Can Implementation Intentions Improve Self-Regulation During Learning with Multimedia?

Dissertation

der Mathematisch-Naturwissenschaftlichen Fakultät
der Eberhard Karls Universität Tübingen
zur Erlangung des Grades eines
Doktors der Naturwissenschaften
(Dr. rer. nat.)

vorgelegt von
Emely Rosa Hoch, M.Sc.
aus Tübingen

Tübingen
2018

Gedruckt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Eberhard Karls Universität Tübingen.

Tag der mündlichen Qualifikation:	10.12.2018
Dekan:	Prof. Dr. Wolfgang Rosenstiel
1. Berichterstatter:	Prof. Dr. Katharina Scheiter
2. Berichterstatter:	Prof. Dr. Caterina Gawrilow

Acknowledgements

I would like to thank everyone who supported and encouraged me along the way of my dissertation in discussing research issues, offering advice and feedback, or just giving me a good time. Especially, I would like to thank the Leibniz-Institut für Wissensmedien as well as the LEAD Graduate School and Research Network for offering me an excellent research environment.

Moreover, I would like to particularly thank the following people for their support without whose help this work would never have been possible:

- my supervisors Prof. Dr. Katharina Scheiter and Dr. Anne Schüler who gave me much valuable advice and support throughout all the stages of my dissertation.
- Prof. Dr. Caterina Gawrilow who agreed to be the second reviewer of this dissertation.
- Prof. Dr. Kai Sassenberg for helpful feedback on my exposé and progress reports.
- my colleagues from the Multiple Representations Lab.
- Juliane Richter for in-depth discussions and for encouraging me a lot.
- Fabienne Kremer and Molly Hammer for proofreading.
- my family and friends.

Declaration on Contributions to Monography

Although the dissertation is written as a monography, it includes content of two manuscripts that are ready to submit. Passages of the manuscripts are found in the dissertation's theoretical chapters (Chapter 1 to 5) and General Discussion (Chapter 10). The empirical findings of Manuscript 1 are presented in Chapter 6. Manuscript 2 includes three experiments which are presented in Chapters 7, 8, and 9. Prof. Dr. Katharina Scheiter and Dr. Anne Schüler are co-authors of these manuscripts. Their proportional contributions to the manuscripts are presented in the subsequent tables.

Manuscript 1

Author	Author position	Scientific ideas %	Data generation %	Analysis & interpretation %	Paper writing %
Emely Hoch	first author	50 %	100 %	100 %	65 %
Katharina Scheiter	second author	50 %	0 %	0 %	20 %
Anne Schüler	third author	0 %	0 %	0 %	15 %

Title of paper: Can implementation intentions related to self-regulatory processes enhance learning in a multimedia environment?

Status in publication process: submitted

Manuscript 2

Author	Author position	Scientific ideas %	Data generation %	Analysis & interpretation %	Paper writing %
Emely Hoch	first author	70 %	100 %	100 %	70 %
Katharina Scheiter	second author	15 %	0 %	0 %	20 %
Anne Schüler	third author	15 %	0 %	0 %	10 %

Title of paper: Implementation Intentions for Improving Self-Regulation in Multimedia Learning: Why Don't They Do their Work?

Status in publication process: submitted

Table of Contents

Table of Contents

Table of Contents

Table of Contents

1 Introduction

Learning environments are becoming increasingly complex with the use of new media. The mere number of pictures used in school textbooks doubled over the last 50 years (Lee, 2010); however, these multimedia materials (i.e., text presented together with pictures) are often not designed in a way to be helpful for learning (Lee, 2010; Prangsma, Boxtel, Kanselaar, & Kirschner, 2009). Moreover, pictorial representations accompanying the text have to be actively processed in an integrated manner which has been shown to be challenging for learners (e.g., Scheiter, Schüler, & Eitel, 2017). At the same time, learners more and more frequently have to study autonomously. Thus, it becomes increasingly important that learners know how to manage their learning activities on their own, that is, how to self-regulate their learning (Bjork, Dunlosky, & Kornell, 2013). According to Pintrich (2000), self-regulation includes choosing adequate cognitive strategies (cognitive self-regulation), being confident about one's own learning abilities (motivational self-regulation), and investing sufficient effort in learning (behavioral self-regulation).

Within four experiments it was investigated whether supporting learners to self-regulate their learning in a multimedia environment would improve learning outcomes. Support was given for cognition, motivation, and behavior in self-regulation via implementation intentions. Implementation intentions (if-then plans) are a self-regulatory strategy for goal striving that helps to translate any kind of plan into action (Gollwitzer, 1999). It was expected that supporting learners in cognitively, motivationally, or behaviorally self-regulating their learning via implementation intentions would improve the learning outcome on a subsequent test.

In the following, the theoretical background of multimedia learning and common challenges that learners face in multimedia learning will be described. Then, a framework of self-regulated learning will be introduced and the challenges of multimedia learning will be categorized against the backdrop of this framework. Implementation intentions will be introduced as a strategy to support self-regulation and to overcome the self-regulatory challenges of multimedia learning. An overview of the research questions that were tested in four experiments will be given. The four experiments will then be described in more detail in the respective chapters. Finally, the findings will be summarized, set into the theoretical context, and discussed against the backdrop of the theory. Strengths, as well as limitations of the work, will be outlined.

2 Learning with Multimedia

Multimedia learning refers to the learning of simultaneously presented words and visualizations (Mayer, 1997, 2014a). Words can be presented as written or spoken text that is displayed on paper, computer screens, or as audio. Visualizations include static illustrations, graphics, photos, pictures, or charts, as well as dynamic graphics, videos, animations, or simulations. Learning from text and pictures is supposed to promote learning compared with learning from text alone (Anglin, Vaez, & Cunningham, 2004; Carney & Levin, 2002; Levie & Lentz, 1982), which is referred to as *multimedia principle* (Butcher, 2014; Fletcher & Tobias, 2005; Mayer, 1997, 2009, 2014c). In the following, two influential models of learning with text-picture combinations will be described, namely the *Cognitive Theory of Multimedia Learning* (CTML: Mayer, 2009, 2014a) and the *Integrated Model of Text and Picture Comprehension* (ITPC: Schnotz & Bannert, 2003; Schnotz, 2014).

2.1 Cognitive Models of Multimedia Learning

The CTML (Figure 1) describes the cognitive processing of multimedia messages to happen in multiple memory systems including sensory memory, working memory, and long-term memory (Atkinson & Shiffrin, 1968, 1971). The CTML is based on three central assumptions (Mayer, 2014a). First, related to the dual coding theory (Clark & Paivio, 1991; Paivio, 1986, 1991, 2006), it is assumed that text and pictures are processed in separate channels for auditory/verbal representations and visual/pictorial representations, respectively. Second, the limited-capacity assumption states that the amount of information that can be processed through those two channels at the same time is constrained, which closely relates to Baddeley’s model of working memory (Baddeley, 1992, 2000). Third, the active processing assumption concerns the learners who have to actively pay attention, select, organize, and integrate the information (Mayer, 2014a).

The CTML distinguishes five basic cognitive processes that are necessary for multimedia learning to be successful (Mayer, 2009, 2014a). Learners have to (1) select relevant words, (2) select relevant images, (3) organize the selected words to build a coherent verbal model, (4) organize the selected images to build a coherent pictorial model, and (5) integrate the verbal and pictorial model together with prior knowledge to acquire one coherent mental representation. The coordination of these processes and especially the integration of the verbal and the pictorial model is assumed to be extremely cognitively demanding. Thus, it is recommended to design multimedia messages so that learners are supported in executing these cognitive processes, which should prevent the working memory from being overloaded (Mayer, 2014a; Renkl & Scheiter, 2017). Two kinds of support can be distinguished: offloading and facilitating. Offloading refers to reducing unnecessary load for learners, for example, by eliminating information that is irrelevant for the task at hand. Facilitating, on the other hand, refers to ensuring adequate processing of the provided material, for instance, by making relevant information more salient without adding new content-related information (Renkl & Scheiter, 2017; Scheiter et al., 2017).

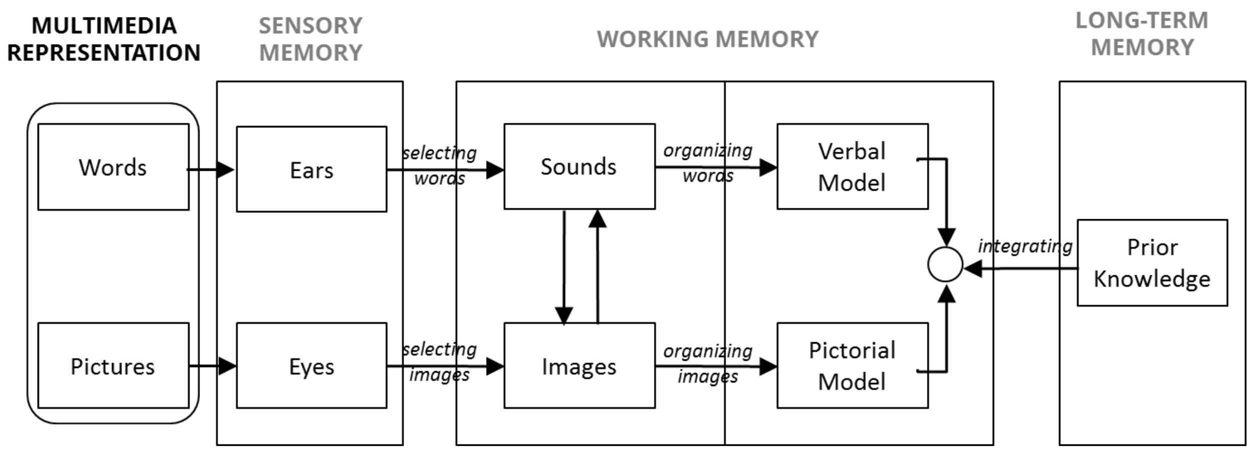

Figure 1. The cognitive theory of multimedia learning (adapted from Mayer, 2014a, p. 52)

An alternative but similar model to the CTML describing the cognitive processes in multimedia learning is the integrated model of text and picture comprehension (Figure 2; Schnotz, 2014; Schnotz & Bannert, 2003). The ITPC differentiates between the processing of descriptions that are arbitrary structures (e.g., text) and the processing of depictions that are analogous representations from which information can be read off directly (e.g., pictures). It also incorporates concepts of multiple memory systems (Atkinson & Shiffrin, 1968, 1971); the most important cognitive processes are assumed to occur in working memory that has a limited capacity (Baddeley, 1992, 2000). The ITPC assumes that descriptive and depictive information is transmitted to working memory through sensory registers. Depictive information is first represented as mental text surface structures and descriptive information as visual images. The learners transfer these representations via semantic deep structure processes to a propositional representation and a mental model. The ITPC incorporates and stresses interactions between the descriptive and depictive subsystems.

Particularly, building connections between the text and visual representations is assumed to happen at an early stage. To carry out these processes the learners are again required to actively engage in information processing.

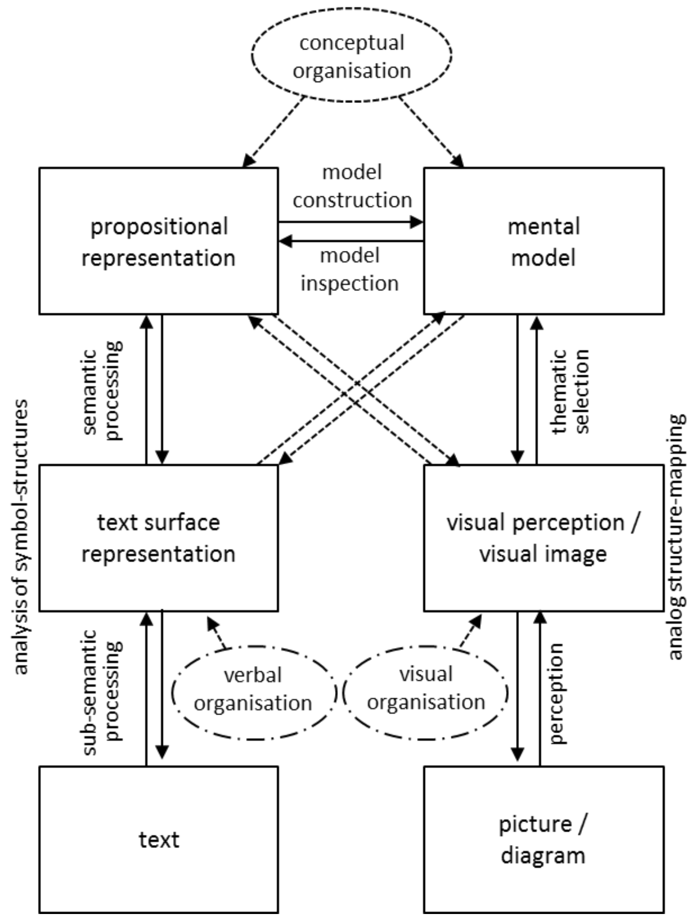

Figure 2. Theoretical framework for the integrated model of text and picture comprehension (adapted from Schnotz, 2014, p.79)

The ITPC like the CTML describes cognitive processes including selection, organization, and integration of information from different sources. In the multimedia literature, these processes are also characterized as coherence formation (Seufert, 2003). Thus, learners have to build a coherent verbal and a coherent pictorial mental model (local coherence), as well as an integrated model from both representations (global coherence). Both theories emphasize that integration of text and picture information and building one coherent mental representation is required for successful multimedia learning (Mayer, 2009, 2014a; Schnotz, 2014; Schnotz & Bannert, 2003).

2.2 Challenges in Multimedia Learning

Even though there is strong empirical evidence that learning with multimedia is advantageous for learning success (for an overview see Butcher, 2014), meaningful learning with multimedia material imposes several challenges onto the learner. This fits well with findings showing that multimedia material is often processed insufficiently when presented without instructional support (Scheiter et al., 2017). In the following, three major challenges learners face in multimedia learning will be distinguished and elaborated in more detail. These are (1) choosing inadequate cognitive strategies, (2) feeling overwhelmed, and (3) feeling underwhelmed.

2.2.1 Choosing inadequate cognitive strategies

First, learners face problems with adequately processing multimedia material at a cognitive level. As outlined in the theories on multimedia learning, learners have to process text and picture information and integrate the information together with prior knowledge to build a coherent mental representation in order to really profit from multimedia representations (Mayer, 2014a; Schnotz, 2014; Schnotz & Bannert, 2014). However, learners seem to struggle with carrying out these cognitive processes. Processing of multimedia material is often text-driven (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Hannus & Hyönä, 1999; Hegarty & Just, 1993; Hochpöchler et al., 2013; Schmidt-Weigand, Kohnert, & Glowalla, 2010; Schwonke, Berthold, & Renkl, 2009). For instance, when recording and analyzing the learners' eye movements during learning with multiple representations, it has been shown that learners largely directed their attention towards the text (Schmidt-Weigand et al., 2010). They tended to inspect the picture only briefly and superficially or ignored it completely. In the same study, it was shown that paying attention to pictures was related to better learning outcomes in multimedia learning. Furthermore, learning outcomes are improved when learners are supported in reducing the overreliance on text information or in making greater use of the picture (Cromley et al., 2013; Eitel, Scheiter, & Schüler, 2013; Schwonke et al., 2009), especially at an early stage of learning (Eitel, Scheiter, & Schüler, 2013). In a study by Eitel, Scheiter, Schüler, Nyström, and Holmqvist (2013) learners were presented with a picture of a pulley system before or while listening to an explanatory text, or they received the auditory text only. Results showed that compared with the text-only group, learning was aided by the presentation of the picture. Learning was improved even if the picture was presented only briefly before learning (600 ms or 2 sec) indicating that the visualization served as a mental scaffold facilitating the construction of a mental representation. Another indicator of insufficient processing in multimedia learning is that learners make only few attempts to integrate information from both representations (Ainsworth, Bibby, & Wood, 2002; Schwonke et al., 2009), although integration is a crucial process in multimedia learning (Mayer, 2009, 2014a; Schnotz, 2014; Schnotz & Bannert, 2003). Integration is even assumed to be necessary for meaningful learning to occur (Mayer, 1997, 2008) as establishing meaningful connections between verbal and graphical features results in a coherent mental representation (Seufert, 2003). Research has shown that learners who integrate more are more successful in learning (e.g., Bodemer & Faust, 2006; Bodemer, Ploetzner, Feuerlein, & Spada, 2004; Mason, Tornatora, & Pluchino, 2013; Seufert, 2003). For instance, Mason et al. (2013) recorded eye-movements of fourth graders while they were studying multimedia learning material on the topic of air. They found that more integrative viewing behavior during learning was associated with a better learning outcome in a subsequent test. Furthermore, supporting learners to integrate information from text and pictures improved learning in several studies (e.g., Cromley et al., 2013; Folker, Ritter, & Sichelschmidt, 2005; Leopold, Doerner, Leutner, & Dutke, 2015; Mason, Scheiter, & Tornatora, 2017; Richter, Scheiter, & Eitel, 2016; Scheiter & Eitel, 2015; Stalbovs, Scheiter, & Gerjets, 2015). Scheiter and Eitel (2015), for example, highlighted corresponding elements in text and picture information (i.e., signaling) in two experiments. The multimedia learning material dealt with the circulatory heart system. The authors showed that learners attended to the signaled information more frequently, which could explain better learning outcomes. Thus, integration was confirmed to be a crucial process in multimedia learning that might not be carried out properly when learning is unguided. Taken together, learners often fail in choosing well-suited cognitive strategies, but supporting learners in using adequate cognitive strategies is beneficial for multimedia learning (Schlag & Ploetzner, 2011).

2.2.2 Feeling overwhelmed

The second problem refers to the fact that multimedia material might be overwhelming for learners. As emphasized in the theories on multimedia learning, processing text and picture information and especially integrating the information is cognitively demanding. Moreover, it is assumed that the cognitive capacity for processing is limited. Thus, the cognitive requirements for successfully processing the multimedia material might exceed the cognitive capacity of the learner. In short, learners might be overwhelmed by the multimedia information (Lowe, 1999, 2003; Lowe & Schnotz, 2014). This is problematic as learners, who were cognitively overwhelmed, were found to be hampered in carrying out deep-level learning activities (van Merriënboer & Sluijsmans, 2009). Similarly, Schnotz and Rasch (2005) found diverse learning effects for learners with low and high learning prerequisites. In the experiment, participants were confronted with a text about time and date differences related to the earth's rotation which was either supplemented by a static picture or an animation. In contrast to earlier research showing positive effects of animations (e.g., Höffler & Leutner, 2007; Lowe & Schnotz, 2014), the animated pictures did not improve learning but were even harmful to learners that held lower learning prerequisites. Furthermore, learners with low learning prerequisites used static pictures more intensely than animated ones. The authors concluded that learners only use and benefit from animated representations when sufficient cognitive resources for processing are available. Accordingly, Hannus and Hyönä found in two experiments that elementary school children's multimedia learning was largely text directed and that a successful use of the pictorial representations supplementing the text information required a certain amount of intellectual abilities. Reliance on only text information (Hannus & Hyönä, 1999; Hegarty & Just, 1993; Schwonke et al., 2009) might, thus, indicate that learners feel overwhelmed by the multimedia presentation and prefer to rely on the more familiar representation for learning, namely text.

2.2.3 Feeling underwhelmed

The third challenge is that multimedia learning material can induce a feeling of being underwhelmed. Although it is cognitively demanding to process multimedia learning material adequately, learners often rely on a *multimedia heuristic* (Serra & Dunlosky, 2010); that is, they expect learning with multimedia material to be easy and to result in better learning outcomes than learning with text. The apparent simplicity of pictorial information and the appearance of multimedia as entertaining (Salomon, 1984) may lead learners to perceive multimedia material as easy to learn from and induce a feeling of being underwhelmed (Lowe, 2003). In a study on the multimedia heuristic participants were asked to study material that explained how lightning storms develop (Serra & Dunlosky, 2010). The material either contained only an explanatory text or an additional schematic picture. Afterwards, participants were asked to judge their learning; that is, they gave a judgment concerning their understanding of the learning material and their expected future test performance. It was found that judgments were higher for multimedia material. However, since learning with multimedia material increased learning outcomes, the higher judgments were plausible and little surprising. Therefore, in a follow-up experiment an additional condition was added that included the explanatory text with photographs of lightning bolts. Although those pictures did not support learning of the relevant content, learners gave higher judgments of their learning than did the control group without any pictures. Thus, learners thought that they would learn better with multimedia material no matter whether the picture actually was helpful for learning or not. Eitel (2016) could confirm these findings of a multimedia heuristic by comparing the given judgments of learning with the learners' actual test performance. Participants were first asked to study an expository text with or without pictures about the functioning of the toilet flushing system and then had to make judgments on their learning success. Again, participants who were studying multimedia material (i.e., expository text with pictures) gave higher judgments than participants who learned only with an expository text. However, the increase in the judgments' magnitude could not be fully traced back to a better test performance indicating that the higher judgments were not reasonable. Similar results were found in experiments that used think-aloud protocols to investigate multimedia learning including static or dynamic visualizations (Kühl, Scheiter, Gerjets, & Gemballa, 2011; Lewalter, 2003). When applying the think-aloud method, learners are asked to verbalize their learning process (Ericsson & Simon, 1993). These verbalizations might give insight into the cognitive processes of learning and the level of understanding. Lewalter (2003) found that dynamic visualizations were perceived as easier to comprehend in multimedia learning than static visualizations. Although the learning outcome did not differ for multimedia materials including static or dynamic visualizations, learners more often expressed that they had understood the content when learning with dynamic visualizations. Similarly, in a study by Kühl et al. (2011) learners less often expressed that they had not comprehended the content when learning with text and static or dynamic visualizations compared with a text only condition. Thus, learning from text and pictures compared with learning from text alone induces a feeling of being underwhelmed and learners fail in accurately evaluating their level of understanding (Ackerman & Leiser, 2014; Eitel, 2016; Jaeger & Wiley, 2014; Serra & Dunlosky, 2010).

2.3 Multimedia Learning – Beyond Cognitive Processing

To take full advantage of multimedia materials learners must process text and pictures adequately, which is jeopardized by the challenging nature of multimedia material. The cognitive theories that were summarized above conceptualize multimedia learning as a purely cognitive process and previous studies hence applied a predominantly cognitive perspective. However, the described challenges in multimedia learning suggest that other factors and dimensions such as students' perceptions of the learning material are involved, which may affect their motivation to engage in learning. This is also proposed by the *Cognitive Affective Theory of Learning with Media* (CATLM: Moreno, 2006, 2007; Moreno & Mayer, 2007) and the *Integrated Cognitive Affective Model of Learning with Multimedia* (ICALM: Plass & Kaplan, 2016). As a consequence, recent studies on multimedia learning increasingly took motivational and affective variables into account (e.g., Knörzer, Brünken, & Park, 2016a, 2016b; Schneider, Dyrna, Meier, Beege, & Rey, 2018; Schneider, Nebel, & Rey, 2016). In the following, a brief overview over both models will be given. Then, research on affective and motivational aspects in multimedia learning will be presented.

The CATLM (Figure 3) builds on the CTML and expands the theory by adding affective, motivational, and self-regulatory factors. The CATLM is based on seven assumptions derived from research on cognition and motivation: (a) there are separate and independent information processing channels for verbal and non-verbal information (Baddeley, 1992), (b) information processing takes place in the working memory which has a limited capacity for actively processing information in each channel; processed information can be stored in the long-term memory which has a virtually unlimited capacity (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965), (c) information and knowledge can be represented in verbal and visual codes (referring to dual-coding theory: Paivio, 1986), (d) for meaningful learning to occur learners have to actively process the new information by selecting, organizing, and integrating the information which requires conscious cognitive effort (Mayer, 2014a; Mayer & Moreno, 2003; Wittrock, 1989), (e) affective and motivational factors mediate (multimedia) learning by the means of increasing or decreasing cognitive engagement (Gottfried, 1990; Moreno, Mayer, Spires, & Lester, 2001; Pintrich, 2003), (f) cognitive processing and affect in learning is regulated by metacognitive factors (Morris, 1990; Thiede, Anderson, & Therriault, 2003), and (g) individual differences like learners' prior knowledge or cognitive abilities affect multimedia learning (Kalyuga, Ayres, Chandler, & Sweller, 2003; Moreno & Durán, 2004; Plass, Chun, Mayer, & Leutner, 1998).

Assumptions (a) to (d) of the CATLM are derived from the CTML. Like the CTML the CATLM distinguishes selection, organization, and integration of information as cognitive processes in multimedia learning. Additionally, in the CATLM motivation and affect are assumed to influence these cognitive processes by increasing or decreasing cognitive engagement (illustrated by the bottom-up arrows from long-term memory to selection, organization, and integration in Figure 3). Furthermore, learners' metacognitive and self-regulatory skills may help to plan, monitor and, if necessary, adjust their learning (illustrated by the arrows from long-term memory top-down to working memory and bottom-up to motivation and affect in Figure 3). Lastly, individual differences in prior knowledge, cognitive abilities, and personality are assumed to affect the efficiency of multimedia learning material. Thus, the CATLM expands the CTML by adding affective, motivational, and metacognitive aspects, as well as individual differences that influence and control the cognitive processes.

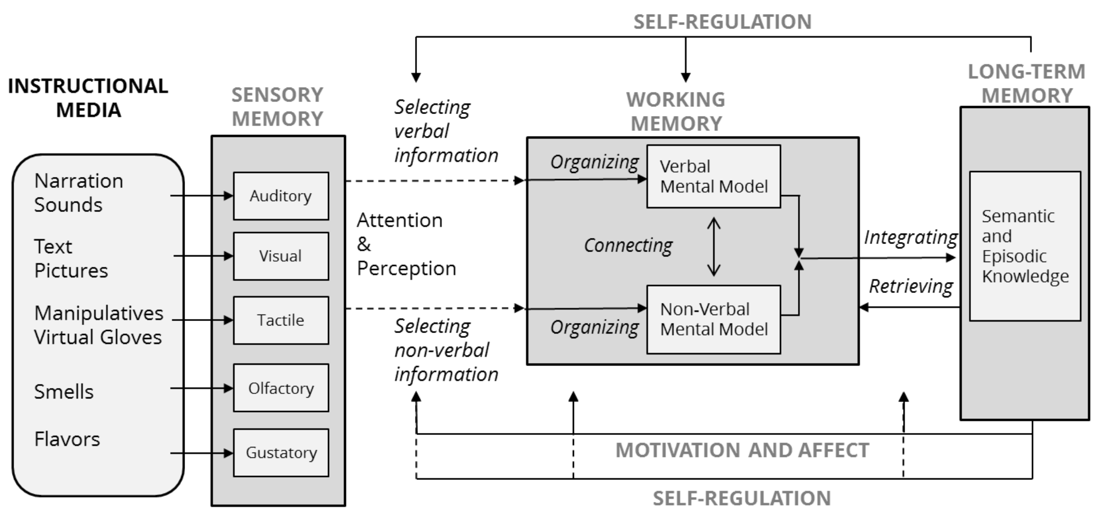

Figure 3. The cognitive affective theory of learning with media (adapted from Moreno, 2006, p. 151).

The integrated cognitive affective model of learning with multimedia (Figure 4, ICALM: Plass & Kaplan, 2016) incorporates the CATLM and further combines it with models dealing with affect (Russell, 2003) or emotion schemas (Izard, 2009). Thus, it further emphasizes the close interconnection between cognitive and affective processes. It not only takes interest and motivation of the learner into account but also the experienced affect of the learning environment. However, whereas the CATLM includes metacognitive processes and self-regulation in general, the ICALM sheds light on emotional self-regulation. The main assumption of the ICALM is that there is an inseparable and interdependent interconnection between cognitive and affective processes influencing the processing of multimedia materials (illustrated by the thick double arrows between cognitive processing of verbal/visual information and affective/motivational processes in Figure 4).

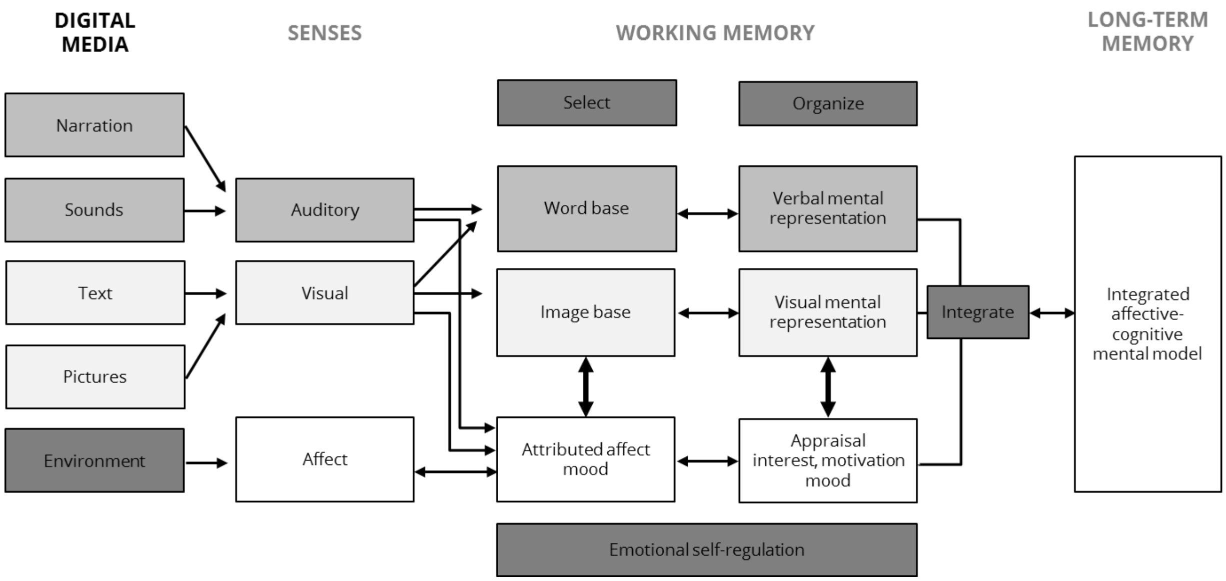

Figure 4. Integrated cognitive affective model of learning with multimedia (adapted from Plass & Kaplan, 2016, p. 150)

Although affective and motivational aspects have gotten more and more into the focus of attention in the field of multimedia learning (Mayer, 2014b; Park, Plass, & Brünken, 2014), empirical evidence for the influence of these non-cognitive factors on learning is still quite sparse. However, affective and motivational factors indeed seem to play a role in multimedia learning. Evidence for this comes from at least three lines of research concerning emotional design of pictures, use of decorative pictures, and the emotional state of the learner. In the following, research will be summarized with focus on these lines of research.

One central problem of processing multimedia materials is that learners mainly ignore the picture and overly rely on text information (Cromley et al., 2010; Hannus & Hyönä, 1999; Hegarty & Just, 1993; Hochpöchler et al., 2013; Schwonke et al., 2009). Thus, one line of research has focused on so-called emotional design to enhance picture processing (Mayer & Estrella, 2014; Plass, Heidig, Hayward, Homer, & Um, 2014; Stark, Brünken, & Park, 2018; Um, Plass, Hayward, & Homer, 2012; Uzun, & Yıldırım, 2018). This term applies to the use of design features within a picture that have no explanatory content but aim at making the picture look more attractive by adding specific colors or shapes. The pictures are relevant for learning; the increase in attractiveness of the materials is assumed to induce positive feelings and tempt the learners to cognitively engage more with the pictorial learning content, thus, improving learning performance. Such features are appealing, saturated, analogous, bright, warm color combinations, or round shapes with human- or face-like characteristics (Mayer & Estrella, 2014). In several studies participants learned with multimedia materials on how immunization works that either included warm colors, round shapes with face-like characteristics, or grey colors, edgy shapes and no face-like characteristics (Mayer & Estrella, 2014; Plass et al., 2014; Um et al., 2012). It was shown that the former (emotional) design compared with the latter induced positive emotions in learners and had a direct positive effect on learning performance. However, no effect of positive emotional design on learning outcomes was found in an eye-tracking study, although learners gave more and longer attention to the pictures with the positive design (Park, Knörzer, Plass, & Brünken, 2015). Thus, results on the effect of emotional design on learning performance are mixed.

A second line of research has focused on using decorative pictures to attract learners' attention to the picture (Magner, Schwonke, Aleven, Popescu, & Renkl, 2014; Schneider et al., 2018; Schneider et al., 2016; Sung & Mayer, 2012). Decorative pictures are attractive pictures that are related to but not relevant for the learning context. However, pictures are assumed to aid learning only if they contain relevant information (Levin, Anglin, & Carney, 1987). Otherwise, they are assumed to use up cognitive resources that could have been used for processing of relevant information, thus, overwhelming the learner. Sung and Mayer (2012) found that solely presenting pictures together with a text triggers positive feelings in the learner. However, only pictures that were directly relevant for learning improved learning performance. Similarly, Magner et al. (2014) assumed that the mere use of decorative illustrations has attentional or affective functions as the illustrations might trigger interest in and liking of the learning task. The decorative pictures indeed triggered interest in the learning task. However, only learners with high prior knowledge benefitted from the decorative pictures and showed an improved learning outcome whereas learners with low prior knowledge were hindered from learning.

A third line of research has focused on how the emotional state of the learner impacts multimedia learning. The idea is that the presence of an emotional state determines learners' cognitive effort, thus, influencing learning performance. In order to investigate this issue, learners were set into a positive or negative emotional state, for instance, by asking them to recollect happy or sad moments of their life, respectively (Knörzer et al., 2016a, 2016b; Park et al., 2015; Plass et al., 2014; Um et al., 2012). However, results for learning performance were inconclusive. For one thing, positive emotions were found to improve learning performance (Park et al., 2015), while negative emotions impaired learning performance in a multimedia learning task (Heidig, Müller, & Reichelt, 2015). More interestingly, the induced positive emotion led learners to increase their invested mental effort and reduced the perceived difficulty of the learning task (Um et al., 2012), which partially mediated the effect of the positive emotional state on learning performance. Other studies, however, found that a positive emotional state hindered learning whereas a negative emotional state improved learning (Knörzer et al., 2016a, 2016b). Thus, findings were again mixed.

In sum, there are many parameters that should be taken into account when dealing with multimedia learning. As shown in the last sections multimedia learning is not a purely cognitive process, but motivational, and affective factors should be taken into account as well. Although these factors are considered in the CATLM and the ICALM; the way they actually influence the learning process has not been further defined. Self-regulation is mentioned as overarching process regulating cognition, motivation, and affect. But, the models yield no precise specifications on the process level. Nevertheless, learners somehow have to monitor and regulate cognitive, motivational, and affective processes in multimedia learning to overcome the three aforementioned challenges: (1) choice of inadequate cognitive strategies, (2) feeling overwhelmed, and (3) feeling underwhelmed. These three challenges can well be conceptualized against the backdrop of theories of self-regulated learning. Categorizing the three challenges within a framework of self-regulated learning might help getting a more conclusive picture on how self-regulation works when learning with multimedia. In the next chapter first an overview of a framework of self-regulated learning will be given. Afterwards, the three challenges will be put into the context of self-regulated learning while elaborating on cognitive, motivational, and affective processes.

3 Self-Regulated Learning

Self-regulated learning refers to how learners manage their own learning, that is, how they direct their thoughts, feelings, and actions towards achieving a goal (Zimmerman, 2000). More specifically, Pintrich (2000) described self-regulated learning as an "active, constructive process, whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment" (p. 453). Self-regulation in learning is important as it has been shown that students' use of self-regulated learning strategies is strongly associated with superior academic functioning (Zimmerman & Martinez-Pons, 1986). Self-regulated learners are described as metacognitively, motivationally, and behaviorally active participants in their own learning process (Zimmerman, 1986). In particular, good self-regulators report to have high self-efficacy beliefs, self-attributions, intrinsic task interest, and display extraordinary effort and persistence while learning (Zimmerman, 1990).

There are various definitions, theories and models of self-regulated learning that emphasize different aspects of self-regulated learning like the selection, combination, and coordination of cognitive strategies, volitional, motivational, and behavioral aspects (Boekaerts, 1999; Corno, 1986, 1989, 2001; Pintrich, 2000; Schunk, 1989; Veenman, 2011b; Zimmerman, 1986, 1990). These models share four basic assumptions (Pintrich, 2000): (1) active constructive assumption – learners have to actively construct meaning by integrating external and internal information; (2) potential for control assumption – learners need to invest effort to monitor, control, and regulate their learning; (3) goal, criterion, or standard assumption – for the decision whether to continue or change their learning behavior learners need to compare their current learning status with a set goal or a reference value; (4) mediator assumption – self-regulatory activities in the learning process are assumed to mediate between personal or contextual characteristics and the actual learning performance.

3.1 Pintrich's Framework for Self-Regulated Learning

Pintrich (2000) summarized and compared the major self-regulation models in education and developed a framework of self-regulated learning. In this framework self-regulated learning is defined to occur in four areas: cognition, motivation, behavior, and context. In each of those areas self-regulation happens in four consecutive phases: (1) planning and activation, (2) monitoring, (3) control and regulation, and (4) reaction and reflection. In the following the four areas that undergo the four phases will be elaborated in more detail. An overview of the framework can be found in Table 1.

3.1.1 Cognition in self-regulated learning

The area of cognition refers to different cognitive strategies that learners might employ. Cognitive strategies are goal-specific, strategic procedures to perform a cognitive task (Pressley, 1986). In the area of cognition in the first phase of Pintrich's model, learners have to plan and activate the cognitive strategies. This includes not only decisions on which cognitive strategies to use, but also how, when, and why to use them. This idea was picked up in the *WWW&H rule* which specifies that for the successful use of cognitive strategies learners need to know *what* to do *when*, *why*, and *how* to do it (Veenman, Van Hout-Wolters, & Afflerbach, 2006). In the second phase, learners have to monitor whether the cognitive strategies are adequate for the learning task, so that they can adapt or change the strategies if necessary. Good strategy users know that the success of a task depends on the use of an appropriate cognitive strategy and the capability of shielding the employment of this strategy from distractions (Pressley, 1986; Pressley, Borkowski, & Schneider, 1987, 1989). The selection and use of cognitive strategies refers to the third phase, that is, the control and regulation of cognition, which is considered to be the central aspect of self-regulated learning. A good strategy user is specified as someone who knows that a specific cognitive action should be executed when particular conditions are met and that the cognitive process should be tailored to the situational demands (Pressley, 1986; Pressley et al., 1987, 1989). In the fourth phase task performance is evaluated in relation to the cognitive strategies that were used.

It seems plausible to assume a positive relationship between cognitive strategy use and learning performance (Hasselhorn & Gold, 2006; Pressley et al., 1987). Research on interventions that foster the use of beneficial strategies has shown that these interventions foster learning performance (e.g., Kombartzky, Ploetzner, Schlag, & Metz, 2010; Spörer, Brunstein, & Kieschke, 2009; Thillmann, Künsting, Wirth, & Leutner, 2009). For instance, sixth-graders, who were instructed and encouraged to use a strategy of processing the learning material, had an

Table 1

Four Phase by Four Area Taxonomy for Regulation (Pintrich, 2000, p. 454).

	Areas for regulation			
Phases	Cognition	Motivation / Affect	Behavior	Context
1. Forethought, planning, and activation	Target goal setting	Goal orientation adoption	[Time and effort planning]	[Perceptions of task]
	Prior content knowledge activation	Efficacy judgments	[Planning for self-observations of behavior]	[Perceptions of context]
	Metacognitive knowledge activation	Ease of learning judgments (EOLs); perceptions of task difficulty		
		Task value activation		
		Interest activation		
2. Monitoring	Metacognitive awareness and monitoring of cognition (FOKs, JOLs)	Awareness and monitoring of motivation and affect	Awareness and monitoring of effort, time use, need for help	Monitoring changing task and context conditions
			Self-observation of behavior	
3. Control	Selection and adaption of cognitive strategies for learning, thinking	Selection and adaption of strategies for managing motivation and affect	Increase / decrease effort	Change or renegotiate task
				Change or leave context
			Persist, give up	
			Help-seeking behavior	
4. Reaction and reflection	Cognitive judgments	Affective reactions	Choice behavior	Evaluation of task
	Attributions	Attributions		Evaluation of context

improved learning outcome compared with sixth-graders, who did not receive such an instruction (Schlag & Ploetzner, 2011). However, the mere teaching of beneficial strategies seems to be insufficient as learners also need to know when and why to use them. For instance, in a study with 64 students from ninth grade it was shown that a strategy training improved strategy knowledge. However, the students did not apply the strategies in a following learning task and, thus, no effect on learning performance could be found (Scheiter, Schubert, Gerjets, & Stalbovs, 2015).

3.1.2 Motivation in self-regulated learning

The area of motivation refers to the learners' self-efficacy beliefs and values, interest and liking of the task, and it includes any positive or negative reaction to the self or the task. Self-efficacy beliefs refer to the confidence in one's own capability to accomplish a task and the expectancy to achieve the desired outcome (Bandura & Locke, 2003; Zimmerman, 2000). In more detail and related to learning, they address the perceived capabilities regarding one's learning or the learner's confidence to master a learning task and one's beliefs about one's own learning skills. Self-efficacy beliefs are built as a result of an evaluation of the feasibility of the learning task. Holding only low self-efficacy beliefs is problematic, as there is a connection between self-efficacy beliefs and the quality of information processing or learning performance (Berger & Karabenick, 2011; Pokay & Blumenfeld, 1990; Zimmerman, 2000).

In the first phase of the motivational area, learners evaluate the feasibility of the task on which they base their self-efficacy beliefs; these are further monitored in the second phase. For such an evaluation ratings of one's own learning capabilities in relation to the difficulty of the task are necessary, which are referred to as judgments of learning (Nelson & Narens, 1990). These judgments can be used to calculate metacognitive accuracy (Nelson, 1996). Metacognitive accuracy describes the relation of learners' judgments to their actual learning performance, that is, whether learners are accurate in the evaluation of their learning. Learners who think they are not capable of fulfilling the learning task are, thus, expected to give judgments of learning that fall below their actual learning performance. Judging one's own learning in a given task as accurately as possible is important, as it is assumed to determine subsequent learning behavior (Bjork et al., 2013; Nelson, Dunlosky, Graf, & Narens, 1994; Thiede & Dunlosky, 1999). Learners who are less confident about their learning (i.e., who feel overwhelmed) might hold low self-efficacy beliefs, telling them that they are not able to learn the materials optimally. This is problematic as learners who are cognitively overwhelmed have been found to be unable to carry out deep-level learning activities (van Merriënboer & Sluijsmans, 2009). In the third phase, self-efficacy beliefs can be regulated and increased through positive self-talk, which means, telling oneself that a given task is feasible (Bayer & Gollwitzer, 2007; Meichenbaum & Goodman, 1971). In the fourth phase, learners make attributions of success or failure for the outcome which then again determine future self-efficacy beliefs for similar tasks. Thus, the concept of self-efficacy beliefs and the motivational area of self-regulated learning closely relate to the expectancy-value theory (Atkinson, 1957; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). This theory describes learning actions, that is, the choice of strategies, persistence, and performance, as a function of the expectations of success that learners hold and how much they subjectively value the learning task (Wigfield & Eccles, 2000).

Self-efficacy or the confidence in one's own abilities is important as it has been shown to be positively related to deeper elaboration in learning and to performance (Bandura & Locke, 2003; Berger & Karabenick, 2011; Multon, Brown, & Lent, 1991; Pokay & Blumenfeld, 1990; Stajkovic & Luthans, 1998; Zimmerman, 2000). In a meta-analysis including 38 studies and 4,998 participants a significant relation between self-efficacy beliefs and academic performance was reported with a medium (to large) effect size of r = .38.

3.1.3 Behavior in self-regulated learning

The area of behavior refers to the general effort that learners invest in the learning task. For meaningful learning sufficient effort has to be invested to meet the cognitive demands of information processing (Kanfer & Ackerman, 1989; Norman & Bobrow, 1975; van Merriënboer & Sweller, 2005). One aspect of effort is learning time which can be considered an observable indicator of how much effort learners put into learning (Vollmeyer & Rheinberg, 2013). The first phase in the area of behavior includes management of effort. That is, learners plan how much time or effort they want to invest in the task. In the second phase learners monitor whether their effort investment fits the task requirements, and, in the third phase, adapt it accordingly (regulation of behavior). Effort regulation is closely related to the judged difficulty of the task in the sense that effort is increased for increased difficulty as long as successful performance is still feasible (Brehm & Self, 1989). Learners who perceive multimedia learning materials as easy, are, thus, expected to give judgments of learning that exceed their actual learning outcome. Judgments of learning are likely to influence the decision whether more or less effort is needed (Bjork et al., 2013; Thiede & Dunlosky, 1999). Thus, learners who are overly confident about their learning (feeling of being underwhelmed) might decide to invest only little effort, or even to stop learning prematurely (Bjork et al., 2013). In line with this Eitel (2016) found in a learning experiment that the more confident learners were about their performance, the less time and effort they spent on learning. In the fourth phase learners reflect on the effort they have spent on learning, allowing them to determine to spend more or less effort in the future on similar learning tasks.

The area of behavior is important as the regulation of effort has been shown to be positively related to academic achievement (Wolters, 1998). For instance, in a longitudinal study the management of effort was found to directly influence academic achievement (Schiefele, Streblow, Ermgassen, & Moschner, 2003).

3.1.4 Context in self-regulated learning

The area of context refers to the external environment and the circumstances of the learning task. In the first phase learners perceive the task and the context. In the second phase it is monitored whether task requirements change. The third phase addresses attempts to structure the circumstances to facilitate or lower learning goals, if necessary. In the fourth phase the learning context and its influence on learning is evaluated, so that appropriate contexts can be chosen for future learning. However, regulation of the context is not specifically incorporated in most models of self-regulated learning (Boekaerts, 1999; Corno, 1986, 1989, 2001; Schunk, 1989; Veenman, 2011b; Zimmerman, 1986, 1990), as it does not refer to regulating the self and mastering a given task but rather to changing an external environment. As the focus of the following experiments is on the regulation of the self only cognition, motivation, and behavior will be further taken into consideration.

3.2 Mapping the Challenges in Multimedia Learning onto the Areas of Self-Regulated Learning

Multimedia learning is complex as it requires the construction of an integrated mental model that contains information from more than one representation. These representations have to be processed adequately by using specific cognitive learning strategies. This requires applying resources appropriately to the learning process; making it necessary to consider not only cognitive, but also motivational and affective parameters. In the chapter on multimedia learning three major challenges were identified that might occur when learning from illustrated texts. These challenges can be conceptualized against the backdrop of Pintrich’s framework of self-regulated learning.

Within this framework the challenges of multimedia learning, that is, insufficient processing, as well as feeling either overwhelmed or underwhelmed, can be related to the areas of self-regulated learning, namely, cognition, motivation, and behavior, respectively.

Insufficient processing in the sense of relying on text information and not connecting it to pictorial information can be classified as a lack of cognitive regulation. Relating to cognition in multimedia learning, learners have to select adequate cognitive strategies to process and integrate text and picture information appropriately (Scheiter et al., 2017). Instructional support in form of self-regulatory aids can help learners to employ adequate strategies or to overcome detrimental obstacles in multimedia learning. In line with this reasoning, sixth-graders were taught a learning strategy that consisted of various learning techniques that were based on the cognitive processes described in the multimedia theories: selection, organization, and integration (Kombartzky et al., 2010). Students studied a multimedia message including spoken text with an animation about the honeybee dance. Those students who got the self-regulatory instruction of the learning strategy were more successful in a subsequent test than students in a control group who were just asked to summarize the content in an essay. Thus, supporting learners to use adequate cognitive strategies to process text and picture information in an integrated manner can be considered to support cognitive self-regulation in multimedia learning.

Feelings of being overwhelmed by processing cognitively demanding multimedia materials can be categorized as a problem of motivational regulation. Reliance on text information (Hannus & Hyönä, 1999; Hegarty & Just, 1993; Schwonke et al., 2009) might be an indicator that learners feel overwhelmed by the multimedia representations. Feelings of being overwhelmed are closely related to the concept of self-efficacy beliefs (Bandura & Locke, 2003) in that these feelings may especially occur for learners who hold low self-efficacy beliefs when learning with multimedia. Therefore, strengthening learners' self-efficacy beliefs should support the motivational area of self-regulation.

On the other hand, feelings of being underwhelmed can be considered a problem of behavioral regulation in multimedia learning. In line with the multimedia heuristic (Serra & Dunlosky, 2010), learners who perceive multimedia materials to be easy to learn from, feel underwhelmed, – or overly confident – and, thus, invest less effort than would be profitable, which results in lower learning performance (Dunlosky & Rawson, 2012; Son & Metcalfe, 2000). Moreover, learners might not be willing to consider both information sources as they might think that it is not worth the additional costs to process two representations (Bodemer & Faust, 2006; Schnotz, 2014; Sweller, van Merriënboer, & Paas, 1998). However, for multimedia learning to be effective, it is necessary to actively engage in cognitive processing which requires the investment of sufficient time and effort (Mayer, 2014a, 2014b; Schnotz, 2014). Interventions aimed at increasing the effort that learners invest in the verbal and the pictorial source of the multimedia learning material can, thus, be seen as a support for behavioral regulation.

Both non-cognitive, - that is, motivational and behavioral challenges – are based on students' evaluation of the learning situation, that is, their judgments of learning and metacognitive accuracy. Learners who feel overwhelmed by the multimedia materials are expected to give judgments of learning that fall below their actual performance. Learners who feel underwhelmed are expected to give judgments of learning that go beyond their actual performance.

To sum up, the challenges that learners face in multimedia learning can be considered to be problems of self-regulated learning. Insufficient cognitive processing relates to the area of cognition, a feeling of being overwhelmed (underestimation of one's own learning) relates to the area of motivation, and a feeling of being underwhelmed (overestimation of one's own learning) relates to the area of behavior. In the following experiments, it is investigated, whether giving self-regulatory support within each of these areas increases learning in a multimedia environment. However, as the areas of self-regulation are quite diverse, a support tool is needed, that is very flexible with regard to its content. In the next chapter implementation intentions are introduced as an instructional tool that specifically addresses self-regulation, and can be adapted to support any kind of action like cognitive, motivational, and behavioral self-regulation.

4 Implementation Intentions: A Self-Regulatory Tool

4.1 Definition of Implementation Intentions

Implementation intentions are a tool that helps to translate any plan into action (Gollwitzer, 1999, 2014). In a meta-analysis implementation intentions have been shown to effectively support goal-oriented behavior with a medium to large effect (*d* = .65; Gollwitzer & Sheeran, 2006). Implementation intentions are if-then action plans that have the format '*If* I encounter situation X, *then* I will perform the goal-directed behavior Y!'. Forming such plans strongly connects a favorable situation (if) with a goal-directed behavioral response (then) which enables goal achievement. The associative link between situation and behavior in implementation intentions is assumed to close the gap between an intention and its corresponding action. Building implementation intentions instead of barely setting a goal is considered to turn action control from top-down to bottom-up (Gilbert, Gollwitzer, Cohen, Oettingen, & Burgess, 2009; Gollwitzer, 2012, 2014). This means that when just setting an abstract goal (e.g., losing weight), actions have to be deduced that help to achieve that goal (e.g., eating healthier or ordering salad). In contrast, an implementation intention sets a particular time and place in the if-part (e.g., in the restaurant at lunch break) that is then linked to a specific action in the then-part (e.g., ordering salad). Once the situation specified in the if-part is encountered, it will automatically trigger the corresponding action, thereby delegating action control from the self to the environment. Implementation intentions can be individually filled with appropriate situations and behaviors and can, thus, be adapted to any kind of goal.

Implementation intentions specifically address self-regulation. In particular, implementation intentions are assumed to help overcoming self-regulatory obstacles no matter whether these obstacles are internal (e.g., lacking cognitive resources) or external (e.g., difficult situations) in nature (Gollwitzer, 2014). Implementation intentions address aspects of self-regulation which refer to how actions are planned, initiated, and preserved particularly under difficult circumstances (Achtziger & Gollwitzer, 2008). The Rubicon model of action phases (Heckhausen, 1987; Heckhausen & Gollwitzer, 1987; Gollwitzer, 1996, 2012) describes the action planning process in four independent, consecutive phases: (1) the predecisional phase, (2) the preactional phase, (3) the actional phase, and (4) the postactional phase. These phases are similar to those of Pintrich's model of self-regulated learning (Pintrich, 2000). The predecisional phase, in which preferences among wishes are formed and a goal is set, relates to the planning and activation phase in the Pintrich model. The preactional phase, in which plans how to realize this goal are made differs slightly from Pintrich's monitoring phase that relates more to observing and comparing of the given conditions with the already set up plan. In the actional phase the goal-directed action is implemented and persistently carried out until the goal is achieved. This phase relates to Pintrich's control and regulation phase including the selection and use of cognitive strategies as well as the adaption of self-efficacy beliefs, time and effort. The Rubicon model's postactional phase like Pintrich's reaction and reflection phase comprises the evaluation of the degree and quality of goal achievement to decide whether further goal striving is needed. The second and third phases, in which goal-directed behavior is translated into action and proceeded, are especially complex since learners have to decide where, when, and how to act; thus, initiating actions and staying on track is challenging. These aspects are particularly addressed by implementation intentions; implementation intentions tell the learners not only how to reach a goal, they also specify the right moment (Achtziger, Gollwitzer, & Sheeran, 2008; Gollwitzer, 1999).

4.1.1 Cognitive efficiency of implementation intentions

There are two peculiarities about implementation intentions that make them very efficient in terms of cognitive resources: the high accessibility of the situation specified in the if-part and the automatic activation of the behavior specified in the then-part (Brandstätter, Lengfelder, & Gollwitzer, 2001; Webb & Sheeran, 2007). The effect of implementation intentions on goal achievement was even found to be mediated by those two conditions (Webb & Sheeran, 2008).

First, it was found that subjects who had internalized implementation intentions had better access to a memory representation of the situation specified in the if-part; that is, a situation was easier and faster to detect if mentioned in the if-part (Aarts, Dijksterhuis, & Midden, 1999; Parks-Stamm, Gollwitzer, & Oettingen, 2007; Webb & Sheeran, 2004, 2007, 2008). For instance, university students had the task to collect a coupon at a secretary's office on their way from the lab to the cafeteria (Aarts et al., 1999). They were divided into two groups. Both groups formed either task-related or task-unrelated implementation intentions: one group was urged to plan how to collect the coupon (task-related) and the other group was urged to plan how to spend the coupon (task-unrelated). In a lexical decision task later on, participants with task-related implementation intentions responded faster to target words (related to the situational cue when and where to collect the coupon that was specified in the if-part of the implementation intention) than participants with task-unrelated implementation intentions. Furthermore, participants with task-related implementation intentions were more successful in collecting the coupon and the accessibility of the task accounted for the probability of collecting the coupon. Thus, forming implementation intentions makes the mental representation of the situational cue highly accessible in memory.

Second, implementation intentions were found to lead to automatic activation of the behavior specified in the then-part (Armitage, 2009; Bayer, Achtziger, Gollwitzer, & Moskowitz, 2009; Gollwitzer & Brandstätter, 1997; Webb & Sheeran, 2007, 2008). In a fMRI study it could be shown that implementation intentions induced a pattern of neuronal activity that is similar to neuronal activity of automatic behavior (Gilbert et al., 2009). Moreover, implementation intentions were shown to be effective even if the underlying goal intention was consciously not accessible (Gollwitzer & Schaal, 1998). The automatic activation of the behavioral response is efficient as it makes cognitive demanding control of behavior dispensable, and, thus, frees up cognitive resources (Brandstätter et al., 2001). This point is underpinned by the findings that implementation intentions improved action control even in subjects whose ability to control their action and to apply self-regulation are hampered (e.g., ADHD children: Gawrilow & Gollwitzer, 2008; Gawrilow, Gollwitzer, & Oettingen, 2011; Gawrilow, Schmitt, & Rauch, 2011; or addicts: Brandstätter et al., 2001). Furthermore, implementation intentions were effective even if cognitive load was high (Stalbovs, 2016). Thus, action initiation is fostered even if there are only few cognitive resources, as implementation intentions delegate effortful cognitive control to the situation.

Delegating action control to the situation is what distinguishes implementation intentions from other interventions. Implementation intentions are conceptually related to prompts (e.g., Bannert, 2009; Kombartzky et al., 2010; Wirth, 2009). Prompts are performance aids that remind learners to activate or execute learning processes that they already possess (Bannert, 2009). However, prompts often only address declarative knowledge (what to do) without instructing learners when and why during learning (Bannert, 2009). Thus, learners have to use up cognitive resources to carry out these learning processes at the right time. Implementation intentions are an optimized version of prompts, because they tell when and where the specific action should be performed. More particularly, they strongly link the behavioral response to the situational cue, thus, triggering to automatically initiate the specified action (Armitage, 2009; Bayer et al., 2009; Gollwitzer & Brandstätter, 1997; Webb & Sheeran, 2007, 2008). In line with this reasoning, implementation intentions have been shown to improve goal achievement more effectively than mere goal intentions or prompts, that means setting a goal without specifying when, where, and how to realize it, or a control group without any goal instructions (Chapman, Armitage, & Norman, 2009; Stalbovs et al., 2015). For instance, one week after participants were instructed to eat more fruit and vegetables, all participants increased their fruit and vegetable intake (Chapman et al., 2009). However, those participants who structured their plans in an if-then-format reported a higher average intake than participants who made their plan without this specific structure. This superiority of implementation intentions over goal intentions or prompts is explained by the cognitive efficiency of implementation intentions.

There is vast empirical evidence for the effectiveness of implementation intentions across the board (e.g., Gollwitzer & Sheeran, 2006). Furthermore, implementation intentions are very flexible regarding their content and can give specific or generic instructional support, and therefore, might serve as a tool to overcome obstacles in self-regulated learning with multimedia material. In the next section, research on implementation intentions in learning scenarios and the educational context will be summarized. In particular, research will be reported that shows implementation intentions supporting cognitive, motivational, and behavioral self-regulation in the learning, educational, and academic context.

4.2 Implementation Intentions to Support Self-Regulation in Education

Implementation intentions have been used to effectively support self-regulation when carrying out cognitive and academic tasks. Hereinafter, first empirical evidence will be summarized which shows that implementation intentions might foster goal achievement throughout a broad spectrum of academic tasks. Thereafter, research on implementation intentions relating to self-regulation of cognition, motivation, and behavior within the educational context will be presented.

In a study on time management of academic work, participants were asked to schedule time for an upcoming academic concern such as preparing a presentation (Oettingen, Kappes, Guttenberg, & Gollwitzer, 2015). One group of participants was instructed to form implementation intentions with an obstacle that could hinder them from fulfilling the task (if-part) and a behavior that could help them to overcome the obstacle (then-part) and to solve the concern. The other groups did not form implementation intentions or filled them with other task-unrelated content. Those participants using implementation intentions to plan their behavior scheduled more time for completing the academic task in the upcoming week than participants who elaborated on the same relevant content but did not use the specific if-then-format, or who used the same format but enriched the if-then-plan with unrelated content. However, it was only observed how much time participants scheduled for the planned behavior rather than how much time they actually spend on executing their plans.

Whether implementation intentions actually have a positive impact on academic performance was investigated in a study with children from an urban public middle school (Duckworth, Kirby, Gollwitzer, & Oettingen, 2013). All children were asked to think of a goal within the school context they have for the next weeks or months. Then, one group elaborated on possible obstacles that could prevent them from achieving the goal and possible behaviors that could help them to overcome the obstacle. Furthermore, this group was asked to form and internalize implementation intentions related to the obstacle (if-part) and the behavior necessary to overcome it (then-part). The other group just thought of achieving this goal without forming any plans. Even though it was not observed whether children really accomplished their individual goals and wishes, there was an effect of implementation intentions on academic performance. Working with implementation intentions led children to have better grades, more reliable attendance, and a better evaluation of their conduct in the remaining school year.

Implementation intentions can also help to get started with academic tasks (Oettingen, Hönig, & Gollwitzer, 2000). University students were presented with a cover story suggesting that researchers were interested in how sleep affects cognitive performance. Then, they were asked to solve math tasks weekly at a certain time. Participants either formed a goal intention ('I will perform as many arithmetic tasks as possible each Wednesday at [self-chosen time]!') or an implementation intention ('If it is Wednesday at [self-chosen time], I will perform as many arithmetic tasks as possible!') to determine their individual time of the day. In the following weeks, those participants who had used the implementation intention adhered to their determined date more strongly than participants who had used the goal intention. The findings show that implementation intentions help to initiate planned behavior.

Effects of implementation intentions that support self-regulation in cognitive tasks could as well be found on a more fine-grained level like reaction times (Wieber, von Suchodoletz, Heikamp, Trommsdorff, & Gollwitzer, 2011). Children at the age of approximately seven years worked on categorization tasks while they were simultaneously presented with distractions that differed in the degree of attractiveness. To help children keep their attention on the categorization task without getting distracted, they were either familiarized with an implementation intention ('If there is a distraction, then I will ignore it!') or a goal intention ('I will ignore distractions!'). Whereas for children who got instructed with goal intentions, the reaction times in the categorization task were determined by the attractiveness of the distractions (longer reaction times for more attractive distractors), children instructed with implementation intentions were more capable of ignoring the distractions. When the distraction was rather attractive, only implementation intentions helped children to ignore the distraction.

The effect of implementation intentions that help to shield a task from distractions also holds true for individuals who in general have difficulties with action control such as children diagnosed with ADHD (Gawrilow, Schmitt et al., 2011). Children with ADHD usually perform poorly in tasks that require cognitive control but this deficiency could be alleviated by the use of relevant implementation intentions. For instance, boys diagnosed with ADHD were presented with distractions (short movie excerpts) while solving math tasks (Gawrilow, Gollwitzer et al., 2011). Additionally, they received implementation intentions connecting the situation of a movie excerpt starting with either the instruction to then concentrate on the math task, or with the instruction to ignore the movie, or they did not receive an implementation intention at all. Both implementation intentions led boys with ADHD to solve the math tasks faster compared with the group of boys with ADHD not receiving implementation intentions. In the same experiment, the implementation intentions did not influence the time of solving the math tasks for boys who were not diagnosed with ADHD. Thus, implementation intentions supported children in concentrating on and staying on track with math tasks.

With regard to the three self-regulatory challenges that have been distinguished in the chapters above, research has already shown that implementation intentions are a promising tool to support the areas of self-regulated learning. In the following, empirical evidence will be summarized showing that implementation intentions help to foster self-regulated learning in the areas of cognition, motivation, and behavior.

In a series of experiments, implementation intentions have been identified to effectively support cognitive self-regulation (Stalbovs, 2016; Stalbovs et al., 2015). Before studying a multimedia message, learners were instructed with implementation intentions that comprised multimedia-specific cognitive strategies, thus, addressing cognitive self-regulation in learning. The implementation intentions were formed by deriving critical situations and the corresponding adequate cognitive strategies from multimedia learning literature. Thus, the implementation intentions related to text processing (e.g., 'If I have finished reading a page, then I will carefully re-read all paragraphs!'), picture processing (e.g., 'If I am looking at a picture, then I will search for its central elements with regard to content.'), and integration of text-picture-information (e.g., 'If I have read a paragraph, then I will search the picture for the contents described therein.'). The learning materials dealt with the topic of cell division. They consisted of 19 pages, each containing an explanatory text with a corresponding picture. During learning, eye movements of the participants were recorded. Then, the learners were tested on the just studied contents in a subsequent knowledge test. It was found that implementation intentions improve participants' learning outcomes compared with a control group that did not receive any instructional support. The eye tracking data, furthermore, revealed that implementation intentions positively affected integration of text and picture information which was predictive for the learning outcome. This is in line with the assumption that integration is crucial for multimedia learning (Mayer, 2014a). Furthermore, support of all three cognitive processes (text processing, picture processing, and integration) proved to particularly enhance the learning outcome compared with supporting only one of the processes. The effect of implementation intentions even lasted against a more conservative control group that received the same information about the multimedia-specific cognitive processes in form of a goal intention, but without the if-then structure typical for implementation intentions (e.g., 'I will search the picture for the contents described in every paragraph!'). Thus, self-regulation in the area of cognition could be supported by using implementation intentions relating to control of cognitive processes.

Relating to the area of motivation in self-regulated learning, in two experiments implementation intentions effectively strengthened self-efficacy beliefs and, in turn, improved test scores (Bayer & Gollwitzer, 2007). Here, the situational cue in the if-part was not connected to a specific goal-directed action but to a motivational response. In the first experiment female high school students were given math tasks and were asked to solve as many tasks as possible. One group of students was additionally asked to internalize an implementation intention to increase self-efficacy through positive self-talk ('And if I start a new problem, then I will tell myself: I can solve it!'). Solving more math tasks correctly, students with the self-efficacy implementation intention outperformed the control group who did not get any instructions via implementation intentions. In a second experiment this advantage of self-efficacy implementation intentions was shown to prevail against a more conservative control group. Male university students were asked to work on an intelligence test and to solve as many tasks as possible. Again the control group did not get any further instructions. The implementation intention group got the same self-efficacy strengthening implementation intention as in the first experiment. A third group, the goal intention group, also received the self-efficacy strengthening instruction, but without the if-then structure (‘And I will tell myself: I can do these problems!’). Results showed that performance improved in the implementation intention group compared with the other two groups. The number of correctly solved tasks in the goal intention group did not differ significantly from the performance in the control group. Thus, implementation intentions supporting the motivational area of self-regulated learning via strengthening self-efficacy beliefs facilitated the students’ task performance.

Implementation intentions relating to the time and effort one is investing in a given task address the behavioral area of self-regulated learning. In a study with high school students, implementation intentions related to self-discipline that sought to improve the preparation of a high-stakes exam (Duckworth, Grant, Loew, Oettingen, & Gollwitzer, 2011). At the beginning of summer, half of the students formed and internalized individual implementation intentions on where, when, and how to prepare for an upcoming exam. The implementation intentions were directed towards completing all practice tests in a supplied workbook, thus, increasing the time and effort students invest in the exam preparation. The other half of the group prepared for the exam with the same workbook but without further instructions. Over the summer the students prepared for the exam with the workbook on their own. In the fall, just after the exam had taken place, the workbooks were collected and analyzed with regard to the number of completed tasks. Those students who had internalized implementation intentions completed about 60% more of the tasks than did students of the control group. Thus, implementation intentions supported the behavioral area of self-regulated learning by increasing the time and effort that students invested in preparing for the exam.

Taken together, implementation intentions seem to be a helpful tool to support self-regulation in education and can particularly be used to support self-regulatory processes of cognition, motivation, and behavior.

4.3 Conditions for Implementation Intentions to Work Well

Implementation intentions have been reported as a rather easy-to-implement, nonetheless, very effective tool. However, there are prerequisites for implementation intentions to work and some conditions under which implementation intentions work particularly well.

Inevitably, implementation intentions have to be formulated and internalized. Implementation intentions work by making a situational cue highly accessible and connecting it to a goal-directed response (e.g., Aarts et al., 1999; Gollwitzer & Schaal, 1998; Webb & Sheeran, 2007, 2008). For this purpose, individuals have to familiarize themselves with the specified future situation and strongly connect it to the desired behavior. Only by making this link, implementation intentions can unfold their potential to bridge the gap between an intention and the action to achieve the underlying goal.

Furthermore, the task-relevant goal that is underlying the implementation intention should be activated (Aarts & Dijksterhuis, 2000; Sheeran, Webb, & Gollwitzer, 2005). That is, the underlying goal should be available and the behavior in the implementation intention needs to fit that goal. In line with this reasoning, participants solved picture puzzles faster when they were instructed with an implementation intention relating to speed than with a task-irrelevant implementation intention (Sheeran et al., 2005). However, this effect only occurred when the goal to be fast was activated in a priming task, but did not occur when the goal to be accurate was activated.

Additionally, the relation between implementation intentions and goal achievement was shown to be qualified by the strength of the individuals’ commitment to the goal (de Nooijer, de Vet, Brug, & de Vries, 2006; Sheeran et al., 2005). In a study on how implementation intentions might help to increase the average consumption of fruits over a week, goal commitment positively affected the influence of implementation intentions on fruit intake (de Nooijer et al., 2006). Similarly, it was found that personal interest in the goal positively influenced an effect of implementation intentions on putting New Year’s resolutions into practice (Koestner, Lekes, Powers, & Chicoine, 2002). Thus, in these studies it was shown that implementation intentions work particularly well when the underlying goal is activated and when commitment to that goal is high.

Specificity of implementation intentions is another boundary condition that is assumed to have an impact on how well implementation intentions work (de Vet, Oenema, & Brug, 2011). In a health-related study participants were asked to formulate implementation intentions with the goal to increase physical activity. The number of implementation intentions as well as their specificity were coded and analyzed for predicting the increase in physical activity two weeks later. Specificity was coded as the number of answers to the questions ‘what?’, ‘when?’, ‘where?’, and ‘how long?’ mentioned within the implementation intentions. Results showed that participants were more likely to put their plans into action when the implementation intentions were more specific. Forming more implementation intentions was only helpful for action initiation if they were high in specificity. Thus, specificity seems to be an important factor for implementation intentions’ effectiveness.

Furthermore, self-efficacy was investigated as a possible moderator of the implementation intentions effect (Wieber, Odenthal, & Gollwitzer, 2010). At first, low or high self-efficacy was induced by giving participants either very difficult or very easy examples of a cognitive task. Then, they were asked to work on the actual cognitive tasks with the goal to solve as many items as possible. All participants were informed that double checking before going on to the next item was a very helpful strategy. Participants of the implementation intention condition additionally received the if-then plan ‘And if I have found an initial solution, then I will double check it!’. As a dependent variable the number of correctly solved items was calculated. Whereas one would assume that implementation intentions compared with mere goal intentions might compensate for low self-efficacy beliefs, no effect of implementation intentions were found when self-efficacy was low. Instead, results suggested that implementation intentions were effective only when items were difficult and self-efficacy was high. However, the implementation intention related to a strategy for task solution. It did not apply to strengthening self-efficacy beliefs themselves, thus, not regulating the self-regulatory challenge that was induced by the self-efficacy manipulation.

Other research has shown that implementation intentions are particularly effective when they are applied to self-regulatory problems. This was investigated with individuals that basically struggle in self-regulation such as drug-addicts under withdrawal, schizophrenic patients, or children with ADHD (Brandstätter et al., 2001; Gawrilow, Gollwitzer et al., 2011; Gawrilow & Gollwitzer, 2008). For instance, drug-addicts were asked to compose a curriculum vitae as part of a workshop on how to apply for a job (Brandstätter et al., 2001). Patients were either still under withdrawal or did not show symptoms of withdrawal anymore. When patients suffer from withdrawal, cognitive resources are mostly occupied by drug urge. Those patients who internalized goal-relevant implementation intentions (when, where, and how to write the curriculum vitae) were more likely to get the task done some hours later than patients who internalized goal-irrelevant implementation intentions (when, where, and how to have lunch). Moreover, the effect was even stronger in the group of patients that still suffered from symptoms of withdrawal.

As outlined in the literature review, challenges in self-regulating multimedia learning occur in the area of cognition, motivation, and behavior. In addition, there already exist studies that aimed at overcoming self-regulatory challenges in learning with the help of implementation intentions. The aim of this work was to examine the differential effects of implementation intentions relating to cognitive, motivational, and behavioral self-regulation in multimedia learning by comparing them with each other. Additionally, depending on the manifestation of the challenges and the specification of the implementation intentions, the influence on the learning outcome might vary. An overview of the research questions and the experiments will be given in the next chapter.

5 Overview of Research Questions and Experiments

Learners have to study with multimedia learning materials more and more often on their own. Learning with such materials is complex as it requires the learner to include information from several representations within one coherent mental model. To benefit from multimedia material, learners have to cope with several challenges which can be conceptualized against the backdrop of self-regulated learning. Learners must choose adequate cognitive strategies for information processing (cognitive self-regulation), they must believe in their own capabilities to learn (motivational self-regulation), and they must provide sufficient effort to master the learning task (behavioral self-regulation). Implementation intentions can give support to overcome these challenges. Previous research has shown that implementation intentions successfully supported self-regulation in the areas of cognition, motivation, and behavior. The goal of the following experiments was to address the relative effectiveness of implementation intentions related to the three areas of self-regulated learning in the context of problems that students may face in multimedia learning. In four experiments, three overarching research questions were investigated. In the following, an overview over these research questions and an outline of the four experiments will be given. The specific hypotheses of every experiment are then described in the respective chapters.

1. The first research question concerns whether supporting self-regulation in multimedia learning via implementation intentions improves the learning outcome in general. Based on multimedia research learners struggle with self-regulating their cognition, motivation, and behavior in multimedia learning. Thus, appropriate implementation intentions were used in all four experiments to help learners overcoming these challenges. It was expected that implementation intentions improve the learning outcome compared with a control group that did not get any instructional support.
2. The second research question deals with the particular effects of implementation intentions supporting cognition, motivation, or behavior. To get an insight whether supports for those areas of self-regulated learning leads to effects in equal size or whether they differ, the learning outcome of implementation intention groups were compared with each other. For instance, Pintrich (2000) assumes the selection and use of adequate cognitive strategies to be the central aspect of self-regulated learning.

Furthermore, differential effects were expected as the implementation intentions vary in specificity which is known to be a boundary condition of implementation intention effects (de Vet et al., 2011).

3. Additionally, a third research question focuses on individual prerequisites of the learners. That is, individual learner characteristics were investigated as possible moderators for an implementation intention effect. Implementation intentions are assumed to work particularly well when they address self-regulatory challenges. In particular, the challenges for self-regulating multimedia learning were investigated to see whether the appropriate implementation intention might compensate for low levels of variables relating to the areas of self-regulation; these are knowledge about and use of cognitive strategies (cognitive self-regulation), existing self-efficacy beliefs (motivational self-regulation), and the amount of effort planned to invest in the learning task (behavioral self-regulation).

In the experiments a control group without instructional support was compared with experimental groups that got instructional support via implementation intentions. Implementation intentions related to cognitive, motivational, and behavioral self-regulation. For cognitive self-regulation, implementation intentions aimed at instructing adequate cognitive strategies for multimedia learning. For motivational self-regulation, implementation intentions aimed at strengthening the learners' self-efficacy beliefs. For behavioral self-regulation, implementation intentions aimed at increasing the effort learners were willing to invest in the learning task. All experiments followed the same procedure. At first, all participants were asked to provide details on learner characteristics such as their knowledge about cognitive strategies, self-efficacy beliefs, and the effort planned for the learning task. In the experimental conditions, prior to learning, participants were instructed via one or several implementation intentions that related to cognitive, motivational, or behavioral self-regulation. Students in the control condition did not receive any support prior to learning. Then they started with studying the multimedia message. The multimedia learning materials comprised an expository text that was accompanied by appropriate schematic pictures. It explained how a tone is produced in an upright piano. After studying the multimedia message the learning outcome of all participants was assessed. The knowledge test included various verbal questions and pictorial tasks that asked for comprehension or recall of the materials.

Overview of Research Questions and Experiments

In the first experiment the learning outcome of a control group without instructional support was compared with the learning outcome from three experimental groups. The experimental groups each got instructed with one implementation intention to either make use of a cognitive strategy that was related to multimedia learning (cognitive self-regulation), to increase their self-efficacy by positive self-talk (motivational self-regulation), or to increase the effort they were willing to invest in the learning task (behavioral self-regulation). However, no effects of implementation intentions were found.

The second experiment replicated the design of the first experiment but improved some methodological features to set better conditions for an implementation intentions effect to occur. In accordance with findings from de Vet et al. (2011), the situational cues were made more specific. Furthermore, three implementation intentions were used per condition as this allowed to replicate implementation intentions relating to cognitive learning strategies, which had already worked well in a study on multimedia learning (Stalbovs et al., 2015). Thus, again a control group was compared with three experimental groups with implementation intentions relating to cognition, motivation, or behavior. It was found that implementation intentions relating to cognition and behavior improved learning, whereas motivational implementation intentions seemed to even hamper learning. The third and fourth experiment followed up on those results.

In the third experiment a control group was compared with two experimental groups receiving implementation intentions, both relating to motivation. Motivational self-regulation might be particularly problematic when working on the test. When solving the test items it is explicitly pointed out whether learning was successful and, thus, it might interfere with existing self-efficacy beliefs. Motivation, operationalized by strengthening learners' self-efficacy beliefs, was, thus, either related to learning or working on the test. However, neither positive nor negative effects of implementation intentions could be observed.

The fourth experiment sought to replicate the positive effect of cognitive and behavioral implementation intentions on learning outcomes from Experiment 2. Moreover, it was investigated whether support of several areas of self-regulation might add up and further improve learning performance. Thus, a control group was compared with three implementation intention groups receiving either cognitive or behavioral implementation intentions, or a combination of both. However, the effect of cognitive and behavioral implementation intentions could not be replicated, and neither was a combination of cognitive and behavioral implementation intentions particularly helpful for learning.

6 Experiment 1

The first experiment investigated whether implementation intentions relating to cognitive, motivational, or behavioral self-regulation improve learning in a multimedia learning environment. Of particular interest was whether these implementation intentions differ in their effectiveness. Additionally, learning time and how accurate learners judge their learning was measured to ascertain how implementation intentions affect learning. Furthermore, it was examined how learner characteristics influence the effectiveness of implementation intentions. In particular, characteristics that jeopardize an appropriate regulation of cognition, motivation, and behavior were assessed; those were knowledge about multimedia-specific cognitive strategies, pre-existing self-efficacy beliefs, and the effort learners plan to invest in learning, respectively.

6.1 Hypotheses

It was assumed that implementation intentions support self-regulation in multimedia learning and thus increase the learning outcome. Therefore, all implementation intention groups should outperform the control group.

> H1: The implementation intention groups show higher learning outcomes than the control group.

Selecting and using appropriate cognitive strategies (cognitive self-regulation) was assumed to be central for self-regulating learning, therefore the implementation intention relating to cognition was expected to affect the learning outcome more strongly than those relating to motivation or behavior. Furthermore, the cognitive implementation intention more specifically related to cognitive mechanisms, whereby specificity is known to increase an effect of implementation intentions (de Vet et al., 2011). As motivational and behavioral implementation intentions related to more unspecific processes of self-regulated learning no differences regarding learning outcome were expected between these groups.

> H2: The cognitive implementation intention yields higher learning outcomes than the motivational and behavioral implementation intention groups which do not differ from each other.

Beyond learning outcome, learning time, judgments of learning, and judgments of performance were assessed. An increase in effort and temporal engagement from behavioral implementation intentions should be reflected in an increase in learning time (Vollmeyer & Rheinberg, 2013).

H3: Implementation intentions relating to behavioral self-regulation increase learning time compared with the other groups.

Judgments of learning were assessed to test for metacognitive accuracy during learning. The metacognitive accuracy of the control group could, thus, indicate which self-regulatory problem, that is, over- or underestimation of learning, would be more pronounced. Implementation intentions relating to motivation and behavior both addressed issues which are grounded in an inadequate metacognitive accuracy during learning. Motivational problems refer to learners being overwhelmed by multimedia materials, which might lead them to underestimate their actual learning performance. In contrast, behavioral problems refer to learners being underwhelmed by multimedia materials due to relying on a multimedia heuristic which might lead them to overestimate their actual learning performance. The motivational and behavioral implementation intention should, thus, increase or decrease the judgments of learning, respectively. It was assumed that implementation intentions that foster motivation should boost self-efficacy and therefore, increase the judgments of learning compared with the control group. Implementation intentions relating to behavior were assumed to increase the effort in learning, reduce the influence of a multimedia heuristic, and thus decrease the judgments of learning compared with the control group.

H4a: Implementation intentions relating to motivational self-regulation increase judgments of learning compared with the control group.

H4b: Implementation intentions relating to behavioral self-regulation decrease judgments of learning compared with the control group.

Furthermore, judgments of performance were assessed, that is, metacognitive accuracy for the test. Implementation intentions only addressed the study phase and should thus only evoke differences for metacognitive accuracy during learning. During the test, participants encountered new reference points on which they could base their judgments of performance. Therefore, implementation intentions were not expected to affect judgments of performance; rather, they were assessed in order to make sure that any differences found regarding judgments of learning would be specific to the intervention related to the learning process.

H5: Groups do not differ in the judgments that learners give on their test performance.

Additionally, learner characteristics were analyzed exploratively for their possible interactions with implementation intention effects on the learning outcome. In particular, knowledge about multimedia-specific cognitive strategies, academic self-efficacy beliefs, and planned effort were assessed as they refer to the areas of self-regulated learning that were addressed by the three implementation intentions. One might expect that implementation intentions would compensate for low levels of these learner characteristics, whereby learners having problems with cognition, motivation, and/or behavior should only benefit from the implementation intention relating to the respective problem they have. For example, learners holding low self-efficacy beliefs should particularly benefit from the implementation intention relating to motivation. On the other hand, learners with high levels of these characteristics might not have problems in the specified areas of self-regulated learning, which is why they might not profit from an intervention relating to cognition, motivation, or behavior.

H6 – explorative: Individual differences in learner characteristics moderate an effect of implementation intentions on learning outcome.

6.2 Methods

6.2.1 Participants and design

Participants were undergraduate students of a southwestern German university. Students with a major in physics or music were not allowed to participate in the experiment due to content-related closeness to the learning material (mechanical explanation of a musical instrument). One participant who was studying physics as well as two participants who did not follow instructions on implementation intentions (i.e., they did not copy the pre-phrased implementation intention properly) were excluded from the analyses, which left a sample of 119 participants (102 female; Mage = 22.72 years, SD = 2.94). A post-hoc power analysis with the program GPower (Erdfelder, Faul, & Buchner, 1996) was conducted based on an alpha-level of $\alpha = .05$, the sample size of N = 119, and the effect size of $f = .325$ taken from the implementation intention meta-analysis (in the meta-analysis reported as $d = .65$: Gollwitzer & Sheeran, 2006). The statistical power with the given sample was 0.845 and, thus, the experiment had sufficient power to detect an effect of implementation intentions. Participants received 10 Euros for participation or course credits. They were randomly assigned to one of four conditions: three experimental conditions who received an implementation intention that was related to either cognition, motivation, or behavior, or a control group, which received no instructional support via implementation intentions.

6.2.2 Instructional materials

In the study phase the way a piano mechanism works was explained in a computer-based multimedia message (Figure 5). The message covered how a tone is produced in an upright piano when someone presses a key and how the mechanism returns to its starting position when the key is released again. There are two coordinated causal chains of components that can be distinguished in the mechanism. They move in parallel with multiple components interacting. The multimedia material was presented in 9 pages. Each of the pages contained text on the left half and a corresponding picture on the right half of the page that showed different states of the mechanism. Text and picture information were complementary and both were necessary for comprehension. The pictures in the form of an animation, as well as a verbal comprehension test and the open recall question have already been used in other studies (Boucheix & Lowe, 2010; Boucheix, Lowe, & Bugaiska, 2015; Boucheix, Lowe, Putri, & Groff, 2013; Lowe & Boucheix, 2011; Lowe & Boucheix, 2016).

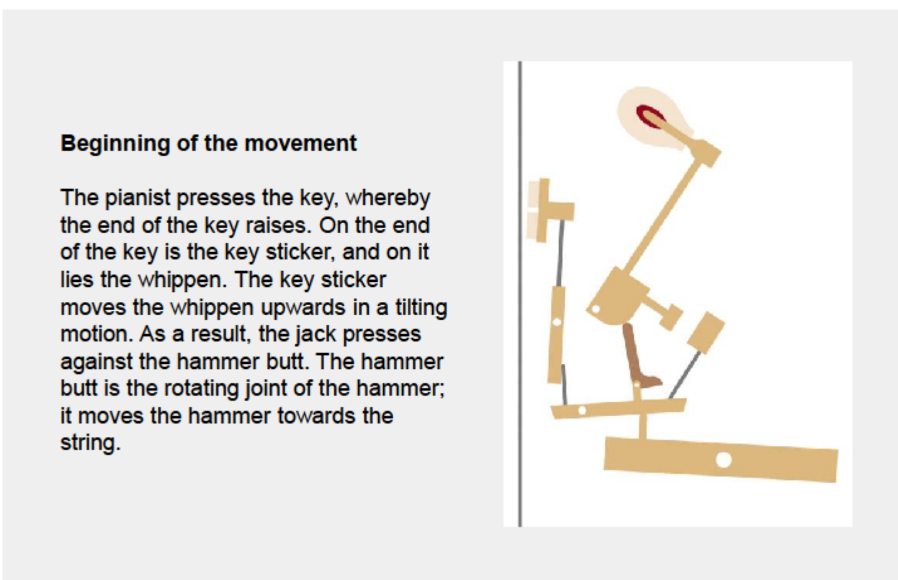

Figure 5. Screenshot from one page of the multimedia learning material (a German version was used in the experiment).

6.2.3 Measures

6.2.3.1 Control variables

Learner characteristics, in particular academic self-efficacy beliefs, planned effort and knowledge about multimedia-specific cognitive strategies were assessed as control variables to ensure that groups did not differ on those characteristics before manipulation. Furthermore, they were tested as possible moderators for an effect of implementation intentions. In a questionnaire, participants were asked to rate their self-efficacy beliefs (11 items, e.g., 'I think I am up to the difficulty of this task.', Cronbachs $\alpha = .876$) and the effort they planned to invest in the learning task (4 items, e.g., 'I am really going to try as hard as I can on this task.', Cronbachs $\alpha = .955$) both on a scale from 1 *disagree* to 7 *agree*. The items were adopted from validated questionnaires but some words were adapted to fit the university context (ASKU: Beierlein, Kemper, Kovaleva, & Rammstedt, 2013; PISA: Kunter et al., 2002; FAM: Vollmeyer & Rheinberg, 2006). Means were calculated separately for self-efficacy beliefs and planned effort for each participant. Knowledge about multimedia-specific cognitive strategies was assessed with a list of 24 efficient and inefficient strategies in multimedia learning (e.g., 'I look at the picture to check my understanding of the text.'), from which participants chose which strategies they normally use when learning with text and pictures (adapted from Scheiter et al., 2015). Only strategies that address integration of text and picture information were analyzed, as this was the strategy addressed by the cognitive implementation intention that was used in the experiment. Furthermore, interconnecting verbal and pictorial information is assumed to be an efficient and central process in multimedia learning (Mayer, 2009, 2014a; Schnotz, 2014; Schnotz & Bannert, 2003). The number of efficient multimedia cognitive strategies was added up for each participant with a maximum of 6 efficient strategies.

6.2.3.2 Learning outcome

Verbal comprehension, open recall, and pictorial recall were assessed to test for successful learning. The verbal comprehension test and the open recall question were adapted from Boucheix and Lowe (2010), as well as from Lowe and Boucheix (2011). The verbal comprehension test contained 23 verification items (max. 23 points; 1 point for each correct item), which referred to either the configuration of the piano elements (7 items) or the local kinematics (16 items) of the system. For each statement, participants judged whether it was true or false. The open recall test asked for the overall functional mental model of the piano. Participants were asked to write down everything they remembered about what happens inside a piano when a key is pressed. Points were given for every correctly remembered aspect (max. 24.5 points), whereas points were deduced for wrong descriptions. No points were given or deduced for omissions. In the pictorial recall test (max. 23.5 points) participants were instructed to name all elements, draw a missing part of the system (Figure 6), and sort pictures of the piano mechanism in the right order. Open recall and pictorial recall items from 20% of the participants were coded by two independent raters with good interrater reliability (Cohens $\kappa = .854$). Learning outcome was computed across all three tests and translated into percentage of total score (max. 71 points, Cronbachs $\alpha = .882$).

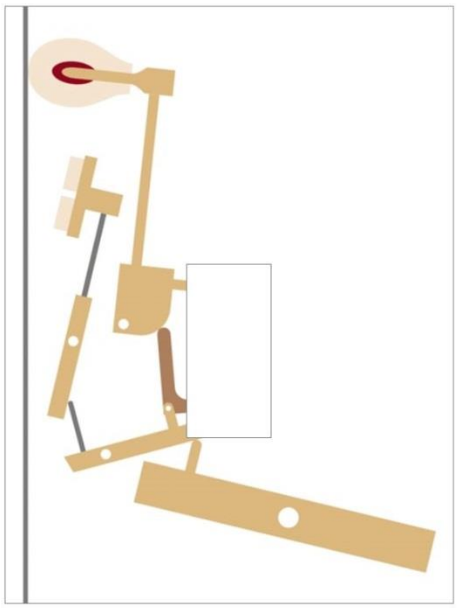

Figure 6. One example of the pictorial test items where participants had to draw a missing part of the piano mechanism.

6.2.3.3 Metacognitive judgments

Participants were asked to indicate their level of understanding twice throughout the experiment (Bjork et al., 2013; Nelson & Narens, 1990). They were asked to judge their learning in terms of the expected percentage correct on an upcoming test (judgments of learning, from 0 to 100) and to later judge their performance in the actually taken test (judgments of performance, from 0 to 100). The accuracy of the participants' judgments was calculated as the discrepancy between their judgments and their actual learning outcome as an indicator of metacognitive accuracy (de Bruin

& van Gog, 2012; Nelson, 1996). It was calculated by subtracting the percentage correct of learning outcome from the judgments. Therefore, 0 points indicate perfect estimation, whereas positive values show an overestimation and negative values show an underestimation of one's own learning. Accuracy of participants' judgments of performance was calculated as discrepancy only from the proportional scoring in the verbal comprehension test (which was corrected for guessing probability) because the judgments of performance only referred to this part of the knowledge test (see procedure).

6.2.4 Procedure

Participants were tested in groups of up to 7 individuals. They were working at separate workspaces in the same room, but no interaction was allowed between participants. The sessions lasted about 60 to 75 minutes. The participants first answered questions on demographic data (age, sex, subject of studies, instruments they play) and filled in the questionnaires on learner characteristics (self-efficacy beliefs, planned effort, and knowledge about multimedia-specific cognitive strategies). Then, participants in the experimental groups were introduced to implementation intentions as a tool that may help them to translate intentions into actions to reach a specific goal. They were asked to have the goal of making optimal use of the learning material with the help of the respective implementation intention. Furthermore, participants were asked to mentally imagine how they realize the implementation intention in the study phase. This instruction was adopted from Stalbovs et al. (2015) and reads as follows (translated from German):

> Have you ever experienced that you had built a strong intention to do something, but did not do it after all? This happens to almost everyone from time to time! However, there is something that can help you in such cases. Implementation intentions are concrete 'if-then' plans that should help you to translate an intention (e.g. "I want to go to the gym!") into an action. In the case of implementation intentions, you connect a condition under which you want to realize the action with this action.
>
> Example: "If I come home from work on Friday, then I will take my gym bag and go to the gym!"
>
> In this experiment, we ask you to learn with the goal and the intention to make optimal use of the learning material. Implementation intentions can help you to make the best use of the learning material.

> Therefore, please copy the following implementation intention three times and imagine thereby, how you will realize this implementation intention afterwards in the study phase. It is important that you really want to realize the implementation intention.

Next, the participants wrote down their group's specific pre-phrased implementation intention three times (see Table 2 for exact wording of implementation intentions). This procedure was adopted from previous studies (cf. for similar procedures e.g., Achtziger et al., 2008; Gollwitzer, Schwörer, Stern, Gollwitzer, & Bargh, 2017; Stalbovs, et al., 2015). The cognitive implementation intention related to building referential connections between text and picture information, thus, supporting integration of information from both representations which is considered an efficient multimedia-specific cognitive strategy. The motivational implementation intention aimed at strengthening self-efficacy beliefs via positive self-talk. The behavioral implementation intention related to increasing the effort learners were willing to invest in learning, which was operationalized as increasing concentration on the multimedia representation.

Table 2

Implementation Intention Instruction as a Function of Condition in Experiment 1.

	n	Implementation Intention
Cognition	30	If I start a new page, then I will search the picture for the contents described in the text.
Motivation	28	If I start a new page, then I will tell myself: I can learn it!
Behavior	31	If I start a new page, then I will particularly concentrate on the content presented.

Note: Control group (*n* = 30) did not get instructed with implementation intentions. The cognitive implementation intention was adapted from Stalbovs et al. (2015). The motivational implementation intention was adapted from Bayer and Gollwitzer (2007).

All implementation intention groups used the same if-part ('If I start a new page…'), since an effect on learning outcome could then be traced back to the varying action in the then-part only. Participants in the control group proceeded to the learning material without any instruction on implementation intentions. Then, the learning material was presented on laptops and participants could determine learning time on their own. Learners could move forward in the material by clicking a ‘continue’ button, but were not able to go back to previously learned pages. After the study phase, participants were asked to judge their learning in terms of their expected performance on a knowledge test about the piano mechanism (judgment of learning). After answering the verification items, participants estimated their performance on this just taken verbal comprehension test (judgment of performance). Then, participants worked on the open recall question and the pictorial recall test (both paper-pencil tests). At the end participants from the experimental groups were asked to write down the implementation intention they had been instructed with to check if they still remembered it.

6.3 Results

Means and standard deviations of all control variables and dependent measures are summarized in Table 3.

6.3.1 Control variables and manipulation check

Analyses of variance (ANOVAs) were conducted to test whether groups differed in learner characteristics. There were no significant differences between conditions in knowledge about multimedia strategies, $F(3, 115) = 1.80$, $p = .150$, $\eta_p^2 = .04$, or self-efficacy beliefs, $F(3, 115) = 0.52$, $p = .670$, $\eta_p^2 = .01$. However, despite randomization there was a significant difference between groups with regard to the effort they planned to invest in the learning task, $F(3, 115) = 2.73$, $p = .047$, $\eta_p^2 = .07$. Bonferroni-adjusted post-hoc comparisons showed that participants in the control group planned to invest more effort into the learning task than participants who received a cognitive implementation intention, $p = .045$. The other groups did not differ significantly from each other, all $p_s > .1$. Including planned effort as a covariate or eliminating group differences by excluding outliers did not change the pattern of results. Thus, planned effort was not added as a covariate to keep analyses simple and all participants were kept in the sample to maintain statistical power.

Table 3

Means and Standard Deviations of Control Variables and Dependent Measures for the Control Group and the Implementation Intention Groups (II) in Experiment 1.

	Control Group	II Cognition	II Motivation	II Behavior

Experiment 1

Knowledge about multimedia strategies (0-6)	4.13 (1.46)	4.00 (1.68)	4.79 (1.03)	4.26 (1.21)
Self-efficacy beliefs (1-7)	5.28 (0.89)	5.03 (0.90)	5.06 (0.84)	5.18 (0.72)
Planned effort (1-7)	6.14 (0.76)	5.43 (1.41)	5.97 (1.04)	5.92 (0.73)
Learning outcome (%)	52.44 (11.17)	51.13 (14.10)	52.99 (16.09)	51.09 (12.64)
Learning time (min)	6.88 (3.81)	7.33 (3.78)	7.23 (3.47)	5.87 (1.90)
Judgment of learning (0-100)	66.33 (21.41)	56.67 (22.64)	66.07 (26.71)	59.68 (23.02)
Accuracy JoL	13.89 (18.01)	5.54 (16.58)	13.08 (17.94)	8.59 (19.08)
Judgment of performance (0-100)	50.33 (22.51)	43.00 (24.66)	48.57 (28.64)	40.97 (24.95)
Accuracy JoP	25.41 (26.36)	15.46 (24.81)	20.31 (25.38)	9.97 (24.49)

Note: Accuracy of judgments of learning (JoL) and judgments of performance (JoP) is given as discrepancy between participants' judgments and scored performance of the learning outcome, whereby 0 points indicate perfect estimation, positive values indicate overestimation, and negative values indicate underestimation. It should be noted that the accuracy for judgments of performance only relates to performance in the verbal comprehension test.

At the end of the experiment participants in the implementation intention groups were asked to remember and write down the implementation intention that they had internalized before (manipulation check). Fisher's exact tests showed that there were no differences between implementation intention groups in the number of participants who did not remember the content of the implementation intention (n = 15), p = .465, or the if-then structure of the written down implementation intention (n = 23), p = 1, or even both (n = 9), p = .938. As implementation intentions are supposed to work automatically without holding them actively in mind, memory of wording would be a strong assumption for the effectivity of implementation intentions. Thus, all of these participants were kept in the sample for the analyses.

6.3.2 Dependent measures

ANOVAs were calculated separately for each dependent measure to test for main effects of implementation intentions.

Experiment 1

6.3.2.1 *Learning outcome*

Contrary to the hypothesis learning outcome did not differ between conditions, $F(3, 115) = 0.15$, $p = .932$, $\eta_p^2 = .004$. Thus, none of the implementation intention groups outperformed the control group (contradicting H1), and the implementation intention groups did not differ from each other (partly confirming H2).

6.3.2.2 *Learning time*

There was no significant main effect of implementation intentions on learning time, $F(3, 115) = 1.23$, $p = .301$, $\eta_p^2 = .03$. Contradicting the expectations, learning times did not increase for participants of the behavior group compared with the other groups (H3).

6.3.2.3 *Metacognitive judgments*

Judgments of learning, $F(3, 115) = 1.24$, $p = .299$, $\eta_p^2 = .03$, did not differ as a function of implementation intention group. Thus, other than expected the motivation group and the behavior group did not differ from the control group regarding judgments of learning (contradicting H4a and H4b, respectively). There were no group differences regarding judgments of performance, $F(3, 115) = 0.94$, $p = .425$, $\eta_p^2 = .02$, which is in line with predictions (confirming H5).

In general, participants tended to overestimate their learning, which speaks in favor of learners relying on a multimedia heuristic and, thus, having more problems in the behavioral area of self-regulated learning. This was reflected in the accuracy for judgments of learning being significantly larger than 0, $t(118) = 6.18$, $p < .001$, $d = 1.14$. This was also true when looking at the accuracy for judgments of learning in each group separately, control group: $t(29) = 4.23$, $p < .001$, $d = 1.57$, cognition: $t(29) = 1.83$, $p = .039$, $d = 0.68$, motivation: $t(27) = 3.86$, $p < .001$, $d = 1.49$, behavior: $t(30) = 2.51$, $p = .009$, $d = 0.92$. Accuracy for judgments of learning did not differ among conditions, $F(3, 115) = 1.42$, $p = .240$, $\eta_p^2 = .04$.

In general, participants also tended to overestimate their performance, which was reflected in the accuracy for judgments of performance being significantly larger than 0, $t(118) = 7.53$, $p < .001$, $d = 1.39$. This was also true when looking at the accuracy for judgments of performance in each group separately, control group: $t(29) = 5.28$, $p < .001$, $d = 1.96$, cognition: $t(29) = 3.41$, $p < .001$, $d = 1.27$, motivation: $t(27) = 4.23$, $p < .001$, $d = 1.63$, behavior: $t(30) = 2.27$, $p = .015$, $d = 0.83$. Accuracy for judgments of performance did not differ among conditions, $F(3, 115) = 2.08$, $p = .107$, $\eta_p^2 = .05$.

6.3.2.4 *Moderating role of learner characteristics*

Regression analyses were conducted to test whether learner characteristics (knowledge about multimedia-specific cognitive strategies, self-efficacy beliefs, and planned effort) would moderate a possible effect of implementation intentions on learning outcome (referring to H6 – explorative). Separate regression analyses were run for each of the three learner characteristics. Regression models always contained one of the learner characteristics, the implementation intention conditions, and the two-way interaction as predictors. Implementation intention conditions were dummy-coded with the control group as the baseline category. The continuous learner characteristic variables were z-standardized.

Knowledge about multimedia-specific cognitive strategies, $F(1, 111) = 2.06$, $p = .154$, $\eta_p^2 = .02$, and planned effort, $F(1, 111) = 2.55$, $p = .113$, $\eta_p^2 = .02$, were not predictive for learning outcome and did not significantly interact with implementation intention conditions, both *F*s < 1. However, there was a positive effect of self-efficacy beliefs, $F(1, 110) = 25.08$, $p < .001$, $\eta_p^2 = .19$, as well as a significant interaction of self-efficacy beliefs with implementation intentions, $F(3, 110) = 3.23$, $p = .025$, $\eta_p^2 = .08$ (data of one participant were excluded for this regression analysis due to a Cook's distance > .10, indicating an overly strong influence on the regression models outcome, Cook & Weisberg, 1980). The regression model (Table 4) explained about 20% of variance in the data, $F(7, 110) = 5.12$, $p < .001$, $R^2 = .197$.

Table 4

Regression Model to Predict Learning Outcome (Percentage of Total Score) from Self-Efficacy Beliefs and Implementation Intentions.

	B	SE_b	β
Intercept	50.704	2.289	
Self-efficacy beliefs	5.517	2.255	0.411*
II behavior	0.195	3.146	0.016
II motivation	3.447	3.234	0.257

II cognition	0.581	3.184	0.490
II behavior x self-efficacy beliefs	1.514	3.374	0.113
II motivation x self-efficacy beliefs	4.849	3.186	0.409
II cognition x self-efficacy beliefs	-4.426	3.041	-0.330

Model: $F(7, 110) = 5.12$, $p < .001$, $R^2 = .197$

$^{+}$ $p \leq .10$, * $p \leq .05$, ** $p \leq .01$, *** $p \leq .001$

Note: Control group functions as baseline category. Implementation intention is abbreviated by 'II'.

To probe the interaction effect, a simple slopes analysis for low (-1 SD, light grey bars in Figure 7) and high (+1 SD, dark grey bars in Figure 7) values of the continuous variable self-efficacy beliefs was conducted (see Aiken & West, 1991). There were no differences between conditions for learners holding low self-efficacy beliefs, $F(3, 110) = 1.07$, $p = .362$, whereas the differences between conditions for learners holding high self-efficacy beliefs were marginally significant, $F(3, 110) = 2.37$, $p = .075$. The other possible perspective on the interaction was also tested to see whether implementation intentions differentially influenced the effect of self-efficacy beliefs. Simple slopes analyses revealed that the relationship between self-efficacy beliefs and learning outcome differed between groups. There was a significant positive effect of self-efficacy beliefs in the control group, $B = 5.52$, $SE = 2.26$, $\beta = 0.41$, $p = .016$. This relationship was even stronger in the groups with an implementation intention corresponding to behavior, $B = 7.03$, $SE = 2.51$, $\beta = 0.52$, $p = .006$, and strongest in the group with an implementation intention corresponding to motivation, $B = 10.37$, $SE = 2.25$, $\beta = 0.77$, $p < .001$. However, there was no relationship between self-efficacy beliefs and learning outcome in the group with an implementation intention corresponding to cognition, $B = 1.09$, $SE = 2.04$, $\beta = 0.08$, $p = .594$.

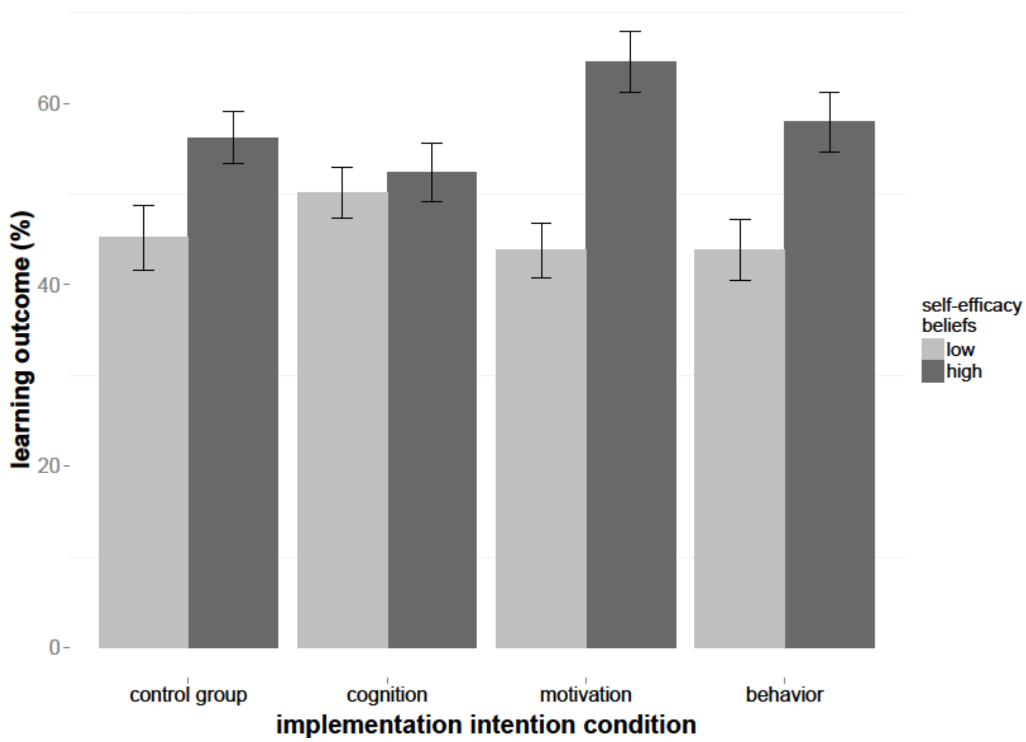

Figure 7. Learning outcome (percentage of correct answers) as a function of experimental condition and self-efficacy beliefs (means at low and high levels of self-efficacy beliefs are estimated based on the simple slope analyses at -1 SD and +1 SD, respectively)

6.4 Discussion

The aim of this experiment was to test the effects of implementation intentions on self-regulated learning from multimedia material. The implementation intentions were designed to support areas of self-regulated learning that could be problematic in multimedia learning. In particular, learners might not use appropriate cognitive strategies and therefore process the learning materials insufficiently (problem of cognition). Second, learners might hold only low self-efficacy beliefs as a consequence of being overwhelmed by the complexity of multimedia materials (problem of motivation). Third, learners might invest too little effort in information processing because they rely on a multimedia heuristic which induces overconfidence in one’s level of understanding (problem of behavior). Accordingly, different types of implementation intentions were designed that tackled each of the potential self-regulatory problems separately. In the experiment, learners were either instructed with one of three implementation intentions relating to cognition, motivation, or behavior, or they did not receive any instructional support prior to learning a multimedia message. Implementation intentions were expected to support self-regulatory processes of multimedia learning and, thereby, improving learning outcome in a subsequent test. In addition, the most specific implementation intention (relating to cognition) was expected to be most effective and, thus, to yield the highest test scores. Furthermore, implementation intentions were expected to affect judgments of learning and learning time, representing self-regulatory processes in the areas of motivation and behavior.

Contrary to these assumptions no effects of the implementation intentions relating to self-regulation of cognition, motivation, or behavior on the learning outcome were found. Additionally, neither learning time nor judgments of learning were influenced by the implementation intentions. However, implementation intentions interacted with learners' pre-existing self-efficacy beliefs.

At the core of this experiment is the argument that learners face various self-regulatory problems when learning with multimedia material. Although there is a considerable amount of empirical evidence for these problems in multimedia learning, it might be that in this experiment there were no problems of self-regulation to begin with. In line with this, the scores of the control variables (self-efficacy beliefs, planned effort, and knowledge about multimedia-specific cognitive strategies) were all above the scale midpoint. However, the performance in the control group suggests otherwise. Given that learning outcome in the control group was merely around 52%, indicates that multimedia learning was challenging for the participants and that instructional support was indeed needed to improve learning. In addition, independent of condition, learners gave judgments of learning that exceeded test performance, suggesting that they slightly overestimated their learning. This indicates that learners indeed might have had problems with the behavioral area of self-regulated learning in that they applied the multimedia heuristic (Serra & Dunlosky, 2010) when monitoring their level of understanding. Based on this overestimation, one would expect implementation intentions relating to behavior to be helpful, since they require learners to invest more effort even when they feel (over-)confident in their performance. On the other hand, implementation intentions relating to motivation should hinder learning since they would only increase overconfidence by boosting students' self-efficacy beliefs. However, none of the implementation intentions affected the learning outcome.

One possible explanation for the lack of significant effects of the implementation intentions on judgments of learning, learning time, and especially learning outcome is that these findings resulted from methodological weaknesses of the experiment. For instance, at the time when learners were instructed with the implementation intentions they knew the topic of the learning material, but had not yet seen the learning environment itself. This might have made it difficult for the learners to imagine the learning scenario and to internalize it as the situational cue for the implementation intentions. Another issue relates to the particular if-part of the implementation intentions. The if-part was the same in all experimental conditions to increase experimental control. The specified situation ('If I start a new page') only occurred once on each page which means that the action that was linked to the situation was only rarely triggered during learning. Furthermore, the situation in fact occurred before and not during processing the content of the page. Accordingly, the different actions specified in the then-part might have been triggered before but not during learning the content of a certain page, which may explain why none of the implementation intentions had an influence on the dependent variables. In addition, as specificity is known to positively influence the effectiveness of implementation intentions (de Vet et al., 2011), the low specificity of the implementation intentions might account for the missing implementation intention effect in this experiment compared with other studies. The cognitive implementation intention was adapted from Stalbovs et al. (2015), but could not replicate its positive effect. However, Stalbovs et al. (2015) tied the cognitive strategies more specifically to the problematic situation to facilitate cognitive processing (i.e., 'If I have finished reading a page, then I will carefully re-read all paragraphs'). In contrast, in this experiment, the situation referred to in the implementation intentions did not explicitly address a particular self-regulatory challenge. However, part of the effectiveness of implementation intentions result from addressing specific and critical situations and tie them to helpful and goal-oriented behavior. It is possible that the critical situations differ for cognitive, motivational, and behavioral self-regulation and hence, the implementation intentions need to be formulated in a more specific way. As none of the three different implementation intentions improved the learning outcome, the lacking specificity of the shared situational cue plus its rare occurrence would be a plausible explanation for this finding.

Despite these unexpected results regarding the absent main effect of the implementation intentions, an interesting finding of the present experiment is the interaction between learners' self-efficacy beliefs and the implementation intentions. There was a positive effect of self-efficacy beliefs on learning outcome for all learners that disappeared when they were instructed with a specific cognitive strategy. Berger and Karabenick (2011) explain the positive effect that results from high self-efficacy beliefs by assuming that high self-efficacy beliefs foster the use of more elaborated strategies. Instructing high self-efficacious learners in the cognition group with one multimedia-specific cognitive strategy then might have interfered with the more elaborated and more adaptive strategies they might have used by themselves. Importantly, these findings regarding the moderating role of pre-existing self-efficacy beliefs need to be interpreted with caution as the analysis of the interaction was exploratory. Furthermore, the findings somewhat contradict the results that were found in a previous study on self-efficacy as a moderator of an implementation intentions effect (Wieber et al., 2010). In that study it was found that implementation intentions only were effective in difficult tasks when self-efficacy was high. However, the mismatching results across the experiments could be caused by differences in content of implementation intentions or the task at hand. Thus, self-efficacy as a moderator of implementation intentions needs to be further investigated and the effect has to be replicated before more definite conclusions can be drawn.

Taken together, the results from the present experiment revealed that implementation intentions relating to cognitive, motivational, and behavioral self-regulatory problems did not improve learning outcome. However, the experiment contained several methodological weaknesses. Further research is needed to resolve these weaknesses and to further investigate how implementation intentions can be adjusted to help learners to overcome the self-regulatory challenges – cognitive, motivational, and behavioral self-regulation – during multimedia learning.

7 Experiment 2

Experiment 2 replicates the design of the first experiment, while addressing weaknesses that could account for the lacking effect of implementation intentions. A pre-training task was included before introducing the implementation intentions to familiarize learners with the type of learning material they would later encounter, instead of only naming the topic. This should facilitate imagining how the situation of the implementation intention is encountered and building the connection between the situational cue and the behavioral response. Thus, implementation intentions were expected to be more effective compared with Experiment 1. Furthermore, it should be ensured that the implementation intentions and especially the situational cue were specific enough and suitable to support multimedia learning. Thus, for the cognition condition the implementation intentions relating to multimedia-specific cognitive strategies were adopted from Stalbovs et al. (2015), who successfully used those to improve multimedia learning. In the most successful condition of that study three implementation intentions were used to support multimedia-specific cognitive strategies (whereas in Experiment 1 only one implementation intention was used per condition). The implementation intentions of Stalbovs et al. were adopted for the cognition group and implementation intentions for the other two conditions were created as similar as possible in terms of the if-part, but altered the specified action of the then-part to relate the specified situation to either motivational or behavioral self-regulation. Thus, the conditions were conceptually still the same as in Experiment 1, but three implementation intentions with more specific situational cues were used in each condition. Taking into consideration these changes, there was expected to be an effect of self-regulatory implementation intentions on multimedia learning in Experiment 2.

Two more changes were made compared with Experiment 1. First, the questionnaire on knowledge about multimedia-specific cognitive strategies was shifted to the end of the experiment. Three efficient cognitive strategies on integration of text-picture-information were listed together with three inefficient strategies for multimedia learning. Participants should indicate to what extent they had used those strategies during the experiment. Thus, the questionnaire served as an indicator whether the implementation intention was set into action. Waiving on the baseline measurement of knowledge about multimedia-specific cognitive strategies was accepted as empirical evidence for problems in cognitive self-regulation is strongest (e.g., Scheiter et al., 2017). Furthermore, it was feared that presenting cognitive strategies before learning might trigger to use them throughout the experimental learning phase. Second, the judgments of learning and judgments of performance were not assessed due to economic reasons.

7.1 Hypotheses

Like in the first experiment the main hypothesis was that implementation intentions improve learning, and thus, the three experimental groups were expected to show higher learning outcomes than the control group.

> H1: The implementation intention groups show higher learning outcomes than the control group.

Furthermore, the cognition group was expected to show the highest learning outcome, since cognition is considered to be the most important area in the self-regulated learning framework (Pintrich, 2000). The motivation and behavior groups were not expected to differ from each other in terms of learning outcomes.

> H2: The cognitive implementation intention group shows higher learning outcomes than the motivational and behavioral implementation intention groups that do not differ from each other.

In addition, it was hypothesized that the behavioral implementation intentions influence learning time and that the cognitive implementation intentions influence the use of multimedia-specific cognitive strategies. Since the participants in the behavior condition received implementation intentions that addressed the effort that is put into learning, this group was expected to have the longest learning times. The three other groups were not expected to differ in how much time they spent with the materials.

> H3: Implementation intentions relating to behavioral self-regulation increase learning time compared with the other groups.

Participants in the cognition group received implementation intentions relating to multimedia-specific cognitive strategies. Thus, the cognition group was expected to report a more frequent use of such multimedia-specific cognitive strategies, which was assessed in a questionnaire at the end of the experiment. The three other groups were not expected to differ in their use of multimedia-specific cognitive strategies.

> H4: Implementation intentions relating to cognitive self-regulation report a greater use of the multimedia-specific cognitive strategies.

Again, the moderating role of learner characteristics, that is self-efficacy beliefs and planned effort, was investigated. The focus was on self-efficacy beliefs as a significant interaction of self-efficacy beliefs and implementation intentions was found in the first experiment. Since results regarding self-efficacy from Experiment 1 did not correspond to findings from previous experiments (Wieber et al., 2010), the direction of the hypothesis was again left open.

> H5 – explorative: Individual learner characteristics, in particular preexisting self-efficacy beliefs, moderate an effect of implementation intentions on learning outcome.

7.2 Methods

7.2.1 Participants and design

Participants were again undergraduate students from the same university as in Experiment 1. Because the same learning material was used (the mechanical explanation of an upright piano), again students majoring in physics or music were not allowed to participate. Furthermore, data from two participants were excluded from the analysis because they failed to follow the implementation intention instruction (i.e., they did not copy the pre-phrased implementation intentions properly). The remaining sample were 130 participants (90 female) aged 18 to 34 years (M = 22.87 years, SD = 3.51). They received course credit or were paid 10 Euros for participation. Participants were randomly assigned to a control group without implementation intentions or to one of the three experimental groups with implementation intentions that were either related to cognitive, motivational, or behavioral self-regulation in multimedia learning. Statistical power was calculated analogous to Experiment 1. Based on an alpha level of $\alpha = .05$, the sample size of N = 130, and the effect size of $f = .325$, the statistical power in Experiment 2 was 0.879.

7.2.2 Instructional materials

In the learning material again the functionality of a piano mechanism was explained. It was explained what happens inside a piano, how a tone is produced when a key of the piano is pressed and released again. The materials were a slightly revised version from those used in Experiment 1. Mainly the page that named all the components of the mechanism was omitted as the participants were already given a labeled picture of the piano mechanism in the pre-training task before entering the study phase. The contents were presented on eight pages presenting text on the left half of the page and a corresponding picture on the right half of the page. Information from text and pictures were complementary, thus, both representations were needed to fully understand the mechanism.

7.2.3 Measures

7.2.3.1 Control variables

In a pre-training task participants studied a labeled picture of the piano mechanism (Figure 8) and then were instructed to label an unlabeled version of the picture. One point could be scored for each of the 12 labels (Cronbach's α = .799).

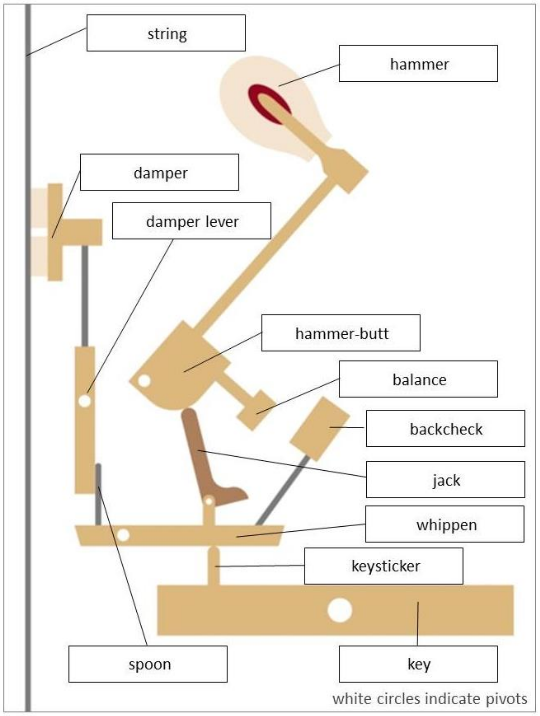

Figure 8. Labeled picture of the piano mechanism that was used for pre-training (translated from German)

Furthermore, learner characteristics (academic self-efficacy beliefs and planned effort) were assessed as control variables and possible moderators for an effect of implementation intentions. Academic self-efficacy beliefs (Cronbach's α = .920) and the effort participants planned to invest in the learning task (Cronbach's α = .920) were measured with the same questionnaire as in Experiment 1. Items were again rated on a 7-point scale, from 1 *disagree* to 7 *agree*, and were then averaged for self-efficacy and planned effort separately.

7.2.3.2 *Learning outcome*

In order to measure learning outcome, the open recall question, the verbal comprehension task, and the pictorial recall tasks from Experiment 1 were used again. Learning outcome was computed of open recall, verbal comprehension, and pictorial recall, as the total score (max. 71 points) converted to percentages (Cronbach's $\alpha = .886$). For 20% of the sample open recall and pictorial recall items were coded by two independent raters who achieved good agreement (Cohen's $\kappa = .837$).

7.2.3.3 *Use of multimedia-specific cognitive strategies*

To assess which multimedia-specific cognitive strategies participants had used during the experiment, six cognitive strategies were listed (e.g., 'I searched for corresponding contents in text and picture.') and participants indicated to what extent they had used these strategies throughout the study phase on a scale from 1 *infrequently* to 7 *frequently* (Cronbach's $\alpha = .718$). Three of the strategies related to the integration of text-picture-information. The remaining three strategies were inefficient for learning and were therefore reverse coded for the analyses. Thus, high values on this variable indicate a competent use of cognitive strategies. Additionally, there was a blank space for participants to add any personal strategy they had used. Since only few participants used the space and most answers repeated one of the above listed strategies, this personal strategy was not analyzed. The strategies were adapted from the questionnaire that listed efficient and inefficient strategies for multimedia learning which was used in Experiment 1.

7.2.4 Procedure

The procedure was similar to the procedure of Experiment 1. Data collection took place in groups up to 8 participants simultaneously, whereby participants worked individually on computers at separated workspaces, but were not allowed to interact with each other. After participants had signed an informed consent, they answered some questions on demographic data and were informed about the upcoming learning task. For the pre-training, participants were asked to memorize the twelve labels of the piano mechanism. Their ability to remember the labels was tested immediately afterwards with a picture of the unlabeled piano mechanism. This pre-training was done to familiarize participants with the learning environment to make it easier for them to imagine the learning situation (if-part) as a prerequisite for properly internalizing the implementation intentions. After the pre-training, participants continued on the computer and filled in the questionnaire on self-efficacy beliefs and the effort they planned to invest in the learning task. In the experimental groups, implementation intentions were then introduced as a useful tool to translate plans into action. Participants were instructed to learn with the goal of fully understanding the materials with the help of the pre-phrased implementation intentions relating to cognition, motivation, or behavior. The instruction was adopted from Experiment 1, but different implementation intentions were used (see Table 5 for exact wording). In each experimental condition participants were instructed with three implementation intentions that related to processing the picture, processing the text, and processing both representations together. The instruction was to imagine how the specified situations of the implementation intentions occur and how the respective behavior is then carried out. The cognition group received implementation intentions that related to the more frequent use of multimedia-specific cognitive strategies. The motivation group was instructed with implementation intentions that related to increasing self-efficacy. The behavior group received implementation intentions that related to increasing the amount of effort that participants put into learning. To ensure that the implementation intentions were internalized, students were instructed to copy each of them twice. Participants in the control group did not get any instruction with implementation intentions, but directly continued with learning the multimedia message. Right after learning, participants continued with the knowledge test, which included the open recall task and the verbal comprehension items on the computer, as well as the pictorial recall tasks on paper. Participants from the experimental conditions were then asked to remember and write down the wording of the three implementation intentions they had gotten before learning. Afterwards, all participants filled in the paper-based questionnaire on their use of multimedia-specific cognitive strategies. Finally, they were debriefed, remunerated and thanked for participation. The entire experiment lasted about 60 to 75 minutes.

Table 5

Implementation Intention Instruction as a Function of Condition in Experiment 2.

Condition	*n*	Implementation Intentions
Control Group	32	No instruction via implementation intentions.

Cognition	32	If I am looking at a picture, then I will search for its central elements with regard to content! If I am reading a paragraph, then I will search for its central elements with regard to content! If I have read a paragraph, then I will search the picture for the contents described therein!*
Motivation	32	If I open a new page, then I tell myself: I am able to learn it! If I am looking at a picture, then I will tell myself: I am able to understand the pictorial contents! If I am reading a paragraph, then I will tell myself: I am able to understand the textual contents!
Behavior	34	If I open a new page, then I will particularly concentrate to understand the contents! If I am looking at a picture, then I will particularly concentrate to understand the contents presented in the picture!* If I am reading a paragraph, then I will particularly concentrate to understand the contents presented in the text!*

Note: Implementation intentions marked with an asterisk were used for a combined condition (mix) in Experiment 4.

7.3 Results

Descriptive values of all control variables and dependent measures are displayed in Table 6. Two participants failed to complete parts of the paper-based knowledge test, the manipulation check, as well as the questionnaire on the use of multimedia-specific cognitive strategies. Their missing values were replaced by the respective group means (Downey & King, 1998; Wilks, 1932).

Table 6

Means and Standard Deviations of Control Variables and Dependent Measures for the Control Group and the Implementation Intention Groups (II) in Experiment 2.

	Control Group		II Cognition		II Motivation		II Behavior	
Pre-training (0-12)	8.70	(2.49)	9.67	(2.22)	8.03	(3.39)	8.84	(2.71)
Self-efficacy beliefs (1-7)	5.22	(1.10)	5.26	(0.87)	4.87	(1.16)	4.86	(0.94)

Experiment 2

Planned effort (1-7)	6.09 (0.74)	6.03 (0.81)	5.70 (1.24)	6.10 (0.79)
Learning outcome (%)	57.64 (13.50)	64.37 (13.05)	53.85 (12.76)	60.98 (14.34)
Learning time (min)	4.97 (1.74)	4.94 (1.67)	5.09 (2.35)	6.34 (2.86)
Use of multimedia-specific cognitive strategies (1-7)	5.55 (1.05)	6.13 (0.74)	5.70 (1.09)	5.65 (0.83)

7.3.1 Control variables and manipulation check

Groups did not differ from each other in their pre-training scores, $F(3, 126) = 1.94$, $p = .127$, $\eta^2 = .04$, their self-efficacy beliefs, $F(3, 126) = 1.44$, $p = .235$, $\eta^2 = .03$, or the effort they planned to invest in the learning task, $F(3, 126) = 1.33$, $p = .266$, $\eta^2 = .03$. At the end of the experiment only 9 participants (2 cognition, 3 motivation, 4 behavior) remembered none of the three implementation intentions. Groups did not differ in the number of implementation intentions that they remembered correctly in terms of the content and the if-then structure, $F(2, 95) = 1.78$, $p = .174$, $\eta^2 = .04$. None of those participants was excluded from the analyses.

7.3.2 Dependent measures

Analyses of variance (ANOVAs) were conducted to test whether groups differed regarding the dependent measures. Following up on the recommendation of the APA Task Force on Statistical Inference (Wilkinson & Task Force on Statistical Inference, 1999) planned contrasts were used to more parsimoniously and directly test the hypotheses (Abelson & Prentice, 1997; Furr & Rosenthal, 2003). This method allows testing whether a specific hypothesized pattern which is described in a focal contrast fits the data, or whether several residual contrasts make a better fit. For $k = 4$ groups, three orthogonal contrasts ($k - 1$) had to be defined to use all the degrees of freedom: one focal contrast and two residual contrasts (Rosenthal, Rosnow, & Rubin, 2000). The three contrasts were entered simultaneously into the ANOVA. The hypothesized data pattern of group differences is considered to best explain the data when the focal contrast is significant while the residual contrasts are not. The residual contrasts were tested together as a set, which is a more conservative test of the assumption that they do not explain a significant amount of variance in the data (cf. Niedenthal, Brauer, Robin, & Innes-Ker, 2002).

Experiment 2

7.3.2.1 Learning outcome

There was a significant main effect of implementation intentions for learning outcome, $F(3, 126) = 3.61$, $p = .015$, $\eta^2 = .08$. The hypothesized pattern – the control group showing the lowest test score, the motivation and the behavior condition having medium test scores, and the cognition condition showing the highest test score – was tested in a focal contrast (FC: control group -1 / cognition 1 / motivation 0 / behavior 0) against two orthogonal residual contrasts (RC1: control group 1 / cognition 1 / motivation -3 / behavior 1 and RC2: control group 1 / cognition 1 / motivation 0 / behavior -2). Although the focal contrast was significant, indicating that the hypothesized pattern fits the data, $F(1, 126) = 4.02$, $p = .047$, $\eta^2 = .03$, the residual contrasts also explained a significant part of variance in learning outcome, $F(1, 126) = 6.82$, $p = .010$, $\eta^2 = .05$. Thus, the focal contrast alone did not describe the data sufficiently. Additional analyses for the two residual contrasts separately showed that residual contrast 1 significantly explained parts of the data, $F(1, 126) = 6.81$, $p = .011$, $\eta^2 = .05$, describing a pattern with the motivation group having the lowest test score. Residual contrast 2 was not significant, $F < 1$. Descriptively, the cognition group showed the highest test scores, followed by the behavior group and the control group, supporting the hypothesis (partly confirming H1 and H2). However, other than expected, the motivation group had the lowest tests scores, which is reflected in the significant residual contrast (partly contradicting H1 and H2).

7.3.2.2 Learning time

The main effect of implementation intentions on learning time was significant, $F(3, 126) = 3.07$, $p = .030$, $\eta^2 = .07$. It was assumed that learners in the behavior condition would invest more effort in the learning task than the other groups, which should be reflected in longer learning times. This pattern, described in a focal contrast (FC: control group -1 / cognition -1 / motivation -1 / behavior 3), was significant, $F(1, 126) = 9.14$, $p = .003$, $\eta^2 = .07$, while the two residual contrasts (RC1: control group -1 / cognition -1 / motivation 2 / behavior 0 and RC2: control group -1 / cognition 1 / motivation 0 / behavior 0) were not significant, $F < 1$. Thus, the hypothesis that the behavior group compared with all other groups would spend more time learning was confirmed (confirming H3).

7.3.2.3 Use of multimedia-specific cognitive strategies

An ANOVA revealed a marginally significant implementation intentions effect for the use of multimedia-specific cognitive strategies, $F(3, 126) = 2.41$, $p = .070$, $\eta^2 = .05$. The hypothesis was that learners in the cognition group would report a higher use of effective multimedia-specific cognitive strategies than all the other groups. The focal contrast (FC: control group -1 / cognition 3 / motivation -1 / behavior -1) describing the hypothesized pattern was significant, $F(1, 126) = 6.78$, $p = .010$, $\eta^2 = .05$, while the two residual contrasts (RC1: control group -1 / cognition 0 / motivation 2 / behavior -1 and RC2: control group -1 / cognition 0 / motivation 0 / behavior 1) were not significant, $F < 1$, indicating that the cognition group indeed reported to have used the multimedia-specific cognitive strategies more frequently than the other groups (confirming H4).

7.3.2.4 Moderating role of learner characteristics

Again separate regression analyses were conducted for the two learner characteristics (self-efficacy beliefs and planned effort) to test whether those would moderate the effect of implementation intentions on learning outcome (exploratively testing H5). Regression models contained one of the learner characteristics, the implementation intention conditions, and the two-way interaction as predictors.

Planned effort, $F(1, 122) = 15.82$, $p < .001$, $\eta_p^2 = .09$, positively predicted learning outcome, but did not significantly interact with implementation intention conditions, $F(3, 122) = 1.43$, $p = .238$, $\eta_p^2 = .03$. There was a positive effect of self-efficacy beliefs on learning outcome, $F(1, 119) = 37.09$, $p < .001$, $\eta_p^2 = .23$; however, the interaction of self-efficacy beliefs with implementation intentions from Experiment 1 was not replicated, $F(3, 119) = 2.01$, $p = .116$, $\eta_p^2 = .05$ (data of three participants were excluded due to a Cook’s distance > .10).

7.4 Discussion

Like in the first experiment it was investigated whether supporting self-regulatory processes in multimedia learning via implementation intentions improves learning outcome. However, in Experiment 1 none of the implementation intentions affected learning outcome which was suggested to be due to methodological weaknesses. Thus, some changes were made to overcome those shortcomings and make the implementation intentions more effective in Experiment 2. First, a pre-training task was included before receiving the implementation intentions to familiarize participants with the learning content and, thus, facilitate to internalize the implementation intentions. Second, three more specific implementation intentions were used in every condition that either related to self-regulation of cognition, motivation, or behavior, replicating the design of Experiment 1. The results showed that in line with the assumptions, instructing learners with cognitive or behavioral implementation intentions increased learning outcome compared with a control group, whereas the cognition group had the highest test score. Furthermore, confirming the hypotheses the behavioral implementation intentions increased learning time and the cognitive implementation intentions increased the frequency of using multimedia-specific cognitive strategies. However, unexpectedly, motivational implementation intentions seemed to hamper learning, with the motivation group showing the lowest test scores. Additionally, learner characteristics were not found to moderate the effect of implementation intentions on learning outcome. As those results were fragile and in parts unexpected, two more experiments were conducted to consolidate and follow up on the results from Experiment 2.

First, the effect that motivational implementation intentions hampered the learning outcome was rather unexpected. This effect of motivational implementation intentions should be explored in more detail. One explanation for their negative effects could be that fostering self-efficacy in a learning situation that is perceived as easy (Serra & Dunlosky, 2010) may lead learners to become overly confident with regards to their learning. Overconfidence, like it had been found in the first experiment, may have led learners to inappropriate learning decisions (Bjork et al., 2013). Unfortunately, in Experiment 2 no measures of metacognitive accuracy were assessed which leaves the explanation in terms of overconfidence speculative. Furthermore, the implementation intentions in the motivation group were based on the self-efficacy implementation intention that was used in the study from Bayer and Gollwitzer (2007). However, strengthening self-efficacy in their study was referred to solving mathematical tasks instead of studying a given topic. Thus, problems of self-regulation in the area of motivation might be less of a problem during learning, but rather when working on the test. Experiment 3 aimed at replicating the negative results from the motivational group and additionally measured how well participants judged their learning (i.e., judge how well they would perform in a subsequent knowledge test, Bjork et al., 2013; Nelson & Narens, 1990) to test the explanation that motivational implementation intentions induced overconfidence. Furthermore, it was tested whether motivational implementation intentions aimed at increasing self-efficacy during testing rather than learning would be more effective.

Experiment 2

Second, the behavior and the cognition group had descriptively confirmed the hypothesis that implementation intentions improve learning. Both groups had higher test performance scores than the control group, whereas the cognition group had the highest scores. Furthermore, those two groups supported the hypotheses in terms of learning time and the use of multimedia-specific learning strategies. The behavior group had longer learning times, and the cognition group reported having used the multimedia-specific cognitive strategies more frequently than the other groups. These findings suggest that the participants in those groups indeed had carried out the actions that had been specified in the implementation intentions. To ensure that the cognitive and the behavioral implementation intentions indeed improve learning, Experiment 4 aimed at replicating those two conditions. However, the self-regulatory challenges in multimedia learning cannot be considered to be exclusive; this means that learners might suffer from more than one self-regulatory problem at the same time. Thus, it was furthermore tested whether a combined condition including implementation intentions relating to cognition and behavior simultaneously would be particularly helpful for self-regulating learning, because it supported two areas of self-regulation.

Finally, learner characteristics were analyzed for their possibly moderating role of an implementation intentions effect on learning outcome. In Experiment 1 it had been found that pre-existing self-efficacy beliefs moderated the effect of implementation intentions on test performance. However, this moderation could not be replicated in Experiment 2. Thus, the influence of learner characteristics and particularly self-efficacy beliefs on the effects of implementation intentions remains puzzling. The possible moderations will be re-examined in the following experiments.

In sum, the results from Experiment 2 were fragile and in parts unexpected. Thus, in a third experiment it was tested whether motivational regulation is more of a problem when working on a test instead of learning. Furthermore, it was evaluated whether the rather speculative explanation regarding overconfidence hold true provided for the unexpected negative effects of the motivation group. Experiment 4 aimed at consolidating the findings that the cognitive and behavioral implementation intentions were indeed beneficial for learning and whether the effects would add up when supporting both areas of self-regulation simultaneously.

8 Experiment 3

Experiment 3 further investigated the presumable negative effect of motivational implementation intentions that had been found in Experiment 2. In particular, the focus was on whether the decline in learning outcome was due to the learners feeling overly confident regarding their own learning after they had been instructed with motivational implementation intentions. Overconfidence may lead to inadequate regulation of learning (Bjork et al., 2013), and could thus explain why implementation intentions aimed at boosting self-efficacy during learning would hamper rather than aid performance. Furthermore, it should be explored whether motivational support would be more effective when working on the knowledge test. The motivational implementation intention in Experiment 1 and Experiment 2 were based on the study from Bayer and Gollwitzer (2007), but could not replicate the finding that strengthening self-efficacy beliefs (motivational self-regulation) increases test performance. However, one main difference was that in the Bayer and Gollwitzer study the motivational implementation intentions focused on strengthening self-efficacy beliefs when working on the test rather than during learning. During the test learners are confronted with what they cannot remember from the learning material, which might induce low self-efficacy beliefs. Thus, strengthening self-efficacy during the test should help learners to cope with the knowledge test. Consequently, in Experiment 3 two conditions using motivational implementation intentions (m-learn and m-test) were compared with a control group. In both experimental conditions implementation intentions related to motivational self-regulation, which should strengthen self-efficacy beliefs and increase confidence. The m-learn condition received motivational implementation intentions that aimed at strengthening motivational self-regulation during learning (replicating the motivation condition from Experiment 2). The m-test condition received a motivational implementation intention that aimed at strengthening motivational self-regulation when working on the test (similar to the implementation intention used in the study from Bayer & Gollwitzer, 2007).

8.1 Hypotheses

The main hypothesis was that learning outcome should differ as a function of implementation intentions. The m-learn group was expected to show lower learning outcomes than the control group due to the implementation intentions inducing overconfidence (replicating the results from

Experiment 2). Participants in the m-test group were expected to be more confident when working on the knowledge test; thus, they should show higher learning outcomes compared with the control group.

H1: The m-learn group shows lower learning outcomes than the control group, whereas the m-test group shows higher learning outcomes than the control group.

Because the implementation intentions were aimed at strengthening the learners' self-efficacy beliefs and increasing their confidence, they were expected to influence how participants judge their learning or test performance. Thus, participants were asked to judge their level of understanding. Judgments were assessed three times during the experiment: before learning (ease-of-learning judgment as a baseline), after learning (judgment of learning), and after testing (judgment of performance). The m-learn group was expected to have higher judgments of learning than the other groups, because the implementation intentions referred to motivational regulation during learning. Furthermore, the m-test group was expected to have higher judgments of performance than the other groups, because the implementation intention referred to motivational regulation during testing.

H2a: Implementation intentions relating to motivational self-regulation during learning increases judgments of learning compared with the other groups.

H2b: Implementation intentions relating to motivational self-regulation during testing increases judgments of performance compared with the other groups.

Again learner characteristics were tested for possibly moderating an effect of implementation intentions. However, to replicate the moderation from Experiment 1 (a positive effect of self-efficacy was found in all groups except for the cognition group), a group with cognitive implementation intentions would have been needed which was not part of Experiment 3. Furthermore, in the previous experiments no moderating effect of planned effort has been observed. Thus, no directed hypotheses regarding the moderating role of learner characteristics on an implementation intention effect are formulated, but the moderation was again tested exploratively.

H3 – explorative: Individual learner characteristics moderate an effect of implementation intentions on learning outcome.

8.2 Methods

Experiment 3

8.2.1 Participants and design

The sample came from the same population as in Experiment 1 and Experiment 2 containing undergraduate students of a southwestern German university. Again students of music or physics were not allowed to participate. Three participants did not copy the implementation intentions according to the instructions and therefore their data were excluded from the analyses. Data were analyzed from 105 students (83 female) aged 18 to 35 years (M = 22.00 years, SD = 3.15). They received course credit or were paid 10 Euros for participation. Participants were randomly assigned to one of three conditions: a control group without implementation intention instruction (n = 36) and two experimental groups with an implementation intention instruction relating to motivational self-regulation. The implementation intentions aimed at motivational regulation either during learning (m-learn, n = 33) or during testing (m-test, n = 36). Statistical power was calculated analogous to the previous experiments. Based on an alpha level of $\alpha = .05$, the sample size of N = 105, and the effect size of $f = .325$ the statistical power in Experiment 3 was 0.845.

8.2.2 Instructional materials

The learning material was the same as in Experiment 2 explaining the functionality of an upright piano.

8.2.3 Measures

8.2.3.1 Control variables

The pre-training task (Cronbach's $\alpha = .771$) as well as the questionnaire on learner characteristics (academic self-efficacy beliefs: Cronbach's $\alpha = .878$, planned effort: Cronbach's $\alpha = .966$) were the same as in the previous experiments. The questionnaire on multimedia-specific cognitive strategies (Cronbach's $\alpha = .711$) was used again from Experiment 2, but served only as a control variable because none of the implementation intentions related to the regulation of cognitive strategies.

8.2.3.2 Learning outcome

The knowledge test consisted of the open recall question, the verbal comprehension items, and the pictorial recall tasks from the previous experiments. Again, a total score (max. 71 points) was calculated for test performance (Cronbach's $\alpha = .834$) and is reported as percentage of correct answers. Data from 20% of the participants were again coded by two independent raters with good reliability (Cohen's κ = .790).

8.2.3.3 *Metacognitive judgments*

Participants were asked to judge their level of knowledge three times during the experiment. First, before the implementation intention manipulation and before starting to study the materials, participants judged how easy they thought it would be to learn the materials on the piano mechanism (ease-of-learning judgment). The second judgment was assessed right after learning and asked for how well participants thought they had learned, that is, how confidently they would be able to answer questions in an upcoming knowledge test (judgment of learning). The third time, immediately after answering the test items participants judged how well they thought they performed on the knowledge test. All judgments were given on a scale from 0 *not at all* to 100 *very much*. The accuracy of participants' judgments of learning and judgment of performance was calculated as the discrepancy between judgments and actual performance (accuracy = judgment – performance, cf. Nelson, 1996). Thus, 0 indicates an accurate estimation, while positive values indicate overestimation, and negative values indicate underestimation.

8.2.4 Procedure

Data collection took place in groups up to 8 participants with participants working individually on separated workspaces. The procedure was similar to that of the previous experiments. Participants first signed informed consent forms and then answered demographic questions. They were then informed about the topic of the learning material, and they gave their ease-of-learning judgment, worked on the pre-training task, and filled in the questionnaires on self-efficacy beliefs and planned effort. Before starting the study phase, participants in the m-learn condition were instructed with the same three implementation intentions of the motivation condition from the second Experiment (see Table 5, p. 59). Then, all participants started with learning the multimedia message. When they were done with learning, they gave their judgment of learning. Before starting with the knowledge test, participants in the m-test condition were instructed with a single implementation intention aimed at increasing their self-efficacy when working on the knowledge test ("If I start a new task, then I will tell myself: I am able to solve it!."). In line with Bayer and Gollwitzer (2007) participants only received one implementation intention. All participants then worked on the tasks of the knowledge test. Afterwards, they gave their judgment of performance and filled in the questionnaire on the use of multimedia-specific cognitive strategies. Finally, participants were debriefed, paid, and thanked for their participation. Participants in the control group did not receive implementation intentions at any time during the experiment. The experiment lasted for about 60 to 75 minutes. Different from Experiment 1 and Experiment 2, participants from the experimental groups were not asked to write down the implementation intentions again.

8.3 Results

Descriptive values of all control variables and dependent measures are displayed in Table 7. Two participants did not fill in the judgment of performance and failed to complete the questionnaire on the use of multimedia-specific cognitive strategies. Their missing values were replaced by the respective group means.

8.3.1 Control variables

Analyses of variance (ANOVAs) revealed that despite randomization, groups differed in their ease-of-learning judgments, $F(2, 102) = 3.09$, $p = .050$, $\eta^2 = .06$. Bonferroni adjusted post-hoc pairwise comparisons revealed that the control group had marginally significant higher judgments than the m-test group, $p = .079$. The other groups did not differ from each other, control group/m-learn: $p > .999$, m-learn/m-test: $p = .140$. Furthermore, groups differed on their pre-training scores, $F(2, 102) = 3.57$, $p = .032$, $\eta^2 = .07$. Bonferroni-adjusted post-hoc pairwise comparisons revealed that the control group had higher pre-training scores than the m-learn group, $p = .048$, and the m-test group had marginally significant higher pre-training scores than the m-learn group, $p = .093$, whereas there were no differences between the control group and the m-test group, $p > .999$. Considering both variables (ease-of-learning judgment and pre-training scores) as covariates in the analyses of the dependent measures did not change the pattern of results. Thus, the statistical tests will be reported without these covariates for reasons of simplification. Groups did not differ in terms of their self-efficacy beliefs, $F(2, 102) = 0.86$, $p = .427$, $\eta^2 = .02$, the effort participants planned to invest in the learning task, $F(2, 102) = 0.16$, $p = .854$, $\eta^2 = .003$, their learning time, $F < 1$, or the use of multimedia-specific cognitive strategies, $F(2, 102) = 0.12$, $p = .889$, $\eta^2 = .002$.

<u>Experiment 3</u>

Table 7

Means and Standard Deviations of Control Variables and Dependent Measures for the Control Group and the Implementation Intention Groups (II) in Experiment 3.

	Control Group	II M-Learn	II M-Test
Ease-of-learning (0-100)	61.64 (21.58)	60.64 (21.83)	50.19 (21.17)
Pre-training (0-12)	10.47 (2.00)	9.18 (2.62)	10.33 (1.90)
Self-efficacy beliefs (1-7)	5.22 (0.88)	5.13 (0.98)	4.95 (0.82)
Planned effort (1-7)	6.02 (1.31)	5.86 (1.29)	5.93 (1.06)
Learning time (min)	5.90 (2.42)	6.25 (3.36)	5.75 (2.23)
Learning outcome (%)	68.04 (9.59)	61.78 (12.86)	64.48 (10.77)
Judgments of learning (0-100)	69.33 (18.63)	67.09 (19.72)	61.22 (18.91)
Accuracy JoL	1.30 (15.10)	5.31 (18.13)	-3.25 (16.35)
Judgments of performance (0-100)	54.34 (26.23)	45.78 (30.56)	49.75 (21.39)
Accuracy JoP	-13.69 (25.07)	-16.00 (29.53)	-14.73 (19.47)
Use of multimedia-specific cognitive strategies (1-7)	5.80 (0.96)	5.76 (1.07)	5.69 (0.92)

Note: Accuracy of judgments of learning (JoL) and judgments of performance (JoP) is given as discrepancy of the given judgment from the learning outcome, whereby 0 indicates perfect estimation, positive values indicate overestimation and negative values indicate underestimation.

8.3.2 Dependent measures

Analyses of variance (ANOVAs) were conducted to test whether groups differed regarding the dependent measures that were followed up with contrast analysis, if necessary.

8.3.3 Learning outcome

An ANOVA revealed that the effect of implementation intentions for learning outcome was marginally significant, $F(2, 102) = 2.77$, $p = .068$, $\eta^2 = .05$. However, the focal contrast (FC: CG 0 / m-learn -1 / m-test 1) according to which the m-test group should outperform the control group, while the m-learn group would have the lowest test scores, was not significant, $F < 1$. Thus, the hypothesis could not be confirmed (contradicting H1).

8.3.4 Metacognitive judgments

There was no significant main effect of implementation intentions for judgments of learning, $F(2, 102) = 1.73$, $p = .183$, $\eta^2 = .03$. Thus, the hypothesis that the judgments of learning would be higher in the m-learn condition was not supported (contradicting H2a). In general, participants were quite accurate in their judgments of learning; accuracy did not differ significantly from 0, $t(104) = 0.61$, $p = .542$, $d = 0.12$. This was also true when looking at the accuracy for judgments of learning in each group separately, control group: $t(35) = 0.52$, $p = .610$, $d = 0.18$, m-learn: $t(32) = 1.68$, $p = .102$, $d = 0.59$, m-test: $t(35) = -1.19$, $p = .241$, $d = 0.40$. Accuracy for judgments of learning did not differ among conditions, $F(2, 102) = 2.32$, $p = .103$, $\eta^2 = .04$.

The main effect of implementation intentions to predict judgments of performance was not significant, $F(2, 102) = 0.92$, $p = .400$, $\eta^2 = .02$. Thus, the hypothesis that learners in the m-test condition would have the highest judgments of performance could not be confirmed (contradicting H2b). In general, participants tended to underestimate their performance as reflected in their accuracy being significantly smaller than 0, $t(104) = -6.14$, $p < .001$, $d = 1.20$. This was also true when looking at the accuracy for judgments of performance in each group separately, control group: $t(35) = -3.28$, $p = .001$, $d = 1.11$, m-learn: $t(32) = -3.11$, $p = .002$, $d = 1.10$, m-test: $t(35) = -4.54$, $p < .001$, $d = 1.54$. Accuracy for judgments of performance did not differ among conditions, $F < 1$.

8.3.4.1 Moderating role of learner characteristics

Again separate regression analyses were conducted for the two learner characteristics – self-efficacy beliefs and planned effort – to test whether those would moderate an effect of implementation intentions on learning outcome (H3 – explorative). Regression models always contained one of the learner characteristics, the implementation intention conditions, and the two-way interaction as predictors.

Planned effort, $F(1, 99) = 11.31$, $p = .001$, $\eta_p^2 = .10$, positively predicted learning outcome, but did not significantly interact with implementation intention conditions, $F < 1$ (exclusion of data due to Cook's distance did not change the pattern of results). Also, there was a positive effect of self-efficacy beliefs on learning outcome, $F(1, 99) = 22.14$, $p < .001$, $\eta_p^2 = .18$, but no interaction with implementation intentions, $F(2, 99) = 1.01$, $p = .369$, $\eta_p^2 = .02$.

8.4 Discussion

In Experiment 2 it had been found that implementation intentions strengthening self-efficacy during learning reduced performance in a subsequent test. To follow up on these negative effects of motivational implementation intentions, two conditions receiving instructional support via implementation intentions were compared with a control group. Implementation intentions related to increasing motivational self-regulation during learning or during working on the test. It was hypothesized that implementation intentions related to motivational self-regulation during learning induces overconfidence in terms of the learners' level of understanding and to, thus, hamper learning outcome (replication of the negative effect of motivational implementation intentions from Experiment 2). In contrast, it was expected that motivational self-regulation is indeed needed when working on the test; thus, implementation intentions relating to motivational self-regulation during working on the test were expected to improve learning outcome. However, the two experimental groups with implementation intentions did neither differ from the control group without implementation intentions nor did they differ from each other. Thus, the hypotheses were not confirmed. Furthermore, implementation intentions did neither influence judgments of learning, nor judgments of performance which also contradicts the expectations.

The findings from Experiment 2 where implementation intentions aimed at improving self-efficacy during learning led to reduced performance were not replicated. While at the descriptive level the m-learn group achieved a lower test performance than the other groups, this difference was statistically not significant. A possible explanation for the findings from Experiment 2 was that implementation intentions related to motivation caused learners to become overconfident. However, Experiment 3 also failed to show that the motivational implementation intentions altered participants' confidence in their learning or test performance. In general, participants were quite accurate in their judgments of learning, suggesting that motivational regulation is not a problem during learning in the first place. Moreover, the current findings stand in contrast with those obtained by Bayer and Gollwitzer (2007), since implementation intentions related to motivation during testing also did not improve learning outcome.

The findings from this experiment give a hint that implementation intentions do not lead to effects as compellingly and reliably as it is suggested by the literature (e.g., Gollwitzer & Sheeran, 2006). Possible reasons and boundary conditions for this are addressed in the overall discussion (see chapter 10).

9 Experiment 4

Starting from the assumption that among other things learners struggle with the selection of adequate cognitive strategies (cognitive self-regulation) and investing sufficient time and effort (behavioral self-regulation) when learning with multimedia material, supporting those areas of self-regulated learning should improve learning outcomes. In Experiment 2 the use of cognitive and behavioral implementation intentions supporting self-regulation in learning led to higher test performance scores than in a control group without implementation intentions; however, those results were rather fragile. The aim of Experiment 4 was to consolidate the findings regarding the cognitive and behavioral implementation intentions. Thus, these two conditions and the control group were replicated. However, the self-regulatory challenges in multimedia learning are not assumed to occur in isolation as more than one of those problems can arise simultaneously. Supporting more than one area of self-regulation at a time could help learners to cope with the various self-regulatory challenges. Thus, a combined condition (mix) was investigated in which learners received cognitive as well as behavioral implementation intentions.

9.1 Hypotheses

The main hypothesis was that implementation intentions would improve the learners' test performance. Like in Experiment 1 and Experiment 2, it was expected that the behavioral implementation intentions would improve learning outcome compared with a control group without implementation intentions and that the more specific cognitive implementation intentions would even further improve test performance. For the combined condition, the learners were expected to be particularly successful because both self-regulatory areas (cognition and behavior) are addressed, and the effects of cognitive and behavioral implementation intentions might possibly add up.

> H1: The control group shows the lowest learning outcomes, followed by the behavior group, which is outperformed by the cognition group, whereas the mix group shows the highest learning outcomes.

Furthermore, learners in the two conditions receiving implementation intentions related to behavioral self-regulation (behavior, mix) were expected to put more effort into learning, which should be reflected in longer learning times compared with the two other groups (control group, cognition group).

H2: Learners in the behavior and the mix group have longer learning times than the control group and the cognition group.

In addition, problems of behavioral self-regulation are assumed to stem from inadequate metacognitive judgments due to relying on a multimedia heuristic (Serra & Dunlosky, 2010). Thus, support of behavioral self-regulation should reduce overconfidence being reflected in lower judgments of learning in the behavior and mix group compared with the cognition and control group.

H3: Learners in the behavior and the mix group show lower judgments of learning than the cognition and the control group.

Moreover, learners in the two conditions receiving implementation intentions related to cognitive self-regulation (cognition, mix) were expected to report a more frequent use of the multimedia-specific cognitive strategies compared with the two other groups (control group, behavior group).

H4: Learners in the cognition and the mix group report a greater use of multimedia-specific cognitive strategies than the behavior and the control group.

Finally, learner characteristics (self-efficacy and planned effort) were again tested for possibly moderating an effect of implementation intentions. In particular, self-efficacy beliefs were of interest as those interacted with an implementation intention effect in Experiment 1 which could not be replicated again in Experiment 2.

H5 – explorative: Individual differences in learner characteristics moderate an effect of implementation intentions on learning outcome.

9.2 Methods

9.2.1 Participants and design

Participants were from the same population as in the previous experiments. Those were undergraduate students not studying music or physics. Data from two participants were excluded from analysis because they did not copy the implementation intentions according to the instruction. The remaining sample consisted of 137 students (100 female) and aged between 18 and 31 years (*M* = 22.86 years, *SD* = 3.10). Participants received course credits or 10 Euros for participation.

Experiment 4

Each participant was randomly assigned to the control group (*n* = 34), or an implementation intention group. Implementation intentions related to either cognition (*n* = 35), behavior (*n* = 33), or both areas of self-regulated learning (mix: *n* = 35). Statistical power was calculated analogous to the previous experiments. Based on an alpha level of $\alpha = .05$, the sample size of $N = 137$, and the effect size of $f = .325$ the statistical power in Experiment 4 was 0.897.

9.2.2 Instructional materials

Learning material was the same as in Experiment 2 and Experiment 3 explaining the functionality of an upright piano.

9.2.3 Measures

9.2.3.1 Control variables

Again pre-training performance (Cronbach's $\alpha = .757$), and the learner characteristics academic self-efficacy beliefs (Cronbach's $\alpha = .902$), and planned effort (Cronbach's $\alpha = .946$) were used as control variables.

9.2.3.2 Learning outcome

Learning outcomes were again assessed by the means of the open recall question, the verbal comprehension tasks, and the pictorial recall tasks from the previous experiments. Learning outcomes were computed as the average of performance in all three outcome measures and transferred into percentage of correct answers (Cronbach's $\alpha = .876$). Data of 20% of the participants were coded by two independent raters with good interrater reliability (Cohen's $\kappa = .820$).

9.2.3.3 Metacognitive judgments

Like in Experiment 3, ease-of-learning judgments, judgments of learning, and judgments of performance were assessed before learning, after learning, and after working on the test, respectively. All judgments were given on a scale from 0 to 100. Accuracy was again calculated as the discrepancy of the judgments from the learning outcome.

9.2.3.4 Use of multimedia-specific cognitive strategies

The frequency of using multimedia-specific cognitive strategies was measured again with the questionnaire from the previous experiments (Cronbach's $\alpha = .643$).

9.2.4 Procedure

The procedure was exactly the same as for the m-learn group in Experiment 3, only using different implementation intentions. Cognitive and behavioral implementation intentions were adopted from Experiment 2. For the mix condition three implementation intentions were chosen from the cognition and behavior conditions to keep the number of implementation intentions the same across conditions (the three implementation intentions are marked with an asterisk in Table 5, p. 59). For this combined condition, an implementation intention relating to integration was chosen from the cognitive implementation intentions, because learners have been shown to particularly struggle with building referential connections between text and picture information (Mason et al., 2013). Implementation intentions related to the allocation of time and effort to text and pictures were selected from the behavioral implementation intentions, as this might be more of a problem for behavioral regulation (Bjork et al., 2013; Son & Metcalfe, 2000).

9.3 Results

Descriptive values of all control variables and dependent measures are displayed in Table 8. One participant did not answer the judgment of performance item; the missing value was replaced by the respective group mean.

9.3.1 Control variables

Despite randomization, analyses of variance (ANOVAs) revealed that groups differed in the ease-of-learning judgments (before the experimental manipulation), $F(3, 133) = 2.66$, $p = .050$, $\eta^2 = .06$, and the pre-training scores, $F(3, 133) = 2.88$, $p = .039$, $\eta^2 = .06$. Bonferroni-adjusted post-hoc pairwise comparisons showed significantly lower ease-of-learning judgments for the behavior than the mix group, $p = .048$ (all other comparisons ps > .1). Post-hoc pairwise comparisons with Bonferroni adjustment for the pre-training scores showed significantly lower scores for the behavior group than the control group, $p = .042$ (all other comparisons ps > .1). Including these two variables as covariates did not change the pattern of results for the main assumptions, so

Experiment 4

ANOVAs without covariates will be reported for reasons of simplicity. Groups did not differ regarding self-efficacy beliefs, $F(3, 133) = 1.60$, $p = .192$, $\eta^2 = .03$, or the effort participants planned to invest in the learning task, $F < 1$.

Table 8

Means and Standard Deviations of Control Variables and Dependent Measures for the Control Group and the Implementation Intention Groups (II) in Experiment 4.

	Control group	II Cognition	II Behavior	II Mix
Ease-of-learning (0-100)	53.65 (21.07)	49.83 (20.37)	43.61 (24.93)	57.89 (19.89)
Pre-training (0-12)	10.19 (2.37)	9.26 (2.16)	8.65 (2.61)	9.81 (2.03)
Self-efficacy beliefs (1-7)	4.85 (0.88)	4.85 (1.04)	4.55 (1.03)	5.06 (0.89)
Planned effort (1-7)	5.96 (0.83)	5.57 (1.49)	5.79 (1.20)	5.81 (1.07)
Learning time (min)	4.97 (1.83)	6.15 (3.34)	5.36 (2.32)	5.24 (1.82)
Learning outcome (%)	60.94 (12.47)	59.72 (14.16)	55.25 (12.26)	60.38 (12.16)
Judgments of learning (0-100)	61.00 (23.83)	58.69 (20.10)	54.12 (26.07)	63.74 (16.00)
Accuracy JoL	0.64 (19.95)	-1.03 (17.87)	-1.13 (20.55)	3.36 (14.63)
Judgments of performance (0-100)	49.27 (23.39)	44.14 (27.37)	39.70 (27.47)	50.77 (27.41)
Accuracy JoP	-11.66 (19.89)	-15.58 (24.14)	-15.55 (25.77)	-9.61 (26.80)
Use of multimedia-specific cognitive strategies (1-7)	5.56 (0.94)	5.59 (1.06)	5.85 (0.74)	6.06 (0.69)

Note: Accuracy of judgments of learning (JoL) and judgments of performance (JoP) is given as discrepancy of the given judgment from the learning outcome, whereby 0 indicates perfect estimation, positive values indicate overestimation and negative values indicate underestimation.

9.3.2 Dependent measures

ANOVAs were conducted to test whether groups differed regarding the dependent measures that were followed up with contrast analysis, if necessary.

9.3.3 Learning outcome

Contrary to the hypothesis, the ANOVA did not reveal any significant group differences in terms of the learning outcome, $F(3, 133) = 1.37$, $p = .254$, $\eta^2 = .03$. Thus, cognitive or behavioral implementation intentions did not improve learning compared with a control group; neither did a combination of both (contradicting H1).

9.3.4 Learning time

Other than expected, learning time also did not differ among implementation intention conditions, $F(3, 133) = 1.52$, $p = .212$, $\eta^2 = .03$ (contradicting H2).

9.3.5 Metacognitive judgments

Other than expected, judgments of learning did not differ among conditions, $F(3, 133) = 1.19$, $p = .317$, $\eta^2 = .03$ (contradicting H3). Accuracy of judgments of learning did not differ significantly from 0, $t(136) = 0.22$, $p = 0.828$, $d = 0.04$. This was also true when looking at the accuracy for judgments of learning in each group separately, control group: $t(33) = 0.02$, $p = .985$, $d = 0.01$, cognition: $t(34) = -0.34$, $p = .735$, $d = 0.12$, behavior: $t(32) = -0.32$, $p = .754$, $d = 0.11$, mix: $t(34) = 1.39$, $p = .183$, $d = 0.48$. Thus, participants were quite accurate in their judgments of learning. Also, the accuracy of judgments of learning did not differ as a function of implementation intention conditions, $F < 1$.

No hypothesis was formulated regarding group differences for judgments of performance. There was no significant difference among conditions with regard to judgments of performance, $F(3, 133) = 1.23$, $p = .300$, $\eta^2 = .03$, and the accuracy of judgments of performance, $F < 1$. Overall participants underestimated their test performance, $t(136) = -6.33$, $p < .001$, $d = 1.09$, indicated by the accuracy scores being significantly smaller than 0. This was also true when looking at the accuracy for judgments of learning in each group separately, control group: $t(33) = -3.42$, $p < .001$, $d = 1.19$, cognition: $t(34) = -3.82$, $p < .001$, $d = 1.31$, behavior: $t(32) = -3.47$, $p < .001$, $d = 1.23$, mix: $t(34) = -2.12$, $p = .021$, $d = 0.73$.

9.3.6 Use of multimedia-specific cognitive strategies

There were marginally significant differences between conditions in terms of the use of multimedia-specific cognitive strategies, $F(3, 133) = 2.55$, $p = .058$, $\eta^2 = .05$. However, since the focal contrast (FC: control group -1 / cognition 1 / behavior -1 / mix 1) was not significant, $F(1,$

133) = 0.68, p = .413, η^2 = .005, the hypothesis that learners of the cognition and the mix groups would report a more frequent strategy use was not confirmed (contradicting H4).

9.3.6.1 Moderating role of learner characteristics

Regression analyses were again conducted for the two learner characteristics – self-efficacy beliefs and planned effort – to test whether those would moderate an effect of implementation intentions on learning outcome. Regression models always contained one of the learner characteristics, the implementation intention conditions, and the two-way interaction as predictors (relating to H5 – explorative).

Planned effort, $F(1, 126) = 11.58$, $p < .001$, $\eta_p^2 = .08$ positively predicted learning outcome, but did not significantly interact with implementation intention conditions, $F(3, 126) = 1.19$, p = .315, $\eta_p^2 = .03$ (data of three participants were excluded due to a Cook's distance > .10). There was a positive effect of self-efficacy beliefs on learning outcome, $F(1, 129) = 14.75$, $p < .001$, $\eta_p^2 = .09$, but the no interaction with implementation intentions was found, $F < 1$.

9.4 Discussion

In Experiment 2 it had been found that groups receiving cognitive or behavioral implementation intentions improved learning outcome compared with a control group without implementation intentions. Furthermore, behavioral implementation intentions had increased learning time, while learners with cognitive implementation intentions had used multimedia-specific cognitive strategies more frequently. This study aimed at replicating these results. Moreover, it investigated whether supporting cognitive and behavioral regulation simultaneously via implementation intentions particularly improved learning.

However, the hypothesis that supporting cognition, behavior or both areas of self-regulation via implementation intentions improves learning could not be confirmed. Thus, the findings from Experiment 2 were not replicated. Furthermore, the implementation intentions neither affected learning time nor the use of multimedia-specific cognitive strategies. Thus, in contrast to Experiment 2, it seems that learners had not even carried out the behavior that was specified in the then-part of the implementation intentions. It remains unclear why learners did not realize the actions that were specified in the implementation intentions, as they are assumed to be triggered automatically.

Experiment 4

However, learners having problems in behavioral self-regulation was based on the assumption that they rely on a multimedia heuristic and overestimate their level of understanding. However, learners were very accurate in their judgments of learning and did not show the assumed overconfidence. Thus, it seems that learners had not suffered from poor behavioral self-regulation.

Furthermore, the moderation of an implementation intention effect by learners' self-efficacy beliefs that had been found in Experiment 1 could again not be replicated (like in Experiment 2). This indicates that the significant moderation from Experiment 1 might have been a statistical product of chance.

Although, implementation intentions are reported as an effective and reliable tool to support self-regulation in various domains, supporting self-regulation of cognition and behavior in a multimedia learning environment did not improve learning outcome. Possible reasons and boundary conditions are discussed in the overall discussion (chapter 10).

10 General Discussion

Multimedia materials, that is, the joint presentation of text and pictures, have been shown to aid learning compared with learning from only one representation (Anglin et al., 2004; Butcher, 2014; Carney & Levin, 2002; Fletcher & Tobias, 2005; Levie & Lentz, 1982; Mayer, 1997, 2009, 2014c). However, the positive effect of multimedia presentations for learning should not be taken for granted (Anglin et al., 2004; Scheiter et al., 2017). Aside from the complex cognitive processes that are necessary for meaningful learning, learners have to regulate motivational, affective, and behavioral aspects of learning (Moreno, 2006, 2007; Moreno & Mayer, 2007; Plass & Kaplan, 2016). Especially when learning is unguided, learning from multimedia materials imposes several challenges onto learners. These challenges can be conceptualized as challenges regarding the self-regulation of learning in the areas of cognition, motivation, and behavior.

First, learners struggle in self-regulating cognitive processes during multimedia learning in that they often choose inadequate cognitive strategies. In particular, they rely on text information at the expense of pictorial information and make only few attempts to integrate both information sources (Ainsworth et al., 2002; Cromley et al., 2010; Hannus & Hyönä, 1999; Hegarty & Just, 1993; Hochpöchler et al., 2013; Schmidt-Weigand et al., 2010; Schwonke et al., 2009). Second, learners are challenged in self-regulating their motivation in that they may easily feel overwhelmed due to the high cognitive demands imposed during multimedia learning (Lowe, 1999, 2003; Lowe & Schnotz, 2014). Overload of the learners' cognitive resources, then, may result in low self-efficacy beliefs and hamper learning activities (van Merriënboer & Sluijsmans, 2009). Third, learners struggle in self-regulating their behavior, that is, their regulation of investing sufficient effort in learning. Multimedia materials may induce overconfidence and feelings of being underwhelmed in learners; which may cause them to invest only little effort in learning (Eitel, 2016; Jaeger & Wiley, 2014; Lowe, 2003; Lowe & Schnotz, 2014; Salomon, 1984; Serra & Dunlosky, 2010).

The focus of the present experiments was to overcome these self-regulatory challenges by means of a generic intervention method that can easily be adjusted to the particular challenge faced by learners, namely, implementation intentions (Gollwitzer, 1999). Implementation intentions are if-then-action-plans that strongly connect a situational cue to a goal-oriented, behavioral response, and, thus, enhance goal achievement (Gollwitzer & Sheeran, 2006). Forming implementation intentions makes the specified situation easy to detect and leads to an automatic initiation of the behavior (Aarts et al., 1999; Armitage, 2009; Bayer et al., 2009; Gollwitzer & Brandstätter, 1997; Parks-Stamm et al., 2007; Webb & Sheeran, 2004, 2007, 2008). Implementation intentions can be used very flexibly as they can be enriched with any kind of situation or behavior. Moreover, implementation intentions are shown to effectively improve cognitive, motivational, or behavioral self-regulation in academic tasks (Bayer & Gollwitzer, 2007; Duckworth et al., 2011; Stalbovs, 2016; Stalbovs et al., 2015). Thus, implementation intentions might as well be used to support cognitive, motivational, or behavioral self-regulation in multimedia learning.

Accordingly, the aim of the presented experiments was to investigate how supporting these areas of self-regulated learning by using implementation intentions improves learning with multimedia materials. The experiments sought to give answers to three overarching research questions. The first research question focused on whether supporting self-regulation in multimedia learning via implementation intentions improves learning outcomes in general. More in detail the second research question dealt with the particular effects of implementation intentions supporting the areas of cognition, motivation, and behavior in self-regulated learning. The third research question concerned individual prerequisites of the learners that might moderate an effect of implementation intentions. To this end, implementation intentions were designed to support either cognitive, motivational, or behavioral self-regulation. Learners of the experimental groups were instructed with implementation intentions prior to learning a multimedia message. Learners of a control group did not receive such an instruction. After a multimedia learning phase, learning performance was measured with a knowledge test. This procedure was kept constant throughout the experiments.

The four experiments built upon each other. Thus, after a short recapitulation of the experiments' design and findings, the results will be discussed jointly. Theoretical and practical implications will be derived as well as strengths and limitations, and future directions will be outlined thereafter.

10.1 Summary of Results

Experiments 1 and 2 investigated the differential effects of implementation intentions relating to cognitive, motivational, or behavioral self-regulation on learning performance. To this end, three experimental groups who were instructed with implementation intentions were compared with a control group as well as with each other. The implementation intentions either related to the use of multimedia-specific cognitive strategies (cognitive self-regulation), to increase self-efficacy (motivational self-regulation), or to increase the effort that learners invest into learning (behavioral self-regulation).

In Experiment 1 learners of the experimental groups were each instructed with one implementation intention. The implementation intentions all shared a joint situational cue in the if-part ('If I start a new page, then…'), but included varying behavioral responses in the then-part as a function of the condition. However, no effects of implementation intentions on the learning outcome were observed. Neither did the implementation intention groups outperform the control group, nor did the implementation intention groups differ from each other. Pre-existing self-efficacy beliefs of learners were found to interact with implementation intentions to predict the learning outcome. A positive relationship between preexisting self-efficacy beliefs and the learning outcome was found in all groups, except for the cognition group.

In Experiment 2 some methodological changes were made while keeping the design of Experiment 1. The changed features sought to improve the effectiveness of implementation intentions. Implementation intentions still related to cognitive, motivational, and behavioral self-regulation as a function of condition. However, within each experimental group, three implementation intentions were used that were more specifically tailored to multimedia learning and related to text processing, picture processing, and integration of text-picture information. Furthermore, a pre-training task was included to familiarize learners with the multimedia materials and facilitate internalization of implementation intentions. A significant effect of instruction with implementation intentions was revealed. In line with expectations, implementation intentions relating to behavioral self-regulation improved the learning outcome compared with a control group; moreover, implementation intentions relating to cognitive self-regulation led learners to obtain the highest learning performance. In addition, learning time was longer when learners had been instructed with behavioral implementation intentions and learners reported a more frequent use of multimedia-specific cognitive strategies when they had been instructed with cognitive implementation intentions. Both measures, thus, indicated that the underlying mechanism of behavioral and cognitive implementation intentions was executed, respectively. Unexpectedly, the motivation group had lower learning outcomes than the control group. Also, the effect of pre-existing self-efficacy beliefs as a moderating factor from Experiment 1 was not replicated and none of the other learner characteristics had an impact on the implementation intention effect.

Experiments 3 and 4 followed up on the results from Experiment 2. On one hand, the aim was to replicate the findings from Experiment 2. On the other hand, new questions had arisen that were investigated in Experiments 3 and 4. Results from these two experiments were expected to allow further insights on how to best support self-regulation in multimedia learning via implementation intentions.

Experiment 3 addressed the unexpected negative effect of implementation intentions relating to motivational self-regulation. To this end, again one group was instructed with implementation intentions relating to motivational self-regulation during learning to replicate the motivation group from Experiment 2. However, only while taking the knowledge test learners actually realize how much they can or cannot remember. Thus, low self-efficacy beliefs might be problematic when working on the knowledge test. Strengthening self-efficacy beliefs to cope with the knowledge test might enhance test performance. Therefore, another group received implementation intentions that related to motivational self-regulation while working on the knowledge test. However, no significant differences were found between the three groups. Additionally, judgments of learning and judgments of performance provided no indications that motivational implementation intentions increased confidence in learning or test performance. None of the assessed learner characteristics could be identified as a moderator of the implementation intention manipulation.

Experiment 4 sought to replicate the positive effects of implementation intentions relating to cognitive and behavioral self-regulation from Experiment 2. In an additional condition it was tested whether jointly supporting cognitive as well as behavioral self-regulation further improves the learning outcome. Other than expected, the effect of cognitive and behavioral implementation intentions could not be replicated and neither did the combined implementation intentions affect the learning outcome. Moreover, other than in Experiment 2, a manipulation with implementation intentions did not impact learning time or the use of multimedia-specific cognitive strategies. Again, none of the assessed learner characteristics could be identified as a moderator of the implementation intention manipulation.

10.2 Effects of Implementation Intentions – Why Don't They Work?

Taken together, the findings of the presented experiments do not yield convincing evidence for implementation intentions as a means to improve self-regulation and learning performance in multimedia learning. No conclusive effects of implementation intentions were found and differential effects regarding the variants of cognitive, motivational, and behavioral implementation intentions could also not be identified.

Implementation intentions are reported to be an effective and reliable tool in the literature (Gollwitzer & Sheeran, 2006). However, in the presented experiments the evidence in favor of using implementation intentions to improve learning outcomes was weak and not reliable. This clearly shows the necessity of direct and conceptual replications in research to be able to evaluate the reproducibility and generalizability of effects (Amir & Sharon, 1990; Diener & Biswas-Diener, 2017). In a direct replication, the same experiment is conducted again with a similar sample from the same population and shows whether an effect is reproducible. A conceptual replication uses the same design but with a sample from another population, different materials, or another but similar operationalization of the manipulation to show the generalizability of an effect. From an experimental perspective, the experiments systematically followed upon each other using samples from the same population. Experiment 2 was a conceptual replication of Experiment 1 using the same design but slightly changing the manipulation with implementation intentions and minor details of the learning materials. Under these improved conditions an effect of implementation intentions was found. Then, two subsequent experiments were following upon the second experiment's effects of implementation intentions relating to cognitive, motivational, and behavioral self-regulation in multimedia learning. That is, Experiments 3 and 4 sought to replicate the three conditions from Experiment 2, but also addressed new questions that had arisen. The cognition group in Experiment 2 conceptually replicated the results from Stalbovs et al. (2015) showing higher learning outcomes for implementation intention groups when studying multimedia materials. However, the effects of any of the implementation intentions from Experiment 2 could not be replicated in the follow-up experiments. Furthermore, the effect on test-related motivational implementation intentions from the Bayer and Gollwitzer study (2007) could not be conceptually replicated, either. Thus, the experiments question both the reproducibility and the generalizability of the effects of implementation intentions on learning outcomes in general.

The question rises why implementation intentions were effective in similar studies, but did not have an impact on learning in the presented experiments. One explanation could be that there exist boundary conditions for an implementation intention effect that were met in other studies, but not in the presented experiments. Several of these boundary conditions as an explanation for the absence of an implementation intention effect as well as further possible explanations will be discussed hereinafter.

One prerequisite of implementation intentions to be effective is commitment to the underlying goal. Although participants were asked to learn with the goal to make best use of the materials and comprehend the content as well as possible, it remains unclear how much learners were committed to that goal. Other studies mostly used implementation intentions that were self-created or personally relevant to the participants (e.g., Duckworth et al., 2011; Gollwitzer & Brandstätter, 1997; Oettingen et al., 2000; Sheeran & Orbell, 2000; Stadler, Oettingen, & Gollwitzer, 2009). Personal interest and valuing a goal as meaningful relate to goal activation and strong goal commitment which were both found to strengthen an effect of implementation intentions (Koestner et al., 2002; Sheeran et al., 2005). The instruction to make best use of the materials, to comprehend the content as well as possible, and the wording of cognitive and motivational implementation intentions of the presented experiments were adopted from other studies that had actually found an effect of implementation intentions (Bayer & Gollwitzer, 2007; Stalbovs et al., 2015). One major difference from these studies, however, was the (learning) assignments' content. Relevance of to be learned contents may have had an impact on goal commitment of learners. For instance, Stalbovs et al. (2015) used the topic of mitosis, which is typical for content taught in school. Similarly, Bayer and Gollwitzer (2007) measured how well students solved math tasks. In both studies, content was strongly related to school curricula. Therefore, participants might have valued those materials as relevant and, thus, might have been more committed to the underlying learning goal. In the current experiments, the learning content related to the functionality of the piano mechanism. This is not part of the school curricula and also can be considered relatively unique content that not all students might find equally interesting. Hence, learners might have been less willing to learn about it. A lack of goal commitment because of little personal interest or value of the learning contents, thus, may have accounted for the missing effects of implementation intentions on learning outcomes. A replication of the experiments with other learning materials that more strongly relate to school curricula or that are personally more relevant for learners could resolve whether this explanation holds true.

Another boundary condition and possible explanation for why there was no effect of implementation intentions is that there might have been no (pronounced) problems of self-regulation to begin with. Although participants did not score high on posttest measures, there is no direct evidence that the employed learning material indeed induced the self-regulatory challenges that had been presupposed. Implementation intentions were found to be especially helpful in individuals who have problems in self-regulation such as children suffering from ADHD (Gawrilow & Gollwitzer, 2008; Gawrilow, Gollwitzer et al., 2011; Gawrilow, Schmitt et al., 2011). However, samples of the presented experiments comprised university students who were presumably trained leaners and might, thus, be considered good at self-regulating their learning. In addition, learning materials in the presented experiments were rather short compared with those used by Stalbovs et al. (2015). One might presume that self-regulatory challenges are more likely to occur with longer materials. Longer materials inherently give more opportunities to struggle in self-regulation and require sustaining cognitive, motivational, and behavioral self-regulatory processes. Whether effects of implementations intentions related to students' self-regulation of learning occur for other samples that are more prone to face learning difficulties or for longer learning materials should be tested in future research.

More in detail, when turning to learners' difficulties in multimedia learning in the present experiments, there is no explicit evidence regarding the relative relevance of the self-regulatory problems in cognition, motivation, and behavior at the baseline. The learner characteristic variables measuring knowledge about multimedia-specific cognitive strategies (only assessed in Experiment 1), self-efficacy beliefs, and planned effort all showed values above the scale midpoint. This may suggest that learners had adequate multimedia-specific cognitive strategies available, perceived the learning task as feasible for themselves, and were willing to invest sufficient effort in learning. In short, they did not report facing any of the aforementioned problems in serious ways. However, self-reports are a subjective measure and have been critiqued as being invalid indicators in the context of self-regulated learning (Veenman, 2011a, 2011b). To clarify this, more specific and more objective measures of the self-regulatory challenges are needed. Online measures such as recordings of eye-movements or verbal protocols could give insight in which self-regulatory challenges really occur during learning with multimedia. Furthermore, they would allow providing tailor-made support by selecting implementation intentions that best fit a particular student's challenge.

Another reason for not having found an effect of implementation intentions could be that effects were not detected due to low statistical power. Although, power of above 80% was calculated for the four experiments, there might actually have been an effect which was smaller than the effect size identified in the meta-analysis (Gollwitzer & Sheeran, 2006). Post-hoc power analyses using GPower (Erdfelder et al., 1996) were conducted to deduce sensitivity, the minimum effect size that could be detected with the given sample. This was based on an alpha-level of α = .05, power determined at 80% and the sample sizes of N = 119 for Experiment 1, N = 130 for Experiment 2, N = 105 for Experiment 3, and N = 137 for Experiment 4. This sensitivity power analysis revealed that the sizes of the minimal detectable effects in the experiments were d = .62, d = .59, d = .61, and d = .57, respectively, which are designated to be medium effect sizes (Cohen, 1992). Thus, there was sufficient power to detect an implementation intention effect that is comparable in magnitude to the medium to large effect (d = .65) that was found in the meta-analysis from Gollwitzer and Sheeran (2006). However, the meta-analysis also included studies that had found smaller effects. There are several reasons why effects in the presented experiments could turn out smaller than the overall effect of the meta-analysis. In most other studies implementation intentions were more closely related to the dependent variable. For instance, implementation intentions were related to write a curriculum vitae; then, it was assessed whether the curriculum vitae was written or not (Brandstätter et al., 2001). In the experiments presented here, however, the behavior that was specified in the implementation intentions was only a mediator such as using specific cognitive strategies. This should lead to an improved learning outcome which was, then, measured as dependent variable. Another reason for smaller effects could be that learning situations and the initiated behaviors were more complex than in other experiments, thus, possibly there are more influencing factors that might affect data. Lastly, a lack of goal commitment could have decreased an effect of implementation intentions as it was previously discussed. Although the experimental set-up is based on other studies that found effects of implementation intentions (e.g., Stalbovs, 2016; Stalbovs et al., 2015), it cannot completely be ruled out that there were smaller effects in the experiments presented here that could just not be detected.

In sum, these findings do not corroborate the notion that implementation intentions relating to the cognitive, motivational, or behavioral area of self-regulated learning improve learning outcomes in multimedia learning. Further research is needed to gain more insight in the self-regulatory problems of learners as well as boundary conditions of implementation intentions.

10.3 Do Individual Learner Characteristics Moderate the Effect of Implementation Intentions?

Regarding the exploratory investigation of whether individual learner characteristics moderate an effect of implementation intentions on learning outcome, results were not conclusive, either. While self-efficacy beliefs moderated an implementation intentions effect in Experiment 1, this could not be replicated in the other experiments. This might, however, as well be explained by the composition of learner characteristics in the given samples. As previously discussed, across all experiments, participants indicated relatively high scores on the learner characteristic variables. Consequently, those participants which were considered to only hold low self-efficacy beliefs in the given sample (one standard deviation below the mean) still scored above the scale midpoint. Thus, there was only little variation in the investigated variables, which made it unlikely to obtain moderator effects. Moreover, insufficient validity of the learner characteristics' measures may explain why no moderator effects were found. As noted earlier, learner characteristics were assessed with self-reports that have been critiqued as lacking validity in the field of self-regulated learning (Veenman, 2011a, 2011b). Therefore, it cannot be ruled out that learners who really score low on these variables (e.g., below the scale midpoint) might actually profit more from an intervention with implementation intentions that specifically tackle the respective, problematic learner characteristic. Further research with more heterogeneous samples and more objective measures of self-regulatory variables might shed light on these issues.

10.4 Theoretical Implications

From a theoretical point of view, the hypotheses that were tested within the four experiments rest on a homogenous framework. Pintrich's framework of self-regulated learning (2000) was adapted to multimedia learning scenarios and relevant aspects were underpinned with findings from multimedia research. Even though this is a clear theory-driven approach, it still remains difficult to derive effective interventions from it. This follows from the fact that the applied theories are rather unspecific; especially, they lack a more fine-grained description of relevant learning processes. For instance, the CATLM (Moreno, 2006, 2007; Moreno & Mayer, 2007) includes motivation, affect, and self-regulation as influencing factors; however, it is only mentioned that these factors have an impact on processing learning contents, but nothing is said about the quality of this influence. Furthermore, motivation, affect, and self-regulation are rather broad concepts with various dimensions and their influence on (multimedia) learning was shown to be equivocal (see, for instance, literature on emotions in multimedia learning: Park et al., 2015; Knörzer et al., 2016b).

However, no differentiation is made between such dimensions in most theories so far. More specific theories – in particular concerning details of process levels of learning – are needed that offer precise anchors for interventions. Thus, the practical implementation of interventions that closely relate to theoretical conceptualizations remains an objective for future research.

10.5 Practical Implications

At the present moment, practical implications should only be derived with caution. Against the backdrop of the presented experiments, implementation intentions do not seem to be the method of choice for supporting self-regulation in multimedia learning. No convincing evidence could be found across the experiments that implementation intentions relating to cognitive, motivational, or behavioral self-regulation improve multimedia learning. However, to indeed rule out that implementation intentions do not improve self-regulation and multimedia learning, a closer look should be taken at the differences between the present experiments and other studies that have found an effect of implementation intentions on learning. It should be investigated whether effects depend on characteristics of learning content such as domain-specificity (along with relevance) or length of materials. However, although the presented results do not speak in favor of using implementation intentions as an intervention, it could be worth putting more effort in exploring conditions of successfully using implementation intentions in multimedia learning; implementation intentions are still a tool that can easily be implemented in everyday learning scenarios without costing much time or any money.

10.6 Strengths, Limitations, and Future Directions

When interpreting the results of the present experiments, it should be kept in mind that there are strengths to be appreciated and limitations that could be overcome in future research. Both are discussed in the following.

First, the scientific ideas of the experiments were derived from well-established theories; thus, they were conducted against a strong theoretical backdrop. Assumptions from theories of multimedia learning and self-regulated learning were combined to derive a particular intervention and respective hypotheses for self-regulation in the specific case of multimedia learning.

Connecting theoretical frameworks from different fields might help to further understand the complex construct of learning.

Another strength relates to the fact that the four experiments systematically built upon one another. Subsequent experiments aimed at replicating and consolidating the findings from preceding ones. Replications are important as they allow to draw conclusions on reliability and validity of effects. When doing replications it is important that experiments are comparable and at least some features are held constant across experiments. However, such comparability can be a drawback at the same time. Using the same population and the same materials across all experiments might as well limit the generalizability of the findings. In the present experiments, the materials that were used across all four experiments might have had idiosyncratic features that were unfavorable for an implementation intention effect to occur. This could, for instance, be the length of the learning materials as it was already discussed above. Other materials that are longer, from another domain, or include not only static, but also dynamic pictures, might be more challenging for self-regulation and, thus, increase the need for self-regulatory support via implementation intentions. Furthermore, using a sample from a population with less trained learners might also result in different findings. These issues should be addressed in future research.

A major limitation in the experiments is that no process-oriented measures were used; rather self-regulatory challenges were only assessed by self-report measures. Thus, no valid proposition can be made on whether the self-regulatory challenges did actually occur during learning of the multimedia message. On the other hand, there is a vast amount of literature with evidence for the aforementioned challenges in multimedia learning that actually use process-oriented measures (e.g., Hannus & Hyönä, 1999; Hegarty & Just, 1993; Kühl et al., 2011; Schmidt-Weigand et al., 2010). Thus, the assumption of self-regulatory challenges to occur in multimedia learning is based on strong empirical evidence.

Furthermore, ecological validity is limited because all of the studies were conducted in laboratory settings with a sample from a restricted population. Here, again, the reasoning of personal relevance can be brought up. Conducting learning experiments in realistic learning scenarios might increase the personal relevance of learners for the content and might, thus, provide stronger evidence for the respective findings. Future studies in the field could expand the validity to more realistic settings with learning content that is more relevant to learners.

10.7 Conclusions

The presented experiments investigated whether implementation intentions can support cognitive, motivational, and behavioral self-regulation in multimedia learning, thereby improving learning outcomes. The results do not support the notion that implementation intentions cause effects as reliably and under all conditions as it is suggested in the literature. Further research is needed to investigate the self-regulatory problems themselves, how implementation intentions can be adjusted to help learners to overcome these self-regulatory problems, and finally, how implementation intentions should be tailored to meet the learners' individual characteristics. Furthermore, it is important to consolidate findings and identify boundary conditions of implementation intentions under various conditions.

11 Summary

The presented experiments aimed at investigating whether implementation intentions support cognitive, motivational, and behavioral self-regulation, thereby improving learning outcome in a multimedia learning environment. Multimedia material, that is a combination of text and pictures, is shown to improve learning compared with learning from text only (Butcher, 2014). However, to make best use of multimedia learning materials learners must actively engage in the learning process to be able to integrate the information of both types of representations adequately, which is rather challenging for learners (Anglin et al., 2004; Scheiter et al., 2017). Challenges of multimedia learning can be conceptualized against the backdrop of a self-regulated learning framework (Pintrich, 2000). Particularly, in multimedia learning scenarios, learners may suffer from poor cognitive, motivational, and behavioral self-regulation. First, a lack of cognitive self-regulation can be observed when learners rely on text information only, or fail to connect text and picture information, suggesting that they do not select adequate cognitive strategies for multimedia learning (e.g., Hannus & Hyönä, 1999; Schmidt-Weigand et al., 2010). Carrying out such strategies is, however, cognitively demanding. Second, multimedia learning might lead learners to feel overwhelmed and to not confide in their own capabilities which points towards a lack of motivational self-regulation in the sense of lacking self-efficacy (e.g., Lowe, 2003; Lowe & Schnotz, 2014). Third, behavioral self-regulation is at risk when learners rely on a multimedia heuristic, perceive multimedia material as easy to learn from, and invest too little time and effort in learning (e.g., Eitel, 2016; Serra & Dunlosky, 2010). Implementation intentions are found to be a helpful tool to improve self-regulation in a variety of contexts (Gollwitzer & Sheeran, 2006). Implementation intentions are if-then plans that connect a situational cue to a specific action, and, thus, help to automatically initiate this action and foster goal achievement (Gollwitzer, 1999).

Four experiments were conducted to investigate whether supporting self-regulation via implementation intentions in the areas of cognition, motivation, and behavior in a multimedia learning environment improves learning outcome. Learners were asked to learn with the goal to make the best use of the learning materials and to comprehend the contents to the greatest possible extent. Then, experimental groups received instructional support via implementation intentions, whereas a control group did not receive such instructions. Afterwards, participants studied a multimedia message. It was expected that in general implementation intentions improve performance in a subsequent knowledge test. Additionally, the group receiving implementation

intentions relating to cognitive self-regulation was expected to obtain the best learning outcome, as they received the most specific implementation intentions relating to the most central process in self-regulated learning. Furthermore, learner characteristics were explored as being possible moderators.

The first experiment investigated whether a single implementation intention relating to cognitive, motivational, or behavioral self-regulation improves learning outcomes compared with a control group and whether the effect differs as a function of the self-regulatory areas addressed in the implementation intention. However, results showed no effects of implementation intentions on learning outcomes at all. Self-efficacy was identified as a moderator which could, however, not be replicated in the following experiments.

The second experiment was similar to the first but some methodological changes were made to set better conditions for an implementation intention effect to occur. As expected, implementation intentions relating to behavioral self-regulation improved learning outcomes compared with the control group and cognitive implementation intentions led learners to obtain even higher test scores. Thus, some evidence for implementations intentions to foster self-regulation and learning was found. Unexpectedly, implementation intentions relating to motivational self-regulation seemed to reduce learning outcomes compared with the control group. Two subsequent experiments followed up on these results.

To gain further insight into the unexpected negative effect of implementation intentions relating to motivational self-regulation, Experiment 3 investigated whether support of motivational self-regulation is actually more apt when working on the test instead of during learning. Thus, implementation intentions relating to motivational self-regulation were either instructed before learning or before testing, whereas a control group received no implementation intentions at all. However, no effect of implementation intention instruction on learning outcomes was found.

Experiment 4 aimed at replicating the positive effects of implementation intentions relating to cognition and behavior on learning outcome from Experiment 2. However, effects could not be replicated. Additionally, participants of a mixed condition that jointly used implementation intentions relating to cognitive as well as behavioral self-regulation did not obtain higher learning outcomes either.

In conclusion, no sound evidence for an effect of implementations intentions to support self-regulation in multimedia learning could be found. Thus, findings contradict the promising

effects of implementation intentions reported in the literature. Future research should consider testing boundary conditions for an effective use of implementation intentions such as goal commitment. Besides, more insight is needed in the particular self-regulatory challenges occurring during multimedia learning to enable the provision of interventions that are specifically tailored to the learners needs.

12 Zusammenfassung

Die vorgestellten Experimente zielen darauf ab, zu untersuchen, ob Vorsätze Selbstregulation auf einer kognitiven, motivationalen und verhaltensbedingten Ebene unterstützen und dadurch die Lernergebnisse beim Lernen mit multimedialem Material erhöhen. Multimediales Material, also eine Kombination aus Text und Bildern, verbessert das Lernen im Vergleich zum reinen Textlernen (Butcher, 2014). Lernende müssen sich jedoch aktiv am Lernprozess beteiligen, um multimediale Lernmaterialien optimal nutzen zu können und die Informationen beider Repräsentationen adäquat zu integrieren, was für Lernende herausfordernd sein kann (Anglin et al., 2004; Scheiter et al., 2017). Die Herausforderungen beim multimedialen Lernen können vor dem Hintergrund eines Rahmenmodells zum selbstregulierten Lernen konzeptualisiert werden (Pintrich, 2000). Besonders in multimedialen Lernumgebungen werden Lernenden vor selbstregulatorische Herausforderungen auf kognitiver, motivationaler und verhaltensbedingter Ebene gestellt. Erstens kann ein Mangel an kognitiver Selbstregulation auftreten, wenn sich Lernende nur auf Textinformationen verlassen oder Text- und Bildinformationen nicht miteinander verknüpfen, was darauf hindeutet, dass sie keine geeigneten kognitiven Strategien für multimediales Lernen nutzen (z.B. Hannus & Hyönä, 1999; Schmidt-Weigand et al., 2010). Die Durchführung solcher Strategien ist jedoch kognitiv beanspruchend. Zweitens könnte dies folglich dazu führen, dass die Lernenden sich überfordert fühlen und nicht auf ihre eigenen Fähigkeiten vertrauen, was auf einen Mangel an motivationaler Selbstregulation im Sinne von mangelnder Selbstwirksamkeit hindeutet (z.B. Lowe, 2003; Lowe & Schnotz, 2014). Drittens ist die Selbstregulation auf verhaltensbedingter Ebene gefährdet, wenn sich die Lernenden auf eine Multimedia-Heuristik verlassen, also multimediales Material als leicht zu erlernen empfinden und folglich zu wenig Zeit und Anstrengung in das Lernen investieren (z.B. Eitel, 2016; Serra & Dunlosky, 2010). Vorsätze wurden bereits als hilfreiches Instrument zur Verbesserung der Selbstregulation in verschiedenen Kontexten verwendet (Gollwitzer & Sheeran, 2006). Vorsätze sind Wenn-Dann-Pläne, die einen situativen Hinweis mit einer konkreten Handlung verknüpfen, und so helfen sollen, diese Handlung automatisch zu initiieren und die Zielerreichung zu fördern (Gollwitzer, 1999).

In vier Experimenten wurde untersucht, ob die Unterstützung der Selbstregulation in den Bereichen Kognition, Motivation und Verhalten mithilfe von Vorsätzen das Lernergebnis beim Lernen mit multimedialen Materialien verbessert. Die Lernenden wurden aufgefordert, mit dem Ziel zu lernen, die Lernmaterialien optimal zu nutzen und die Inhalte bestmöglich zu verstehen.

Die Experimentalgruppen erhielten zudem eine instruktionale Unterstützung durch Vorsätze, während eine Kontrollgruppe keine solchen Instruktionen erhielt. Anschließend sollten sie multimedial aufbereitete Inhalte lernen. Es wurde erwartet, dass Vorsätze die Leistung in einem anschließenden Wissenstest generell verbessern. Darüber hinaus wurde von der Gruppe, die Vorsätze bezogen auf kognitive Selbstregulation erhielt, erwartet, dass sie das beste Lernergebnis erzielt, da die Vorsätze am spezifischsten waren und sich auf den zentralen Prozess beim selbstregulierten Lernen bezogen. Darüber hinaus wurden Lernereigenschaften explorativ als mögliche Moderatoren untersucht.

Im ersten Experiment wurde untersuchte, ob ein einzelner Vorsatz bezogen auf kognitive, motivationale oder verhaltensbedingte Selbstregulation das Lernergebnis im Vergleich zu einer Kontrollgruppe verbessert und ob sich dieser Effekt in Abhängigkeit von den verschiedenen Ebenen der Selbstregulation unterscheidet, die in den Vorsätzen adressiert wurden. Die Ergebnisse zeigten jedoch keinerlei Effekte der Vorsätze auf das Lernergebnis. Selbstwirksamkeit wurde als Moderator identifiziert, was jedoch in den folgenden Experimenten nicht repliziert werden konnte.

Das zweite Experiment war vergleichbar mit Experiment 1. Es wurden jedoch einige methodische Veränderungen vorgenommen, um bessere Randbedingungen für das Auftreten eines Vorsatzeffekts zu schaffen. Wie erwartet, verbesserten Vorsätze bezogen auf verhaltensbedingte Selbstregulation im Vergleich zur Kontrollgruppe das Lernergebnis und mit kognitiven Vorsätzen wurden sogar noch höhere Testergebnisse erzielt. Es ergaben sich somit Hinweise darauf, dass Vorsätze Selbstregulation und Lernen fördern. Entgegen der Erwartung, reduzierten die Vorsätze in Bezug auf motivationale Selbstregulation jedoch das Lernergebnis im Vergleich zur Kontrollgruppe. In zwei nachfolgenden Experimenten wurden diese Ergebnisse weiter untersucht.

Um weiter auf die unerwarteten negativen Effekte von Vorsätzen zur motivationalen Selbstregulation einzugehen, wurde in Experiment 3 untersucht, ob die Unterstützung motivationaler Selbstregulation möglicherweise besser wirkt, wenn sie auf die Testbearbeitung und nicht auf das Lernen gerichtet ist. So wurden die Vorsätze in Bezug auf motivationale Selbstregulation entweder vor dem Lernen oder vor dem Test dargeboten, während eine Kontrollgruppe keine Vorsätze erhielt. Es wurde jedoch kein Einfluss der Vorsätze auf das Lernergebnis gefunden.

Experiment 4 zielte darauf ab, die positiven Effekte kognitiver und verhaltensbedingter Vorsätzen auf das Lernergebnis von Experiment 2 zu replizieren. Die Effekte zeigten sich jedoch nicht erneut. Auch Probanden einer gemischten Bedingung, die gleichzeitig Vorsätze in Bezug auf kognitive und verhaltensbezogene Selbstregulation erhielten, erzielten kein besseres Lernergebnis.

Zusammenfassend lässt sich sagen, dass keine fundierten Hinweise auf einen Effekt von Vorsätzen zur Unterstützung der Selbstregulation beim multimedialen Lernen gefunden werden konnten. Damit widersprechen die Ergebnisse den Effekten, die in der Literatur für Vorsätze berichtet wurden. Zukünftige Forschung sollte Randbedingungen für den erfolgreichen Einsatz von Vorsätzen prüfen, wie beispielsweise die zugrundeliegende Zielbindung. Darüber hinaus ist ein vertieftes Verständnis der spezifischen Herausforderungen der Selbstregulation im multimedialen Lernen notwendig, um auf die Bedürfnisse der Lernenden zugeschnittene Interventionen anbieten zu können.

13 References

Aarts, H., & Dijksterhuis, A. (2000). Habits as knowledge structures: Automaticity in goal-directed behavior. *Journal of Personality and Social Psychology, 78,* 53-63. doi:10.1037/0022-3514.78.1.53

Aarts, H., Dijksterhuis, A. P., & Midden, C. (1999). To plan or not to plan? Goal achievement or interrupting the performance of mundane behaviors. *European Journal of Social Psychology*, *29*, 971-979. doi:10.1002/(SICI)1099-0992(199912)29:8<971::AID-EJSP963>3.0.CO;2-A

Abelson, R. P., & Prentice, D. A. (1997). Contrast tests of interaction hypothesis. *Psychological Methods*, *2,* 315-328. doi:10.1037/1082-989x.2.4.315

Achtziger, A., & Gollwitzer, P. M. (2008). Motivation and volition during the course of action. In J. Heckhausen & H. Heckhausen (Eds.), *Motivation and action* (pp. 272-295). London: Cambridge University Press.

Achtziger, A., Gollwitzer, P. M., & Sheeran, P. (2008). Implementation intentions and shielding goal striving from unwanted thoughts and feelings. *Personality and Social Psychology Bulletin*, *34,* 381-393. doi:10.1177/0146167207311201

Ackerman, R., & Leiser, D. (2014). The effect of concrete supplements on metacognitive regulation during learning and open-book test taking. *British Journal of Educational Psychology*, *84,* 329-348. doi:10.1111/bjep.12021

Aiken, L. S., & West, S. G. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park, CA: Sage.

Ainsworth, S., Bibby, P., & Wood, D. (2002). Examining the effects of different multiple representational systems in learning primary mathematics. *The Journal of the Learning Sciences*, *11*, 25-61. doi:10.1207/s15327809jls1101_2

Amir, Y., & Sharon, I. (1990). Replication research: A 'must' for the scientific advancement of psychology. *Journal of Social Behavior & Personality*, *5*, 51-69.

Anglin, G. J., Vaez, H., & Cunningham, K. L. (2004). Visual representations and learning: The role of static and animated graphics. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology (*Vol. 2, pp. 865-916). Mahwah, NJ: Erlbaum.

References

Armitage, C. J. (2009). Effectiveness of experimenter-provided and self-generated implementation intentions to reduce alcohol consumption in a sample of the general population: A randomized exploratory trial. *Health Psychology*, *28*, 545-553. doi:10.1037/a0015984

Atkinson, J. W. (1957). Motivational determinants of risk-taking behavior. *Psychological Review*, *64*, 359-372. doi:10.1037/h0043445

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (Volume 2, pp. 89-195). New York: Academic Press. doi:10.1016/s0079-7421(08)60422-3

Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short-term memory. *Scientific American*, *225*, 82-90. doi:10.1038/scientificamerican0871-82

Baddeley, A. (1992). Working memory. *Science*, *255*, 556-559. doi:10.1126/science.1736359

Baddeley, A. (2000). The episodic buffer: A new component of working memory?. *Trends in Cognitive Sciences*, *4*, 417-423. doi:10.1016/s1364-6613(00)01538-2

Bandura, A., & Locke, E. A. (2003). Negative self-efficacy and goal effects revisited. *Journal of Applied Psychology*, *88*, 87-99. doi:10.1037/0021-9010.88.1.87

Bannert, M. (2009). Promoting self-regulated learning through prompts. *Zeitschrift für Pädagogische Psychologie*, *23*, 139-145. doi:10.1024/1010-0652.23.2.139

Bayer, U. C., Achtziger, A., Gollwitzer, P. M., & Moskowitz, G. B. (2009). Responding to subliminal cues: Do if-then plans facilitate action preparation and initiation without conscious intent?. *Social Cognition*, *27*, 183-201. doi:10.1521/soco.2009.27.2.183

Bayer, U. C., & Gollwitzer, P. M. (2007). Boosting scholastic test scores by willpower: The role of implementation intentions. *Self and Identity*, *6*, 1-19. doi:10.1080/15298860600662056

Beierlein, C., Kemper, C. J., Kovaleva, A., & Rammstedt, B. (2013). Kurzskala zur Erfassung allgemeiner Selbstwirksamkeitserwartungen (ASKU). *Methoden, Daten, Analysen (mda)*, *7*, 251-278.

Berger, J. L., & Karabenick, S. A. (2011). Motivation and students' use of learning strategies: Evidence of unidirectional effects in mathematics classrooms. *Learning and Instruction*, *21*, 416-428. doi:10.1016/j.learninstruc.2010.06.002

References

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, *64*, 417-444. doi:10.1146/annurev-psych-113011-143823

Bodemer, D., & Faust, U. (2006). External and mental referencing of multiple representations. *Computers in Human Behavior*, *22*, 27-42. doi:10.1016/j.chb.2005.01.005

Bodemer, D., Ploetzner, R., Feuerlein, I., & Spada, H. (2004). The active integration of information during learning with dynamic and interactive visualisations. *Learning and Instruction*, *14*, 325-341. doi:10.1016/j.learninstruc.2004.06.006

Boekaerts, M. (1999). Self-regulated learning: Where we are today. *International Journal of Educational Research*, *31*, 445-457. doi:10.1016/s0883-0355(99)00014-2

Boucheix, J. M., & Lowe, R. K. (2010). An eye tracking comparison of external pointing cues and internal continuous cues in learning with complex animations. *Learning and Instruction*, *20*, 123-135. doi:10.1016/j.learninstruc.2009.02.015

Boucheix, J. M., Lowe, R. K., & Bugaiska, A. (2015). Age differences in learning from instructional animations. *Applied Cognitive Psychology*, *29*, 524-535. doi:10.1002/acp.3131

Boucheix, J. M., Lowe, R. K., Putri, D. K., & Groff, J. (2013). Cueing animations: Dynamic signaling aids information extraction and comprehension. *Learning and Instruction*, *25*, 71-84. doi:10.1016/j.learninstruc.2012.11.005

Brandstätter, V., Lengfelder, A., & Gollwitzer, P. M. (2001). Implementation intentions and efficient action initiation. *Journal of Personality and Social Psychology*, *81*, 946-960. doi:10.1037/0022-3514.81.5.946

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology*, *40*, 109-131. doi:10.1146/annurev.ps.40.020189.000545

Butcher, K. R. (2014). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd edn, pp.174-205). New York, N.Y.: Cambridge University Press.

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review*, *14*, 5-26. doi:10.1023/A:1013176309260

References

Chapman, J., Armitage, C. J., & Norman, P. (2009). Comparing implementation intention interventions in relation to young adults' intake of fruit and vegetables. *Psychology and Health*, *24*, 317-332. doi:10.1080/08870440701864538

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review*, *3*, 149-210. doi:10.1007/bf01320076

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*, 155-159. doi:10.1037/0033-2909.112.1.155

Cook, R. D., & Weisberg, S. (1980). Characterizations of an empirical influence function for detecting influential cases in regression. *Technometrics*, *22*, 495-508. doi:10.1080/00401706.1980.10486199

Corno, L. (1986). The metacognitive control components of self-regulated learning. *Contemporary Educational Psychology*, *11*, 333-346. doi:10.1016/0361-476x(86)90029-9

Corno, L. (1989). Self-regulated learning: A volitional analysis. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theory, research, and practice* (pp. 111-141). New York: Springer-Verlag.

Corno, L. (2001). Volitional aspects of self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (2nd ed., pp. 191-226). Mahwah, NJ: Erlbaum.

Cromley, J. G., Bergey, B. W., Fitzhugh, S., Newcombe, N., Wills, T. W., Shipley, T. F., & Tanaka, J. C. (2013). Effects of three diagram instruction methods on transfer of diagram comprehension skills: The critical role of inference while learning. *Learning and Instruction*, *26*, 45-58. doi:10.1016/j.learninstruc.2013.01.003

Cromley, J. G., Snyder-Hogan, L. E., & Luciw-Dubas, U. A. (2010). Cognitive activities in complex science text and diagrams. *Contemporary Educational Psychology*, *35*, 59-74. doi:10.1016/j.cedpsych.2009.10.002

De Bruin, A. H., & van Gog, T. (2012). Improving self-monitoring and self-regulation: From cognitive psychology to the classroom. *Learning and Instruction*, *22*, 245-252. doi:10.1016/j.learninstruc.2012.01.003

De Nooijer, J., de Vet, E., Brug, J., & de Vries, N. K. (2006). Do implementation intentions help to turn good intentions into higher fruit intakes?. *Journal of Nutrition Education and Behavior*, *38*, 25-29. doi:10.1016/j.jneb.2005.11.021

References

De Vet, E., Oenema, A., & Brug, J. (2011). More or better: Do the number and specificity of implementation intentions matter in increasing physical activity?. *Psychology of Sport and Exercise*, *12*, 471-477. doi:10.1016/j.psychsport.2011.02.008

Diener, E., & Biswas-Diener, R. (2017). The replication crisis in psychology. In R. Biswas-Diener & E. Diener (Eds), *Noba textbook series: Psychology*. Champaign, IL: DEF publishers. DOI:nobaproject.com

Downey, R. G., & King, C. V. (1998). Missing data in Likert ratings: A comparison of replacement methods. *The Journal of General Psychology*, *125*, 175-191. doi:10.1080/00221309809595542

Duckworth, A. L., Grant, H., Loew, B., Oettingen, G., & Gollwitzer, P. M. (2011). Self-regulation strategies improve self-discipline in adolescents: Benefits of mental contrasting and implementation intentions. *Educational Psychology*, *31*, 17-26. doi:10.1080/01443410.2010.506003

Duckworth, A. L., Kirby, T. A., Gollwitzer, A., & Oettingen, G. (2013). From fantasy to action: Mental contrasting with implementation intentions (MCII) improves academic performance in children. *Social Psychological and Personality Science*, *4*, 745-753. doi:10.1177/1948550613476307

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students' learning and retention. *Learning and Instruction*, *22*, 271-280. doi:10.1016/j.learninstruc.2011.08.003

Eitel, A. (2016). How repeated studying and testing affects multimedia learning: Evidence for adaptation to task demands. *Learning and Instruction*, *41*, 70-84. doi:10.1016/j.learninstruc.2015.10.003

Eitel, A., Scheiter, K., & Schüler, A. (2013). How inspecting a picture affects processing of text in multimedia learning. *Applied Cognitive Psychology*, *27*, 451-461. doi:10.1002/acp.2922

Eitel, A., Scheiter, K., Schüler, A., Nyström, M., & Holmqvist, K. (2013). How a picture facilitates the process of learning from text: Evidence for scaffolding. *Learning and Instruction*, *28*, 48-63. doi:10.1016/j.learninstruc.2013.05.002

Erdfelder, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers*, *28*, 1-11. doi:10.3758/BF03203630

References

Ericsson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data* (rev. ed.). Cambridge, MA: MIT Press.

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 117-133). New York, NY: Cambridge University Press.

Folker, S., Ritter, H., & Sichelschmidt, L. (2005). Processing an integrating multimodal material - The influence of color-coding. In B. G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), *Proceedings of the 27th annual conference of the Cognitive Science Society* (pp. 690-695). Mahwah, NJ: Erlbaum.

Furr, R. M., & Rosenthal, R. (2003). Evaluating theories efficiently: The nuts and bolts of contrast analysis. *Understanding Statistics: Statistical Issues in Psychology, Education, and the Social Sciences*, *2*, 33-67. doi:10.1207/s15328031us0201_03

Gawrilow, C., & Gollwitzer, P. M. (2008). Implementation intentions facilitate response inhibition in children with ADHD. *Cognitive Therapy and Research*, *32*, 261-280. doi:10.1007/s10608-007-9150-1

Gawrilow, C., Gollwitzer, P. M., & Oettingen, G. (2011). If-then plans benefit executive functions in children with ADHD. *Journal of Social and Clinical Psychology*, *30*, 616-646. doi:10.1521/jscp.2011.30.6.616

Gawrilow, C., Schmitt, K., & Rauch, W. (2011). Kognitive Kontrolle und Selbstregulation bei Kindern mit ADHS. *Kindheit und Entwicklung*, *20*, 41-48. doi:10.1026/0942-5403/a000039

Gilbert, S. J., Gollwitzer, P. M., Cohen, A. L., Oettingen, G., & Burgess, P. W. (2009). Separable brain systems supporting cued versus self-initiated realization of delayed intentions. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 905-915. doi:10.1037/a0015535

Gollwitzer, A., Schwörer, B., Stern, C., Gollwitzer, P. M., & Bargh, J. A. (2017). Up and down regulation of a highly automatic process: Implementation intentions can both increase and decrease social projection. *Journal of Experimental Social Psychology*, *70*, 19-26. doi:10.1016/j.jesp.2016.12.006

References

Gollwitzer, P. M. (1996) Das Rubikonmodell der Handlungsphasen. In J. Kuhl & H. Heckhausen (Hrsg.), *Motivation, Volition und Handlung (Enzyklopädie der Psychologie, Serie Motivation und Emotion, Bd.* 4, S. 531-582). Göttingen: Hogrefe.

Gollwitzer, P. M. (1999). Implementation intentions: Strong effects of simple plans. *American Psychologist*, *54*, 493-503. doi:10.1037/0003-066X.54.7.493

Gollwitzer, P. M. (2012). Mindset theory of action phases. In P. Van Lange, A. W. Kruglanski, & E. T. Higgins (Eds.), *Handbook of theories of social psychology* (Vol.1, pp. 526-545). London: Sage Publications.

Gollwitzer, P. M. (2014). Weakness of the will: Is a quick fix possible?. *Motivation and Emotion*, *38*, 305-322. doi:10.1007/s11031-014-9416-3

Gollwitzer, P. M., & Brandstätter, V. (1997). Implementation intentions and effective goal pursuit. *Journal of Personality and Social Psychology*, *73*, 186-199. doi:10.1037/0022-3514.73.1.186

Gollwitzer, P. M., & Schaal, B. (1998). Metacognition in action: The importance of implementation intentions. *Personality and Social Psychology Review*, *2*, 124-136. doi:10.1207/s15327957pspr0202_5

Gollwitzer, P. M., & Sheeran, P. (2006). Implementation intentions and goal achievement: A meta-analysis of effects and processes. *Advances in Experimental Social Psychology*, *38*, 249-268. doi:10.1016/s0065-2601(06)38002-1

Gottfried, A. E. (1990). Academic intrinsic motivation in young elementary school children. *Journal of Educational Psychology*, *82*, 525-538. doi:10.1037/0022-0663.82.3.525

Hannus, M., & Hyönä, J. (1999). Utilization of illustrations during learning of science textbook passages among low- and high-ability children. *Contemporary Educational Psychology*, *24*, 95-123. doi:10.1006/ceps.1998.0987

Hasselhorn, M., & Gold, A. (2006). *Pädagogische Psychologie: Erfolgreiches Lernen und Lehren*. Stuttgart: Kohlhammer.

Heckhausen, H. (1987). Wünschen-Wählen-Wollen. In H. Heckhausen, P. M. Gollwitzer & F. E. Weinert (Eds.), *Jenseits des Rubikon: Der Wille in den Humanwissenschaften* (pp. 3-9). Heidelberg: Springer-Verlag.

References

Heckhausen, H., & Gollwitzer, P. M. (1987). Thought contents and cognitive functioning in motivational versus volitional states of mind. *Motivation and Emotion*, *11*, 101-120. doi:10.1007/bf00992338

Hegarty, M., & Just, M. A. (1993). Constructing mental models of machines from text and diagrams. *Journal of Memory and Language*, *32*, 717-742. doi:10.1006/jmla.1993.1036

Heidig, S., Müller, J., & Reichelt, M. (2015). Emotional design in multimedia learning: Differentiation on relevant design features and their effects on emotions and learning. *Computers in Human Behavior*, *44*, 81-95. doi:10.1016/j.chb.2014.11.009

Hochpöchler, U., Schnotz, W., Rasch, T., Ullrich, M., Horz, H., McElvany, N., & Baumert, J. (2013). Dynamics of mental model construction from text and graphics. *European Journal of Psychology of Education*, *28*, 1105-1126. doi:10.1007/s10212-012-0156-z

Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction*, *17*, 722-738. doi:10.1016/j.learninstruc.2007.09.013

Izard, C. E. (2009). Emotion theory and research: Highlights, unanswered questions, and emerging issues. *Annual Review of Psychology*, *60*, 1-25. doi:10.1146/annurev.psych.60.110707.163539

Jaeger, A. J., & Wiley, J. (2014). Do illustrations help or harm metacomprehension accuracy?. *Learning and Instruction*, *34*, 58-73. doi:10.1016/j.learninstruc.2014.08.002

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist*, *38*, 23-31. doi:10.1207/s15326985ep3801_4

Kanfer, R., & Ackerman, P. L. (1989). Motivation and cognitive abilities: An integrative/aptitude-treatment interaction approach to skill acquisition. *Journal of Applied Psychology*, *74*, 657-690. doi:10.1037/0021-9010.74.4.657

Knörzer, L., Brünken, R., & Park, B. (2016a). Emotions and multimedia learning: The moderating role of learner characteristics. *Journal of Computer Assisted Learning*, *32*, 618-631. doi:10.1111/jcal.12158

Knörzer, L., Brünken, R., & Park, B. (2016b). Facilitators or suppressors: Effects of experimentally induced emotions on multimedia learning. *Learning and Instruction*, *44*, 97-107. doi:10.1016/j.learninstruc.2016.04.002

Koestner, R., Lekes, N., Powers, T. A., & Chicoine, E. (2002). Attaining personal goals: Self-concordance plus implementation intentions equals success. *Journal of Personality and Social Psychology, 83*, 231-244. doi:10.1037/0022-3514.83.1.231

Kombartzky, U., Ploetzner, R., Schlag, S., & Metz, B. (2010). Developing and evaluating a strategy for learning from animations. *Learning and Instruction*, *20*, 424-433. doi:10.1016/j.learninstruc.2009.05.002

Kühl, T., Scheiter, K., Gerjets, P., & Gemballa, S. (2011). Can differences in learning strategies explain the benefits of learning from static and dynamic visualizations?. *Computers & Education, 56*, 176-187. doi:10.1016/j.compedu.2010.08.008

Kunter, M., Schümer, G., Artelt, C., Baumert, J., Klieme, E., Neubrand, M., … Weiß, M. (2002). *PISA 2000: Dokumentation der Erhebungsinstrumente. Materialien aus der Bildungsforschung (Band 72) [PISA 2000: Documentation of assessment tools. Instruments from educational research (Vol. 72)]*. Berlin: Max-Planck-Institut für Bildungsforschung

Lee, V. R. (2010). Adaptions and continuities in the use and design of visual representations in US middle school science textbooks. *International Journal of Science Education*, *32*, 1099-1126. doi:10.1080/09500690903253916

Leopold, C., Doerner, M., Leutner, D., & Dutke, S. (2015). Effects of strategy instructions on learning from text and pictures. *Instructional Science*, *43*, 345-364. doi:10.1007/s11251-014-9336-3

Levie, W. H., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Communication & Technology Journal*, *30*, 195-232.

Levin, J. R., Anglin, G. J., & Carney, R. N. (1987). On empirically validating functions of pictures in prose. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration (Vol. 1, pp. 51-85).* New York: Springer.

Lewalter, D. (2003). Cognitive strategies for learning from static and dynamic visuals. *Learning and Instruction*, *13*, 177-189. doi:10.1016/S0959-4752(02)00019-1

Lowe, R. K. (1999). Extracting information from an animation during complex visual learning. *European Journal of Psychology of Education*, *14*, 225-244. doi:10.1007/BF03172967

Lowe, R. K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction*, *13*, 157-176. doi:10.1016/S0959-4752(02)00018-X

References

Lowe, R. K., & Boucheix, J. M. (2011). Cueing complex animations: Does direction of attention foster learning processes?. *Learning and Instruction*, *21*, 650-663. doi:10.1016/j.learninstruc.2011.02.002

Lowe, R. K., & Boucheix, J. M. (2016). Principled animation design improves comprehension of complex dynamics. *Learning and Instruction*, *45*, 72-84. doi:10.1016/j.learninstruc.2016.06.005

Lowe, R. K., & Schnotz, W. (2014). Animation principles in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd edn, pp.513-546). New York: Cambridge University Press.

Magner, U. I. E., Schwonke, R., Aleven, V., Popescu, O., & Renkl, A. (2014). Triggering situational interest by decorative illustrations both fosters and hinders learning in computer-based learning environments. *Learning and Instruction*, *29*, 141-152. doi:10.1016/j.learninstruc.2012.07.002

Mason, L., Scheiter, K., & Tornatora, M. C. (2017). Using eye movements to model the sequence of text–picture processing for multimedia comprehension. *Journal of Computer Assisted Learning*, *33*, 443-460. doi:10.1111/jcal.12191

Mason, L., Tornatora, M. C., & Pluchino, P. (2013). Do fourth graders integrate text and picture in processing and learning from an illustrated science text? Evidence from eye-movement patterns. *Computers & Education*, *60*, 95-109. doi:10.1016/j.compedu.2012.07.011

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist*, *32*, 1-19. doi:10.1207/s15326985ep3201_1

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist*, *63*, 760-769. doi:10.1037/0003-066x.63.8.760

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York, NY: Cambridge University Press.

Mayer, R. E. (2014a). Cognitive theory of multimedia learning. In R. E, Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 43-71). New York, NY: Cambridge University Press.

Mayer, R. E. (2014b). Incorporating motivation into multimedia learning. *Learning and Instruction*, *29*, 171-173. doi:10.1016/j.learninstruc.2013.04.003

References

Mayer, R. E. (2014c). Introduction to multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 1-24). New York, NY: Cambridge University Press.

Mayer, R. E., & Estrella, G. (2014). Benefits of emotional design in multimedia instruction. *Learning and Instruction*, *33*, 12-18. doi:10.1016/j.learninstruc.2014.02.004

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*, 43-52. doi:10.1207/s15326985ep3801_6

Meichenbaum, D. H., & Goodman, J. (1971). Training impulsive children to talk to themselves: A means of developing self-control. *Journal of Abnormal Psychology*, *77*, 115-126. doi:10.1037/h0030773

Moreno, R. (2006). Does the modality principle hold for different media? A test of the method-affects-learning hypothesis. *Journal of Computer Assisted Learning*, *22*, 149-158. doi:10.1111/j.1365-2729.2006.00170.x

Moreno, R. (2007). Optimising learning from animations by minimising cognitive load: Cognitive and affective consequences of signalling and segmentation methods. *Applied Cognitive Psychology*, *21*, 765-781. doi:10.1002/acp.1348

Moreno, R., & Durán, R. (2004). Do multiple representations need explanations? The role of verbal guidance and individual differences in multimedia mathematics learning. *Journal of Educational Psychology*, *96*, 492-503. doi:10.1037/0022-0663.96.3.492

Moreno, R., & Mayer, R. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, *19*, 309-326. doi:10.1007/s10648-007-9047-2

Moreno, R., Mayer, R. E., Spires, H. A., & Lester, J. C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents?. *Cognition and Instruction*, *19*, 177-213. doi:10.1207/s1532690xci1902_02

Morris, C. C. (1990). Retrieval processes underlying confidence in comprehension judgments. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*, 223-232. doi:10.1037/0278-7393.16.2.223

Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology*, *38*, 30-38. doi:10.1037/0022-0167.38.1.30

References

Nelson, T. O. (1996). Consciousness and metacognition. *American Psychologist*, *51*, 102-116. doi:10.1037/0003-066X.51.2.102

Nelson, T. O., Dunlosky, J., Graf, A., & Narens, L. (1994). Utilization of metacognitive judgments in the allocation of study during multitrial learning. *Psychological Science*, *5*, 207-213. doi:10.1111/j.1467-9280.1994.tb00502.x

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 125-173). New York, NY: Academic Press. doi:10.1016/S0079-7421(08)60053-5

Niedenthal, P. M., Brauer, M., Robin, L., & Innes-Ker, Å. H. (2002). Adult attachment and the perception of facial expression of emotion. *Journal of Personality and Social Psychology*, *82*, 419-433. doi:10.1037/0022-3514.82.3.419

Norman, D. A., & Bobrow, D. G. (1975). On data-limited and resource-limited processes. *Cognitive Psychology*, *7*, 44-64. doi:10.1016/0010-0285(75)90004-3

Oettingen, G., Hönig, G., & Gollwitzer, P. M. (2000). Effective self-regulation of goal attainment. *International Journal of Educational Research*, *33*, 705-732. doi:10.1016/s0883-0355(00)00046-x

Oettingen, G., Kappes, H. B., Guttenberg, K. B., & Gollwitzer, P. M. (2015). Self-regulation of time management: Mental contrasting with implementation intentions. *European Journal of Social Psychology*, *45*, 218-229. doi:10.1002/ejsp.2090

Paivio, A. (1986). *Mental representation: A dual-coding approach*. Oxford, England: Oxford University Press.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology*, *45*, 255-287. doi:10.1037/h0084295

Paivio, A. (2006). *Mind and its evolution: A dual coding approach*. Mahawah, NJ: Lawrence Erlbaum.

Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers & Education*, *86*, 30-42. doi:10.1016/j.compedu.2015.02.016

Park, B., Plass, J. L., & Brünken, R. (2014). Cognitive and affective processes in multimedia learning. *Learning and Instruction*, *29*, 125-127. doi:10.1016/j.learninstruc.2013.05.005

References

Parks-Stamm, E. J., Gollwitzer, P. M., & Oettingen, G. (2007). Action control by implementation intentions: Effective cue detection and efficient response initiation. *Social Cognition*, *25*, 248-266. doi:10.1521/soco.2007.25.2.248

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekarts, P.R. Pintrich & M. Zeidner (eds.), *Handbook of self-regulation* (pp. 451-502). San Diego, CA: Academic.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, *95*, 667-686. doi:10.1037/0022-0663.95.4.667

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (1998). Supporting visual and verbal learning preferences in a second-language multimedia learning environment. *Journal of Educational Psychology*, *90*, 25-36. doi:10.1037/0022-0663.90.1.25

Plass, J. L., Heidig, S., Hayward, E. O., Homer, B. D., & Um, E. (2014). Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction*, *29*, 128-140. doi:10.1016/j.learninstruc.2013.02.006

Plass, J. L., & Kaplan, U. (2016). Emotional design in digital media for learning. In S. Tettegah, & M. Gartmeier (Eds.), *Emotions, technology, design, and learning* (pp. 131-162). New York, NY: Elsevier. doi:10.1016/b978-0-12-801856-9.00007-4

Pokay, P., & Blumenfeld, P. C. (1990). Predicting achievement early and late in the semester: The role of motivation and use of learning strategies. *Journal of Educational Psychology*, *82*, 41-50. doi:10.1037/0022-0663.82.1.41

Prangsma, M. E., Boxtel, C. A., Kanselaar, G., & Kirschner, P. A. (2009). Concrete and abstract visualizations in history learning tasks. *British Journal of Educational Psychology*, *79*, 371-387. doi:10.1348/000709908x379341

Pressley, M. (1986). The relevance of the good strategy user model to the teaching of mathematics. *Educational Psychologist*, *21*, 139-161. doi:10.1207/s15326985ep2101&2_8

Pressley, M., Borkowski, J. G., & Schneider, W. (1987). Cognitive strategies: Good strategy users coordinate metacognition and knowledge. In R. Vasta & G. Whitehurst (Eds.), *Annals of child development* (Vol. 4, pp. 89-129). New York, NY: JAI Press.

References

Pressley, M., Borkowski, J. G., & Schneider, W. (1989). Good information processing: What it is and how education can promote it. *International Journal of Educational Research*, *13*, 857-867. doi:10.1016/0883-0355(89)90069-4

Renkl, A., & Scheiter, K. (2017). Studying visual displays: How to instructionally support learning. *Educational Psychology Review*, *29*, 599-621. doi:10.1007/s10648-015-9340-4

Richter, J., Scheiter, K., & Eitel, A. (2016). Signaling text-picture relations in multimedia learning: A comprehensive meta-analysis. *Educational Research Review*, *17*, 19-36. doi:10.1016/j.edurev.2015.12.003

Rosenthal, R., Rosnow, R. L., & Rubin, D. B. (2000). *Contrasts and effect sizes in behavioral research: A correlational approach*. Cambridge, UK: Cambridge University Press.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, *110*, 145-172. doi:10.1037/0033-295x.110.1.145

Salomon, G. (1984). Television is “easy” and print is “tough”: The differential investment of mental effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology*, *76*, 647-658. doi:10.1037/0022-0663.76.4.647

Scheiter, K., & Eitel, A. (2015). Signals foster multimedia learning by supporting integration of highlighted text and diagram elements. *Learning and Instruction*, *36*, 11-26. doi:10.1016/j.learninstruc.2014.11.002

Scheiter, K., Schubert, C., Gerjets, P., & Stalbovs, K. (2015). Does a strategy training foster students’ ability to learn from multimedia? *The Journal of Experimental Education*, *83*, 266-289. doi:10.1080/00220973.2013.876603

Scheiter, K., Schüler, A., & Eitel, A. (2017). Learning from multimedia: Cognitive processes and instructional support. In S. Schwan & U. Cress (Eds.), *The psychology of digital learning* (pp. 1-19). Cham, Switzerland: Springer International Publishing.

Schiefele, U., Streblow, L., Ermgassen, U., & Moschner, B. (2003). Lernmotivation und Lernstrategien als Bedingungen der Studienleistung: Ergebnisse einer Längsschnittstudie. *Zeitschrift für Pädagogische Psychologie*, *17*, 185-198. doi:10.1024//1010-0652.17.34.185

Schlag, S., & Ploetzner, R. (2011). Supporting learning from illustrated texts: Conceptualizing and evaluating a learning strategy. *Instructional Science*, *39*, 921-937. doi:10.1007/s11251-010-9160-3

References

Schmidt-Weigand, F., Kohnert, A., & Glowalla, U. (2010). Explaining the modality and contiguity effects: New insights from investigating students' viewing behaviour. *Applied Cognitive Psychology*, *24*, 226-237. doi:10.1002/acp.1554

Schneider, S., Dyrna, J., Meier, L., Beege, M., & Rey, G. D. (2018). How affective charge and text–picture connectedness moderate the impact of decorative pictures on multimedia learning. *Journal of Educational Psychology*, *110*, 233-249. doi:10.1037/edu0000209

Schneider, S., Nebel, S., & Rey, G. D. (2016). Decorative pictures and emotional design in multimedia learning. *Learning and Instruction*, *44*, 65-73. doi:10.1016/j.learninstruc.2016.03.002

Schnotz, W. (2014). Integrated model of text and picture comprehension. In R. E, Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 72-103). New York: Cambridge University Press.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction, 13*, 141-156. doi:10.1016/s0959-4752(02)00017-8

Schnotz, W., & Rasch, T. (2005). Enabling, facilitating, and inhibiting effects of animations in multimedia learning: Why reduction of cognitive load can have negative results on learning. *Educational Technology Research and Development*, *53*, 47-58. doi:10.1007/BF02504797

Schunk, D. H. (1989). Social cognitive theory and self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theory, research, and practice* (pp. 83-110). New York: Springer-Verlag.

Schwonke, R., Berthold, K., & Renkl, A. (2009). How multiple external representations are used and how they can be made more useful. *Applied Cognitive Psychology*, *23*, 1227-1243. doi:10.1002/acp.1526

Serra, M. J., & Dunlosky, J. (2010). Metacomprehension judgements reflect the belief that diagrams improve learning from text. *Memory, 18*, 698-711. doi:10.1080/09658211.2010.506441

Seufert, T. (2003). Supporting coherence formation in learning from multiple representations. *Learning and Instruction*, *13*, 227-237. doi:10.1016/S0959-4752(02)00022-1

References

Sheeran, P., & Orbell, S. (2000). Using implementation intentions to increase attendance for cervical cancer screening. *Health Psychology*, *19*, 283-289. doi:10.1037/0278-6133.19.3.283

Sheeran, P., Webb, T. L., & Gollwitzer, P. M. (2005). The interplay between goal intentions and implementation intentions. *Personality and Social Psychology Bulletin*, *31*, 87-98. doi:10.1177/0146167204271308

Son, L. K., & Metcalfe, J. (2000). Metacognitive and control strategies in study-time allocation. *Journal of Experimental Psychology: Learning Memory, and Cognition*, *26*, 204-221. doi:10.1037/0278-7393.26.1.204

Spörer, N., Brunstein, J. C., & Kieschke, U. (2009). Improving students' reading comprehension skills: Effects of strategy instruction and reciprocal teaching. *Learning and Instruction*, *19*, 272-286. doi:10.1016/j.learninstruc.2008.05.003

Stadler, G., Oettingen, G., & Gollwitzer, P. M. (2009). Physical activity in women: Effects of a self-regulation intervention. *American Journal of Preventive Medicine*, *36*, 29-34. doi:10.1016/j.amepre.2008.09.021

Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological Bulletin*, *124*, 240-261. doi:10.1037/0033-2909.124.2.240

Stalbovs, K. (2016). *Supporting cognitive processing in multimedia learning: The use of implementation intentions.* (Dissertation, Universität Tübingen). Retrieved from http://hdl.handle.net/10900/67917

Stalbovs, K., Scheiter, K., & Gerjets, P. (2015). Implementation intentions during multimedia learning: Using if-then plans to facilitate cognitive processing. *Learning and Instruction*, *35*, 1-15. doi:10.1016/j.learninstruc.2014.09.002

Stark, L., Brünken, R., & Park, B. (2018). Emotional text design in multimedia learning: A mixed-methods study using eye tracking. *Computers & Education*, *120*, 185-196. doi:10.1016/j.compedu.2018.02.003

Sung, E., & Mayer, R. E. (2012). When graphics improve liking but not learning from online lessons. *Computers in Human Behavior*, *28*, 1618-1625. doi:10.1016/j.chb.2012.03.026

Sweller, J., Van Merriënboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*, 251-296.

References

Thiede, K. W., Anderson, M. C. M., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology*, *95*, 66-73. doi:10.1037/0022-0663.95.1.6

Thiede, K. W., & Dunlosky, J. (1999). Toward a general model of self-regulated study: An analysis of selection of items for study and self-paced study time. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *25*, 1024-1037. doi:10.1037/0278-7393.25.4.1024

Thillmann, H., Künsting, J., Wirth, J., & Leutner, D. (2009). Is it merely a question of “what” to prompt or also “when” to prompt? The role of point of presentation time of prompts in self-regulated learning. *Zeitschrift für Pädagogische Psychologie*, *23*, 105-115. doi:10.1024/1010-0652.23.2.105

Um, E., Plass, J. L., Hayward, E. O., & Homer, B. D. (2012). Emotional design in multimedia learning. *Journal of Educational Psychology*, *104*, 485-498. doi:10.1037/a0026609

Uzun, A. M., & Yıldırım, Z. (2018). Exploring the effect of using different levels of emotional design features in multimedia science learning. *Computers & Education*, *119*, 112-128. doi:10.1016/j.compedu.2018.01.002

Van Merriënboer, J. G., & Sluijsmans, D. (2009). Toward a synthesis of cognitive load theory, four-component instructional design, and self-directed learning. *Educational Psychology Review*, *21*, 55-66. doi:10.1007/s10648-008-9092-5

Van Merriënboer, J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, *17*, 147-177. doi:10.1007/s10648-005-3951-0

Veenman, M. V. J. (2011a). Alternative assessment of strategy use with self-report instruments: A discussion. *Metacognition and Learning*, *6*, 205-211. doi:10.1007/s11409-011-9080-x

Veenman, M. V. J. (2011b). Learning to self-monitor and self-regulate. In R. Mayer, & P. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 197-218). New York: Routledge.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning*, *1*, 3-14. doi:10.1007/s11409-006-6893-0

References

Vollmeyer, R., & Rheinberg, F. (2006). Motivational effects on self-regulated learning with different tasks. *Educational Psychology Review*, *18*, 239-253. doi:10.1007/s10648-006-9017-0

Vollmeyer, R., & Rheinberg, F. (2013). The role of motivation in knowledge acquisition. In R. Azevedo & V. Aleven (eds.), *International handbook of metacognition and learning technologies* (pp. 697-707). Springer: New York. doi:10.1007/978-1-4419-5546-3_46

Waugh, N. C., & Norman, D. A. (1965). Primary memory. *Psychological Review*, *72*, 89-104. doi:10.1037/h0021797

Webb, T. L., & Sheeran, P. (2004). Identifying good opportunities to act: Implementation intentions and cue discrimination. *European Journal of Social Psychology*, *34*, 407-419. doi:10.1002/ejsp.205

Webb, T. L., & Sheeran, P. (2007). How do implementation intentions promote goal attainment? A test of component processes. *Journal of Experimental Social Psychology, 43*, 295-302. doi:10.1016/j.jesp.2006.02.001

Webb, T. L., & Sheeran, P. (2008). Mechanisms of implementation intention effects: The role of goal intentions, self-efficacy, and accessibility of plan components. *British Journal of Social Psychology*, *47*, 373-395. doi:10.1348/014466607X267010

Wieber, F., Odenthal, G., & Gollwitzer, P. (2010). Self-efficacy feelings moderate implementation intention effects. *Self and Identity*, *9*, 177-194. doi:10.1080/15298860902860333

Wieber, F., von Suchodoletz, A., Heikamp, T., Trommsdorff, G., & Gollwitzer, P. M. (2011). If-then planning helps school-aged children to ignore attractive distractions. *Social Psychology*, *42*, 39-47. doi:10.1027/1864-9335/a000041

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*, *6*, 49-78. doi:10.1007/bf02209024

Wigfield, A., & Eccles, J. S. (1992). The development of achievement task values: A theoretical analysis. *Developmental Review*, *12*, 265-310. doi:10.1016/0273-2297(92)90011-p

Wigfield, A., & Eccles, J. S. (2000). Expectancy–value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68-81. doi:10.1006/ceps.1999.1015

Wilkinson, L., & Task Force on Statistical Inference, American Psychological Association, Science Directorate. (1999). Statistical methods in psychology journals: Guidelines and explanations. *American Psychologist*, *54*, 594-604. doi:10.1037/0003-066x.54.8.594

References

Wilks, S. S. (1932). Moments and distributions of estimates of population parameters from fragmentary samples. *The Annals of Mathematical Statistics*, *3*, 163-195. doi:10.1214/aoms/1177732885

Wirth, J. (2009). Promoting self-regulated learning through prompts. *Zeitschrift für Pädagogische Psychologie*, *23*, 91-94. doi:10.1024/1010-0652.23.2.91

Wittrock, M. C. (1989). Generative processes of comprehension. *Educational Psychologist*, *24*, 345-376. doi:10.1207/s15326985ep2404_2

Wolters, C. A. (1998). Self-regulated learning and college students' regulation of motivation. *Journal of Educational Psychology*, *90*, 224-235. doi:10.1037/0022-0663.90.2.224

Zimmerman, B. J. (1986). Becoming a self-regulated learner: Which are the key subprocesses? *Contemporary Educational Psychology*, *11*, 307-313. doi:10.1016/0361-476x(86)90027-5

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational Psychologist*, *25*, 3-17. doi:10.1207/s15326985ep2501_2

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology*, *25*, 82-91. doi:10.1006/ceps.1999.1016

14 List of Figures

15 List of Tables