober, L., Wachsmuth, S., Gray, R., & Höner, O. (2021). Ein systematischer Review zum Einfluss der Vermittlungsmethodik auf den Erwerb fußballspezifischer Fertigkeiten. In O. Höner, S. Wachsmuth, M. L. Reinhard, & F. Schultz (Eds.), *Talententwicklung und Coaching im Sport*. 53. Jahrestagung der Arbeitsgemeinschaft für Sportpsychologie (S. 191-192). Universität Tübingen.

Appendix 2. Supplementary Materials Study 1

Supplement I: Systematic Search Documentation and Database Settings.

Documentation of the systematic database search (Nov 22nd, 2020) of each of the four electronic databases: SPORTDiscus, MEDLINE, PsycInfo & Web of Science (including the categories Sports Science & Psychology).

For each of the searches listed below, the databases were searched from their inception or date of the earliest available publication. The reported times in brackets for the coverage represent the end of the search in the respective database.

SPORTDiscus	Coverage: 1965 – 22.11.2020 (11:54 CET)
Platform: EBSCOHost	Hits: 4,408
SPORTDiscus was searched with the following filters: peer-reviewed, academic journal & English language.	
Search Strategy: (football* OR soccer) [Title & Keywords] AND (intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing") [Title & Keywords] NOT (novice OR referee OR injur* OR pupil* OR class OR goalkeeper* OR NFL OR "american football" OR "australian football") [Title & Keywords]	
MEDLINE	Coverage: 1965 – 22.11.2020 (12:12 CET)
Platform: EBSCOHost	Hits: 4,643
Note: MEDLINE was searched for titles and “MW Word in Subject Heading”, which is equivalent to the “Keyword” search in the other databases.	
Search Strategy: (football* OR soccer) [Title & MW Word in Subject Heading] AND (intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing") [Title & MW Word in Subject Heading] NOT	

(novice OR referee OR injur* OR pupil* OR class OR goalkeeper* OR NFL OR "american football" OR "australian football") [Title & MW Word in Subject Heading]	
PsycInfo	Coverage: 1914 – 22.11.2020 (12:23 CET)
Platform: EBSCOHost	Hits: 1,324
PsycInfo was searched with the following filters: Peer Reviewed & English language	
Search Strategy: (football* OR soccer) [Title & Keywords] AND (intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing") [Title & Keywords] NOT (novice OR referee OR injur* OR pupil* OR class OR goalkeeper* OR NFL OR "american football" OR "australian football") [Title & Keywords]	
Web of Science (Core Collection)	Coverage: 1965 – 22.11.2020 (12:36 CET)
Platform: Web of Science	Hits: 2,968
Web of Science was searched with the following filters: Articles & English language. Moreover, the search results were limited for the categories <i>Sports Science</i> and <i>Psychology</i> .	
Note: Web of Science database offers two ways for keyword search (Author Keywords & Key Words Plus). We decided to use the Author Keyword function which only searches for the keywords that were added by the authors in the original publication.	
Search Strategy: (football* OR soccer) [Title & Author Keywords] AND (intervention OR train* OR program* OR approach OR pract* OR effect* OR impact OR improv* OR learn* OR perform* OR coach* OR "skill acquisition" OR cognit* OR ecologic* OR constraints OR "information processing") [Title & Author Keywords] NOT (novice OR referee OR injur* OR pupil* OR class OR goalkeeper* OR NFL OR "american football" OR "australian football") [Title & Author Keywords]	

Note. The exported files were searched for hits in other languages than English and other publication types than journal articles. No incorrect hits were found in MEDLINE and PsycInfo. In Web of Science 15 documents were found that were not labeled as journal articles. These 15 documents were deleted manually. In SPORTDiscus, 10 items were found in other languages than English.

Supplement II: Quality in Reporting and Risk of Bias in Individual Studies.**Supplement IIa: Results of the Downs & Black Checklist.**

Study	Reporting										External Validity			Internal Validity - bias							Internal Validity - confounding (selection bias)								Power		Score in %
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Arslian et al., 2020	1	1	1	0	0	1	1	/	1	0	1	UD	1	/	UD	1	1	0	UD	1	1	1	1	0	0	NA	NA	1	0	0	57.69
Barquero-Ruiz et al., 2020	1	1	1	1	0	1	1	/	0	1	1	UD	UD	/	1	1	1	1	1	1	0	1	1	0	1	1	NA	UD	0	0	66.67
Bekris et al., 2012	1	1	0	0	0	1	1	/	0	1	UD	UD	UD	/	UD	1	UD	1	UD	1	1	UD	UD	0	1	UD	NA	UD	0	0	37.04
Boraczynski et al., 2017	1	1	0	1	0	1	1	/	0	1	UD	UD	1	/	UD	1	1	1	1	1	1	0	UD	0	1	UD	NA	1	0	0	55.56
Bozkurt, 2018	1	1	0	0	0	1	1	/	1	1	UD	UD	1	/	UD	1	1	1	UD	1	1	1	UD	0	0	NA	NA	1	0	0	53.85
Coutinho et al., 2018	1	1	1	0	1	1	1	/	0	NA	1	UD	1	/	UD	1	UD	1	UD	1	1	1	1	0	0	NA	0	UD	0	1	57.69
Gaspar et al., 2019	1	1	0	0	0	1	1	/	0	NA	UD	UD	1	/	0	1	1	1	UD	1	0	1	UD	0	NA	NA	NA	UD	0	1	45.83
Guilherme et al., 2015a	1	1	1	0	1	1	1	/	1	1	1	1	1	/	UD	1	1	1	UD	1	1	1	1	1	1	UD	0	1	1	0	78.57
Guilherme et al., 2015b	1	1	1	0	0	1	1	/	1	1	1	1	1	/	UD	1	1	1	UD	1	1	1	1	0	1	UD	NA	1	1	0	74.07
Haaland & Hoff, 2003	1	1	0	0	0	1	0	/	1	1	UD	UD	1	/	1	1	UD	1	UD	0	1	0	UD	0	1	UD	NA	1	0	1	48.15
Harvey et al., 2010	1	1	0	1	0	1	1	/	0	1	1	UD	1	/	UD	1	1	1	1	1	1	1	1	1	0	NA	NA	UD	0	1	65.38
Holt et al., 2012	1	1	0	1	0	1	0	/	1	NA	1	UD	UD	/	0	1	1	1	UD	1	0	1	1	0	NA	NA	NA	1	NA	NA	59.09
Hossner et al., 2016	1	1	1	0	0	1	0	/	1	1	1	UD	1	/	UD	1	1	1	UD	0	1	1	1	0	0	NA	NA	1	1	0	61.54
Kösal et al., 2020	1	1	0	0	0	1	1	/	1	1	UD	UD	UD	/	UD	1	1	0	UD	1	1	1	1	0	1	UD	NA	1	1	0	55.56
Miranda et al., 2013	1	1	0	0	0	0	1	/	1	0	1	UD	UD	/	UD	1	1	1	UD	1	0	1	UD	0	NA	NA	NA	1	0	0	44.00
Montesano & Mazzeo, 2019	1	0	0	0	0	1	0	/	1	NA	UD	UD	UD	/	UD	1	UD	1	UD	0	1	UD	UD	0	0	NA	NA	1	NA	NA	30.43
Ouzak & Çağlayan, 2019	1	1	0	0	0	1	1	/	1	1	1	UD	1	/	UD	1	1	1	UD	1	1	1	UD	0	0	NA	NA	1	0	0	57.69
Práxedes et al., 2016	1	1	0	0	0	1	1	/	1	1	1	1	UD	/	1	1	UD	1	UD	1	1	1	UD	0	0	NA	NA	1	0	0	57.69
Práxedes Pizarro et al., 2017	1	1	1	0	0	1	1	/	0	1	1	UD	UD	/	UD	1	1	1	UD	1	0	1	UD	0	NA	NA	NA	UD	0	0	48.00
Práxedes, Moreno et al., 2018	1	1	0	1	0	1	1	/	1	1	1	UD	UD	/	UD	1	1	1	1	1	1	0	UD	0	0	NA	NA	1	0	0	57.69
Práxedes, Del Villar et al., 2018	1	1	1	0	0	1	1	/	0	1	1	1	UD	/	UD	1	UD	1	UD	1	1	1	UD	0	0	NA	NA	UD	0	0	50.00
Práxedes et al., 2019	1	1	0	1	0	1	1	/	0	1	1	UD	UD	/	UD	1	1	1	1	1	0	1	1	1	NA	NA	NA	UD	0	0	60.00
Raastad et al., 2016	1	1	0	1	0	1	0	/	1	1	1	UD	UD	/	UD	1	1	1	1	0	1	0	1	1	0	NA	NA	1	0	0	57.69
Radziminski et al., 2013	1	1	0	1	0	1	1	/	1	1	UD	UD	UD	/	UD	1	1	1	UD	1	1	1	UD	0	1	UD	NA	1	0	0	55.56
Roberts et al., 2020	1	1	0	1	1	1	1	/	1	1	1	1	1	/	UD	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0	78.57
Santos et al., 2018	1	1	0	1	0	1	1	/	1	1	1	UD	1	/	UD	1	1	1	1	1	1	1	1	0	1	UD	NA	1	0	0	70.37
Schöllhorn et al., 2006 (study 1)	1	1	0	0	0	1	0	/	0	1	1	1	UD	/	UD	1	UD	1	UD	0	1	1	UD	0	0	NA	NA	UD	0	0	38.46
Schöllhorn et al., 2006 (study 2)	1	1	0	0	0	1	0	/	1	1	1	1	UD	/	UD	1	UD	1	UD	0	1	1	UD	1	1	UD	NA	1	0	0	51.85
Schöllhorn et al., 2012	1	1	0	0	0	1	1	/	1	0	1	UD	1	/	UD	1	1	1	UD	0	1	1	UD	1	1	1	NA	1	0	0	59.26
Schwab et al., 2018	1	1	0	1	0	1	1	/	1	1	1	1	1	/	UD	1	1	1	UD	0	1	1	UD	1	1	UD	NA	1	0	0	66.67
Sierra-Rios et al., 2020	1	1	0	1	0	1	1	/	1	1	UD	1	UD	/	UD	1	UD	1	1	1	1	1	1	0	1	UD	NA	1	1	0	66.67
Teixeira et al., 2005	1	1	0	0	0	1	1	/	1	0	UD	UD	0	/	UD	1	1	1	UD	0	1	UD	UD	0	NA	NA	NA	1	0	0	40.00
Weigelt et al., 2000	1	1	0	0	0	1	0	/	1	0	1	UD	UD	/	UD	1	UD	1	1	0	1	0	UD	0	0	NA	NA	1	0	0	38.46
Witkowski et al., 2011	1	1	0	0	0	0	0	/	0	0	1	UD	UD	/	UD	1	1	0	UD	1	1	1	UD	0	0	NA	NA	UD	0	0	30.77
Zago et al., 2016	1	1	1	1	1	1	1	/	1	0	1	1	1	/	UD	1	1	1	1	1	1	1	1	0	1	UD	0	1	0	0	75.00
Σ	35	34	9	13	4	33	26	/	24	24	25	10	16	/	3	35	25	32	11	25	29	27	15	6	15	3	0	25	5	4	
Agreement R1 & R2 in %	100	100	97.14	88.57	94.29	91.43	97.14	/	94.29	100	88.57	94.12	91.43	/	100	100	91.43	100	97.14	94.29	100	94.29	91.43	100	100	97.14	94.29	88.57	1	/	95.76
Cohen's κ	1	1	0.93	0.75	0.71	0.68	0.93	/	0.87	1	0.73	0.87	0.83	/	1	1	0.78	1	0.93	0.85	1	0.82	0.83	1	1	0.94	0.72	0.75	100	/	0.91

Note. "1" = yes; "0" = No; "UD" = unable to determine; "NA" = item not applicable; items 8 and 14 are not applicable for quality assessment in this systematic review.

Further explanations of item 30 (calculation of statistical power):

To examine the individual studies power (item 30), a post-hoc power analysis was conducted using G*power (version 3.1.9.6; Faul et al., 2007) to investigate whether the study provides a power of $1-\beta = 80\%$ ($\alpha = .05$) to detect a moderate effect (i.e., $d = .50$) according to Cohen (1988). The statistical power was recalculated for all studies, because the five studies that conducted an a priori power analysis (see item 29) used different conventions for effect sizes, calculated the power for small or large effects, or used different α -levels. For a few non-parametric tests (e.g., Friedman test), the power cannot be calculated using G*Power. In these cases, we used correction factors referred to as the asymptotic relative efficiency (ARE) to estimate the study's power (Prajapati et al., 2010). Further, correlations among repeated measures are required to calculate the power for study designs with dependent samples. If the correlation was not reported in the original publication, conventions of Cohen (1988) for a moderate effect (i.e., $r = .30$) were used.

Two studies used magnitude-based inferences for the investigation of outcome effects (Coutinho et al., 2018; Gaspar et al., 2019). For these two studies, a spreadsheet for sample size calculation for magnitude-based inferences was used (Hopkins, 2020).

Two other studies (Holt et al., 2012; Montesano & Mazzeo, 2019) presented their results descriptively so that both items of the subscale power were rated as “not applicable” and were not considered for the calculation of the scores.

Supplement IIb: Results of the TIDieR Checklist.

Study	1	2	3	4	5	6	7	8	9	10	11	12	Score in %
Arslan et al., 2020	1	1	0	1	0	1	0	1	NA	NA	0	NA	55.56
Barquero-Ruiz et al., 2020	1	1	0	1	1	1	0	1	NA	NA	1	1	80.00
Bekris et al., 2012	1	0	0	0	0	0	0	0	NA	NA	0	NA	11.11
Boraczynski et al., 2017	1	1	1	1	0	1	0	1	NA	NA	1	1	80.00
Bozkurt, 2018	1	1	0	0	0	1	1	1	NA	NA	0	NA	55.56
Coutinho et al., 2018	1	1	1	0	0	1	1	1	NA	NA	0	NA	66.67
Gaspar et al., 2019	1	1	0	1	0	0	0	1	NA	NA	0	NA	44.44
Guilherme et al., 2015a	1	1	0	0	0	1	1	1	NA	NA	0	NA	55.56
Guilherme et al., 2015b	1	1	0	0	0	1	1	1	NA	NA	0	NA	55.56
Haaland & Hoff, 2003	1	1	0	0	0	1	0	0	NA	NA	0	NA	33.33
Harvey et al., 2010	1	1	0	1	1	1	1	1	NA	NA	1	1	90.00
Holt et al., 2012	1	1	1	0	1	1	0	1	1	NA	0	NA	70.00
Hossner et al., 2016	1	1	1	0	0	1	1	1	NA	NA	0	NA	66.67
Kösal et al., 2020	1	1	0	1	0	1	0	1	NA	NA	0	NA	55.56
Miranda et al., 2013	1	1	0	0	0	1	0	0	NA	NA	0	NA	33.33
Montesano & Mazzeo, 2019	0	1	1	0	0	0	0	0	NA	NA	0	NA	22.22
Ouzak & Çağlayan, 2019	1	1	1	1	0	1	0	1	NA	NA	0	NA	66.67
Práxedes et al., 2016	1	1	0	1	0	1	0	1	NA	NA	0	NA	55.56
Práxedes Pizarro et al., 2017	1	1	0	1	1	1	0	1	NA	NA	0	NA	66.67
Práxedes, Moreno et al. 2018	1	1	0	1	0	1	0	1	NA	NA	1	1	70.00
Práxedes, Del Villar et al., 2018	1	1	0	1	1	1	0	1	NA	NA	0	NA	66.67
Práxedes et al. 2019	1	1	0	1	0	1	0	1	NA	NA	1	1	70.00
Raastad et al., 2016	1	1	1	1	NA	1	0	1	NA	NA	1	0	77.78
Radziminski et al., 2013	1	1	1	1	0	1	1	1	NA	NA	0	NA	77.78
Roberts et al., 2020	1	1	1	1	1	1	1	1	1	NA	1	1	100
Santos et al., 2018	1	1	1	1	0	1	1	1	NA	NA	0	NA	77.78
Schöllhorn et al., 2006 (study 1)	1	1	0	0	0	0	0	0	NA	NA	0	NA	33.33
Schöllhorn et al., 2006 (study 2)	1	1	0	0	0	0	0	1	NA	NA	0	NA	44.44
Schöllhorn et al., 2012	1	1	0	1	0	1	0	1	NA	NA	0	NA	55.56
Schwab et al., 2018	1	1	1	1	0	1	1	1	NA	NA	0	NA	77.78
Sierra-Rios et al., 2020	1	1	0	1	1	1	0	1	NA	NA	1	0	70.00
Teixeira et al., 2003	1	1	0	0	0	1	0	1	NA	NA	0	NA	44.44
Weigelt et al., 2000	1	1	1	0	NA	0	0	1	NA	NA	0	NA	50.00
Witkowski et al., 2011	0	1	0	0	0	0	0	0	NA	NA	0	NA	11.11
Zago et al., 2016	1	1	1	1	1	1	1	1	NA	NA	1	1	100
Σ	33	34	13	20	8	28	11	29	2	0	9	7	
Agreement R1 & R2 in %	100	100	94.29	94.29	100	94.29	94.29	94.29	100	/	88.57	97.14	96.43
Cohen's κ	1	1	0.87	0.88	1	0.8	0.87	0.82	1	/	0.74	0.65	0.92

Note. "1" = yes; "0" = No; "NA" = item no applicable.

Supplement III: Detailed Description of Intervention Content and Methods.

Supplement IIIa: Detailed description of the practice content and methods from studies investigating theory-driven instructional approaches.

Author (year)	Practice content and delivery		Methods		
	Experimental group	Other groups (e.g., CGs)	Measurements	Instruments	Reliability
<i>Differential Learning (DL; n = 9)</i>					
Bozkurt (2018)	The <i>DL</i> group practiced nine target exercises that aimed at improving passing, dribbling, and feet-juggling. The exercises included high inter-trial variability through movement variations in the standing or kicking leg, arms, trunk, head, as well as ball. The techniques were practiced in blocked order. No corrective feedback was delivered.	<i>TL</i> focused on ideal movement archetypes. Nine exercises were practiced for target-passing, dribbling, and feet-juggling, respectively. Techniques were practiced in blocked order. Numerous repetitions were conducted, and error-based corrections were delivered by a coach.	1. pre-test 2. 4-week post-test	<i>Skill tests:</i> -Mor-Christian soccer test (Passing) -German Football Association test (dribbling, agility, and juggling)	yes (but reference is missing in the reference list)
Coutinho et al. (2018)	The <i>DL</i> groups' practice consisted of physical literacy combined with technical exercises as well as SSGs. All exercises were grounded in a high movement variability and unpredictability.	The CGs participated in their usual team practice sessions and did not receive an enrichment program.	1. pre-test 2. 10-week post-test	<i>Syst. Observation:</i> -technical performance observation -CBATs (5v5 + GK)	yes (Santos et al., 2017) Syst. Observation: intra-RR: ICC < .88
Gaspar et al. (2019)	<i>Differential Learning protocol:</i> <i>DL</i> in a blocked order was conducted to improve kicking accuracy. Participants kicked the ball by applying a high variability in their movement (18 variations). No corrective feedback was delivered. The players kicked 36 shots from three different positions. Six shots were made static and after short dribblings.	No other groups were included.	1. baseline 2. post-test 3. post-test after a match lasting 35 min.	<i>Skill tests:</i> -shooting accuracy and speed	yes (Markovic et al., 2006)

	<i>Traditional training protocol:</i> Thirty-six kicking repetitions in blocked order from three positions were made. The participants were encouraged to kick the ball with maximum accuracy and speed. Corrective feedback, focusing on error description, movement-oriented correction, and metaphoric instruction was delivered.				
Hossner et al. (2016)	<i>Differential Learning:</i> The program aimed at improving the goal-shot precision and included 13 sources of variation focusing on the supporting leg, the kicking foot, as well as the trunk position. Moreover, movement variants regarding the kicking movement and ball characteristics were used. No instructions were delivered. <i>Differential Learning & Feedback:</i> The protocol was similar to the <i>DL</i> group but additional augmented feedback by an instructor was delivered.	The CG practiced according to <i>TL</i> methods. The practice consisted of methodologically structured practice exercises to improve goal-shot precision, following principles such as "from easy to complex". Exercises aimed at improving the sweet-spot kick, the inside and outside kick. Three to four exercises were conducted per session, each lasting eight to ten minutes. The participants received augmented feedback from an instructor based on an ideal movement technique.	1. pre-test 2. 8-week post-test 3. 1-week ret-test	<i>Skill test:</i> -shooting accuracy test	no
Ozuak & Çağlayan (2019)	After a "standard" warm-up of 15 minutes, the <i>DL</i> group participated in exercises that were characterized by a high inter-trial variability through random perturbations (e.g., different movements or changes in equipment). Coaches' feedback was reduced to a minimum.	The CG participated in their usual practice that was not further specified.	1. pre-test 2. 8-week post-test	<i>Skill test:</i> -creative speed test -ball dribbling test -ball juggling test -passing test	yes (Bangsbo & Mohr, 2011; Bradford & Strand, 1993; Sulalp, 2018)

Santos et al. (2018)	<i>DL</i> was conducted at the beginning of the players' team practice sessions and aimed at improving the in-game creativity. The practice program consisted of SSGs in a random order (e.g., 1v2; 3v3; 1v1), focusing on intertrial variability. No error corrections were delivered.	Game-based practice within different SSGs was delivered according to methodological principles, such as 'from easy to complex'. Specific instructions and corrections were delivered.	1. pre-test 2. 20-week post-test	<i>Syst. Observation:</i> -CBATS -positional data (5v5 + GK)	yes (Santos et al., 2017) intra-RR: ICC > .81
Schöllhorn et al. (2006; study 1)	The IG participated in a supplemental <i>DL</i> program to improve players' dribbling and passing skills. No specifications of the practice program were provided but authors referred to methods reported by Schöllhorn (1999).	TL group participated in practice sessions with detailed descriptions of an ideal movement technique for slalom dribbling and passing. A high number of repetitions and many corrective instructions were delivered by a coach.	1. pre-test 2. 4-week post-test	<i>Skill test:</i> -dribbling & passing complex test	no
Schöllhorn et al. (2006; study 2)	The additional practice of the experimental group was based on the principles of <i>DL</i> and aimed at improving players' shooting skills. The practice was characterized by no specific repetitions. The coaches did not deliver any corrective or error-based feedback.	The <i>TL</i> group practiced according to conventional methods associated with chip shot including a high number of repetitions and corrective feedback (error description, movement-oriented correction, & metaphoric instructions) after each shot.	1. pre-test 2. 6-week post-test 3. 1-year ret-test	<i>Skill test:</i> -goal shooting accuracy test	no
Schöllhorn et al. (2012)	<i>Differential Learning (blocked)</i> : Practice of goal shot and ball control was delivered according to principles of <i>DL</i> (high number of variations of the movement) in blocked order without corrective feedback. The practice aimed to seek and explore functional movement patterns. <i>Differential Learning (random)</i> : Same practice content as in the	The CG practiced the goal shot and ball control technique by using a "classical" <i>TL</i> approach focusing on an ideal movement technique. Both techniques were practiced in blocks (first shooting, then ball control). Error corrections in form of instructions were delivered by a coach.	1. pre-test 2. 4-week post-test 3. ret-test	<i>Skill tests:</i> -goal-shooting accuracy -ball reception test	no

	blocked group but the practice was conducted in random order.				
Teaching Games for Understanding (TGfU; n = 5)					
Barquero-Ruiz et al. (2021)	Two practice groups participated in a <i>TGfU</i> intervention, led by trained coaches. The intervention aimed at improving offensive and defensive principles of play. Each session started with a game form (20 min.). Then, a physically inactive reflection phase ("teaching for understanding"; 5-7 min.) was applied followed by technical drill practice (15 min.). After that, another game form (25 min.) was conducted, before "review and closure" (5-7 min.).	No other groups were included.	1. pre-test 2. 4-week post-test	Syst. Observation: -GPAI (5v5)	yes (Oslin et al., 1998) inter-RR: 81.5-93.7 % ICC < .93
Harvey et al. (2010)	A similar practice program for both the varsity and first-year teams was conducted: The <i>TGfU</i> intervention aimed at developing the players in "defending as a unit of three players". The sessions focused on defensive off-the-ball aspects. All sessions related to the tactical problem of "preventing scoring by defending space in the field". SSGs, phases of play (e.g., attack vs. defense), and functional practice (e.g., game that ascertains technical and tactical abilities) were applied.	No other groups were included.	1. baseline (4 sessions) 2. int-1 (1 session) 3. int-2 (1 session) 4. int-3 (1 session)	Syst. Observation: -GPAI (3v3 + GK for the defending team)	yes (García López et al., 2013) inter-RR: < 80 %
Práxedes et al. (2016)	The IG participated in a <i>TGfU</i> program that consisted of modified SSGs. Four tasks, each lasting 15	The CG participated in TL with the same structure of 4x15 minute exercises as in the IG but based on a technical approach.	1. pre-test (3 matches) 2. post-test (3 matches)	Syst. Observation: -GPET (n. r.)	yes (García López et al., 2013)

	minutes, were carried out that focused on one tactical principle in the attack (e.g., keeping possession of the ball). Task constraints were grounded in the pedagogical principles of representation and exaggeration. The coach acted as a facilitator by using a question-and-answer approach.	Explicative and prescriptive instructions were used by the coach.			intra-RR: $\kappa > .90$ time reliability analysis: $\kappa > .85$
Práxedes Pizarro et al. (2017)	The intervention program followed the methodological principles of <i>TGfU</i> . In each session, four 15-minute playing forms were conducted where determining factors (e.g., number of players) were modified. The trained coach applied a question-and-answer approach to coaching. The complexity of the practice program increased progressively.	No other groups were included.	1. pre-test 2. int-test (6 matches) 3. final test (5 matches)	<i>Syst. Observation:</i> -GPET (7v7)	yes (García López et al., 2013) intra-RR: $\kappa > .90$ time reliability analysis: $\kappa > .85$
Sierra-Ríos et al. (2020)	A comprehensive teaching program based on principles of <i>TGfU</i> was delivered by a trained coach. SSGs were conducted after a playful warm-up. In an initial reflection, the objective of the session was introduced. The sessions consisted of modified games where the coach applied a question-and-answer approach focusing on the tactical aim of the sessions (e.g., generate free spaces or progression by numerical superiority).	The CG participated in a practice program based on direct instruction following the same structure as the <i>TGfU</i> group: warm-up (continuous running & mobility), technical/analytical exercises, a game, and, finally, stretching exercises. The coach used a direct instructional approach to achieve the session's objectives (e.g., create combined actions with passes or dribbling).	1. pre-test 2. 6-week post-test	<i>Syst. Observation:</i> -GPET (n. r.)	yes (García López et al., 2013) reliability: $\alpha = .75$

Non-linear pedagogy (NLP; n = 4)					
Práxedes, Moreno et al. (2018)	The same protocols were used for both the low- and average performance groups. <i>Intervention 1:</i> A practice program based on principles of <i>NLP</i> by using SSGs with numerical superiority in the attack was delivered. The principles representation, tactical complexity, and exaggeration were applied. <i>Intervention 2:</i> The practice program also followed the principles of <i>NLP</i> but using modified games with numerical equality.	No other groups were included.	1. pre-intervention 1 (3 matches) 2. intervention 1 (7 matches) 3. pre-intervention 2 (3 matches) 4. intervention 2 (7 matches)	Syst. Observation: -GPET (n. r.)	yes (García López et al., 2013) inter-RR: agreement > 90 % $\kappa > .81$
Práxedes, Del Villar et al. (2018)	The practice program was grounded on principles of <i>NLP</i> by using modified games and numerical superiority in the attack. All exercises are aimed at achieving tactical offensive and defensive objectives. Every session consisted of four 15-minute exercises and referred to a principle of play.	The CG participated in a practice program that was developed based on a <i>TL</i> approach, prioritizing technical components. The coach applied a direct instructional approach.	1. pre-intervention (3 matches) 2. intervention (7 matches)	Syst. Observation: -GPET (8v8)	yes (García López et al., 2013) inter-RR: $\kappa < .90$ intra-RR: $\kappa < .92$
Práxedes et al. (2019)	The practice program of the IGs based on the principles of <i>NLP</i> . Each session referred to an offensive or defensive principle of play (e.g., maintain possession of the ball or preventing passing lines). SSCGs (2 to 5 players a-side) with numerical superiority at one side were used.	No other groups were included.	1. pre-intervention (3 matches) 2. intermediate (3 matches) 3. final (4 matches) 4. retention (3 matches)	Syst. Observation: -GPET (7v7)	yes (García López et al., 2013) inter-RR: $\kappa > .90$ intra-RR: $\kappa > .92$
Roberts et al. (2019)	Practice aimed at improving players' individual learning objectives	The practice of the control period corresponded to a linear approach, based on information-	1. pre-intervention 2. 8-week post-test	Skill test: -LSST	yes (Ali et al., 2007)

	by using a <i>NLP</i> approach, integrating technical and tactical skills. A 'representative learning design' was chosen by using predominantly playing form activities to create perception-action couplings and promote self-organization processes. The role of the full-time professional and trained youth academy coach was to manipulate task constraints to refine the practice activities to the players' requirements.	processing theory. The full-time professional youth academy coach acted as an expert who aimed at fostering pre-determined outcomes. A controlled and predictable environment, by using predominantly training form activities and high volumes of instructions, was created.			

Note. CG = control group; *DL* = Differential Learning; ICC = intraclass correlation coefficient; *TGfU* = Teaching Games for Understanding; *TL* = Traditional Learning; LSST = Loughborough Shooting Skill Test; *NLP* = Non-Linear Pedagogy; RR = rater-reliability.

Supplement IIIb: Detailed description of the practice content and methods from studies investigating specific aspects of practice or coaching.

Author (year)	Practice content and delivery		Methods		
	Experimental group	Other groups (e.g., CGs)	Measurements	Instruments	Reliability
Effects of technical drill practice (with subsequent SSGs or coordination exercises; $n = 7$)					
Boraczyński et al. (2019)	The practice sessions of the proprioceptive-coordination group (PCT) aimed at improving generic and specialized coordination skills, speed, and individual soccer-specific technique through targeted drills and SSCGs (e.g., 3v3 or 5v5). Before the sessions, the proprioceptive-coordinative group additionally received a series of 24 multimode proprioceptive exercises where soccer-specific techniques were combined with proprioceptive-coordination elements.	<i>Regular training group:</i> The sessions are aimed at improving generic and specialized coordination skills, speed, and individual technique through targeted drills and SSCGs (e.g., 3v3 or 5v5). Instead of the PC-T exercises, the regular training group participated in SSCGs. <i>Control group:</i> No soccer-specific practice.	1. pre-test 2. 6 months peri-training 3. 6-months post-training	<i>Skill tests:</i> -Movement rhythm test -Motor adaption test -Static balance test -Kinaesthetic differentiation test	yes (relative reliability: .59 ≤ ICC ≤ .77)
Holt et al. (2012)	After seven baseline practices of the “passing square” the players participated in five sessions for improving awareness (i.e., over shoulder glance to check position and movement of the support player at the next cone), six sessions for passing, and four sessions for first touch skills. Two practices of the respective skills were included in each session and were immediately followed by a 4v4 SSG. The intervention consisted of peer-assessed feed-	No other groups were included.	1. Baseline (7 sessions) 2. Awareness (5 sessions) 3. Passing (6 sessions) 4. First touch (4 sessions)	<i>Syst. Observation:</i> -predetermined technical criteria (technical drill)	inter-RR: overall IRA: 83.4 % mean IRA: 87.8 %

	back, goal setting, and group contingency. The players self-set goals regarding a percentage of correct executions they would like to achieve during the intervention.				
Kösal et al. (2020)	The sessions of the coordination group included a warm-up (10 min.), football-specific exercises (50 min.), and cooling (15 min.). Additionally, the players participated in a specific coordination program lasting for 30 min., combining coordination and soccer-specific technical exercises.	<i>Control group regular training:</i> The sessions included a warm-up (10 min.), football-specific exercises (50 min.), and cooling (15 min.). Instead of coordination exercises, the players participated in their usual care practice. <i>Control group without coach-led training:</i> The players participated in soccer-specific practice that was not led by coaches and did not follow a specific protocol.	1. pre-test 2. 10-week post-test	<i>Skill tests:</i> -Mor & Christian test battery -Yeagley's Test - Johnson football skill test	yes (Mor & Christian, 1979; Vanderford et al., 2004)
Miranda et al. (2013)	The players of the IG participated in a soccer-specific positional practice as well as general technical-tactical exercises (e.g., the attack against the defence in reduced fields) and simulated matches.	No other groups were included.	1. pre-test 2. post-test	<i>Skill tests:</i> -zigzag dribbling test -lob pass test -juggling test	yes (VanRosum & Wijbena, 1991; Vaeyens et al., 2006)
Montesano & Mazzeo (2019)	The players of the IG participated in additional practice sessions to improve technical and physical characteristics. The sessions started with mobilization exercises followed by real game situations. The additional exercises included strengthening and continuous technical exercises.	The same protocol as in the IG except for the additional exercises was applied.	1. initial test 2. intermediate test 3. final test	<i>Skill tests:</i> -passing precision -goal shooting accuracy	no

Weigelt et al. (2000)	The IG participated in an additional practice program where feet juggling was practiced. The participants did not receive any guidance or feedback.	The CG did not participate in any additional practice.	1. pre-test 2. 4-week post-test	<i>Skill tests:</i> -juggling test -ball reception test (strong & weak foot)	no
Zago et al. (2016)	The IG participated in a practice program where tape matrix structures as three-dimensional spatio constraints were used for identifying specific areas on the ground. By using these constraints, analytical/technical drills, and phases of play games (e.g., 1v1 or 2v1) were conducted.	The CG participated in a practice program with the same content but without three-dimensional spatio constraints. The sessions included a warm-up, soccer-specific technical drills, situation games, and SSGs. The practice followed methodological recommendations of the Italian Football Associations.	1. pre-test 2. 22-week post-test	<i>Skill tests:</i> -LSPT -shuttle Dribble Test -slalom Dribble Test	yes (Ali et al., 2007; Lemmink et al., 2004)
Practice to reduce lateral asymmetries or improve the non-dominant leg performance (n = 5)					
Guilherme et al. (2015a)	The additional non-dominant leg practice included technical exercises of specific motor skills (i.e., receiving, passing, driving, dribbling, shooting, and disarm/interception). The drill-based practice was conducted during the first 20 minutes of the team practice sessions.	While one group participated in the intervention program, the other group did not participate in any additional practice.	1. baseline 2. 4-month assessment 3. 8-month assessment	<i>Syst. Observation:</i> -SAFALL-FOOT (5v5)	yes (Guilherme et al., 2012) (no IRR proofed in the study)
Guilherme et al. (2015b)	The IG participated in a technical practice program to improve soccer-specific motor skills (i.e., receiving, passing, driving, dribbling, shooting, disarm/interception) focusing on the non-preferred leg. Practice was conducted during the first 20 minutes of the team session and only included technical drills.	The CG participated in practice that does not include special exercises of the lower limbs and that does not include any guidance.	1. pre-test 2. 6-months post-test	<i>Syst. Observation:</i> -SAFALL-FOOT (5v5)	yes (Guilherme et al., 2012) (no IRR proofed in the study)

Haaland & Hoff (2003)	The IG participated in an increased volume of soccer practice with the left, non-preferred leg. No specific practice was conducted but the players only used their left leg in all practice parts, except full play.	The CG participated in all practice sessions by using both legs and no other restrictions.	1. pre-test 2. 8-week post-test	<i>Skill tests:</i> -slalom dribble test -receiving & direct volley shot test -one-touch passing test	no
Teixeira et al. (2003)	The IG used in three out of five weekly sessions only the non-preferred leg in technical drills as well as small games (45 min. per session). During the intervention period, the complexity of the tasks was increased regarding the accuracy and force in the kicks, the control and speed in the dribbling tasks, as well as by combining these basic skills into serial motor tasks.	Players that were not assigned to the IG participated in all sessions by using both feet.	1. pre-test 2. 4-month post-test	<i>Skill tests:</i> -speed of dribbling -kicking for accuracy -kicking for force	no
Witkowski et al. (2011)	<i>Experimental group 1:</i> The players participated in a practice program where the non-dominant leg was predominantly used in technical exercises. <i>Experimental group 2:</i> The players participated in a practice program where both the dominant and non-dominant leg were trained equally.	The players in the CG participated in a regular practice without specifications regarding the use of the dominant or non-dominant leg.	1. pre-test 2. 6-month int-test 3. 6 month-post-test	<i>Skill tests:</i> -test battery of Witkowski & Ljach (2006)	yes (Witkowski & Ljach, 2006)
Effects of game-base practice programs (n = 2)					
Arslan et al. (2020)	<i>SSG group:</i> The players participated in a practice program based on SSGs. SSGs were applied by using small goals, floater players, as well as SSGs with goalkeepers.	<i>HIIT group:</i> After the warm-up, the players participated in a High Intensity Interval Training (HIIT) program. At the end of the sessions, 11v11 matches were conducted.	1. pre-test 2. 8-week post-test	<i>Skill tests:</i> -zigzag agility with ball -speed dribbling test	yes (Little et al., 2005; Taşkin, 2008)

	At the end of the sessions, 11v11 matches were conducted.				
Radziminski et al. (2013)	<i>SSG group</i> : The players participated in 3v3 SSGs that were applied with modifications, for example through the use of floater players. In each session, 5 games á 4 min. were conducted.	<i>Running group</i> : The players conducted an interval training program, including high-intensity exercises.	1. pre-test 2. 16-week post-test	<i>Skill tests</i> : -juggling -rotation pass -passing -dribbling -heading -bench passing -shooting accuracy	yes (test of the German Football Association but reference in the reference list is missing)
Practice with modified ball sizes (n = 2)					
Bekris et al. (2012)	<i>Competitive group</i> : Practising with size-2 ball coordination and game situations. <i>20-Min group</i> : Practising 20-minute sessions with a size-2 ball (no specification of the practice protocol was made). <i>30-min group</i> : Practising 30-minute sessions with a size-2 ball (no specification of the practice protocol was made).	<i>Control group</i> : Same content as the 20-Min group by using a size 4-ball.	1. pre-test 2. post-test	<i>Skill tests</i> : -Passing -Juggling -Running with the ball -Turns	yes (Rosch et al., 2000; Russel, 1991; Vale et al., 2009)
Raastad et al. (2016)	Both groups (i.e., smaller & larger ball groups) participated in a practice program where only soccer juggling with the respective smaller or larger ball was conducted. No instructions or feedback were delivered to any of the groups.	No other groups were included.	1. pre-test 2. 6-week post-test 3. 6- to 7-week ret-test	<i>Skill tests</i> : -ball juggling -ball reception test	Juggling: no Ball reception: yes (Retest-R.: .98 ≤ ICC ≤ .99)
Internal and external focus feedback (n = 1)					
Schwab et al. (2019)	<i>External group</i> : Participants practiced the knuckle ball free kick technique and received external focus feedback after every third shot. The practice was conducted	<i>Internal group</i> : Participants practiced the knuckle ball freekick technique and received internal focus feedback (i.e., fo-	1. pre-test 2. 5-week post-test 3. 3-week ret-test	<i>Skill test</i> : -Adidas miCoach smart ball	no

	before the team sessions. Instructions focused on the movement effects, for example, on the ball velocity or movement of the ball (i.e., "Make sure to hit the ball just below its midline to lift the ball").	cus on the movement themselves) after every third shot. The practice sessions were conducted before the team sessions. Instructions focused on the movement (i.e., "concentrate on hitting the ball exactly with the inner side of your foot").			

Note. CG = control group; IG = intervention group; TL = Traditional Learning; RR = rater-reliability; SAFALL-FOOT = System of Assessment of Functional Asymmetry of the Lower Limbs in Football; succ. = successful

Supplement IV: Narrative Summary of Results from Studies without a Control Group.

Author (year)	Groups	Intervention duration		Statistical Analysis	Outcome variables	Main results
		Sessions (min.)	Weeks			
Gaspar et al. (2019) ^a	-all players ($n = 20$) participated in one session DL and one session TL	20 (25)	10	Non-clinical magnitude-based inferences	<i>Skill-test:</i> -shooting velocity -shooting accuracy	Better acute effects after <i>DL</i> compared to the <i>TL</i> protocol were found regarding a small increase in shooting velocity. <i>DL</i> did not impact the overall shooting accuracy, although slightly better accuracy in the higher scoring zones was found.
Barquero-Ruiz et al. (2021) ^a	- <i>TGfU</i> 1 ($n = 10$) - <i>TGfU</i> 2 ($n = 10$)	6 (90)	1	t-tests	<i>In-game (on-the-ball):</i> -decision-making -skill execution -succ. game performance -number of decisions made -game involvement	The number of decisions made as well as the overall game involvement increased from pre- to post-test. Improvements in the players' decision-making, skill execution, and successful game performance were found.
Harvey et al. (2010)	-first year ($n = 18$) -varsity ($n = 18$)	8 (45-60)	12	t-tests	<i>In-game:</i> -decision-making (on- and off-the-ball) -skill execution (on- and off-the-ball) -adjust (off-the-ball) -cover (off-the-ball)	Improvements from baseline to last assessment in both teams were found regarding appropriate adjusts. First-year players' appropriate covers, efficient skill execution, overall game involvement, and successful game performance increased. In the varsity team, more inappropriate covers were found at post-test. Game involvement remained equal but an increase in unsuccessful actions was found.
Práxedes Pizarro et al. (2017)	- <i>TGfU</i> ($n = 9$)	22 (60)	12	Friedmann	<i>In-game:</i> -decision-making (passing & dribbling) -skill execution	Significant improvements were found for the decisions and executions in passing as well as for the executions in dribbling. No improvements regarding decisions to dribble were found. Improvements were also found in the

					(passing & dribbling)	total game performance in decision-making and skill execution. Significant differences were only found when the whole intervention was completed.
Práxedes, Moreno et al. (2018a)	-low skill ($n = 9$) -average skill ($n = 10$)	Int. 1: 14 (60) Int. 2: 14 (60)	2 x 7	Repeated measures MANOVA	<i>In-game:</i> -decision making of passes -skill execution of passes	In average-skill players, the numerical superiority intervention had a positive effect on passing decisions and executions. No improvements in the low-skill group were found. No group improved in the numerical equality intervention. Improvements in low-skill players were found in passing executions after both interventions.
Práxedes et al. (2019)	-NLP ($n = 19$)	14 (60)	7	Friedmann & Wilcoxon	<i>In-game:</i> -decision making (passes) -skill execution (passes)	The decision-making and execution performance of the players was significantly better at the intermediate and final measurements compared to pre-intervention. Significantly higher performance at the re-test compared to the pre-test, but no differences compared to the final measurement, were found.
Holt et al. (2012)	-intervention ($n = 5$)	22 (120)	11	Descriptive	<i>Systematic observation of performance in a drill:</i> -awareness -passing -first touch (each for the strong and weak foot)	All participants improved in awareness, passing, and first touch skills. The performance was more consistent after the intervention so that the individual goals of the players were achieved. The baseline performance of the players as well as the learning rates during the intervention differed between the players. The players' performance after the intervention was maintained in most cases.
Miranda et al. (2013)	-intervention ($n = 13$)	n. r. (n. r.)	10	t-tests	<i>Skill tests:</i> -slalom dribble -lob pass -juggling	Significant improvements after the intervention were found in the players' slalom dribbling and lob pass performance. No improvements in juggling were found.

^a Further soccer-unspecific assessments (e.g., physiological tests) were conducted

Supplement V: PRISMA Checklist.

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	88
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	89
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	94-96
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	99
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	97
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	99; Table 3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	98-99; Supplement 1
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	99-101; Supplement 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	99-101; Figure 15
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	102-103

Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	99; Table 3
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	102
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	103-104
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	103-104
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	/
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	/
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Figure 15
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Tables 4-5; Supplement 3
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Figure 16; Supplement 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	107-111; Tables 6 & 7; Supplement IV
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	/
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	/
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	/
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	128-129

Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	136-137
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	139-140
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	141

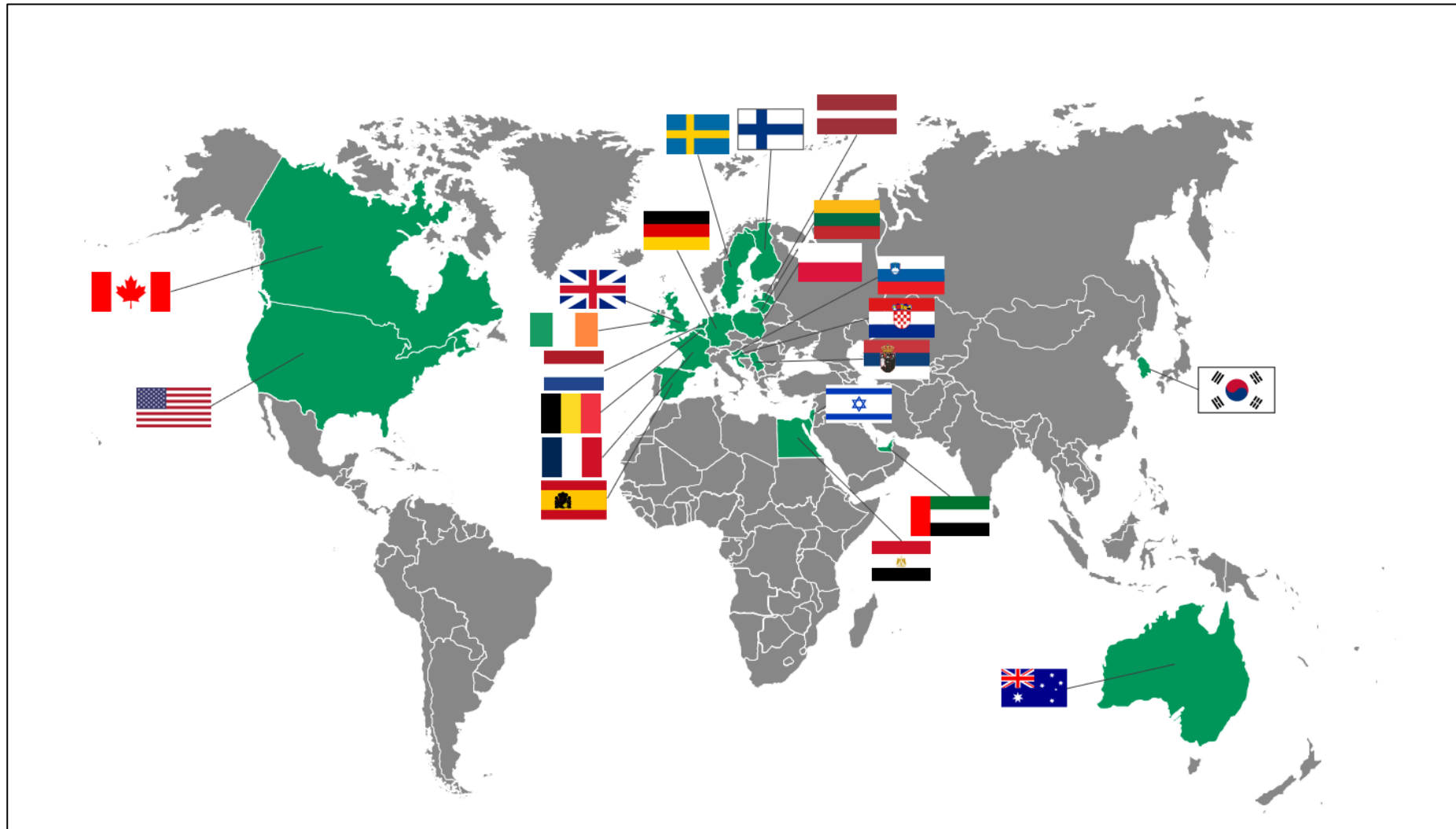
Note. All pages refer to the accepted manuscript as presented in this dissertation.

Appendix 3. Supplementary Materials Study 2

Supplement I: Participant inclusion criteria to guide the purposeful sampling procedure.

Criteria	Coaches	Coach Educators/Developers	Researchers
Main Position	– Full-time coach within a football association or a licenced youth academy	– Full-time coach educator/developer within a football association or a licensed youth academy	– Full-time researcher at a university (at least lecturer level or equivalent)
Formal Qualifications	– A- or PRO-License	– A- or Pro-License	– PhD in Sports Science or Coaching
Experience & further Characteristics¹	– Full-time coaching experience with elite adolescent soccer players (i.e., ‘age group experts’) – This experience was collected in national soccer associations’ talent development programs (e.g., youth national teams) or youth academies licensed on the highest national standards	– Full-time experience in leading formal coach education programs (at least A-License) or coach development programs – This experience was collected within a football association, or a youth academy licensed on the highest national standards	– Research on learning in youth soccer players which is documented in peer-reviewed publications – Research focuses on motor learning, sport psychology/pedagogy, coaching pedagogy, or related fields – At least some practical coaching experience in team sports at any level

Note. ¹ The years of experience were not defined as inclusion criteria as this is related to the expert’s age and a respective heterogeneity was intended. Yet, several years of experience were ensured given the high inclusion criteria defined for formal qualifications (e.g., A- or PRO-License; see also *Table 1* in the original publication). In addition, addressing a wide range of international experiences was mainly ensured by the discussion about potential study participants within the research group. In this regard, it was aimed to cover as much international experience as possible within each of the three groups.

Supplement II: An overview of countries in which participants had gained work experience prior to the interview.

Supplement III: Overview of the interview guide including exemplary questions.

<i>Question blocks</i>	<i>Exemplary Questions</i>
I. Personal information & coaching philosophy in talent development settings	• Can you please briefly describe your current role/job (as a coach/coach educator/researcher)? • From your perspective, what are important beliefs, values, and goals that should guide coaching to optimally support learning in elite youth soccer players? • Can you outline how you envision learning processes in elite youth soccer players and outline aspects which may be especially relevant for U12 to U15 age groups?
II. Overarching principles to practice & coaching in elite youth soccer	• Can you state basic coaching principles which should guide practice and coaching to optimally pursue the presented learning goals? • Can you name some basic principles you expect as supportive to adjust game demands during practice?
III. Planning and modifying conducive practice tasks	• If you think about these overarching principles, can you try to apply them to one of the three task areas and respective learning goals (coaches and coach educators typically used their prepared practice examples)? • For what purposes and in which phase of learning would you use representative practice tasks and when would you recommend using less-representative tasks? Can you name some examples and explain how you come to this decision? • Can you name principles for microstructuring sessions in a practice-to-learn context and outline the Pros and Cons you would consider when developing a microstructure?
IV. Designing a conducive learning environment & in-session coaching	• How would you describe a practice environment that is conducive to learning (the outlined goals)? • If you think about the coach's behavior during the session, what are typical cues coaches should pay attention to during a sessions to determine whether intervening is necessary? • How may interventions look like (e.g., verbal/non-verbal) under which circumstances (e.g., learning goals)?
V. Summary and potential edits	• Based on our conversation, can you please reflect on what the most important methodological strategies and principles were for you to pursue the outlined learning goals?

Note. All questions were slightly adjusted to ask the experts for recommendations throughout their specific perspective.

Supplement IV:²³ Exemplary quotes representing the core essence of themes from Soccer Coaches, Soccer Coach Educators, and Researchers.

Theme I: Differentiating overarching learning goals to address players' individual needs.

Coaches	Coach Educators/Developers	Researchers
'You have to assess him, that takes a few weeks. So, you also have to see what kind of difficulties he has. Does he have problems with passing with his insides? Does he have problems with fly balls? And so on and so forth. And then you select one point. [...] And one really important point is clean passing and that they position themselves open – these are basics every player should learn.' (C2)	'And that's where I try to differentiate. It's exhausting, of course, but on the other hand it's not about me, it's about the boys and girls. [...] We can't adapt everything to everyone, with the masses we have, we can't tailor everything to each individual. You need this game form; another player needs this. [...] But my learning goal is defined differently for everyone or should be defined differently.' (CE1)	'I think that in soccer, there are very individual ways of executing technical skills. [...] This does not mean that we should not teach players that they can shoot with their inside or outside of the foot. I think we should let the children experience different ways of executing a shot but then, there is no reason to not talk about some general structural characteristics of a technique and how these impact the outcome [...] That's for me no contradiction, but we should think very situative and see which variants of a technical skill work.' (R1)
'[Technical skills] are individual. And that's the 'eye of the master' to identify what works for an individual player in the game and how you can support this player in this respect.' (C4)	'There's no ideal way. But there's still the way of, ok, you need to tighten your ankle for example. And you need to use language that they understand at that moment. But there's no way of 'you should do it exactly like this'. It's more about 'the outcome should be this, the outcome should be that' - he receives the pass on this outside foot and that with the weight of the pass should be that the ball can't be intercepted.' (CE5)	'Players are very individual and that's why it's important to have an individual technique [...] And it's about variability to solve the situation and that's what I try to support in each player.' (R3)

²³ Several quotes could not be included in this Supplement because of confidentiality. This was particularly due to specific examples provided that would allow identification of involved persons, clubs, national associations, or universities.

link to a certain extent what they can do and their understanding about how to do it, because that belongs together. What a player understands will be made better on the pitch. And, of course, there are also these intuitive player types. But generally, if you understand what and how to do something in the game, you will do it better.’ (C6)	‘Yeah. So, because there you can observe, what about these basic, we call this the basics. [...] If the basic skills are not okay. So, sometimes we see like, the example that I gave you about finding the free player, the tactical approach is too difficult, because some of them, they don't master the individual skills to make themselves free.’ (CE2)	But you kind of imprinted a little bit of knowledge, but you didn't do it at a time when it was possibly going to change their learning from implicit to explicit. So, to give you an example, if I did that, after the first trial, then it might be that the learning for the rest of this exercise becomes purely explicit. So, the players will start doing it on a rule-based level. So, they'll go if this happens, then I have to do that. But we know this behavior is not robust. [...] But then to move on to a different exercise or to finish the training session, not to come back and say, now we're going to implement all of that we've learned there, because it's useless. You might as well do something else, because you're forcing them into a very descriptive rule based explicit method of learning, which is not going to be good anyway.’ (R5)

Theme II: Designing purposeful training sessions with the game in mind.

Coaches	Coach Educators/Developers	Researchers
‘This was an example how to address the learning goal [here related creating scoring opportunities] without pressure by opponents. But then, I would use a game form. And I would try to position this player not centrally in the field where he would always have pressure from an opponent on his back. I would rather try to create a game where he gets into some situations [in which he needs] to turn with the ball and play a deep pass. But I would try [to create situations so] that he still needs to get free from his opponent but in an easier way. Generally, all exercises should be designed so that the players reach the objective.’ (C2) ‘A lot of times, we will show clips before training, whether it's a positive clip, or a less positive clip – it tends to be positive more than anything else. So, if we can't watch us doing it, we find a positive clip of a professional doing it. And that tends to be what we show	‘First, think about the goal. What do you want to achieve? Then, think about the game components space and time – often caused by opponents – and the width and length of the field. I can make it wider; I can make it smaller, I can make it longer, I can make it a triangle, I can make it like an octagon – I can make it all different insofar it's clear why you do things and how it supports players' behavior.’ (CE5) ‘We have this idea, like a principle. We always want to create a game related scenario. [...] it's always about playing, you know. One of the principles was like, between U-12 to U-15, is that everything has to still remain like the game, well not everything, but like, I would say percentages-wise. So, let's say U-12, we still had like an individual situation, which would be 1v1. And, like, you know, my players [shows a 2v1 on a video clip], let's say 2, 3, or 4 So, let's say, 2v1, 2v2, 3v1, 3v2, 4v2, 4v3, things like this.’ (CE4)	‘For me, everything operates on a continuum, right? So, it's not a case that players either have decision-making skills, or they don't. And it's not a case that we go from not developing decision-making skills to developing them. [...] Decision-making is a contextually specific term because based on my age and stage of development and how good I am, how talented I am, and how able I am to respond to the cues that I'm, you know, being afforded within the environment, will determine what the environment needs to look like for me. Because I might be playing a full version of the game, that might be 5v5, or 7v7. And that version of the game is too complex for me. [...] So, I need the coach to be able to modify and adapt that practice or constrain that practice in some way to enable me to develop my decision-making.’ (R4) ‘I think the best thing you can do is to try and retain perception action couplings [...] Let's say that the aim, or the initial reason is a long pass because you said in the video, you want players to exploit the space behind the defensive line [...] Then, what I

at the beginning, or even make a video of the opposition and what they have a hard time with me like, see if this is going to be good.’ (C1) ‘Well, I think you can use training forms in which you try to present players some solutions, but always different solutions. [...] But robust decision-making in the game, and that’s what we should talk about, that allows to solve game situations. To develop that, you need games with opponents, you need the interaction of space, opponents, ball, teammates and so on. That’s the only way. And I think you need complex forms which are – in first place – playing forms. (C6)	‘You can do drills with colors, easy. So, they learn to turn, to watch, to see, and to decide. Next step, instead of the coach with the cones, there is another player three meters behind. I say to that player you decide to mark him, or you let him free. So, if you see that he’s marking you, you play the ball back one touch to your teammate. If he’s not marking you, you receive the ball, you turn, and you play the ball in the goal. So, this is more the game situation. Do I see if I’m free, or not?’ (CE2)	would do is deconstructing that but still retain perception-action coupling. So, I would have a smaller area of the field in which a player is playing a three versus two, in which the aim is for one player to get in possession of the ball in a zone that is behind the defensive line in which the defenders cannot go with the goalkeeper cannot go either. So, you are providing the player with more space. You’re playing a three versus two, there’s more room for that player to maneuver. And at the same time, I would also make the field wider and less long.’ (R5) ‘I would try to create conditions where their “technical error” reaches its limits, and they can try out how to do it better. Maybe, you create a situation where they understand how the ball must be cut in the first meters so that it gets the height it needs. And they don’t need to execute crosses in their entirety. Instead, they can stand in front of a wall, you mark a line and say: “The next shot has to be right over there at five meters”. They have to do that a few times and experience how it works.’ (R3)

Theme III: Coaching interventions to support player learning within a group environment.

Coaches	Coach Educators/Developers	Researchers
‘You can always distribute the roles within your coaching team: “You focus on this player regarding this and that outcome.” That’s for me individualized support. Similarly important like the design of practice activities. And in the game, it must be ensured that the relevant aspects were individually coached [...] However, I would only interrupt the game, when it’s an exemplary situation which make the players understand how to solve similar situations better in future. If it’s only related to one player do not disturb the group without reason.’ (C2) ‘The difficult thing [in Q&A approaches] is that players learn to give the answer the coach wants to hear. Then, they don’t learn to think and reflect. And that’s the quality of the coach to ask a question and, based on the players’ statements, to potentially ask another one. Ask your questions flexible and give the players the feeling that they found the solution themselves. That’s the quality of a good coach.’ (C5)	‘So, we don’t say one is right and the other is wrong, but it’s more about thinking about it in advance: what do I want to cover through my assistant coaches? So that would mean that we have the game form and in the game form I would say so, because it is relatively complex, that a coach is only responsible for the rules. Then I, as the head coach, don’t have to worry about it and would only coach the transition after winning the ball [which was mentioned as an example]. And the other assistant coach would then switch to losing the ball. So, now you have to consider that you probably have to jump back and forth between two teams mentally. So, you have to weigh up the advantages and disadvantages and say, ‘Maybe I’ll just take over one team with all the phases and the other with the opposite phases.’ And then there are things like that, that I probably have people in the coaching team who perhaps feel more comfortable with certain topics.’ (CE6) ‘So, the question for me comes to the point of making analysis, like, why is this happening? [...] How	‘I am convinced that children at the age we’re talking about learn implicitly at least good as explicitly. [...] and that’s why I would encourage coaches in these age groups for being careful with instructions. Of course, the practice activities must be explained. Regarding the choices they make in the game, the way how they execute it, I would give children much freedom. [...] But like in Teaching Games for Understanding, there is no reason to not include periods of reflection in which you draw on these implicitly made experiences.’ (R1) ‘So, I think it’s a kind of combination of the constraints-led approach during the session, and the Teaching Games for Understanding approach at the end, or maybe between different practice you have so that you learn it in an implicit way during practice, but that you also encourage some explicit reflection processes afterwards.’ (R5)

‘So, that's also because I used to, but it'd be I tried as much as possible to make it a blend. So, like if you're going to say something negative that at least the next few times, it was something positive or like, you know, someone doing that. I think, more than anything, and that's more and more my coaching career that I've shifted more and more towards positive things more than negative things being like this was so goddamn good. Like, because of this, like, did you see how she did this? What were you thinking here? ‘I was thinking this’ – ‘okay, great’. They were like, more than anything, it's been like a hell of a lot of positive reinforcement because players are more of a density to do it and sort of avoiding it.’ (C1)	many decisions can a kid handle before freezing. At the point when he's making five wrong decisions, the question is why? Because he doesn't have the potential to take good decisions, or it's about his technique, or about something else?’ (CE4) ‘So, a typical exercise I would like to do is involving the pressure from one opponent but managing that with the time and the space you have available. So, if you have a player who is struggling with the decision, I would try and give him more space and more time to come to a decision. And as he gets better, I decrease the amount of time and space. And the opponent pressure becomes greater. Does that make sense?’ (CE3)	‘I think if you can bring about a behavior for free, you know, without instructions, and, you know, you really can get what you want, and it's working, then great. I think, though-, there are certain cues and strategies that you can give that can save some agony and speed up the process. And I'm not sure that we know that by speeding up the process that's going to slow overall learning, you know, like to take a side run up. If I tell someone to do that, or they figure it out through, you know, some - I could put some physical constraints so that they can't approach the ball straight on.’ (R6)

Appendix 4. Supplementary Materials Study 3

Supplement I: Overview of the CEP content structured around learning modules and exemplary didactical methods (DM) to coach education.

Module	Brief content summary and exemplary didactical methods to coach education
[duration of recording in hrs.] ¹	
1. Introduction: Learning-supportive coaching in the DFB TD program [08:42]	– introduction of two stereotypical coaches as representatives of conflicting coaching philosophies for talent development. – presenting the program goal to facilitate scientifically informed reflection upon the effectiveness of coaching strategies. – <u>DM</u>: coaches should position themselves toward one coaching approach they perceive as most supportive for player learning.
2. Learning goals: A competency-based philosophy used nationwide [16:04]	– an action theoretical viewpoint (Höner, 2012a; Nitsch & Hackfort, 2016) such as the Player-Environment-Task interrelation as determinants for learning (e.g., skill-level, motivational climate; Hodges & Lohse, 2022; Raabe et al., 2020). – competency-based learning goals used nationwide were linked to the action theoretical viewpoint (Bergmann et al., 2025a). – <u>DM</u>: coaches should define a specific learning outcome for one player (e.g., illustrated by a video clip presenting game scenes).
3. Theoretical Background: From skill learning theory to soccer coaching approaches [21:52]	– main theoretical assumptions of IP- and SO-paradigms were introduced with equal detail and without presenting one as more suitable to inform coaching practice (for reviews Anson et al., 2005; Schöllhorn et al., 2022; Whitall et al., 2020a). – each paradigm's implications were illustrated by practice activities and coaching strategies addressing similar learning goals – <u>DM</u>: developing practice activities in line with IP- and SO-approaches that aim to address the same learning outcome.

3.1 Information-processing [07:28]	– the idea of ‘cognitive’ representations and processing in motor learning is exemplified by the schema theory (Schmidt, 1975; Schmidt et al., 2019). Fitts and Posner (1967) ‘Three stage model’ illustrates youth soccer players skill development across different phases.
3.2 Self-organization [09:08]	– constraints-based (Newell 1986) and ecological approaches (e.g., concept of affordances; Gibson, 1979) are linked and illustrated by their practical consequences with reference to a constraints-led approach (Renshaw et al., 2019).
4. Empirical Findings:	– intervention research indicated the effectiveness of different coaching methods (for a review; Bergmann et al., 2021a).
Effective practice & coaching to support player learning [18:51]	– a context-bound qualitative study illustrated how to differentiate learning goals, the use of a game-centred main philosophy supplemented by various ‘practice tools’ and complemented by a spectrum of coaching interventions (Bergmann et al., 2024a).
	– <u>DM</u> : a digital Quiz on the study findings and their practical consequences could be used.
4.1 Intervention research [07:04]	– findings on the effectiveness are specified for established pedagogical approaches (i.e., <i>DL</i> , <i>TGfU</i> , & <i>NLP</i>).
4.2 Expert interview study [08:18]	– nuanced results on how to individualize learning goals, link practice activities, and optimal coaching interventions were presented.
5. Practical implications:	– research-informed arguments supporting different approaches are presented (depending on pursued goals, intended outcomes, etc.).
Optimal learning support to facilitate talent development [22:29]	– ‘10 maxims for optimal learning support’ were structured around <i>foundations</i> of a supportive environment, <i>optimal practice design</i> and <i>effective coaching interventions</i> to foster competence acquisition based on academic and applied sources (e.g., Wolf, 2024).
	– <u>DM</u> : Selected maxims should be integrated by the coaches into practice activities/coaching interventions and presented on-pitch.

*Note.*¹ Time needed to present the module in a lecture-based format (accessible to all participants at the online platform); DL = Differential Learning; DM = Didactical Methods to Coach Education; IP = information-processing; NLP = Non-linear pedagogy; SO = self-organization; TD = Talent Development; TGFU = Teaching Games for Understanding.

Supplement II: Exemplary interview questions from the interview guides for coaches and multipliers, structured according to the Context–Input–Process–Product (CIPP) Evaluation Model (Stufflebeam & Coyn, 2014).

Multipliers	Coaches
Introduction	
– How did you implement the CEP in your region? – What made you choose this specific way of implementing the CEP in your context?	– Could you briefly introduce yourself and give us an overview of your coaching background? – Can you describe how the CEP was implemented in your region?
Input	
– To what extent had you come across learning theories or research findings on coaching before? What specifically? – You received different CEP materials (e.g., video lectures, slides, ready-made practical sessions), which of those did you find most useful and why?	– What had you already known about the discussed topics beforehand? Have you had worked with any of the content before? – Which parts of the CEP content did you find particularly interesting or useful for your work – and which parts less so? Why?
Process	
– Overall, how satisfied were you with the preparation/training you received to deliver the CEP to your coaches? Why? – How did you go about designing your own version of the CEP and structuring the delivery so that it fit your purposes? – Which didactical strategies worked best when applying the CEP with your coaches?	– What did you like about the way the CEP was organized and delivered – and what less so? Why? – Which of the didactical methods used in the CEP stood out as particularly effective – and which didn't work so well in your opinion? Why? – What did you think about the contrasting theoretical perspectives presented by the two coaches in the CEP?
Product	
– In your view, what impact did the CEP have on your regional coaches? – If any, what behavioral changes have you noticed among the coaches after the CEP? – How do you think the CEP could be improved further?	– What did you learn about coaching and the theoretical thinking behind it? – In what ways did the CEP content come up in your day-to-day coaching? – Have you changed anything in your coaching after completing the CEP, or have you started paying more attention to certain things? With what effect?

Supplement III: Initial Template and a priori themes structured around the dimensions of evaluation according to the CIPP-Model (Stufflebeam & Coryn, 2014) and further specified by the coach education and development literature.

Level I: Dimension of Evaluation	Level II: Reference to Coach Education/Development Literature
1. Context: Accounting for contextual requirements in the CEP implementation	1.1 Considering organizational conditions and personal circumstances (e.g., available time; learning resources; Wachsmuth et al., 2022; Walker et al., 2018). 1.2 Learner-centredness relating to coaches' individual needs (Ciampolini et al., 2019; Paquette & Trudel, 2018).
2. Input: Meaningful content tailored for case-specific implementation	2.1 Evidence-informed, appealing and practice-related materials (Lyle, 2018; Wachsmuth et al., 2022). 2.2 Contextually relevant, application-specific objective (Paquette & Trudel, 2018; Wachsmuth et al., 2022).
3. Process: Case-specific implementation	3.1 Emphasizing the program's contextual relevance (Ciampolini et al., 2019; Stodter & Cushion, 2017). 3.2 Interactive didactical measures to facilitate coaches' reflexive involvement (Ciampolini et al., 2019; Paquette & Trudel, 2018; Wang et al., 2023).
4. Product: Facilitating practice-relevant outcomes	4.1 Stimulating coaches' self-reflection (i.e., cognitive; Ciampolini et al., 2019). 4.2 Applying implications into coaching practice (i.e., behavioral; Allan et al., 2018; Walker et al., 2018).
5. Factors or ("Barriers") that limit transfer into practice	5.1 Individual (Stodter & Cushion, 2017; Walker et al., 2018). 5.2 Contextual (Stodter & Cushion, 2017; Walker et al., 2018).

Note. References relate to a theoretical model on coach learning (Stodter & Cushion, 2017), the use of a multiplier approach to coach education within a talent development program (Wachsmuth et al., 2022). Furthermore, literature reviews on coaches' experiences and perceptions during coach education (Ciampolini et al., 2019; Wang et al., 2023), learner centred coach education (Paquette & Trudel, 2018), research-informed coach development (Allan et al., 2018), and informal/non-formal coach learning (Walker et al., 2018).

Appendix 5. Supplementary Materials Study 4

Supplement I: Models 1 and 2 aiming to predict players' participation in the U17 Bundesliga.

Criterion Variable	Omnibus-Tests			Predictor	Logistic regression coefficients				$(e^b)^{SD(\#)}$
	$\chi^2 (df)$	p	Nagelkerke R^2		b	Wald	p	e^b [95%-CI]	
Subjective Assessment (Model 1)	18.48 (4)	< .01	0.09	Constant	-2,07	-	-	-	-
				<i>Endurance</i>	0.38	1.77	0.18	1.46 [0.84; 2.56]	-
				<i>Tactical Skills</i>	0.38	0.83	0.36	1.46 [0.65; 3.31]	-
				<i>Psychosocial Skills</i>	0.15	0.3	0.58	1.17 [0.67; 2.02]	-
				<i>Kicking Skills</i>	0.04	0.01	0.92	1.04 [0.49; 2.18]	-
Objective Assessment (Model 2)	22.24 (5)	< .001	0.11	Constant	12.23	-	-	-	-
				Dribbling	-0,62	6.49	< .05	0.54 [0.34; 0.87]	1.51
				Sprint	-2,16	5.21	< .05	0.12 [0.02; 0.74]	1.41
				Ball control	-0,18	2.29	0.13	0.84 [0.67; 1.05]	-
				Agility (CODS)	0.42	1.04	0.31	1.52 [0.68; 3.38]	-
				Juggling	0	0.01	0.93	1.00 [0.95; 1.06]	-

Supplement II: Models 1 and 3 aiming to predict players' participation in the U17 Youth National Teams.

Criterion Variable	Omnibus-Tests			Predictor	Logistic regression coefficients				$(e^b)^{SD(\#)}$
	$\chi^2 (df)$	p	Nagelkerke R^2		b	Wald	p	e^b [95%-CI]	
Subjective Assessment (Model 1)	7.17 (4)	0.13	0.07	Constant	-4.49	-	-	-	-
				<i>Tactical Skills</i>	1.31	2.54	0.11	3.72 [0.74; 18.66]	-
				<i>Endurance</i>	0.63	1.09	0.3	1.87 [0.58; 6.10]	-
				<i>Kicking Skills</i>	-0,75	1.08	0.3	0.47 [0.12; 1.95]	-
				<i>Psychosocial Skills</i>	-0.4	0.44	0.51	0.67 [0.21; 2.16]	-
Subjective & objective As- sessment (model 3)	21.42 (9)	< .01	0.21	Constant	11.2	-	-	-	-
				Ball control	-0,71	4.38	< .05	0.49 [0.25; 0.96]	2.52
				Sprint	-3,91	4.04	< .05	0.02 [0.00; 0.91]	1.86
				<i>Tactical skills</i>	0.93	1.09	0.3	2.54 [0.44; 14.67]	-
				<i>Kicking skills</i>	-0,81	0.97	0.32	0.45 [0.09; 2.22]	-
				<i>Endurance</i>	0.55	0.7	0.4	1.73 [0.48; 6.30]	-
				Juggling	0.04	0.63	0.43	1.04 [0.94; 1.15]	-
				Agility (CODS)	0.44	0.29	0.59	1.56 [0.31; 7.84]	-
				<i>Psychosocial skills</i>	-0,26	0.17	0.68	0.77 [0.23; 2.63]	-
				Dribbling	0.09	0.03	0.87	1.09 [0.39; 3.03]	-

Supplement III: Models 1 and 2 aiming to predict players' participation in the Women's Bundesliga.

Criterion Variable	Omnibus-Tests			Predictor	Logistic regression coefficients				$(e^b)^{SD(\#)}$
	$\chi^2 (df)$	p	Nagelkerke R^2		b	Wald	p	e^b [95%-CI]	
Subjective Assessment (Model 1)	18.11 (4)	< .01	0.18	Constant	-5.43	-	-	-	-
				<i>Tactical Skills</i>	2.67	7.77	< .01	14.37 [2.21; 93.62]	4.96
				<i>Psychosocial Skills</i>	-1.25	3.59	0.06	0.29 [0.08; 1.04]	-
				<i>Kicking Skills</i>	0.26	0.12	0.73	1.30 [0.29; 5.76]	-
				<i>Endurance</i>	-0.2	0.12	0.73	0.82 [0.26; 2.60]	-
Objective Assessment (Model 2)	20.21 (5)	< .01	0.2	Constant	14.7	-	-	-	-
				Sprint	-4.03	4.37	< .05	0.02 [0.00; 0.78]	1.89
				Ball control	-0.67	3.95	< .05	0.51 [0.27; 0.99]	2.38
				Juggling	0.08	2.09	0.15	1.08 [0.97; 1.20]	-
				Agility (CODS)	0.58	0.46	0.5	1.79 [0.33; 9.63]	-
				Dribbling	-0.28	0.25	0.62	0.76 [0.25; 2.27]	-

Appendix 6. Supplementary Materials Study 5

Supplement 1a: Bivariate correlations across predictors for the U12 ($n = 1594$).

Performance factor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Sprint (20m)	-							
(2) Agility (CODS)	.50***	-						
(3) Dribbling	.19***	.40***	-					
(4) Ball control	.10***	.14***	.31***	-				
(5) Juggling	-0.05	-0.09***	-0.22***	-0.24***	-			
(6) GK-specific Technical skills	-0.18***	-0.20***	-0.23***	-0.21***	0.17***	-		
(7) GK-specific Tactical skills	-0.13***	-0.15***	-0.18***	-0.19***	0.12***	0.78***	-	
(8) Current PL (holistic)*	-0.19**	-0.21***	-0.25***	-0.20***	0.17***	0.81***	0.74***	-

Note. *For the holistic rating of GKs current performance level, non-parametric rank correlations were estimated; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Supplement 1b: Bivariate correlations across predictors for the U13 ($n = 929$).

Performance factor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Sprint (20m)	-							
(2) Agility (CODS)	0.46***	-						
(3) Dribbling	0.20***	0.47***	-					
(4) Ball control	0.05	0.17***	0.31***	-				
(5) Juggling	-0.02	-0.08**	-0.25***	-0.24***	-			
(6) <i>GK-specific Technical skills</i>	-0.21***	-0.17***	-0.24***	-0.19***	0.21***	-		
(7) <i>GK-specific Tactical skills</i>	-0.19***	-0.13***	-0.18***	-0.17***	0.16***	0.78***	-	
(8) <i>Current PL (holistic)*</i>	-0.23**	-0.17***	-0.18***	-0.18***	0.17***	0.77***	0.73***	-

Note. *For the holistic rating of GKs current performance level, non-parametric rank correlations were estimated; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Supplement 1c: Bivariate correlations across predictors for the U14 ($n = 576$).

Performance factor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Sprint (20m)	-							
(2) Agility (CODS)	0.48***	-						
(3) Dribbling	0.24***	0.48***	-					
(4) Ball control	0.04	0.16***	0.26***	-				
(5) Juggling	-0.07	-0.11**	-0.28***	-0.28***	-			
(6) <i>GK-specific Technical skills</i>	-0.19***	-0.18**	-0.22***	-0.12**	0.19***	-		
(7) <i>GK-specific Tactical skills</i>	-0.12**	-0.12**	-0.17***	-0.06*	0.14***	0.77***	-	
(8) <i>Current PL (holistic)*</i>	-0.19***	-0.13**	-0.16***	-0.05	0.19***	0.77***	0.72***	-

Note. *For the holistic rating of GKs current performance level, non-parametric rank correlations were estimated; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Supplement Id: Bivariate correlations across predictors for the U15 ($n = 332$).

Performance factor	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Sprint (20m)	-							
(2) Agility (CODS)	0.45***	-						
(3) Dribbling	0.16**	0.50***	-					
(4) Ball control	-0.04	0.15**	0.29***	-				
(5) Juggling	0.04	-0.12*	-0.25***	-0.22***	-			
(6) <i>GK-specific Technical skills</i>	-0.10	-0.11*	-0.16**	-0.07	0.19***	-		
(7) <i>GK-specific Tactical skills</i>	-0.15**	-0.13*	-0.16**	-0.05	0.15**	0.80***	-	
(8) <i>Current PL (holistic)*</i>	-0.12*	-0.13*	-0.17**	-0.05	0.10	0.76***	0.72***	-

Note. *For the holistic rating of GKs current performance level, non-parametric rank correlations were estimated; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Appendix 7. Full Manuscript of Study 6

The full reference of the published article is:

Bergmann, F., Danner, J., Schultz, F., Pollmann, D., & Höner, O. (2021). Talentdiagnostik von Fußballtorhütern. Entwicklung und Evaluation eines sensomotorischen Koordinationstests [Talent Assessment in Soccer Goalkeepers. Development and Evaluation of a Coordination Test]. *Leistungssport*, 51(1), 50-55.

Zusammenfassung

Bei der Talentsichtung und -förderung im Sport hat sich der Einsatz diagnostischer Verfahren als Ergänzung zur subjektiven Trainerbeurteilung etabliert. Insbesondere im Fußball kann auf eine Vielzahl von Testverfahren zurückgegriffen werden, die jedoch vor allem das Anforderungsprofil der Feldspieler in den Blick nehmen. Leistungsdiagnostische Verfahren für Fußballtorhüter sind in der Literatur seltener zu finden. Speziell für das Alter der frühen Adoleszenz – als besonders relevante Entwicklungsphase der Talentsichtung – liegt keine Diagnostik für Fußballtorhüter vor. Das Ziel dieser Studie war die Entwicklung und Evaluation eines sensomotorischen Koordinationstests zur Talentdiagnostik von Fußballtorhütern. Die Testbatterie besteht aus sieben Einzeltests und wurde im Rahmen von einer Pilot- und einer Hauptstudie evaluiert. In der *Pilotstudie* wurden mit Torhütern des DFB-Talentförderprogramms ($n = 19$) die Auswertungsobjektivität und die Retest-Reliabilität überprüft. Die Auswertungsobjektivität kann für alle Testitems sowie für den aus allen Tests berechneten Gesamtscore bestätigt werden. Die Retest-Reliabilität liegt bei sechs der sieben Tests in akzeptablen bis guten Bereichen sowie für den aus allen zuverlässigen Tests ermittelten Gesamtscore in einem sehr guten Bereich. In der *Hauptstudie* wurde die Kriteriumsvalidität der sechs zuverlässigen Tests mit weiteren Torhütern des

DFB-Talentförderprogramms ($n = 62$) geprüft. Dazu wurden die Torhüter nach einer dreitägigen Sichtungsmaßnahme durch eine Expertenbeurteilung in drei Leistungsgruppen unterteilt. Die laut Rating leistungsstärksten Torhüter erzielten im Gesamtscore sowie auf Einzeltestebene die besten Testergebnisse, sodass auch die Kriteriumsvalidität bestätigt werden kann. Die entwickelte Testbatterie stellt somit eine geeignete Grundlage dar, um die Praxis perspektivisch durch eine Talentdiagnostik für Fußballtorhüter zu unterstützen.

Schlagwörter: Fußballtorhüter; Talent; Leistungsdiagnostik; Koordination; Sensomotorik

Einleitung

Für die Sichtung und Förderung sportartspezifisch talentierter Kinder ist die Entwicklungsphase der frühen Adoleszenz von besonderem Interesse (Höner, Larkin, Leber & Feichtinger, 2020). Als Unterstützung des subjektiven Trainerurteils werden deshalb in vielen Sportarten wissenschaftlich evaluierte Testverfahren eingesetzt, die einzelne Talentprädiktoren objektiv erfassen sollen (Johnston, Wattie, Schorer & Baker, 2018; Sieghartsleitner, Zuber, Zibung & Conzelmann, 2019).

Die zunehmende Evidenzbasierung bei der Talentdiagnostik ist u.a. im Fußballsport zu beobachten (vgl. dazu ausführlich Ali, 2011; Bergkamp, Niessen, Hartigh, Frencken & Meijer, 2019; Russel & Kingsley, 2011). Im Talentförderprogramm des Deutschen Fußball-Bunds wird beispielsweise eine technomotorische Diagnostik (Lottermann, Laudenklos & Friedrich, 2003) eingesetzt, deren diagnostische und prognostische Validität in zahlreichen Studien bestätigt werden konnte (z. B. Höner, 2013; Höner, Leyhr & Kelava, 2017; Höner, Votteler, Schmid, Schultz & Roth, 2015; Leyhr, Kelava, Raabe & Höner, 2018). Die Testanforderungen dieser und weiterer fußballspezifischer Diagnostiken fokussieren jedoch primär das Anforderungsprofil der Feldspieler.

Da Fußballtorhüter ein deutlich anderes Anforderungsprofil aufweisen (z. B. Hughes, Caudrelier, James, Redwood-Brown, Donnelly, Kirkbridge & Duschesne, 2012; Rechner & Memmert, 2010), ist eine spezifische Talentdiagnostik für eine aussagekräftige Unterstützung bei der Talentsichtung und -förderung von Torhütern wünschenswert. Im Sinne eines multidimensionalen Talentverständnisses sollten dabei grundsätzlich eine Vielzahl an Prädiktoren und Einflussfaktoren berücksichtigt werden (Höner et al., 2020). Ein bedeutsamer Einflussfaktor bei der Identifikation talentierter Torhüter ist, dass die überwiegende Mehrheit der Kinder das organisierte Fußballspielen als Feldspieler beginnt und sich der Zeitpunkt der Torwartspezialisierung oftmals erheblich unterscheidet. Damit einhergehend – und aufgrund der strukturellen Voraussetzungen vieler Vereine – unterscheidet sich der Zugang zu einer spezifischen Förderung (bspw. systematisches Torwarttraining) vor allem in frühen Phasen der Talentförderung in vielen Fällen erheblich. Als *spezifische Talentmerkmale* in der frühen Adoleszenz sind daher torhüterspezifische Grundlagenfähigkeiten von besonderem Interesse, die einen entscheidenden Ausgangspunkt für die Talentförderung der Torhüter bilden. In der trainingspraktischen Fachliteratur zum Torwartspiel werden als solche Grundlagenfähigkeiten die Koordination und Bewegungsgeschicklichkeit, z. B. als Voraussetzungen für das Erlernen von komplexen Bewegungsabläufen, hervorgehoben (Greiber, 2015). Die Bedeutung koordinativer Fähigkeiten für das Torhüterspiel wurde bereits vor rund 20 Jahren von verschiedenen Experten herausgestellt (Koitka, 2002; Pabst & Simon, 1998; Pabst & Simon, 1999) und wird auch in aktuelleren Publikationen weiterhin postuliert (z. B. Busch, 2017; DFB, 2016; Greiber, 2015). Insbesondere koordinative Bewegungsaufgaben mit unterschiedlichen Ballarten (z. B. Kollath, 2005) sowie die visuelle Wahrnehmung und im Speziellen die Auge-Hand-

Koordination (z. B. Mulqueen & Woitalla, 2011; Schlieck, 2010) werden in diesem Zusammenhang vielfach betont. Greiber (2015) fasst diese Fähigkeiten unter der torhüterspezifischen Koordination zusammen. Da die genannten Fähigkeiten über die Bewegungskoordination hinausgehen und auch sensorische Komponenten umfassen, kann von der torhüterspezifischen sensomotorischen Koordination als einer bedeutsamen Grundlagenfähigkeit von Fußballtorhütern gesprochen werden.

In leistungsdagnostischen Studien wurden primär die anthropometrischen Grundvoraussetzungen sowie die physiologische Leistungsfähigkeit der Fußballtorhüter untersucht und oftmals mit Leistungen von Feldspielern verglichen (für einen Überblick z. B. West, 2018; White, Hills, Cooke, Batten, Kilduff, Cook, Roberts & Russel, 2018). Unterschiede ergaben sich unter anderem hinsichtlich der konstitutionellen Voraussetzungen sowie der Ausdauerleistungsfähigkeit, die bei Torhütern geringer ausgeprägt ist, was mit den positionsspezifischen Anforderungen erklärt werden kann (vgl. White et al., 2018, S. 2512).

Von besonderem Interesse für die Fußballpraxis sind jedoch Leistungsdiagnostiken, bei denen Torhüter mit Testanforderungen konfrontiert werden, die ihrem spezifischen Anforderungsprofil entsprechen (vgl. Tab. 1). Ferrauti, Knoop, Pischetsrieder und Lange (2009, S. 16) zeigten auf, dass solche – insbesondere wissenschaftlich evaluierte – Diagnostiken „eine Ausnahme“ sind. Die Autoren verwiesen lediglich auf einen Ansatz von Leitert (2001), der eine videogestützte *Technik-/Taktik-Analyse* und *konditionelle Diagnostik* entwickelte, welche jedoch nicht empirisch überprüft wurde. Als Konsequenz aus der geringen Anzahl an entsprechenden leistungsdagnostischen Verfahren entwickelten

und evaluierten Ferrauti et al. (2009) eine aus vierzehn Einzeltests bestehende Testbatterie, die *offensive, defensive und elementare*²⁴ Anforderungsbereiche des Torwartspiels aufgreift. In einer Folgestudie von Knoop, Fernandez-Fernandez und Ferrauti (2013) wurde das Messinstrument zur Erfassung der komplexen Aktionsschnelligkeit bei seitlichen Abdruckbewegungen validiert. In den vergangenen Jahren wurden weitere Diagnostiken mit Schwerpunkten auf verschiedenen Komponenten des Torwartspiels konzipiert. Für den Bereich der *kognitiven* Leistungsfähigkeit untersuchte Schultz (2014; siehe auch Schultz, Daniel & Höner, 2018) die Antizipationsleistung von Torhütern in einer Laborstudie. Rebelo-Gonçalves, Figueiredo, Coelho-e-Silva und Tessitore (2016) entwickelten zwei Testverfahren zur Erfassung der *Schnelligkeit bei torwartspezifischen Defensivaktionen*, bei denen die Torhüter nach vorgegebenen Sprintwegen über wenige Meter vor dem Tor installierte Bälle möglichst schnell mit den Händen berühren müssen. In einem anderen Ansatz wurden kinetische und kinematische *Bewegungsanalysen* von seitlichen Abdruckbewegungen von Fußballtorhütern untersucht, wodurch Erkenntnisse über Gelenkwinkel, Kraftparameter sowie etwaige Lateralitätseffekte generiert werden konnten (Ibrahim, Kingma, de Boode, Faber & van Dieën, 2019).

²⁴ Elementare Anforderungen wurden als Überbegriff für drei athletische Testverfahren (Squat-Jump, Counter-Movement-Jump und Tapping-Test) verwendet.

Tabelle 1. Übersicht torwartspezifischer Diagnostiken und Befunde der Reliabilität und Validität.

Autor (Jahr)	Erläuterung	Probanden (Niveau der TW)	Ergebnisse (Reliabilität & Validität)
Leitert (2001)	Videogestützte Technik-/Taktik-Analyse sowie konditionelle Leistungsdiagnostik	n = 36 • Profis (n=18) • U16-U21 Elite (n=18)	R.: k. A. V.: k. A. (z. T. Vorteile der Profis vs. U16-U21)
Ferrauti et al. (2009)	14 Tests (offensive, defensive, elementare Anforderungen)	n = 17 • Profi (n=1) • U19-BL (n=16)	R.: r=.5 - .7 (nur defensive Aktionsschnelligkeit). V.: Größtenteils Vorteile des Profis vs. U19
& Knoop et al. (2013)	Validierung eines Messinstruments zur Erfassung der komplex-defensiven Aktions-schnelligkeit	n = 34 • U19-BL (n=21) • U14-Auswahl (n=13)	R.: ICC=.68-.95 V.: Vorteile der Stammtorhüter sowie U19 vs. U14
Rebello-Gonçalves et al. (2016)	2 Tests zur Schnelligkeitserfassung bei torwartspezifischen Falltechniken (flach) nach Kurzsprints	n = 66 • Elite (n=18) • Amateure (n=22) • Jugend (n=26)	R.: ICC=.83-.91 V.: Vorteile der Elite-TW
Schultz et al. (2018)	Kognitive Diagnostik zur Antizipationsleistung bei Tor-schüssen	n = 45 • U18-LV (n=24) • U15-LV (n=21)	R.: α=.94 V.: Vorteile erfahrener TW u.a. durch effektiveres Blickverhalten
Ibrahim et al. (2019)	Kinematische und kinetische Bewegungsanalyse seitlicher Abdruckbewegungen sowie der TW-Grundstellung	n = 10 • Profis (n=8) • U17 Elite (n=2)	R.: k. A. V.: k. A.

Die dargelegten Testverfahren stellen in ihrem intendierten Kontext geeignete Ansatzpunkte für eine torwartspezifische Leistungsdiagnostik dar. Keine dieser Diagnostiken erfasst jedoch schwerpunktmäßig die torhüterspezifischen Grundlagenfähigkeiten. Die Zielgruppen der bestehenden Messinstrumente sind zudem Torhüter im höheren Jugend- bzw. im Erwachsenenalter. Ein Desiderat ergibt sich somit genau dort, wo die Talentförderung von Torhütern beginnt – in den Altersstufen der frühen Adoleszenz. Um die bestehende diagnostische Lücke zu schließen, wurde eine Talentdiagnostik für den Einsatz in dieser Altersstufe entwickelt, die torwartspezifische sensomotorisch-koordinative Fähigkeiten erfasst (Abb. 1; Bergmann, 2019).²⁵ Der Entwicklungsprozess wurde durch Expertengespräche (z.B. mit DFB-Torwarttrainern) begleitet, in denen insbesondere diskutiert

²⁵ Das ausführliche Testmanual (inkl. Vorgaben zum Testaufbau) finden Sie auf www.leistungssport.net

wurde, ob die entwickelten Testverfahren für Fußballtorhüter relevante Grundlagenfähigkeiten abbilden.²⁶ Zudem wurden hohe Anforderungen an die Testökonomie gestellt, um die Tests perspektivisch unabhängig von strukturellen Voraussetzungen der Vereine einsetzen zu können. Nach mehreren Pre-Tests wurden in einer Diskussionsrunde mit Experten des Torwartspiels aus Wissenschaft und Sportpraxis sieben Testverfahren ausgewählt und einer empirischen Güteprüfung unterzogen.

Evaluation der Testbatterie

Das *Ziel* der vorliegenden Untersuchung war eine erste testtheoretische Prüfung der entwickelten Torwartdiagnostik. Um die Testbatterie perspektivisch in der Sportpraxis einsetzen zu können, ist es notwendig, dass die gewonnenen Testergebnisse objektiv und zuverlässig (reliabel) sind. Darüber hinaus gilt es zu untersuchen, ob die Testbatterie das Leistungsniveau der Torhüter abbilden kann (Kriteriumsvalidität). Hierzu wurden eine Pilot- und eine Hauptstudie mit folgenden Fragestellungen durchgeführt:

Pilotstudie: Erfüllen die entwickelten Testverfahren die wissenschaftlichen Hauptgütekriterien der Auswertungsobjektivität und der Retest-Reliabilität?

Hauptstudie: Bilden die individuellen Testergebnisse Trainerurteile zur Leistungsfähigkeit von Torhütern ab und bestätigen somit die Kriteriumsvalidität?

²⁶ An dieser Stelle möchten wir Efthimios Kompodietas für wertvolle Anregungen bei der Testentwicklung, u. a. durch sein Training mit den deutschen Juniorennationaltorhütern, danken.

Testablauf		Operationalisierung
Dominierende Testanforderung: Auge-Hand-Feinkoordination		
	1. Wurf- und Fang-Test (WFT I) Der TW wirft aus einer schulterbreiten Armhaltung zwei Jonglierbälle zeitgleich von der einen in die andere Hand. Ein im voraus festgelegter Ball (farblich markiert) muss dabei immer über den anderen Ball geworfen werden.	Werden beide Bälle gefangen, erhält der TW einen Punkt. Er versucht in der Testdauer so viele Punkte wie möglich zu erzielen. Testdauer: 30 Sekunden
	2a/b. Wurf- und Fang-Test gekreuzt (WFT II) Der TW wirft aus einer schulterbreiten Armhaltung zwei Jonglierbälle zeitgleich in die Luft und fängt sie mit gekreuzten Armen wieder auf. Nächste Würfe erneut aus paralleler Armhaltung. Die obere Fanghand wird vorgegeben. Zwei Testdurchgänge für die li. (Test 2a) und re. Hand (Test 2b) als obere Fanghand.	Werden beide Bälle gefangen, erhält der TW einen Punkt. Er versucht in der Testdauer so viele Punkte wie möglich zu erzielen. Testdauer: 30 Sekunden
Dominierende Testanforderung: Auge-Hand-Koordination		
	3. Rückprall-Test (RT) Der TW wirft zwei Fußbälle aus 1,2 Metern Entfernung zeitgleich gegen die Hallenwand und fängt sie mit derselben Hand wieder auf.	Werden beide Bälle gefangen, erhält der TW einen Punkt. Er versucht in der Testdauer so viele Punkte wie möglich zu erzielen. Testdauer: 30 Sekunden
	4. Ballfang-Test (BT) Der TW wirft einen Fußball aus 1,4 Metern Entfernung beidhändig von unten (unterhalb der Ellenbogen) gegen die Hallenwand und fängt ihn oberhalb der eigenen Ellenbogen beidhändig wieder auf.	Wird der Ball oberhalb der Ellenbogen gefangen, erhält der TW einen Punkt. Er versucht in der Testdauer so viele Punkte wie möglich zu erzielen. Testdauer: 20 Sekunden
Dominierende Testanforderung: Bewegungsgeschicklichkeit		
	5. Schritt-Test (ST) Der TW fängt vom Testleiter leicht seitlich neben den TW angeworfene Fußbälle aus 1,8 Metern Entfernung einhändig und setzt zeitgleich den gegengleichen Fuß in das vordere Markierungsfeld. Anschließend wirft er den Ball zurück zum Testleiter und erwartet den nächsten angeworfenen Ball.	Wird der Ball gefangen und der gegengleiche Fuß ins vordere Markierungsfeld gesetzt, erhält der TW einen Punkt. Er versucht in der Testdauer so viele Punkte wie möglich zu erzielen. Testdauer: 30 Sekunden
	6. Torwart-Bewegungs-Test (TBT) Der TW wirft einen Fußball in die Luft, setzt sich schnellstmöglich auf den Hallenboden, steht wieder auf und fängt den Ball möglichst hoch in der Luft wieder auf. Im Anschluss hat der TW Zeit zur Erholung und startet anschließend den nächsten Wurf. Die Güte des Durchgangs wird anhand einer vierstufigen Skala (siehe Operationalisierung) beurteilt.	Der TW hat fünf Würfe pro Testdurchgang, deren Punktzahl addiert wird (max. 15 Pkt.). Bewertungsskala: Der Ball wird... ...nicht gefangen (0 P.). ...unterhalb des Kinns gefangen (1 P.). ...oberhalb des Kinns gefangen (2 P.). ...oberhalb des Kopfes mit Absprung gefangen (3 P.).
Dominierende Testanforderung: Reaktionsschnelligkeit		
	7. Drei-Felder-Reaktions-Test (DFRT) Der TW fängt zurückprallende, vom Testleiter in drei Zielfeldern an der Wand geworfene (Distanz zur Wand: 1,95 Meter), Tennisbälle (linkes Feld - rechte Hand; rechts Feld - linke Hand und mittleres Feld - beidhändig). Die Bälle werden in festgelegten und den TW nicht bekannten Reihenfolgen vom Testleiter in die Felder geworfen.	Es werden vier Bälle pro Feld (12 Bälle pro Serie) absolviert, deren Punktzahl addiert wird. Bewertungsskala: Berührung des Balles mit der richtigen Hand = 1 Punkt. Festhalten des Balles mit der richtigen Hand = 2 Punkte.
Allgemeine Anmerkungen: Die Torhüter absolvieren vor allen Tests eine festgelegte Anzahl an Probeversuchen. Anschließend werden zwei Testdurchgänge absolviert, wobei der jeweils bessere Durchgang zur Auswertung herangezogen wird. Bei allen Tests mit einem großen Einfluss des Testleiters (z. B. durch das Anwerfen der Bälle) werden diesem präzise Vorgaben für sein Handeln gegeben, um die Testbedingungen zu objektivieren.		

Abbildung 1. Vorstellung der sieben Testverfahren des Koordinationstests für Fußballtorhüter.

Pilotstudie: Objektivität und Reliabilität

In der *Pilotstudie* wurden männliche Torhüter ($n = 19$; Durchschnittsalter 12.2 ± 0.8 Jahre) im Test-Retest-Design getestet. Alle Probanden waren durch das DFB-Talentförderprogramm gesichtete DFB-Stützpunkt-Torhüter im Fußball- und Leichtathletik Verband Westfalen (FLVW). Die Datenerhebung erfolgte bei Stützpunktwochenschulungen in der Sportschule Kaiserau. Die Torhüter durchliefen die Testbatterie am selben Tag zweimal. Alle Einzeltests wurden durch DFB-Stützpunkttrainer durchgeführt und die Ergebnisse vor Ort in einem Testprotokoll dokumentiert. Parallel wurden alle Torhüter bei der Testdurchführung gefilmt und die Testergebnisse videobasiert ausgewertet. Die entsprechenden Korrelationskoeffizienten können als Gütemaß der *Auswertungsobjektivität* angesehen werden, wohingegen die Ermittlung der *Retest-Reliabilität* auf Basis der zweimaligen Testdurchführung erfolgte. Zur Auswertung wurde der bessere von zwei Testdurchgängen herangezogen (vgl. Tab. 2).

Tabelle 2. Koeffizienten (Pearson) der Auswertungsobjektivität und Retest-Reliabilität.

Test	Objektivität	Reliabilität
Score	.99***	.95***
1	.91***	.66**
2a	.94***	.89***
2b	.90***	.86***
3	.98***	.80***
4	.90***	.67**
5	.96***	.65**
6	.98***	.68***
7	.99***	.42

Anmerkungen: Bei Test 2 sind jeweils zwei Werte angegeben, da die Auswertung für die linke (Test 2a) und die rechte Hand (Test 2b) als obere Fanghand separat durchgeführt wurde; Zur Absicherung wurden aufgrund der kleinen Personenstichprobe Rangkorrelationen berechnet, welche diese Resultate bestätigen.

*** $p < .001$, ** $p < .01$, * $p < .05$.

Die Auswertungsobjektivität aller Tests kann als gegeben betrachtet werden, da die Werte ausschließlich in „hohen“ und „sehr hohen“ Bereichen liegen (Bös, 2017, S. 819). Die Retest-Reliabilität kann für sechs der sieben Testverfahren ebenfalls bestätigt werden. Ihre Koeffizienten liegen in Anlehnung an Bös (2017, S. 821) in „mäßigen“ (Tests 1, 4, 5 und 6) bis „sehr guten“ (Test 2a/b und 3) Bereichen. Test 7 ist als nicht-zuverlässig zu bewerten und wurde deshalb aus der Testbatterie eliminiert. Erklärt werden kann dieser Befund mit einem zu großen Einfluss des Testleiters durch das Anwerfen der Tennisbälle. Um die Testbatterie insgesamt bewerten zu können, wurde ein *Gesamtscore* aus den Mittelwerten der T-standardisierten Rohwerte aller Einzeltests berechnet.²⁷ In den Gesamtscore flossen bei der Auswertungsobjektivität alle Testverfahren, bei der Retest-Reliabilität lediglich die sechs zuverlässigen Tests ein. Zuvor durchgeführte Konsistenzanalysen mittels odd-even Testhalbierungsmethode (Spearman Brown) belegen für Test ($r_{tt} = .89$) und Retest ($r_{tt} = .89$) zufriedenstellende Werte. Die Auswertungsobjektivität und Retest-Reliabilität des Gesamtscores liegen in sehr guten Bereichen (vgl. Tab. 2).

Hauptstudie: Kriteriumsvalidität

In der *Hauptstudie* wurden männliche Torhüter des DFB-Stützpunktprogramms ($n = 62$; Durchschnittsalter 12.7 ± 1.2 Jahre) im Rahmen von Torwartwochenschulungen des FLVW in der Sportschule Kaiserau getestet. Bei diesen Sichtungsmaßnahmen trainieren die Auswahltorhüter an drei Lehrgangstagen mit DFB-Stützpunkt-Torwarttrainern. Die interne Konsistenz der Testbatterie lag auch in der Hauptstudie in einem zufriedenstellenden Bereich ($\alpha = .80$).

²⁷ T-standardisierte Werte wurden den üblicherweise verwendeten z-Werten vorgezogen, da Testergebnisse um einen Wert von 50 deutlich anschaulicher und somit v.a. auch für Kinder leichter nachzuvollziehen sind.

Nach der Maßnahme wurde jeder Torhüter durch die Trainerteams in drei Leistungskategorien eingestuft (vgl. Tab. 3). Die Torwarttrainer hatten bei ihrer Beurteilung keine Kenntnis über die in der Zwischenzeit erhobenen Testergebnisse der Torhüter, um eine mögliche Beeinflussung auszuschließen. Das Expertenurteil diente der Operationalisierung des individuellen Leistungsniveaus, um dieses als Kriterium zur Validitätsprüfung der Testbatterie heranziehen zu können.

Tabelle 3. Leistungskategorien A, B und C der Expertenbeurteilung.

Kategorie	Erläuterung
A	In nahezu allen Anforderungsbereichen auffällig leistungsstarker STP-TW. Der TW ist für nächsthöhere Selektionsstufen (z. B. die LV-Auswahl) geeignet.
B	Durchschnittlicher STP-TW, der zukünftig im STP-Programm gefördert werden sollte. Zum Zeitpunkt der Bewertung kommt der TW jedoch nicht für höhere Selektionsstufen infrage.
C	Unterdurchschnittlicher STP-Torwart, mit Schwächen in mehreren Anforderungsbereichen des TW-Spiels. Der Verbleib des TW im STP-Programm muss diskutiert werden.

Legende: STP-TW = Stützpunkt-Torwart; LV-Auswahl = Landesverbandsauswahl.

Die Trainer ordneten elf Torhüter (17.7%) der leistungsstärksten Gruppe A zu. 31 Torhüter (50.0%) wurden der mittleren Leistungsgruppe B und 20 Torhüter (32.3%) der leistungsschwächsten Gruppe C zugeteilt. Zwischen den drei Leistungsgruppen lagen keine signifikanten Unterschiede des Alters sowie der anthropometrischen Voraussetzungen vor (jeweils $p > .30$), sodass ein Einfluss dieser Merkmale bei der Expertenbeurteilung ausgeschlossen werden kann.

Für die *Kriteriumsvalidität* der Tests wurden die Testleistungen der Probanden mit der Leistungsbeurteilung der Trainerexperten verglichen. Zur Auswertung wurde erneut der bessere von zwei Testdurchgängen herangezogen. Eine einfaktorielle Varianzanalyse (ANOVA) ergab sowohl für den Gesamtscore als auch auf Einzeltestebene signifikante Unterschiede zwischen den drei Leistungsgruppen (vgl. Tab. 4).

Tabelle 4. Rohwerte der Einzeltests und Ergebnisse der einfaktoriellen ANOVA zur Analyse der Kriteriumsvalidität.

Test	Leistungsniveau			ANOVA		
	A (n = 11)	B (n = 31)	C (n = 20)			
	MW ± SD			F(2, 59)	p	η_p^2
Score	57.90 ± 6.83	48.51 ± 5.21	47.95 ± 6.33	12.31	< .001	0.29
1	27.09 ± 9.36	19.29 ± 5.30	19.25 ± 4.20	7.93	.001	0.21
2a	11.09 ± 10.53	5.71 ± 5.18	8.95 ± 6.03	3.17	.049	0.10
2b	16.55 ± 9.28	9.48 ± 7.42	9.00 ± 6.47	4.18	.020	0.12
3	25.91 ± 4.74	18.94 ± 6.52	18.40 ± 5.46	6.70	.002	0.19
4	22.91 ± 3.39	19.80 ± 2.99	19.45 ± 4.94	3.49	.037	0.11
5	16.91 ± 2.62	13.90 ± 3.66	12.60 ± 4.09	4.95	.010	0.14
6	11.45 ± 3.90	7.42 ± 3.28	6.20 ± 3.51	8.39	.001	0.22

Anmerkung: Der Gesamtscore wurde aus dem Mittelwert aller T-Standardisierten Einzeltests berechnet.

Die Ergebnisse der post-hoc Vergleiche mit Bonferroni-Korrektur sind in der Abbildung 2 dargestellt. Im Gesamtscore erzielten die Torhüter der Gruppe A signifikant bessere Testergebnisse als die beiden leistungsschwächeren Gruppen mit jeweils starken Effekten ($1.51 \leq d \leq 1.55$). Keine Unterschiede lagen zwischen den Gruppen B und C vor. Die deskriptive Betrachtung der Rangplätze (vgl. Abb. 3) zeigt, dass 81.8 % ($n = 9$) der Torhüter aus Gruppe A Plätze im vorderen Drittel der Gesamtstichprobe belegten. Unterschiede der Rangplatzierungen zwischen den Gruppen B und C lagen nicht vor. Auch auf Einzeltestebene waren die Torhüter der Gruppe A im Vergleich zu den Gruppen B und C bei allen Tests deskriptiv am leistungsstärksten. Signifikant bessere Testleistungen der Gruppe A im Vergleich zu den Gruppen B und C zeigten sich bei den Tests 2b, 3 und 6 ($0.84 \leq d \leq 1.42$). Bei Test 5 wurde nur der Vergleich mit der leistungsschwächsten Gruppe signifi-

kant ($d = 1.25$). Bei drei weiteren Tests (1, 2a, 4) konnten trotz der signifikanten Gruppeneffekte im Gesamtmodell post-hoc nur deskriptive Unterschiede ermittelt werden. Dies kann auf eine zu geringe Teststärke aufgrund der vergleichsweise kleinen Stichprobe zurückgeführt werden. Die nicht-signifikanten Unterschiede zwischen den Gruppen B und C lassen auf ein sehr homogenes Leistungsniveau und/oder auf eine zu ungenaue Expertenbeurteilung dieser beiden Kategorien schließen. Möglicherweise fiel die Erkennung besonders talentierter Torhüter leichter als die Unterscheidung zwischen Torhütern der Gruppen B und C. Zusammenfassend bestärken die Befunde hypothesenkonform, dass die als besonders talentiert bewerteten Torhüter der Gruppe A auch die besten Testleistungen erzielten, sodass die Kriteriumsvalidität bestätigt werden kann.

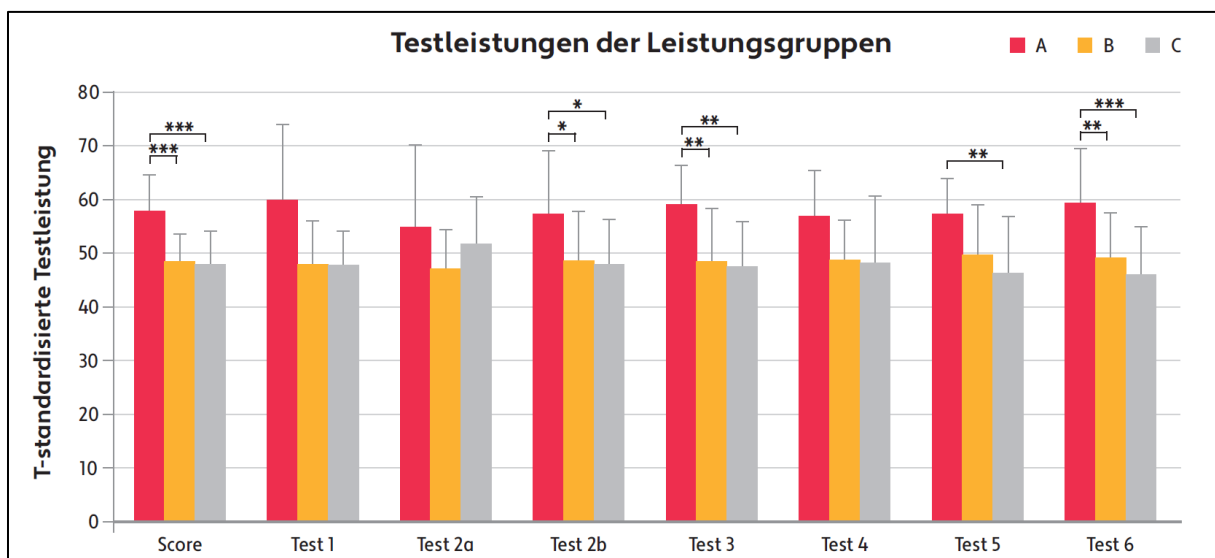


Abbildung 2. Post-hoc Vergleiche der Leistungsgruppen A, B und C (Abbildung aus Bergmann et al., 2021, S. 55; mit freundlicher Genehmigung von Philippka).

Anmerkung. In dieser Abbildung sind die T-standardisierten Mittelwerte für die Einzeltests sowie als Gesamtscore der Mittelwert dieser Werte angegeben. *** $p < .001$, ** $p < .01$, * $p < .05$

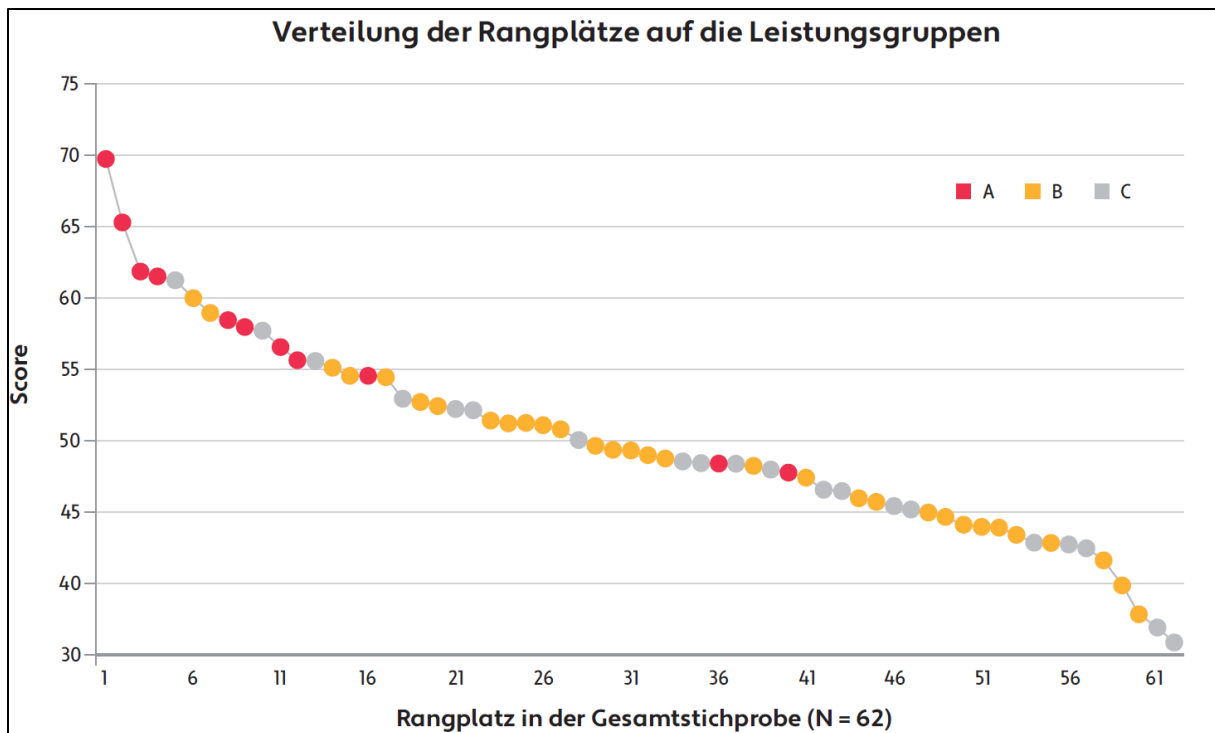


Abbildung 3. Rangplätze des Gesamtscores der Leistungsgruppen A, B und C (Abbildung aus Bergmann et al., 2021, S. 55; mit freundlicher Genehmigung von Philippka).

Diskussion und Ausblick

Die erste wissenschaftliche Evaluation der entwickelten Torwartdiagnostik zeigt, dass für sechs Testverfahren die Hauptgütekriterien Auswertungsobjektivität, Retest-Reliabilität und Kriteriumsvalidität bestätigt werden können. Die Befunde stützen, dass sensomotorisch-koordinative Fähigkeiten relevante Talentmerkmale von Nachwuchstorhütern in der frühen Adoleszenz sind. Der reibungslose organisatorische Ablauf und geringe Zeitaufwand verdeutlichen, dass die Testökonomie, als relevantes Nebengütekriterium leistungsdagnostischer Verfahren, ebenfalls gegeben ist. Inhaltlich erachten die mit dem Test befassten DFB-Stützpunkttrainer und Verbandssportlehrer die Testbatterie als sehr relevant. Zum einen wird die Notwendigkeit einer spezifischen Diagnostik für Nachwuchstorhüter betont und zum anderen die praxistaugliche Zusammenstellung dieser Testbatterie herausgestellt. Neben der Erfüllung wissenschaftlicher Gütekriterien ist der

hohe Aufforderungscharakter der Tests anzuführen, was an der großen Motivation der getesteten Torhüter ersichtlich wurde. Dies ist für die Diagnostik bedeutsam, damit die Probanden bei der Testung ihre bestmögliche Leistung abrufen. Insgesamt verdeutlicht diese erste Evaluation große Potenziale der entwickelten Testverfahren für den Einsatz als Talentdiagnostik von Fußballtorhütern. Dennoch lassen sich Ansatzpunkte zur Weiterentwicklung der Testbatterie aufzeigen.

Die *Weiterentwicklung der Tests* wird sich primär darauf konzentrieren, die Anforderungen (v. a. die Testschwierigkeit) für die Zielgruppe weiter zu optimieren. Denkbar ist außerdem, dass weitere Tests in die Testbatterie integriert oder Testverfahren aus der Testbatterie eliminiert werden. Aus Sicht der Trainer sollte ein weiteres Testverfahren mit größerem Bewegungsumfang (z. B. Sprungfolgen) ergänzt werden. Außerdem wird die Durchführung des Tests 5 „Schritt-Test“, insbesondere das Anwerfen der Bälle durch einen Testleiter als vergleichsweise komplex empfunden und sollte diesbezüglich überdacht werden. Für weitere Erkenntnisse und Rückmeldungen durch die Trainer und Torhüter ist ein Einsatz der aktuellen Testbatterie und möglicher weiterer Tests in der Sportpraxis unerlässlich. Bezüglich der Ergebnismeldung an die Torhüter ist geplant, diese in Form von individuellen Leistungsprofilen anschaulich und altersadäquat aufzubereiten.

Weitere *empirische Analysen* sind mit einer größeren Stichprobe erforderlich. Folgestudien mit Torhütern aus höheren Leistungsniveaus (z. B. Nachwuchsleistungszentren) sollen differenziertere Analysen zur Trennschärfe der Tests ermöglichen. Langfristig werden vor allem längsschnittliche Studien bedeutsam sein, um beispielsweise überprüfen zu können, ob adoleszente und erwachsene Torhüter des Hochleistungsbereichs im Kindesalter bessere Testergebnisse erzielten als Torhüter niedrigerer Leistungsniveaus. Die

dadurch messbare prognostische Validität ist eine Voraussetzung, um die Testbatterie als aussagekräftige Unterstützung im Rahmen der begleitenden Talentdiagnostik im Nachwuchsfußball einsetzen zu können.

Für die *Sportpraxis* lässt sich vor dem Hintergrund eines multidimensionalen Talentverständnisses (Höner et al., 2020) festhalten, dass motorische Diagnostiken zur Erfassung einzelner Talentprädiktoren keinesfalls das Trainer- beziehungsweise Torwarttrainerurteil ersetzen können oder sollen. Die vorliegende Diagnostik stellt jedoch einen ersten Ansatzpunkt dar, um auch im Bereich des Torwartspiels auf objektive Daten für die Talententwicklung zurückgreifen zu können, die als Ergänzung des Trainerurteils angesehen werden sollten. Sofern sich die positiven Befunde dieser ersten wissenschaftlichen Evaluation auch in den Folgeuntersuchungen bestätigen, könnte die Testbatterie bei der begleitenden Talentdiagnostik im Nachwuchsfußball eingesetzt werden. Ein perspektivisches Ziel könnte nach weiteren Modifikationen darin liegen, die Ergebnisse auch zur individuellen Trainingssteuerung heranzuziehen.

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Appendix 8. Supplementary Materials Study 7

Supplement I: Five Sequential Steps of Test Development.

Step 1: Inductive Development of an Initial Test Battery.

The test development was based on a co-design of practitioners and researchers. In specific, an expert panel was assembled comprising of GK experts working for the German Football Association's (DFB) TID program (i.e., full-time practitioners with several years of experience) and researchers working for the program's scientific support (i.e., researchers on TID, motor testing). Involvement of expert practitioners who will eventually apply the test battery in practice aimed at contributing to the content validity and feasibility (Phillips et al., 2023). Given the assessment's specific focus, this expert panel initially defined three practical criteria to be fulfilled by each test:

- a) The demands of individual tests should emphasize relevant aspects of motor coordination for football GKs. The practitioners considered both fine- and gross-motor demands as relevant and emphasized the relevance of demands termed as 'eye-hand coordination' as well as 'ball control'.
- b) All tests should be based on ball control demands as most GK-specific movements need to be coordinated with ball movements. Further justification for basing each test on ball control demands was provided by motivational factors during the assessment.
- c) To ensure the assessment's practical feasibility, each test should be applicable with basic equipment available at most local soccer clubs.

Based on these criteria, the expert panel developed test prototypes inductively. Further, the (applied) GK literature and recommended coordinative practice exercises were reviewed (e.g., Busch, 2017; Elleray, 2021; Otte et al., 2023). These sources supported, for example, basing individual tests around ball control demands given repeatedly high-

lighted the relevance of attributes such as “ball handling” (Otte et al., 2023, p. 114). Overall, individual tests should assess domain-specific motor coordination via motor tasks demanding ball control, thus, creating dynamic environments. Yet, to ensure that performance in the motor coordination assessment is not primarily underpinned by a participant’s performance level in one ball skill, individual tests should be based on different skills (i.e., throwing, catching, bouncing, etc.). This developmental process led to the initial test battery comprising seven tests (Bergmann et al., 2021c for the test manual).

Step 2: Pilot study I.

In a first pilot study, the test battery’s test-retest reliability and procedural objectivity were evaluated with a subsample of GKs ($N = 19$) selected for the DFB TID program (Bergmann et al., 2021b). Across individual tests, this initial application and evaluation revealed good to very good objectivity ($.90 \leq r_{xy} \leq .99$) and moderate to good test-retest reliability ($.66 \leq r_{xy} \leq .89$).

Step 3: Pilot study II.

In a second pilot study, the concurrent validity was investigated with another subsample of GKs ($N = 62$) selected for the DFB TID program. It was found that the individual tests reveal diagnostic power to discriminate between already selected GKs yet judged as differently talented by GK experts ($.10 \leq \eta_p^2 \leq .22$; Bergmann et al., 2021b).

Step 4: Further Development of the Test Battery by the Expert Panel.

Despite these promising findings found within the pilot studies (i.e., steps II & III), practical experiences when conducting the assessment and statistical results encouraged the expert panel to further optimize the test battery. Four out of seven tests were retained in the test battery (i.e., “Juggling-Ball-Change” [JBC]; “Ball-Wall-Rebounder - one ball” [BWR I]; “Ball-Wall-Rebounder - two balls” [BWR II]; “Throwing, Sitting Catching” [TSC];

see *Table 1* in the manuscript). Three other tests were eliminated due to a) comparably low reliability or validity coefficients, b) too large correlations between tests, or c) practitioners' feedback (e.g., too complex to apply).

The expert panel further decided that one further test stressing the control of a laterally moving ball and another test stressing whole-body movements would provide further relevant perspectives to the four already included tests. This has led to a second development phase in which the tests "Double-Ball-Bouncing" (DBB; two laterally moving balls) and "Bouncing-Turning-Catching" (BTC; whole-body movements) were added to the test battery.

Step 5: Expert Rating of the Content and Face Validity as well as the Practical Feasibility. The test battery underwent an independent rating by GK experts ($N = 8$) who were not part of the expert panel that developed the test battery. Three GK coaches were recruited from DFB base camp (BC; "competence center"), representing a potential context for implementation (2x A-License; 1x UEFA B⁺ License & GK-coach certifications). Three experts worked as GK coaches at YAs (1x UEFA A License, 1x B License; 1x GK B-License; 1x additional GK-coach certification), thus, representing a potential further target group for the assessment. Lastly, two experts (1x UEFA PRO-License; 1x UEFA A-License) hold full-time positions at football associations with responsibility for different topics related to TID in GKs.

All experts viewed a five-minute video clip, introducing the assessment's purposes (e.g., motor coordination tests with relevance for GKs, and application at early TID stages). Subsequently, each test was explained and demonstrated in a video clip. All six individual tests were then rated on a five-point Likert scale regarding the *relevance of coordinative test demands for GKs* (i.e., content validity; 1: "not relevant at all" to 5: "very relevant")

and the *degree to which the GK-specific coordination demands were implemented in the ball-related motor task* (i.e., face validity; 1: “not well implemented” to 5: “very well implemented”). In addition, the *feasibility of the test in the daily training routine*, considering the time- and equipment needed, was assessed (i.e., 1: “not feasible at all” to 5 “very feasible”). Two open questions further allowed the experts to provide concrete *suggestions for improvements or any further comments* (e.g., on the need for further tests).

The results of the expert rating demonstrated the test battery’s content and face validity, as well as the practical feasibility (*Table 1*). Across all items, the tests reached average ratings above a mean of four, thus, emphasizing the relevance of test demands and adequate representation by the motor tasks. The JBC was the only test that received a slightly lower average score of 3.9. Within open comments, some experts revealed skepticism on the test’s relevance for GKs given the motor task only relates to arms and hands and, thus, not a gross-motor task. Yet, given sufficient objectivity ($r_{xy} = .91$), test-retest-reliability ($r_{xy} = .66$), and criterion-validity ($\eta_p^2 = .21$) found within the pilot studies (Bergmann et al., 2021b), it was retained in the test battery. All tests finally included to the test battery are presented in the detailed test manual (Bergmann et al., 2024c).

Table 1. *Descriptive statistics (Mean $\pm$ Standard Deviation) of the independent expert ratings based on a five-point Likert scale (coded 1-5).*

	Content	Face	Practical Feasibility
JBC	4.0 $\pm$ 0.9	3.9 $\pm$ 0.6	4.6 $\pm$ 0.7
DBB	4.5 $\pm$ 0.5	4.3 $\pm$ 0.4	5.0 $\pm$ 0.0
BWR I	4.1 $\pm$ 0.8	4.6 $\pm$ 0.5	4.0 $\pm$ 1.1
BWR II	4.4 $\pm$ 0.5	4.5 $\pm$ 0.5	4.1 $\pm$ 1.2
TSC	4.8 $\pm$ 0.4	4.3 $\pm$ 0.7	5.0 $\pm$ 0.0
BTC	4.5 $\pm$ 0.7	4.1 $\pm$ 0.6	4.6 $\pm$ 0.5

Note. JBC = Juggling-Ball-Change; DBB = Double-Ball-Bouncing; BWR I = Ball-Wall-Rebounder - one ball; BWR II = Ball-Wall-Rebounder - two balls; TSC = Throwing-Sitting-Catching; BTC = Bouncing-Turning-Catching.

Supplement II. Screeplot based on the exploratory factor analysis with data at T1.