Awareness of Shared Goals and Adaptation of Information to Support Learning in Museums

BEWUSSTHEIT GETEILTER ZIELE UND ADAPTIVE INFORMATIONSDARBIETUNG
ZUR UNTERSTÜTZUNG VON LERNEN IM MUSEUM

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Mag.[a] rer.nat. Eva Mayr

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Dekan:	Prof. Dr.-Ing. Oliver Kohlbacher
1. Berichterstatter:	Prof. Dr. Dr. Friedrich W. Hesse
2. Berichtersatter:	Prof. Dr. Stephan Schwan

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1 Introduction

One of the most prominent characteristics of the knowledge society nowadays is that learning is no longer situated in educational institutions like schools and universities only, but learning is seen as an omnipresent process during the whole life course. Therefore, a special emphasis is placed on informal learning nowadays. But what is informal learning? The European Commission (2001, p. 32) defines it as

> Learning resulting from daily life activities related to work, family or leisure. It is not structured (in terms of learning objectives, learning time or learning support) and typically does not lead to certification. Informal learning may be intentional but in most cases it is non-intentional (or "incidental"/random).

However, informal learning is nothing "new". It has always been part of human culture–even longer than formal learning. The novelty nowadays lies in the awareness of people that there is knowledge to gain from everyday life. Thereby, informal learning receives a higher perceived value and it is attractive for people to be part of this new movement. They actively participate in this form of learning, making it thereby intentional and structured by their own learning objectives.

This development also influenced the role of museums in our society: In the knowledge society the museums started to change from a "repository of knowledge" to an "active disseminator of knowledge" (Donald, 1991). The "cabinets of curiosity" at the end of the 19th century[1] became places with didactic principles (e.g., labels, thematic exhibitions) in the middle of the last century and finally "engaging museums" at the end of the last century: Beginning with the emergence of science centers (Oppenheimer, 1968), museums started to provide hands-on experiences for visitor engagement. The development of new media technologies – computers, mobile devices, ambient technologies – furthered this trend even more by novel interfaces for visitor interactions (S. Thomas, 2007). A museum visit is no longer a passive experience, but the visitor actively constructs his/her own experiences.

These changes in museum design also led to an increasing number of visitors in the last decades. In Europe up to 183.124 visits per 100.000 inhabitants were counted and up to 52 percent of the population visit a museum at least once a year (Hagedorn-Saupe & Ermert, 2004). But why do visitors come to museums? Because they want to spend a nice day with a friend? Because they have to keep their children engaged on a rainy day? Because they just walk by and get interested? Or maybe because they want to find out something new? There are many "agendas" that bring visitors to a museum (Falk, Moussouri, & Coulson, 1998), but only a small group of visitors comes with the concrete intention to learn something. Studies on people's motivations for visiting a museum have shown that only 18 % come with a specific interest, 26 % come to learn (without further specification), and 20 % come with

[1] Though, even nowadays some museums, for example, the Museo Rocsen in Nono, Argentina, deserve the title "cabinet of curiosity".

some general interest (Black, 2005). Interestingly, Packer (2006) found that of those coming without any (50 %) or without concrete learning intentions in mind (30 %) a huge proportion (70 %) nevertheless reports after the visit that they have learned something.

These numbers show that learning is an important aspect of most museum visits. But what visitors learn in an exhibition varies enormously; every visitor takes home a different message and gains different knowledge – sometimes (s)he even gets something wrong. This can be seen as a problem with respect to the museums' educational mission: Their role in society is to collect, maintain, and impart knowledge. Especially, museums regard themselves as places of expert knowledge. Communication of expert knowledge is the museums' most prominent goal, next to increasing numbers of visitors. But how can museums ensure that visitors really engage with the topic at hand and take home knowledge, which is novel for them and valid? In my dissertation, I address this question.

The goal of this dissertation is to encourage museum visitors' engagement with the topic at hand and to enrich their learning experience by means of new media technologies. This approach is in line with the strategy of the European Commission (2001, p. 11) that

> learning providers of all kinds have a responsibility for the quality and relevance of their learning provision, as well as its coherence within the overall learning offer. […] All actors share a responsibility to work together on lifelong learning […] and to support individuals in taking responsibility for their own learning.

1.1 Personal motivation

When I started writing this dissertation, I asked myself, why informal learning in museums is an attractive field of study to me. I guess the answer to this question lies in my personal museum biography. The first museum visits I do remember were those at the National History Museum in Vienna (Austria): But to admit the truth, I only recall seeing dinosaurs, which might even be only because I got a small plastic one at the museum shop. During high school we had excursions to museums several times a year: hundreds of art museums with my mandatory elective arts classes and museums on ancient history with my Latin and Greek classes. Although I liked these excursions, I am not sure whether this was because I appreciated the museum actually or just because I liked to have a day off school.

I think the point in my life where I fell for museums was in my early twenties, when I first visited museums which used modern exhibition design and new technologies: The technology museum and the house of music in Vienna (Austria) were my first contact points to engaging museums. There, I learned that if you really engage with the exhibition and are interested in the topic you have fun and take experiences (and maybe even some knowledge) back home. As the curious person I am I discovered museums as places that fulfill but also raise curiosity. Since then, I have been a frequent museum goer.

When I started as a Ph.D. student at the Department of Applied Cognitive and Media Psychology (University of Tübingen, Germany), it coincided with the start of a research project on learning in museums at the Knowledge Media Research Center in Tübingen. I found this research topic to be one that integrates my personal interests as a frequent museum visitor and my professional interest as a psychologist on media and lifelong learning. Building on these interests, the aim of my dissertation got to find out what constitutes learning in museums and how it can be supported by means of media technologies. Thereby, I hope to make a small contribution to the museum as a resourceful, supportive learning environment and to the learning experiences of future museum visitors.

1.2 Contexts of this dissertation

As denoted earlier, my dissertation is associated with a larger interdisciplinary research project on learning in museums and the role of media for the re-contextualization of exhibits (cp. Reussner, Schwan, & Zahn, 2007). This project was undertaken from January 2006 to December 2008 by scientists from the Knowledge Media Research Center in Tübingen, the Deutsches Museum in Munich, and the Institute for Science Education in Kiel (all in Germany). The tensions between different institutions, disciplines, and research approaches broadened my view on learning in museums and media design in exhibitions. Whereas the Deutsches Museum and the Institute for Science Education conducted evaluations in the museum with different extent of control, at the Knowledge Media Center we focused on controlled experimental research – mainly in the laboratory. Therefore, an important challenge for my dissertation was to conduct research in a controlled laboratory setting – to gain valuable findings for Cognitive Psychology – but also to make valid statements for museums.

For the research presented here, I held a Ph.D. scholarship from the German Research Association (DFG) as a fellow of the virtual Ph.D. program "Knowledge acquisition and knowledge exchange with new media" (VGK). Financial support enabled me to visit museums all over the world and learn current trends of museum design, technology, and research. I was able to visit two research institutions which conduct research on learning in museums: (1) The Centre for Research on Computer Supported Learning and Cognition (CoCo) at the University of Sydney, where a research project on the use of technology for student tours at the Powerhouse Museum was just starting. (2) The "University of Pittsburgh Center for Learning in Out-of-School Environments" (UPCLOSE), where the American research initiative Museum Learning Collaborative was co-located and where still numerous research projects on learning in museums from a socio-cultural point of view take place.

Last but not least, a very important environment of my dissertation was my working group at the Department of Applied Cognitive and Media Psychology of the University of Tübingen and at the Knowledge Media Research Center, headed by Friedrich W. Hesse. There, my view on media was redirected from the design of existing applications to the potential support media technologies might provide for cognitive processing. Rather than using media technologies for explicit instruction we focused on more implicit guidance and awareness elicited by specifically designed media applications (e.g., Engelmann, Dehler, Bodemer & Buder, 2009).

These experiences and contexts influenced the work presented here, helped me to sharpen my research questions, and shaped my research design.

1.3 Bridging visitor research and psychology

I started my research on learning in museums with a literature survey and found only a hand full of publications in Psychological literature. I moved onwards and did find plenty of studies on this topic in the fields of visitor research and the learning sciences; and quite some of them where written by psychologists. While digging deeper I realized that many constructs and results described there have connections to Cognitive Psychology; and when I came back to Cognitive Psychology many papers were obviously connected and applicable to the field of informal learning in museums. Rightly, Davey (2005, p. 18) notes "a lack of integration between cognitive psychology and visitor studies". As a consequence, my dissertation builds upon literature from different fields: visitor research, the learning sciences, and Cognitive Psychology alike. By integrating these sources I hope this dissertation helps to bridge these disciplines and transfer some knowledge from one to the other and vice versa.

1.4 Outline

My dissertation starts with a definition of informal learning in general, the discussion of different conceptions of informal learning, and the characteristics of the museum setting (chapter 2). From these characteristics I derive two possible approaches how learning in museums can be supported: by setting learning goals (chapter 3) and by supporting deep information processing with adaptation of information (chapter 4). Both approaches are derived from literature from Psychology, visitor research, and the learning sciences.

To conduct empirical research on informal learning some methodological aspects have to be considered (chapter 5). In chapter 6, I present an integrated model of learning in museums that includes the two approaches to support learning in museums and that lays the base of my research. Based on this model I delineate the research questions and central aims of my empirical studies.

I conducted two studies, one in a virtual exhibition (chapter 7) and one in a real exhibition in the laboratory (chapter 8), to empirically verify the two approaches how to support learning in museums. In chapter 9, the results of these two studies are summarized, compared, and discussed with respect to their consequences for Cognitive Psychology, visitor research, new media technologies, and museum design.

I hope you will enjoy the scientific visit to the museum undertaken in this dissertation. “How exciting it gets, you determine by yourself; because the artifacts in a museum mirror whatever you want to see within” (Blühm, 2008, p. 9).[2]

[2] Originally in German, translated by the author: “Wie spannend es wird, bestimmen Sie selbst, denn die Gegenstände in einem Museum sind der Spiegel dessen, was Sie darin sehen möchten.”

2 Informal Learning in Museums

Museums are commonly considered prototypical examples for informal learning settings. This implies that there must be something different from informal learning – that is, formal learning – and that we can clearly distinguish between the two, based on the presence or absence of specific features. What are the distinctive features of formal and informal learning? And how do these distinctive features relate to cognitive processing? To support learners in museums it is necessary to first understand what constitutes informal learning.

2.1 What constitutes informal learning?

An early review on informal and formal learning by Scribner and Cole (1973) drew a rather dichotomous picture of learning: Either one is educated formally (in school like in western cultures) or informally (in the family like in traditional societies). In contrast to formal settings, informal settings are characterized by the interdependence of emotional and cognitive factors (Scribner & Cole, 1973, p. 555) and by social influences (Anderson, Lucas, & Ginns, 2003; Anderson, G. P. Thomas, & Ellenbogen, 2003).

In line with Scribner and Cole (1973) many researchers contrast informal and formal learning by the location: Schools, universities, and colleges are formal settings, whereas museums, libraries, the web, or families are informal. Several characteristics differentiate between of these settings: the presence vs. absence of explicit didactic instruction (Bransford, Barron et al., 2006; Bransford, Vye et al., 2006), the focus on language vs. observation as a means for learning (Scribner & Cole, 1973), the free choice vs. constraint to learn (Dierking & Falk, 1998; Falk, Dierking, & Storksdieck, 2005; Meyers, 2005), intuitive vs. tutored learning (Livingstone, 2001; Martin, 2004), and learning in- vs. out-of-school contexts (Bransford, Barron et al., 2006; Scribner & Cole, 1973), to name only some.

Bu definitions of informal or formal learning by the location, where learning happens, or by only one feature of the setting have been criticized by different research groups as restricted (Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Falk et al., 2005; Malcolm, Hodkinson, & Colley, 2003; Martin, 2004). The efforts by these authors to find a better categorization show that the dichotomization of informal and formal learning goes out of date. Still, there is no common definition of informal and formal learning. In an extensive literature review of 250 texts on informal learning, Malcolm and colleagues (Colley, Hodkinson, & Malcolm, 2004; Malcolm et al., 2003) noted the absence of a clear definition of informal and formal learning. They propose to take multiple characteristics of a setting into account. Similarly, Bransford, Vye et al. (2006, p. 220f.) suggest to reformulate the distinction between informal and formal settings and to look at the structuring properties of a context. As a result of Malcolm and her colleagues' review, they integrate existing characterizations of learning settings and present a list of attributes that characterize the formality or informality of a learning situation within four categories: process, location, purpose, and content (see Table 1). These characteristics are not new (e.g., differences in content were discussed extensively by Scribner & Cole, 1973), but they are not viewed as dichotomous any more: They are conceptualized as continuous characteristics that can take any value in a specific setting and can each be formal or informal to a different extent. By applying these attributes to the museum setting it can be characterized more differentially.

Table 1. Attributes of formality / informality of a learning environment (Colley et al., 2004; Malcolm et al., 2003, p. 315f.)

More Formal		*More Informal*
Structured tasks	*Process*	Incidental to everyday activity
Teacher-controlled		Learner-controlled
Teacher as pedagogue		Peer / colleague as pedagogue
Summative assessment		No assessment
Educational institutions	*Location &*	Workplace, community, family
Timely restricted	*Setting*	No time restriction
Predetermined learning objectives		No predetermined learning objectives
External certification		No external certification
Learning as focus of activity	*Purpose*	Activity without learning focus
Learning to meet external criteria		Learner determined and initiated
Acquisition of expert knowledge	*Content*	Development of something new
Propositional knowledge		Everyday practice
Specified outcomes		Incidental outcomes

2.2 Museums as informal learning environments

When the characterization by Malcolm and colleagues (2003) is applied to a typical museum setting, many informal, but also more formal characteristics can be found.

Process

Overall, the processes of learning are more informal: There are *no predefined tasks* and *no assessments*. Learners are free to choose the information and activities they are interested in (free-choice learning, e.g., Dierking & Falk, 1998). Depending on the visiting situation the *learner can be more or less in control* of his learning activities (e.g., free exploration versus a guided tour).

As a museum visit is a social event in most cases (cp. Black, 2005) learning processes are often *mediated by the social environment*. Co-visitors greatly influence information processing (Packer & Ballantyne, 2005): Dyads share opinions about the exhibits, explain them to each other, and relate information to prior shared experiences. In conversations, visitors elaborate on information in museums and, thereby, raise their learning experience ("conversational elaboration"; Allen, 2002; Leinhardt & Crowley, 1998, 2002; Leinhardt, Crowley, & Knutson, 2002).

Location and setting

Despite its educational mission the museum is not a pure learning but rather a *leisure setting*. About 80 % of the museum visitors already come within their own *social context* with other visitors (see Black, 2005, for an overview on different studies); that is, family groups (e.g., Ash, 2003; Borun, 2002; Crowley & Jacobs, 2002; Dierking & Falk, 1994), school groups (e.g., Cox-Peterson, Marsh, Kisiel, & Melber, 2003; Griffin, 2004), or adult dyads (e.g., Abu-Shumays & Leinhardt, 2002; McManus, 1987a, 1987b). As the museum is a leisure setting, visitors can explore it *without time restriction*. In the *absence of external objectives* visitors are free to engage in different activities (Dierking & Falk, 1998; Falk et al., 2005; Meyers, 2005).

Purpose

As already outlined in the introduction section, for many museum visitors the focus of their activity is not on learning. Visitors' *motivations* rather include social outings, self-fulfillment, entertainment, or recreation (Black, 2005; Briseño-Garzón, Anderson, & Anderson, 2007; Falk et al., 1998; Packer, 2006; Packer & Ballantyne, 2002).

Even though learning is an important part of visiting a museum for most people (Packer, 2006), they do not engage with all information deeply. Research on visiting behavior shows that, on average, visitors spend 20 minutes in an exhibition (Serrell, 1997). Within this restricted time it is not possible to explore all exhibits in depth. Visitors have to select exhibits and information and, as a result, often engage with information only superficially. This might be due to museum fatigue, a general decrease in interest for and attention to the exhibits after about 20 to 30 minutes of visiting a museum (Bitgood, 2002; Davey, 2005; Evans, 1995; Petrelli, Not, & Zanchanaro, 1999). Even though first observations of this phenomenon date back to 1916, no proven explanation has been provided so far. In a review on this topic, Davey (2005) found indicators that heavy demands for cognitive processing as well as arrangement and number of exhibits might cause museum fatigue.

What demands for cognitive processing are present in a museum setting? First, visitors have to select exhibits. The selection can be based on superficial cues (like that an exhibit attracts many visitors, is highlighted in an exhibition guide, or is highly visually salient) or on more elaborate cues (like personal interests). Second, visitors have to evaluate the exhibit; whether it contains something new to them or is already familiar, whether it relates to their own interests, and so on. Third, if the exhibit or information is evaluated relevant, the visitors might process it in a deep manner, elaborate on it, and thereby learn something. Due to many individual characteristics that shape these processes and the visiting behavior (like interests, learning goals, and prior knowledge) learning outcomes do highly differ between visitors (Griffin & Symington, 1998).

Content

Museums aim to *convey expert knowledge* to the public. However, the learning outcome cannot be controlled by the museum; it is *incidental* and may even be wrong. A special feature of the learning content in museums (in contrast to many other settings regarded as informal) is the presence of exhibits serving different functions: Exhibition objects give rise to situational interest and curiosity, can elicit visitor emotions ("aura" of an object, cp. Benjamin, 1936[3]), prior experiences, and knowledge, and provide an illustration and reification of exhibition content. Therefore, authentic objects are regarded as very important for learning in museums (Valdecasas, Correia, & Correas, 2006).

But what actually constitutes learning in a museum? Generally, learning in museums is difficult to define. Donald (1991, p. 372) states that "very different kinds of learning could be expected, not only in terms of content but also in terms of how people think or what people are able to do after their museum experience". There are implicitly quite different assumptions on what constitutes learning in research on informal learning: Conversational elaboration (Allen, 2002; Leinhardt & Crowley, 1998), conceptual change (Anderson, Lucas et al., 2003), the development of scientific literacy and Public Understanding of Science (Durant, 1992; Miles & Tout, 1992; Miller, 2001; G. Thomas & Durant, 1987), and interest generation (Lewalter & Geyer, 2007; Wessel, 2007) are only some examples, how learning in museums is conceptualized. Many authors argue that learning defined like in formal schooling does not fit to informal settings like museums (e.g., Martin, 2004; Schauble, Leinhardt, & Martin, 1997). It is, therefore, very important to broaden the traditional view on learning (e.g., knowledge test results) to the new forms of learning that are applicable to the museum setting to fully understand the informal learning experience of museum visitors.

Based on these findings from visitor research, museums neither can be considered as fully formal nor fully informal. Indeed, museums have many informal characteristics; which explains their categorization as typical informal learning environment. Still, in dependence of the visiting situation, the structuredness of the exhibition, visitors' intentions, and many more the museum as a learning setting can be more formal or more informal – or even both. In this work, I focus on the informal aspects of two different museum settings, that is, a virtual exhibition and a real exhibition.

2.3 Learning in virtual versus real exhibitions

In the last 15 years museums started to make their exhibits available to visitors via the World Wide Web in "virtual museums" [4] (Schweibenz, 2004). Schweibenz (p. 3) defines a virtual museum as a "Web site which presents the museum's collections and invites the virtual visitor to explore them online". An important question for museology is whether a virtual exhibition can provide a similar visiting experience to a conventional, real exhibition.

[3] Benjamin criticized the reproduction of original artwork from the perspective of his time period: The Nazi-regime misused artwork for their propaganda. If his work is interpreted from a regime-critic perspective, the current use of his aura-concept might be interpreted as misuse again. Especially, as until now no empirical studies exist that verify the existence of a (sort of) aura of an exhibit – independent from a visitor's prior knowledge and his knowledge of the exhibit's originality.

[4] Schweibenz (2004) distinguishes between different forms of virtual museums; he calls the form I refer to as "content museum" or "learning museum" (in an adapted variant). A real "virtual museum" in his sense is created by linking the collections of different museums across time and place.

Whereas a virtual exhibition can be visited at home without further preparation, visiting a real exhibition mostly requires planning and traveling to a museum. During visiting a virtual museum less influences by other visitors are present than during visiting a real, maybe even crowded exhibition. But some museologists think that only the original exhibit can generate an authentic visiting experience through its aura (Benjamin, 1936; Frost, 2002; Valdecasas et al., 2006), whereas virtual exhibitions are restricted to two-dimensional reproductions that do not convey a similar experience to the spectator (Schweibenz, 2004). Despite this assumption, Prosser and Eddisford (2004) report that children engage with exhibits in a virtual exhibition like in an immersive environment. In contrast (and in line with the aura-argumentation), Lincoln (2006) reports that students value exhibits more in a real exhibition in comparison to a virtual one. Frost (2002) assumes that differences in representation, for example, exhibits' dimensionality and size, affect their experience.

With respect to processing, Eberbach and Crowley (2005) found that different kinds of conversation emerged around virtual and real objects. Virtual objects promote more process explanations describing what happens. In real objects more explanations are given, how something works. This can again be seen as an indicator that a real object raises curiosity and questions. However, Eberbach and Crowley did not compare virtual and real exhibitions, but rather different kinds of exhibits in a real exhibition. It is possible that in a virtual exhibition all types of conversation can be observed.

Lincoln (2006) compared the knowledge acquisition of students visiting a virtual exhibition or a real exhibition. Virtual exhibition visitors gained higher knowledge than real exhibition visitors. This finding is an indicator that virtual museums are more learning related – and maybe formal – than real museums. The computer-context of a virtual exhibition might activate more formal associations of working, information search, and learning, whereas a trip to real museum might activate more leisurely associations of recreation and holiday.

These findings indicate that processing in virtual and real exhibitions is similar, but not completely equal. Therefore, one question that is empirically addressed in this dissertation is the differences and similarities in information processing in these two settings.

To make this connection, I rely on literature from (virtual and real) museum learning, but also from learning with hypermedia in the theoretical part of this dissertation. Both environments have quite some similarities: They are characterized by a high amount of – thematically more or less coherent – information which is structured in a specific way (Falk, 1997; Shapiro, 1998). Still in both settings, learners often experience disorientation and information overload (Dias, Gomes, & Correia, 1999; Heiß, Eckart, & Schnotz, 2003). Therefore, needs for self-regulation are high in both settings (Boekaerts & Minnaert, 1999; Schmitz, 2003, cp. chapter 3.2). These similarities indicate that it is possible to link research on learning in museums and on learning with hypertexts. They also indicate that further similarities in information processing and exploration of virtual and real exhibitions might be found.

In the following I delineate how the museum can support visitors to both types of exhibitions in setting their own goals, in processing information deeply and collaboratively with other visitors, and ultimately in learning.

2.4 Two approaches to support learning in museums

An important contribution of Cognitive and Educational Psychology to visitor research and museum design can be suggestions how to improve the learning environment to be more supportive to cognitive processing for individual as well as collaborative learning. But at the same time I will argue that the informal characteristics of the museum have a huge potential for learning, for example, in terms of intrinsic motivation, and consequently should not be changed or manipulated. To make such a contribution, the museum as informal learning environment has to be taken seriously and ideas for improvement have to build upon the unique characteristics of this setting. For my dissertation, I chose two informal characteristics to build supportive measures upon: self-set learning goals and deep processing of information.

The first idea for improvement builds upon the absence of externally predefined learning objectives: The activity and whether it relates to learning goals is determined by the visitor himself. "Since museums, virtual or real, are open spaces for learning and visitors are free to follow any path, studying the emergence of goals for the visit can help to shed light on how people learn in such settings" (Corredor, 2006, p. 208). Without taking away visitors' responsibility for this process, museums can encourage visitors to set their own goals. Setting own goals can influence their visiting behavior and learning in exhibitions. I will further elaborate on this idea in chapter 3 from the view of Cognitive and Educational Psychology, review findings from museum research, and discuss how media applications might support this process.

The second idea for improvement builds upon the fact that during everyday activities, like visiting a museum, often little effort is put into cognitive processing and information is processed superficially. On the other hand, the amount of information presented in museums often overwhelms the visitor; when visiting an exhibition, a visitor has to select information, evaluate it, and elaborate on it. These cognitive requirements of the setting lead to museum fatigue quite fast; often shallow processing of information follows. It is an important task for museums to make these processes easier for the visitor. One idea how this challenge can be undertaken is to adapt information to specific visitor characteristics by means of media applications. This idea is further discussed in chapter 4.

Other characteristics of the museum as learning environment were set as framing conditions for this dissertation. The social situation of the museum visit was taken as a prerequisite: Descriptive museum studies (e.g., Black, 2005) show that around 80% of museum visitors come in groups and adult dyads constitute 15 % of them. For that reason, it seems worth to focus on these visitor groups and to dedicate further research on how adult dyads can be supported during a museum visit. McManus (1987a, p. 263) describes the importance of the social situation as follows:

> Clearly, people value the social interaction involved in visiting the museum. This being the case, it is reasonable to assume that the majority of museum visitors will not be inclined to reduce their attention to, and responses to, the social climate they have brought with them when they give their attention to the exhibits.

Also, especially the social aspects of a visit are remembered in the long term (Anderson, 2003). This can be explained by the fact that co-visitors collaboratively engage in knowledge communication at the museum by information sharing, opinion exchange, and relations to common ground (Packer & Ballantyne, 2005). "Learning depends on social interaction; conversations shape the form and content of the concepts that learners construct" (Roschelle, 1995, p. 40). In all parts of this dissertation, I will further discuss how the social situation of a museum visit can assist knowledge acquisition in individual learning in museums. I will discuss both supports, the role of goals and depth of information processing, from an individual and a collaborative perspective.

2.5 New media as support for learning in museums

In this project, the two approaches to support learning in museums – setting learning goals and deep information processing – will be realized by means of new media technologies. Currently, many museums introduce new media applications to their exhibitions (S. Thomas, 2007). An important challenge for media in museums is that they actually support cognitive and collaborative learning processes (Knipfer, Mayr, Zahn, Schwan, & Hesse, 2009; Wessel & Mayr, 2007). However, most advanced technologies in science exhibitions have not been designed to support cognitive processes or knowledge communication among visitors explicitly (Knipfer, Mayr et al., 2009). Consequently, when the first novel technologies were introduced to museums they often did not provide the expected results: For example, many interactive media applications are constrained by very small displays not suited for more than one person (Wessel & Mayr, 2007) or they lack opportunities for direct manipulation by more than one visitor at a time (Heath, vom Lehn, & Osborne, 2005). Another challenge is a trade-off between interactive media use and social interaction: Walter (1996) observed declined visitor-visitor interaction with increased visitor-media interaction. Also, Heath and colleagues (2005) state "that these new tools and technologies, whilst enhancing 'interactivity', can do so at the cost of social interaction and collaboration" (p. 91).

These problems suggest that most advanced technologies in science exhibitions could be improved by explicitly fostering collaborative learning mechanisms and visitor-to-visitor knowledge communication (cp. Knipfer, Mayr et al., 2009). Therefore, one goal of media psychology in the context of museums should be to inform the design of novel technologies that actually support visitors' collaborative learning processes. It is not enough to realize a program technically, it must be integrated into the visit; its psychological effects have to be carefully considered; and its actual use should be closely evaluated.

As outlined before, in this dissertation I present two ways of support for dyadic learning in museums – setting goals and inducing deep processing. I will discuss the behavioral and cognitive consequences and prerequisite of both approaches in chapters 3 and 4 and present ideas, how media can assist these processes.

3 Approach 1: Setting Learning Goals

The importance of goal-setting for museum visits in general and museum website experience in particular rest [sic] on the fact that museums are rich, complex settings. […] the goals determine visitors' paths and, as a result, learning. (Corredor, 2006, p. 208)

Goals and related constructs were shown to be highly influential for cognitive processing (see Austin & Vancouver, 1996, for a review): For example, goals are relevant for information processing, self-regulation, and learning from the view of Cognitive Psychology. In the museum context, however, only some research on goals and goal-related constructs exists. In this chapter, I will review literature from both research strands to show the relevance of goals for individual and collaborative learning in museums and I will discuss how goals can support museum visitors' collaborative information processing.

3.1 Goals and information processing

Setting specific goals is an important part of individual cognitive processing but also group information processing (cp. Hinsz, Tindale, & Vollrath, 1997): With respect to one's goals a person or a group searches for information, selects appropriate information, evaluates this information, and elaborates on the information. As a result, goals influence individual and collaborative learning.

Goal-guided *individual learners* take more time on goal-relevant information, elaborate more on that information, and have better learning outcomes. In an early study, Rothkopf and Billington (1979) found that learners without a goal took more time to read a text than goal-guided learners. But when learners with an assigned goal reached a relevant text passage they took more time to elaborate this content. Consequently, these learners better recalled goal-relevant content. This goal-process was shown in the domain of hypertext learning, too (Shapiro & Niederhauser, 2004, p. 615f.): Learners with a specific learning goal in comparison to learners without a goal invest significantly more time overall and tendentially on goal-relevant information when learning with hypertext (cp. Schnotz & Zink, 1997). With an authentic, motivating goal hypertext learners acquire more knowledge and are better able to apply this knowledge (Zumbach & Reimann, 2002).

Goals are also important in *collaborative learning* processes (for a meta-analysis see O'Leary-Kelly, Martocchio, & Frink, 1994): Weldon, Jehn, and Pradhan (1991) studied the effect of group goals on learning performance. Relevant for higher performance were a high effort (more time, more attention to goal-relevant content), planning behavior (distribution of work, cooperation plan), and adjustment of strategy. Tindale and Kameda (2000) assume that a shared representation within the group is very important for collaborative information processing. „At the group level, information processing involves the degree to which information, ideas, or cognitive processes are shared, and are being shared, among the group members and how this sharing of information affects both individual- and group-level outcomes“ (Hinsz et al., 1997, p. 43). A means for information sharing is communication. Communication is mostly goal-directed with respect to content, referencing, and joint actions (cp. Clark & Brennan, 1991; Clark, Schreuder, & Buttrick, 1983). Russell and Schober (1999) conducted a study on communication in dyads with conflicting goals: Only when individuals were aware of their partner’s discrepant goal they tailored their communication towards this goal and thereby improved the task solution. If they were not aware of their partner’s goal, they assumed it to be the same as their own goal. Therefore, a shared group goal can be regarded as important for collaborative information processing and learning.

Goals can be differentiated with respect to their origin (cp. Austin & Vancouver, 1996; Zumbach & Reimann, 2002): Either someone else sets learning goals (external origin) or the learner sets his own goals (internal origin). In informal learning settings, external learning goals may reduce requirements to set a learning goal oneself. But thereby the setting looses a major informal characteristic. As external goals may not be congruent with a person’s internal learning goals, goal commitment, motivation, and attention may be low (Austin & Vancouver, 1996). Weldon et al. (1991) found that „in many groups, group members set goals for themselves that were different from the assigned goals. […] group members feel that an assigned goal is inappropriate” (p. 565). In contrast, self-set, internal learning goals raise curiosity, intrinsic motivation, and attention towards reaching this goal (Boekarts & Minnaert, 1999; Csikszentmihalyi & Hermanson, 1995) and are more in line with informal learning settings. A preference for internal learning goals is supported by a meta-analysis on the role of group goals on group performance (O’Leary-Kelly et al., 1994): Whereas 100 % of the studies with a participatory set group-goal reported a positive effect on group performance, only 78 % of the studies with an assigned group-goal reported a positive effect.

Austin and Vancouver (1996) also describe other dimensions of goals; besides internal vs. external origin of the goals, two dimensions seem to be of importance for informal learning. The first is level of consciousness, that is, the degree of visitors’ awareness of their goals: Conscious goals are available in working memory and therefore will structure processing of information with respect to this goal. The second goal dimension of interest is difficulty: Learning goals need to be of appropriate complexity and should correspond with the information available to promote a “zone of proximal development” (Ash, 2004; Vygotsky, 1986). That is another reason why internal goals should be preferred to external ones; they match an individual learner’s zone of proximal development in a better way.

Research from Educational and Cognitive Psychology shows that goals are very important for individual and collaborative information processing and learning in formal settings, but also in less structured contexts like hypertexts. Therefore, one might hypothesize that goals are important for information processing in informal settings as well. This is especially the case for self regulation of behavior.

3.2 Goals and self regulation of behavior

Processes of self regulation are centered around goals and are often related to motivational and emotional processes. Puustinen and Pulkkinen (2001, p. 269) define self-regulated learning as "an intermediate construct describing the ways in which individuals regulate their own cognitive processes within an educational setting". In contrast, Carver and Scheier (1998) define self-regulation in a broader way, not only present in educational settings, but in everyday life:

> Human behavior is a continual process of moving toward, and moving from, various kinds of mental goal representations, and that this movement occurs by a process of feedback control. This view treats behavior as the consequence of an internal guidance system inherent in the way living beings are organized. The guidance system regulates a quality of experiences that's important to it. For that reason, we refer to the guidance process as a system of *self regulation*. (p. 2)

Different theories of self-regulation exist (see Puustinen & Pulkkinen, 2001, for a review), but most of them were developed for formal learning settings. Boekaerts and Minnaert (1999) question whether the processes of self-regulation are similar in formal and informal learning settings or not: „What sets informal learning contexts apart from formal learning contexts is the perception of choice" (Boekaerts & Minnaert, 1999, p. 542, see also Puustinen & Pulkkinen, 2001, p. 275, on the influence of choice on self-regulated learning). Boekaerts and Minnaert (1999) suggest that the impact of goals and, therefore, the necessity to regulate the learning process oneself is even greater in informal than in formal learning settings.

In their model on self-regulated informal learning (see Figure 1), Boekaerts and Minnaert (1999) argue that self-regulatory processes depend on the characteristics of the informal learning context: They highlight social influences, realistic authentic information, and the absence of formal assessments. The perception of choice and a positive appraisal of the learning environment "will help them [the learners] to translate their own needs, expectations and wishes into clear intentions" (p. 542). Learners are highly committed to such self-set learning goals. This results in a deeper processing mode as well as better monitoring and regulation processes. The outcomes of these self-regulated informal learning processes differ from self-regulated formal learning processes: Learners engaged in this process are highly intrinsically motivated and, thus, might even experience "flow" (Cszikszentmihalyi & Hermanson, 1995). Also, they further develop their self-regulatory skills. This will help them to engage in this cycle again: They will search for other informal contexts and re-engage in a self-regulated learning process (Boekaerts & Minnaert, 1999).

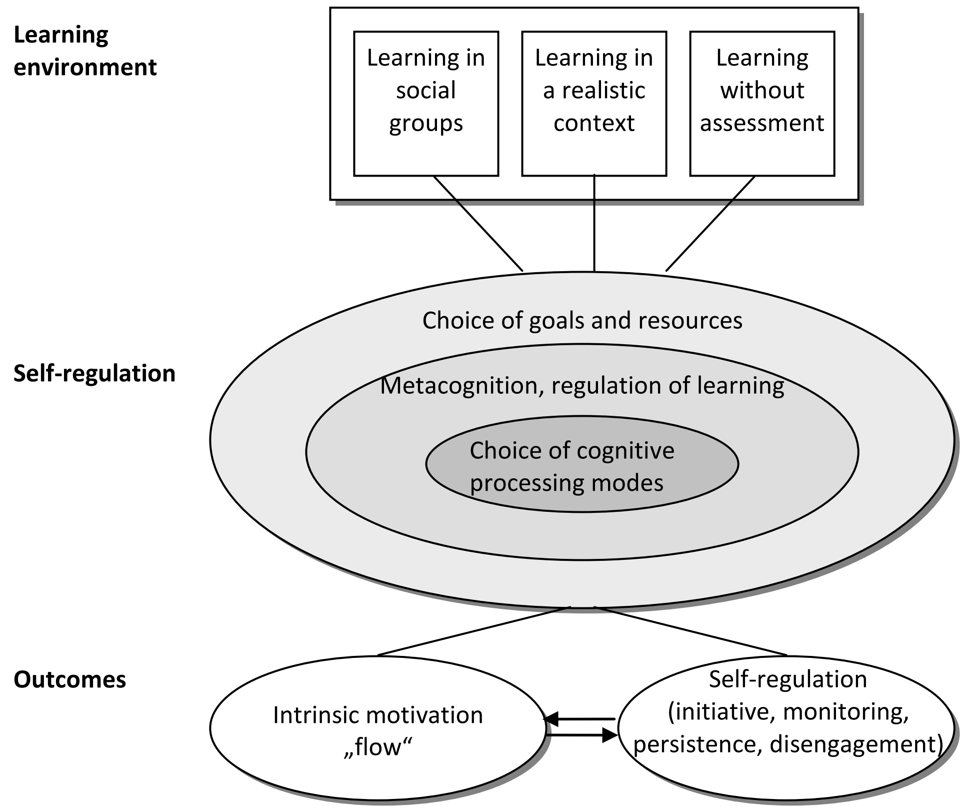


Figure 1. Model of self-regulated learning in informal settings (cp. Boekaerts, 1999, p. 449; Boekaerts & Minnaert, 1999, p. 539)

As outlined in chapter 2, social factors are important in informal settings and will influence self-regulation in these contexts (Järvelä & Volet, 2004). But until now, little attention was given to self-regulation processes in groups. Karoly, Boekaerts, and Maes (2005, p. 306) state that research on self-regulation should also focus on “dyadic self-regulation” and the interdependence of the associated processes. Salonen, Vauras, and Efklides (2005) studied co-regulation between a teacher and a learner as well as between learners in collaboration. Co-regulation “involves coordination of cognitive, metacognitive, affective, and motivational processes, as well as interpersonal and social control processes” (p. 205f.). They found that awareness of these processes in oneself and the learning partner is important for successful co-regulation. Hadwin and Oshige (2007) even go one step further and assume that collaborative groups engage in socially shared regulation; that is, the processes by which multiple group members regulate their collective activity: socially shared cognition, a shared awareness of their goals, and their collaborative progress towards it. Volet, Summers, and Thurman (2009, p. 129) describe shared regulation as the “most effective mode of co-regulation“ and as closely related to co-construction of knowledge.

To conclude, self-regulation is an important process in informal learning as it compensates for the absence of external structures and goals. In learning groups social regulation of learning processes is a prerequisite for active deep engagement and co-construction of knowledge. This in turn requires awareness of the processes and goals of the members in the group and the group as a whole.

3.3 Learning goals in the museum setting

Findings from Cognitive and Educational Psychology show that goals are important for collaborative and individual information processing and self-regulation. But can these results be transferred to the museum setting? To answer this question I reviewed visitor research on learning goals in museums.

As stated in the introduction, only a part of the museum visitors report coming with learning-related motivations to the museum (Black, 2005): Only a small number of visitors comes with a specific interest, which might be similar to a concrete goal (18 %). More come to learn something without further specification (26 %) or come with a general interest (20 %). Most visitors report that learning and entertainment are important aspects of their visit (Falk et al., 1998; Packer, 2006). But also visitors without a learning intention often learn something in the museum (Packer, 2006). This observation questions whether visitors' entrance motivations hold constantly throughout the visit or change, diminish, or build up during the visit and, thereby, loose their influence. Actually, new motivations often emerge due to environmental factors of the setting, but still the entrance motivations are largely fulfilled and can provide a frame for the museum visit (Briseño-Garzón et al., 2007).

However, hardly any museum research addresses concrete, specific learning goals. Some related research focuses on motivations and agendas for visiting (Briseño-Garzón et al., 2007; Falk et al., 1998; Packer, 2006; Packer & Ballantyne, 2002). Despite the rather unspecific operationalization of visitor motivation (place, education, life-cycle, social event, entertainment, or practical issues), Falk and colleagues (1998) found a positive effect of an education and/or an entertainment agenda on learning outcomes. Similarly, in a study by Packer and Ballantyne (2002) visitors with a learning motivation report more motivated learning behavior and a higher learning experience.

Some research attended to the question, whether visitors come with a focused, moderately focused, or no focused strategy; that is, a concrete plan, what to visit and – sometimes – also goals (Briseño-Garzón et al., 2007; Falk et al., 1998). Falk and colleagues (1998) observed that focused and moderately focused visitors spent more time in an exhibition and that focused visitors did acquire more mastery knowledge; they were better able to describe their understanding of the exhibition domain. An open question is whether these effects are due to learning goals and goal-directed behavior or due to a more clearly planned visit.

Only two studies exist that directly addressed the question of concrete, specific learning goals in exhibitions. Corredor (2006, p. 209) studied the setting of goals in the use of museum websites and observed that visitors with high prior knowledge on the exhibition topic set more goals than visitors with low prior knowledge. Goals structured the visit of the museum websites; visitors went deeper into goal-relevant topics and elaborated more on them.

In the dissertation of Zueck (1988) visitors with an induced specific learning goal stayed longer in the exhibition than visitors without a learning goal or with a general learning agenda. In her study setting learning goals did not affect visitors' learning outcomes. However, Zueck cued the visitors that a knowledge test will follow their visit. Thereby, she formalized the study setting and "produced" learning differences between cued and non-cued visitors.

Leinhardt and Knutson (2004) studied the role of visiting motivations for learning in visitor dyads. They found that a dyad's motivation is highly correlated to learning conversation and explanatory engagement. A shared learning goal enhances visitors' motivation (Packer & Ballantyne, 2005). In visitor groups, individual and common interests and motivations constantly interact, influence each other, and operate concurrently (Briseño-Garzón et al., 2007, p. 82). Until now, no study exists on the influence of specific group goals on visiting behavior and learning in museums.

3.4 A support for enhancing learning goals in the museum context

As learning goals and a focused visiting strategy are relevant for learning in museums (Corredor, 2006; Falk et al., 1998; Leinhardt & Knutson, 2004), learning from an exhibition could be improved when it is visited in a more focused way. This assumption is supported by studies in formal learning contexts showing the relevance of goals for more strategic information processing (e.g., Rothkopf & Billington, 1979; Zumbach & Reimann, 2002). Conscious goals are available in working memory and have a high potential to structure information processing (Austin & Vancouver, 1996). Additionally, aware goals raise curiosity, intrinsic motivation and attention towards reaching this goal (Boekarts & Minnaert, 1999; Csikszentmihalyi & Hermanson, 1995; Packer & Ballantyne, 2005).

There are two ways to promote learning goals related to their origin (cp. Austin & Vancouver, 1996; Zumbach & Reimann, 2002): The first way is to set learning goals (external origin) and the second way is to make the learners set their own goals (internal origin). For the museum context, both ways have their pros and cons: Setting external learning goals reduces affordances of self-regulation for the learner. It was also shown to be very effective as a learning support in formal contexts (e.g., Zumbach & Reimann, 2002). But the museum setting would loose an important informal characteristic by setting external goals. As these external goals may not be congruent with a person's internal learning goals, goal commitment, motivation, and attention may be low (Austin & Vancouver, 1996). In addition, external learning goals might be too difficult or too complex and might not meet a visitor's interests and prior knowledge (cp. Corredor, 2006, p. 220). Therefore, internal learning goals should be preferred. As stated above, internal learning goals raise curiosity, intrinsic motivation, and attention towards reaching this goal (Boekarts & Minnaert, 1999; Csikszentmihalyi & Hermanson, 1995). However, in the museum context some visitors do not pursue any (learning) goal (e.g., Black, 2005) and may not be able and motivated to set internal learning goals by themselves. Also, the exhibited artifacts and information might not meet a visitor's internal goals. In this case, the visitors are likely to be disappointed by the exhibition as their goals cannot be satisfied. Visitors need a clear idea what is presented in the exhibition to be able to set themselves useful, reachable, and thereby effective learning goals. That is, why Zueck (1988) argues for museums to provide external learning goals despite their disadvantages:

> The procedure of instigating visitors to accept a goal of learning is not as contrived and forced as it may, at first, seem. […] [Visitors] do not actively establish concrete goals for learning because they are not sure of what particular information is available in a specific exhibit. (p. 7)

In this dissertation a third way is introduced: Visitors are made aware of an internal learning goal. Before visiting an exhibition, visitors receive a list of possible learning goals which are all satisfied in the exhibition. They are asked to choose the one most appropriate to them. The visitors' choices reflect the learning goals which are closest to their interests. "When visitors have interests that can be linked to the pieces of information displayed at the museum, goals that represent the interaction between their interests and the affordances of the learning situation are set" (Corredor, 2006, p. 220).

Making aware internal learning goals combines the benefits of the first two approaches: Similar to providing an external learning goal, the goals are addressed in the exhibition (cp. Zueck, 1988) and, therefore, they can guide exploration behavior in this setting. As with setting internal learning goals by the visitors themselves the availability of choice allows to select goals that are close to the visitors' internal learning goals and match their prior knowledge and interests (cp. Corredor, 2006). Thereby, intrinsic motivation is higher than by providing an external learning goal. Making aware visitors of an internal learning goal motivates them to invest mental effort to process information deeply and makes sure that there is also relevant information in the exhibition worth processing.

To support a visitor group in effective social regulation of informal learning processes and co-construction of knowledge, it is important to make them aware of a shared goal which can guide their collaborative learning process. A shared learning goal was shown to be motivating for museum visitors (Packer & Ballantyne, 2005). Especially if a goal is participatory set by the learners themselves, it enhances learning (O'Leary-Kelly et al., 1994). Additionally, the awareness of collaborative processes is important for social regulation (Salonen et al., 2005) as a shared representation influences information processing in groups (Hinsz et al., 1997; Tindale & Kameda, 2000). Therefore, the visitors' awareness of an internal goal should be manipulated on the group level. By making a visitor dyad aware of a shared goal, this goal becomes part of their common ground and serves as reference for communication (Clark & Brennan, 1991; Russell & Schober, 1999). Conversational elaboration is an important form of information processing during learning in museums (e.g., Leinhardt & Crowley, 1998) and is guided by shared learning goals (Leinhardt & Knutson, 2004).

3.5 *Media for awareness of a shared learning goal*

How can new media be used to support the awareness of shared learning goals in visitor groups? Until now no tools exist for this purpose.

Sumi and Mase (2001) developed a related system called AgentSalon, which creates awareness among unacquainted visitors at museums. It facilitates face-to-face discussion among people with shared interests. "The essential jobs of AgentSalon are to detect and represent shared/different parts of the personal information (e.g., interests and touring records) of several users" (p. 394). The mechanism behind this system is integrating personal agents through a face-to-face discussion of two to five users. Individual visitors "feed" AgentSalon on a mobile device with personal information like interests, experiences, or opinions. Their information then "moves" to a public screen in the form of an animated agent. Agents of two or more visitors automatically start a conversation around their shared interests. Visitors can actively engage in this discourse and meaning-making process by elaborating on their agent's information. By such a system, awareness of shared interests and goals can be created and knowledge communication is triggered. However, the focus of AgentSalon is less on supporting goal-directed collaborative action, but more on community building in museums. Also it focuses on unacquainted visitors rather than visitor coming in a dyad to the museum already.

How else can awareness of shared goals be supported? Regarding the implementation of media in museums, sometimes less is more (Wessel & Mayr, 2007). Therefore, in this dissertation awareness is supported in a rather simple way, which would also be possible without new media with a sheet of paper: Before the visit, visitor dyads answer the question on the screen (of a computer or PDA) what aspect of the exhibition's topic they would like to know more about. They are encouraged to select an aspect, which is of interest to both of them.

For the purpose of this dissertation, they are not free to select whatever they want but choose from a list of four aspects related to the exhibition's topic, that is, nanotechnology. This restriction is implemented due to (1) technical reasons (as will be outlined in chapter 4.3). (2) It is assumed that visitor dyads select the one most appropriate goal that matches their internal goals best. (3) The topic of nanotechnology is rather "new" – only little prior knowledge on this topic exists in society (Waldron, Spencer, & Batt, 2006). Therefore, no specific learning goals and interests related to this topic are assumed (cp. Corredor, 2006 on the role of prior knowledge for goal setting).

Though this realization is technically very simple it should be sufficiently effective for the intended purpose of making aware a shared learning goal to visitors prior to their visit. However, the sheer awareness of a shared goal does not guarantee that this goal will also guide the learning process: In museums often environmental factors distract from a goal (Briseño-Garzón et al., 2007). Additionally, social regulation of information processing does not necessarily lead to high-level processing of content (Volet et al., 2009), but is often also associated with low-level processing. Therefore, an additional support is needed which helps museum visitors to engage in deep processing of information and maintains the awareness of the shared goal throughout the visit. The next chapter is going to address the question how awareness can be maintained and how deep processing of information can be supported.

4 Approach 2: Supporting Deep Information Processing

Museum visitors may at first attend to an exhibit because of curiosity and interest. But unless the exhibit becomes intrinsically rewarding, visitors' attention will not focus on it long enough for positive intellectual or emotional changes to occur. Therefore it is important […] to understand what may motivate a person to look and think about an exhibit for "nor good reason" – that is, in the absence of external rewards.

(Csikszentmihalyi & Hermanson, 1995, p. 69)

An important factor for sustainable informal learning is depth of information processing (Mayr, Tibus, & Knipfer, 2007). The learning material and the learner himself influence depth of information processing: First, the learner himself can be more or less motivated to invest mental effort and to process the information in a deep manner. Also, as outlined in the last chapter, shared internal learning goals can motivate learners to process information thoroughly (Packer & Ballantyne, 2005). Second, the presentation of the learning content can require more or less deep processing. In the case of museums, the exhibition design can influence how deep information has to be processed and what knowledge can be gained by deep or superficial processing of the information (Falk, 1997). This chapter focuses on both aspects and how they support deep information processing. I introduce depth of information processing from its theoretical background in Psychology and discuss its relation and relevance for informal learning in museums. From these findings I delineate how deep information processing in museums can be supported and discuss adaptive media as a technical solution.

4.1 Depth of information processing in informal learning

Museum visitors often regard learning in museums as easy and effortless (Packer, 2006), they come with "different levels of openness to cognitive activity" (Packer & Ballantyne, 2002, p. 187). This finding might explain the high variability of learning outcomes in museums (e.g., Griffin & Symington, 1998, p. 2). Museum visitors alternately engage in phases of deep information processing and phases of skimming information (e.g., Rounds, 2004). To support deep processing of information, an important question is what helps visitors to deeply engage with information and what lets them walk by mindlessly. To answer this question I review theories of information processing first which build upon the concept depth of information processing (DIP) and explain differences in DIP during informal learning. Then, I discuss influences of the environment and learner characteristics on DIP.

4.1.1 Theories on depth of information processing

Various theoretical approaches from the areas of Cognitive, Social, Educational, and Media Psychology deal with DIP or similar concepts. Here, two theories are discussed that might be relevant for informal learning in science museums, namely levels of processing (Craik & Lockhart, 1972) and amount of invested mental effort (Salomon, 1984).

Levels of processing

The levels of processing (LOP; Craik & Lockhart, 1972) framework assumes that memory traces depend on different levels on which stimuli are processed: "Analysis proceeds through a series of sensory stages to levels associated with matching or pattern recognition and finally to semantic-associative stages of stimulus enrichment" (p. 675). First, Craik and Lockhart proposed a continuum of LOP ranging from shallow processing (based on surface, perceptual features) to deep processing (based on processed, meaningful interpretations). Later, they assumed that information is processed bottom up (i.e. driven by the stimulus) and top-town (i.e. driven by activated concepts) not continually from shallow to deep levels but interactively (Craik, 2002; Craik & Tulving, 1975). Deep information processing is assumed to result in longer lasting memory traces. This proposed relationship between LOP and persistence of memory traces could be confirmed in various studies (Craik & Tulving, 1975).

Primarily, the LOP framework was developed for verbal learning but might also be transferred to more complex learning like visiting a museum. Learning in Craik and Tulving's (1975) research on LOP was incidental and can model everyday cognitive processing (Lockhart & Craik, 1990, p. 89). Therefore, assumptions and results from the LOP framework seem to be useful for examining learning in museums, too. It is assumed for both, informal and formal learning alike: "Retention is a function of depth, and various factors […] will determine the depth to which it [the information] is processed" (Craik & Lockhart, 1972, p. 676).

Craik's and Lockhart's LOP theory received much attention in empirical research but was also criticized (see Craik, 2002; Lockhart & Craik, 1990, for reviews). Major points of criticism are (1) the consolidation of deep processing and memory achievement, (2) the absence of objective indices for deep processing, (3) the circulatory argumentation of deep processing and memory achievement, (4) the question whether depth of processing is continuous or categorical, and (5) the fuzzy discrimination of depth and elaboration.

Amount of invested mental effort

Are films processed easier than books? Is that why some people invest less mental effort when they learn with videos compared to print? In the opinion of some researchers this is the case (Krapp & Weidenmann, 2001; Salomon, 1984; Weidenmann, 1989). They assume that films can be processed easier than other media (e.g., print). Therefore, learners invest only little mental effort. Similarly, Packer (2006; Packer & Ballantyne, 2004) showed that learning in museums has an important enjoyment characteristic in visitors' subjective concepts; they regard it as easy and effortless (Packer, 2006). Therefore, it can be assumed that museum visitors invest only little mental effort as well.

Salomon (1984) defines the amount of invested mental effort (AIME) as the "number of nonautomatic elaborations applied to material and measured by learners' self-reports" (p. 647). AIME refers to the mental effort that a learner invests deliberately in order to process media-presented information. AIME varies in dependence of media characteristics and the subjective perceived self efficacy regarding the use of the medium as well as the task demands. Therefore, AIME is influenced by an interaction between emotional-motivational aspects of the learner and his cognitive processing of presented (media) contents: Learners will invest much mental effort if the task demands and the self efficacy are perceived to be either both high or both low. Learners will invest only little mental effort if one variable is high but the other one is low. Thus, one can try to influence AIME by changing the perceived self efficacy or the perceived task demands regarding the medium museum. Koran, Koran, and Foster (1988) suggest that museums could manipulate visitors' perceptions of task difficulty via interindividually different orientation information for different subgroups. Thereby, visitors would engage more with museum exhibits and invest more mental effort.

Salomon's assumptions (1984) have been widely acknowledged in pedagogical psychology research. However, Beentjes (1989; Beentjes & van der Voort, 1991) tried to replicate Salomon's findings with Dutch samples but failed. Unlike their American peers in Salomon's study, Dutch children did not perceive television as an easy medium. The authors explain these findings with the subtitles that are used in Dutch television: Dutch children are used to elaborate television deeper. It seems evident that television is not per se perceived as an easy medium by everybody and that further clarification regarding AIME's generalization is necessary as well as studies with adult participants are missing until now. For further discussion of the AIME concept see Tibus (2008).

A definition of depth of information processing

The theories of LOP and AIME show that DIP is a heterogeneous construct that addresses a range of cognitive processes. Maybe that is due to the fact that the construct itself has not been defined sufficiently yet: "The challenge now (as in 1972) is to refine and specify such concepts as depth, elaboration, and distinctiveness" (Craik, 2002, p. 315). Craik defined DIP as the qualitative type of processing undertaken, whereas he defines elaboration as the quantitative degree of enrichment during encoding. In my opinion, the two constructs "depth of processing" and "elaboration" are confounded: Those types of processing that Craik (2002) defines as "deep" require high elaboration whereas "shallow" types of processing require less elaboration. I agree with Salomon (1984) who considers deep processing as "to entail mental elaborations of the material" (p. 648). Thus, DIP can be defined as the degree to which information is elaborated on, that is, the degree to which information is integrated into and connected with existing memory structures.

I would like to emphasize that DIP is a process not an outcome characteristic of information processing. This is a weakness in both, the methodological procedure and the underlying theoretical assumptions, of the two described theories: They define DIP post hoc as they mostly conclude only from assessed learning outcomes or self-reports whether or not learners processed information deeply or superficially: Learners who demonstrate good learning performance are assumed to have processed information deeply compared to learners who demonstrate poor learning performances and, therefore, processed information only in a shallow manner.

The described theoretical approaches assume that learners might elaborate the content deeper or invest more mental effort - or they might not! Not every person does equally apply deep processing strategies, not for all information and not in every setting. Environmental and individual factors determine to which extent strategies of deep information processing are applied. In the following section, I discuss environmental factors that influence DIP in informal learning settings.

4.1.2 Environmental impact on depth of information processing

DIP depends to some extent on a person's control but to some extent also on contextual factors (Craik & Tulving, 1975, p. 292): In the following, the influences of medium and social context are discussed.

Media influences

The informal setting of a science museum can be described as mass medium itself and influences DIP in its own specific way. An important media feature inherent in the medium museum is its structuredness. In formal learning it was shown that low structured texts (McNamara, Kintsch, Songer, & Kintsch, 1996) and hypertexts (Shapiro, 1998) result in deeper processing of information and higher learning than high structured (hyper)texts. However, these findings are mediated by learners' prior knowledge (McNamara et al., 1996). In contrast to these studies from formal learning with (hyper)texts, in informal learning it must be assumed that learners will invest less mental effort to extract a structure from low coherent material. Partly, this is due to the absence of explicit tasks and specific instructions that are telling them to do so. In part, this might also be due to the general absence of a learning focus.

The museum setting is characterized by a huge amount of presented information and many possible object-object interrelations. Typical problems of navigation and information elaboration found in hypermedia research can also be transferred to the museum setting (Dias et al., 1999): Disorientation and ineffective information processing are just two problems that might arise. Exhibition design principles and media tools which provide structural support for navigation, information selection, and information elaboration have been developed, for example, maps, information terminals, advanced organizers, and (audio) guides (e.g., Falk, 1997; Falk & Storksdieck, 2005; Screven, 2000; Zueck, 1988). They reduce processing capacities needed for orientation and information selection. Valuable capacity is thus free to process the presented information more meaningfully and more deeply. For example, Zueck (1988) found that visitors with a concrete learning goal did explore an exhibition shorter when a conceptual organizer was present. She assumes that the organizer helped these visitors to find goal-relevant information faster and more effectively.

Social influences

As informal settings are highly social in most cases, one has to assume that learning is mediated by the social environment to a great extent (cp. Malcolm et al., 2003). The social environment provides space for communication and this in turn might elicit motivation for deep cognitive processing.

Formal learning in groups is characterized by a high degree of communicative exchange: Information exchange and communication about prior knowledge and individual interpretations of learned information are regarded as main learning potential of collaboration. Asking questions and giving explanations are crucial for learning because they elicit metacognitive processes and self-evaluation (Webb & Palinscar, 1996). Collaborative learning elicits active, constructivist, and explorative learning situations which are crucial for higher learning outcomes (Slavin, 1990).

The social situation at a museum is a central characteristic that influences DIP (see also Knipfer, Mayr, et al., 2009). The social environment might influence DIP twofold: On the one hand, it can reduce the required mental resources by providing some kind of structure: Agendas are often implicitly inhered in an existing group (e.g., a parent-child group often comes with an exploration intention). As outlined in chapter 3, shared motivations and goals guide a group’s behavior. On the other hand, the social context can enhance DIP by providing additional space for elaboration: As in formal contexts, conversational elaboration is an important indicator for learning in museums (Allen, 2002; Leinhardt et al., 2002) and can also serve as an indicator for deep processing (Leinhardt & Knutson, 2004).

Summary and discussion of environmental influences

In this chapter I presented two aspects how the learning environment can influence DIP. Media and the social context determine whether information is processed more or less deeply: If the media environment is more structured information can be processed more deeply and will be better integrated into existing memory structures. The social context motivates to elaborate on information, activates prior knowledge, and thereby gives rise to deeper information processing.

However, the described influences do not hold generally for every learner. For example, multimedia theories like the Cognitive Load Theory by John Sweller and colleagues (e.g., Chandler & Sweller, 1991, for a detailed discussion see Sweller, van Merriënboer, & Paas, 1998) assume that media influences interact with cognitive learner characteristics:

Depending, for example, on prior knowledge visitors to a museum website processed information more or less deeply (cp. also Corredor, 2006). This is not only true for media influences, but for other environmental factors as well. And it does not only hold for prior knowledge, but also for other learner characteristics, as the next chapter will show.

4.1.3 Impact of learner characteristics on depth of information processing

Based on the reviewed theories inter- and intraindividual differences can be expected regarding DIP: For example, Salomon (1984) emphasized the role of perceived self-efficacy. I will describe several cognitive learner characteristics and discuss their impact on DIP in informal learning.

Prior knowledge

Prior knowledge is an essential cognitive variable for learning in formal contexts. It explains between 50 and 60 percent of the variance in knowledge acquisition (Dochy, 1994). Thus, prior knowledge overrules many other variables. But why is this the case? Newly learned content can be integrated into existing prior knowledge structures (Craik, 2002). During this “assimilation” process the new information is elaborated more deeply than when stored as single information piece. More sustainable and qualitatively different knowledge can be generated from learning material when new information is connected with already existing prior knowledge structures.

Similarly, in a museum setting high prior knowledge results in deeper elaboration of content during thinking aloud (Corredor, 2006). However, a more differentiated effect of prior knowledge was found in a study by Falk and Adelman (2003): Visitors with high prior knowledge but also visitors with low prior knowledge but high interest learned most during a visit to an aquarium. Visitors with moderate knowledge did not gain any additional knowledge. This finding indicates that more differential studies on the influence of prior knowledge on informal learning are required. Still, similar to formal learning (Dochy, 1994), prior knowledge seems to be very influential for DIP in informal learning.

Self regulation

As outlined in chapter 3.2, self-regulation processes can lead to deeper processing in individuals (Rozendaal, Minnaert, & Boekaerts, 2003) and groups (Volet et al., 2009). Informal learning in museums requires a relatively high degree of self-regulation (i.e., goal-setting, information selection, and elaboration strategies; Boekaerts & Minnaert, 1999). Therefore, learning is triggered by self-regulated, intrinsically motivated, and elaborative processes. However, results from hypertext research show that such a high degree of learner self-regulation holds a certain amount of risk. For example, Heiß, Eckart, and Schnotz (2003) identify problems of disorientation, cognitive overload, and distraction by irrelevant information. Similarly, navigation problems at the museum can occur (Screven, 1975) and visitors are faced with the cognitive challenge of concept construction from many different exhibits and information pieces (Falk, 1997). These problems explain that especially in informal learning settings like museums no substantial learning goal might be achieved; despite – or even due to – the opportunity of having very individual agendas (Schmitz, 2003).

Cognitive capacity

The limited capacity assumption is based on Baddeley's working memory model (e.g., Baddeley & Hitch, 1974) and refers to the limited processing capacities of the auditory/verbal and the visual/pictorial channel in working memory. In each channel only a limited amount of information can be processed. The limited capacity of working memory is considered to be the "bottleneck" of the learning process (Gerjets & Hesse, 2004).

Research in the field of working memory capacity indicates that there are individual differences regarding cognitive capacity (e.g., Feldman Barrett, Tugade, & Engle, 2004). In the typical memory span task (Baddeley & Hitch, 1974) information is presented to learners for later recall. There are individual differences in memory span located around an average of seven pieces of recalled information. Individual differences in working memory capacity are thought to affect the amount of cognitive resources available to expend on information processing and storage (see Baddeley, 1998). Feldman Barrett and colleagues (2004) state that working memory capacity is related to many other cognitive processes during learning: For example, working memory capacity has an impact on encoding of new information, drawing of inferences, and also on using prior knowledge to integrate new information into existing memory structures. Thus, working memory capacity might moderate and sometimes even increase the effect of prior knowledge on DIP (Feldman Barrett et al., 2004).

As there are many information pieces to be held salient in working memory for knowledge construction, I assume that results from working memory research can be transferred to a museum setting. The influence of individual differences in working memory capacity for learning in museums has not been studied so far. One related and well documented concept in museum research is museum fatigue (Evans, 1995; Petrelli et al., 1999). Davey (2005) assumes that limited processing capacities are one cause for museum fatigue.

Summary and discussion of learner influences

This chapter discussed three cognitive factors which are important for DIP: prior knowledge, self-regulation, and cognitive capacity. There is evidence that these learner characteristics and dispositions are highly relevant for DIP in museums. I consider self-regulation abilities as being of special importance in informal learning settings due to their dependence on visitors' goals and the absence of external guidance in museums. That means that all stages of the learning process must be carried out by the learners themselves, ranging from goal setting to information selection, evaluation, and elaboration. Prior knowledge is at least as important as in formal settings. It is crucial for integration of new information into coherent memory structures and cognitive representations. Cognitive capacity is required to integrate multiple information from museum exhibits (within and across exhibition objects, labels, etc.). There is a lack of research on the impact of cognitive capacity on DIP but I argue that research results from formal contexts can be transferred to informal settings like museums, too.

However, not only cognitive, also motivational learner characteristics influence DIP: For example, a learner's amount of invested mental effort is partly based on his perceived self-efficacy (Salomon, 1984). While reviewing literature in the context of museums I found hardly any studies addressing motivational and emotional learner characteristics (for an exception see Csikszentmihalyi & Hermanson, 1995, on the importance of intrinsic motivation). As Salomon's theory (1984) assumes a link between emotional-motivational learner characteristics and DIP, an influence of these characteristics on DIP in science museums should be considered in further studies, as well.

4.1.4 Conclusion

Based on the reviewed theories and research, depth of information processing can be considered as an important process variable influencing formal as well as informal learning. A broad range of individual and environmental characteristics determines how deep information is processed in informal learning settings. Next to individual learner characteristics, like self-regulation (see also chapter 3.2), prior knowledge and cognitive capacity, the characteristics of the environment, that is, influences of media and the social context are important. It was shown, that these factors are also relevant for informal learning in the museum. However, it also has to be assumed, that learner and environmental factors interact: For example, Davey (2005) shows that both contribute to visitors' experienced museum fatigue and argues that environmental and learner characteristics interactively influence visitors' information processing.

Therefore, it is important to design an environment in a way which serves different visitors and helps them to engage in deep information processing. In the next chapter I am going to present a possible approach how this can be done.

4.2 A support for deep information processing in the museum context

Visitors normally do not process all information in an exhibition deeply but engage in more and less deep phases alternatively. Rounds (2004) argues that such a visiting strategy is useful as visitors should not process each exhibit in an exhibition comprehensively but rather should focus on relevant exhibits and sweep through the rest of the exhibition. But how can visitors identify the exhibits which are relevant for them? Rounds suggests that they use heuristics and quickly scan for exhibits that intuitively attract them. Such a strategy might be applied by museum visitors who have only a general learning agenda (cp. Falk et al., 1998; Zueck, 1988). But if visitors have a more focused learning goal, they might be easily distracted from this goal by highly attractive exhibits in the environment and loose their focus (cp. Briseño-Garzón et al., 2007). So, visitor dyads who are aware of a shared learning goal, as was suggested as a support for learning in museums in chapter 3.4, might be further supported by provision of tailored information and exhibits that matches their goal. But the question is how to make them engage with the right information and exhibits for their learning goals?

One possibility is to cluster exhibits conceptually (Bitgood, Patterson, & Benefield, 1988; Falk, 1997). This exhibition design feature helps visitors to integrate related exhibits into one concept. It reduces the requirements to search for relevant information and thereby supports learning. A second option is to provide visitors with a conceptual organizer of the exhibition (Falk & Storksdieck, 2005; Zueck, 1988). Similar to exhibit clusters, visitors can integrate conceptually similar exhibits more easily, as they receive the information which exhibits might be relevant. A third possibility is to carefully design labels that address the visitors' most important goals and attract their attention (Bitgood, 2000).

A problem of all three approaches is that a museum would need to know what the most important goals for visitors are. Bitgood (2000) suggests using evaluation for effective label design. Still, one exhibit should be able to serve different goals and visitors with different prior knowledge. As learners come with different prerequisites (e.g., prior knowledge, goals) for interaction with an exhibit, they should be given the opportunity to access the exhibit's information in multiple ways. Ash (2004) argues that exhibits should be designed to provide multiple entry points to the "zone of proximal development".[5]

Possibilities for reaching this multifunctionality of one exhibit are personal tours or thematic exhibition guides; or by means of adaptive new media applications. Adaptive systems produce a better fit between the learning environment and the learner and reduce requirements for self-regulation (Leutner, 2004). Therefore, adaptivity is especially effective in open learning environments like informal learning settings that require a high degree of self-regulation. "AH [Adaptive hypermedia] systems can be useful in any application area where a hypermedia system is expected to be used by people with different goals and knowledge" (Brusilovsky, 2003, p. 488). In combination with an aware goal (see chapter 3.4), visitors are supported by adapted provision of relevant information as it re-contextualizes a selected exhibit with respect to this goal. Information that fits visitors' goals reduces the amount of mental effort needed to relate this information to their goals and existing knowledge structures. At the same time, more cognitive capacities are available to elaborate on the information and process it in a deep manner. Additionally, adaptation of content towards learners' goals maintains the awareness of this goal throughout the visit and avoids distraction. Adaptation allows for free choice of exhibits but connects each chosen exhibit to a learner's goal. Thereby, goal-related deep processing of information is possible even though the visitor might select exhibits based on their salience and intuitive attraction. Deep information processing, in turn, leads to higher-level learning outcomes.

[5] The potential for cognitive development depends upon the zone of proximal development (ZPD), a level of development that learners can attain when they engage in social behavior (Vygotsky, 1978, 1986). Learning happens by means of building on ideas provided by others during conversation about an exhibit within the ZPD. The concept of conversational elaboration (Leinhardt & Crowley, 1998) directly builds upon Vygotsky's work.

Quite some adaptive information systems have already been introduced in museums (e.g., Exploratorium, 2001; 2005; Not, Petrelli, Stock, Strapparava, & Zancanaro, 1997; Stock et al., 2007). But most research on adaptive systems in the museum context has focused on technical development (e.g., Oppermann & Specht, 2000) or on visitor acceptance (e.g., Goren-Bar, Graziola, Pianesi, & Zancanaro, 2006), but not on influences on learning processes and outcomes. This dissertation might help to close this gap.

4.3 Adaptive hypermedia as support for deep information processing

Adaptive programming and personalized content for a visitor allow tailoring information to the interests and capabilities of a specific visitor (Naismith, Lonsdale, Vavoula, & Sharples, 2004). Adaptive systems build a model of the visitor and use this model for further interaction (Brusilovsky, 2003). This model can either be created based on explicit or implicit user-input: For explicit adaptation (also macro-adaptivity, cp. Leutner, 2004) visitors provide information about their interests first and receive information, which matches these interests (cp. Goren-Bar et al., 2006; Not et al., 1997). Implicit adaptation (also micro-adaptivity, cp. Leutner, 2004) uses inferences based on visitor behavior (e.g., prior visited exhibits) to create a visitor profile without visitors explicitly providing information (Not et al., 1997; Petrelli & Not, 2005). Goren-Bar and colleagues (2006), revealed high interindividual differences in acceptance and preference of implicit adaptation of mobile museum guides: Depending on personality factors (conscientiousness, emotional stability, locus of control) visitors accepted implicitly adaptive mobile guides to a different extent. Therefore, explicit adaptation should be preferred.

Adaptation can concern selection of information about exhibits, recommendations of interesting exhibits, or presentation format (Wessel & Mayr, 2007). Teo (2005) provided visitors to the Singapore Science Center with an explicitly adapted guided tour based on interests and time budget. This application helps visitors to find relevant exhibits, but cannot avoid that attractive exhibits divert visitors' attention. Additionally, an important aspect of informal learning – free-choice of learning activities and objects (cp. Dierking & Falk, 1998) – diminishes.

More interesting approaches to adaptivity are, therefore, those that adapt the information on exhibits (i.e., labels, additional information on a guide) to individual learner characteristics. To provide personalized information additional and specified content is needed. Ideally, an "intelligent" semantic analysis of visitors' goals and a huge content pool to select adaptive content from should be developed. But this is beyond the possibilities and the focus of this dissertation. The creation of specific texts considering prototypical learning goals is a possible low-tech-solution that is chosen in this research project (Mayr, 2007), as it focuses on the potentials of adaptivity for deep goal-directed information processing rather than technical solutions. For this purpose a low-tech-solution seemed sufficient.

Four parallel text sets were developed that satisfy four different learning goals which are addressed in some parts of the exhibition. As outlined in chapter 3.5, this procedure is no problem due to the exhibition's topic, nanotechnology; little knowledge on this theme exists in society (Waldron et al., 2006) and, therefore, no highly specific learning goals on this topic could be expected. Visitors were asked to select a shared learning goal from the list of four goals at the beginning of their visit and could retrieve information adapted to this goal from a mobile device for each exhibit during their visit.

Before presenting the aims of this research projects, I will discuss methodological considerations that are relevant for the studies conducted.

5 Methodological considerations

The very nature of such learning requires multiple, creative methods for assessing it in a variety of circumstances. Thus, innovative research designs, methods, and analyses are critical. (Dierking et al., 2003, p. 110)

Museums as informal learning environments are quite different from “typical” psychological research settings. To conduct valid research on learning in museums some methodological questions have to be carefully considered. To reduce external influences I decided to conduct research in a laboratory setting. As a consequence I address the question of validity first. A second challenge was the assessment of two main constructs used in this dissertation, namely, depth of processing and learning. A third consideration arises out of the dyadic visiting situation: How can the resulting data be analyzed in the best way?

5.1 Studying learning in museums in the laboratory

A huge problem in informal learning is the high variability of visiting situations, behavior, and outcomes (e.g., Griffin & Symington, 1998). To reduce variability the studies within this dissertation were conducted in a laboratory setting as experiments. To conduct research on informal learning in the laboratory the question of validity has to be addressed. For the research design of my dissertation, I looked once more at the characteristics of informal learning and asked myself how a research setting in the laboratory has to be designed to resemble these characteristics. Table 2 gives an overview on the decisions I made.

Table 2. Characteristics of informal learning and consequences for the research design

Characteristic of the museum as informal learning setting	*Decisions for the research design*
Very heterogeneous visitor groups	Restrict sample to one group of visitors
Absence of instructions, free-choice, little guidance	Provide free-choice in exhibit selection and only little guidance
No social roles	Use peers as visitor groups with equal roles
Free allocation of time	No time restrictions for the visit
Leisure setting, Incidental learning	No learning instruction, avoid learning expectation

As stated in chapter 2.4, for the *sample* I focus only on one group of visitors, namely adult dyads. Quite some research exists already on family and school groups (e.g., Crowley & Jacobs, 2002; Griffin, 2004). In contrast, adult dyads have received less attention (for exceptions see Abu-Shumays & Leinhardt, 2002; McManus, 1987a, 1987b). Additionally, they resemble a collaborative situation, where both members of the dyad equally contribute and co-construct knowledge.

> I suggest that groups which have good social relationships and, presumably, communicate well with each other, also communicate well with exhibits in that they attend to them and are likely to admit exhibit messages to their conversations and thoughts. Unfortunately, we cannot choose our publics on the quality of their social interactions! (McManus, 1987b, p. 40)

Fortunately, in an experimental setting it is possible to choose visitors. I conduct research on pairs of acquaintances (e.g., couples, flat mates, or friends). These dyads have a joint history which serves as a common ground in their conversation. They can relate their visiting experiences to prior personal experiences. Though this is a resource of additional variance within the dyads (see Kenny, Kannetti, Pierro, Livi, & Kashy, 2002, p. 127), relating the information in the exhibition to personal experiences is an important activity in visiting groups (Packer & Ballantyne, 2005) and assists conversational elaboration (Leinhardt & Crowley, 1998; Leinhardt & Knutson, 2004).

In line with a real museum setting, during the visit of the exhibition *little structure* is provided: Visitors are free to select the information and exhibits they want. No roles are assigned to the members of the dyad. They do not have any time restrictions.

For the research environment of this study a *setting* as realistic as possible is chosen to conduct valid research on informal learning. As the Knowledge Media Research Center is associated with research on learning, students from the institute's subject pool are avoided. Additionally, a learning-unrelated study title is communicated in advertising and instruction so that no learning expectation can arise.

Participants in my study have the possibility of *choice*; this requires an exhibition – or at least a part of it, that contains a certain amount of exhibits and thereby allows for study participants' free choice of information (cp. Corredor, 2006). The chosen exhibition is big enough to require selection of information but still small enough to conduct research in a controlled setting.

5.2 Assessment questions

„Quantitative measures of learning can only be achieved by manipulating the system and in doing so the system now understood is not the one that was originally investigated" (Griffin & Symington, 1998, p. 1). Still quantitative measures can be analyzed statistically and results can be easier generalized. Therefore, an important question is the development of quantitative measures for depth of information processing (DIP) and for learning.

5.2.1 Assessing depth of information processing

One of the major challenges of the DIP concept is the question how it can be measured objectively (Craik, 2002). Many studies rely on subjective measures (e.g., Salomon, 1984;

Sweller et al., 1998) or conclude that information was processed deeply from the outcomes. In this chapter I will present some possibilities of measuring DIP introduced in literature – process (online), retrospective and outcome (offline) measures (cp. Table 3) – and discuss their usefulness for the assessment of DIP with respect to this research project.

Table 3. Methods of DIP assessment

Process measures		Outcome measures
Online	Retrospective	
Eye tracking	Time on task	Knowledge acquisition
Time on task	Self-report process measures	
Conversation analysis		

Online process measures

Eye tracking. Craik (2002) suggests the use of neurophysiological measures as an objective index of DIP. He reports evidence that evoked potentials (cp. Nyberg, 2002), eye movements, and heart rates serve as valid indicators of DIP. These measures can, however, be applied in informal learning only with difficulties as many of them are highly invasive and will influence the informality of a setting. There exists the possibility to use mobile eye-tracking data in the museum setting, but it is highly obtrusive (Mayr, Knipfer, & Wessel, 2009; Wessel, Mayr, & Knipfer, 2007). Still, fixation duration can serve as indicator for DIP (for an extensive review of different hypotheses concerning the relation of 'eye' and 'mind' see Kliegl, Nuthmann, & Engbert, 2006).

Think aloud protocols. During thinking aloud participants are continuously reporting what is processed in their working memory while executing a task. These verbalizations are considered as being related to cognitive processes. According to proponents of this method only little information is lost and the actual (meta-)cognitive processes, motivational factors, and the influence of context can be captured (Schellings, Aarnoutse, & van Leeuwe, 2006). Opponents of think aloud methodology contrast that not all thoughts (e.g., non-conscious) can be verbalized and that there are large intra- and interindividual differences regarding the ability to think aloud and verbalize thoughts. Furthermore, it is unclear whether the reported thoughts would be generated without the demand to think aloud or if they are triggered by the method itself (Graesser et al., 2007). Some authors postulate that thinking aloud does not interfere with the actual task; however, think aloud protocols can only be applied if there are sufficient resources available in working memory to formulate the thoughts into words.

To my knowledge, hardly any research in museum context exists where think aloud protocols were applied (for an exception see Corredor, 2006). In informal contexts it might be too invasive to apply, but it might give interesting insights if used by designers and researchers introspectively[6].

With respect to the natural social situation in a science museum, *conversation* among visitors is more relevant for analyzing depth of processing: Leinhardt and Crowley (1998) consider conversation as crucial elaboration activity, conversational analysis can highlight deep processing of presented information (Leinhardt & Knutson, 2004) and might be a more appropriate instrument for research on DIP compared to think aloud protocols.

Retrospective process measures

Time on task. A rather simple indicator of elaboration processes is time on task (or in museum research: holding power of an exhibit). Some studies indicate a relationship between duration of processing and memory (Craik, 2002). Time on task or holding power is a highly general measure of cognitive activity and is not necessarily an indicator of DIP or learning at all. However, several studies in the museum context have shown significant relationships between holding power and outcome measures (Serrell, 1997). Time on task surely is a critical prerequisite for learning. Still, there seem to be differential influences depending on the information itself (e.g., amount of elaboration needed) and learner's expertise. But if time is taken relatively (e.g., time on an exhibit in relation to the average visiting time), it might be a useful index for depth of processing in museums.

Self-report measures. One of the most used – and most often criticized – measurement methods for DIP are self-report questionnaires. They are easy to apply even in informal settings as the concept in focus is assessed retrospectively. For example, Salomon (1984) asked his subjects four questions on their amount of invested mental effort: (1) How hard did you try to understand the film (story)? (2) How hard did your friends in the room try to understand the film (story)? (3) How much did you concentrate while watching (reading)? (4) How easy to understand was the TV (or story) for you? Another popular self report questionnaire in the context of Cognitive Load Theory is the NASA-TLX (Hart & Staveland, 1988). Self-report measures assume that depth of processing is a cognitive activity and accessible consciously. This assumption is often questioned. It is especially questioned whether learners are capable of making correct assumptions about their cognitive processes post-hoc. To improve the validity of self-report methods it is necessary to validate them with other online measurement methods which focus on the process level of cognitive processing (e.g., time on task).

Outcome Measures

A frequent criticism of levels of processing theory (Craik & Lockhart, 1972) is its tight association with specific outcome measures: Morris, Bransford, and Franks (1977; see also Lockhart, 2002) assume that processing has to be appropriate for the kind of recall measure

[6] Kaminsiki (2007) visited the exhibition used in this dissertation in 2007 and recorded his thoughts online. Later he analyzed his think-aloud-protocol to generate a model of information processing in exhibitions.

used afterwards. However, such “transfer appropriate processing” holds only if an assessment is applied after processing of information. As one characteristic of informal learning is the absence of assessments, the theory of transfer appropriate processing cannot be applied. Still it shows the relevance of choosing an appropriate outcome measure.

Acquisition of knowledge. The levels of processing framework (Craik & Lockhart, 1972; Craik & Tulving, 1975) assumes that deeper levels of processing result in stronger memory traces and better learning. The question how knowledge gained from informal learning can be assessed is very important (Mayr, Knipfer, & Hesse, 2006). One possibility would be to use open questions as they allow the assessment of shallow as well as deeper knowledge. For example, Falk and colleagues (1998) used concept maps to assess breadth and depth of knowledge acquisition. Another possibility is usage of multiple choice questions where full knowledge, partial knowledge, and absence of knowledge can be indicated by learners themselves. Ben-Simon, Budescu, and Nevo (1997, p. 65) define partial knowledge as a subjective state where “an examinee knows only part of the answer or is uncertain of the answer”. As knowledge in informal settings is often gained incidentally (Malcolm et al., 2003) gain of partial knowledge seems more appropriate as a learning outcome. However, if information is processed on a deeper level, full knowledge is more likely to result.

Until now, studies on DIP in museums use quite different assessment methods: Corredor (2006) used think aloud protocols and time on task, the Museum Learning Collaborative (e.g., Leinhardt & Knutson, 2004) conversational analysis, Packer and Ballantyne (2002) self-report measures, and Falk and Colleagues (1998) outcome measures. To gain more general results on DIP in museums, it is necessary to triangulate online and offline process and outcome measures.

Consequently, I apply different measures in this dissertation, namely, time on task (exploration duration of specific information), self-report measures (similar to the ones used by Salomon, 1984), outcome measures (multiple choice tests where participants can indicate full, partial, and absence of knowledge), and – at least in a small case study – eyetracking. By comparing and combining different assessment methods I hope to contribute to our understanding of and research on DIP in museums.

5.2.2 Assessing learning in museums

As outlined in chapter 2.2 quite different assumptions exist what constitutes learning in museums and how it should be assessed: Conversational elaboration (Allen, 2002; Leinhardt & Crowley, 1998), conceptual change (Anderson, Lucas et al., 2003), the development of scientific literacy and Public Understanding of Science (Durant, 1992; Miles & Tout, 1992; Miller, 2001; G. Thomas & Durant, 1987), development of personal meaning (Falk et al., 1998; Lelliott, 2009), acquisition of expert knowledge (Zueck, 1988), and interest generation (Lewalter & Geyer, 2007; Wessel, 2007).

Some researchers propose process data as more valid indicators for learning than outcome measures. For example, vom Lehn, Heath, and Hindmarsh (2002) rely on video data of visitors' behaviour to identify learning activities at the museum. Similarly, Leinhardt and Crowley (1998) use conversation protocols to gain insight into elaboration processes. However, these process measures provide only insights into how information is processed, but not into how and whether this information is integrated in memory traces and results in learning. Therefore, I argue that learning outcomes should be assessed too (in combination with process variables) rather than process indicators only. But the question how to assess knowledge acquisition is still tricky.

Many authors argue that learning defined like in formal schooling does not fit to informal settings like museums (e.g., Martin, 2004; Schauble et al., 1997). Two different approaches to meet this challenge were already presented in the last chapter; the use of concept maps ("Personal meaning mapping", Falk et al., 1998) and the introduction of partial knowledge. The idea of concept maps was already taken up by other researchers in the museum contexts (e.g., Lelliott, 2009), but analysis of these maps is quite laborious. Multiple choice questions are easier to analyze and were already used in museum research once by Zueck (1988). However, she did not find any effects in her study; indicating that this methodology might not suit the kind of processing and learning present in informal learning. I hope that by extending the methodology by the possibility to indicate full and partial knowledge (Ben-Simon et al., 1997) multiple-choice questions will gain in usefulness for museum-related research.

5.3 Dyadic data analysis

This dissertation focuses on collaborative learning in museums and participants go through the study procedures as a dyad, but fill out a questionnaire individually after the visit. This results in individual as well as dyadic data. A problem arises due to nonindependence, that is, similarity within dyads, of individual data. Three factors influence this group effect: First, as I recruit natural dyads (acquainted persons) they are already more similar to each other than dyads which are generated only for the purpose of a study (*compositional effect*, cp. Kenny et al., 2002, p. 127). Second, participants visit an exhibition together; they have the same environmental influences and receive the same information during the experiment (*common fate*, cp. Kenny et al., 2002, p. 127). Third, by means of conversational elaboration they influence the evaluation and elaboration of information in the exhibition during the visit (*mutual influence*, Kenny et al., 2002, p. 127). The nonindependence caused by these three factors influences the individual's answers on the questionnaire and makes data more similar within a dyad than across dyads.

A measure for this similarity is the intra-class-correlation (ICC). If the ICC is significant Kenny, Kashy and Cook (2006) recommend analyzing data at a dyadic level. As this procedure reduces sample size and, therefore, power of analysis, a better solution offers hierarchical linear modeling (cp. Hox, 2002; Raudenbush & Bryk, 2002). However, the 30-30-rule of thumb (30 individuals per group, 30 groups) is violated in research on groups with two members. Simulation studies (e.g., Maas & Hox, 2005) show that the number of groups is more important for parameter estimation than group size. However, no simulation studies exist for groups as small as two members and such an analysis would require a huge number of dyads.

Due to these restrictions and deficits in my statistical know-how regarding multilevel analysis, I decided to use a different strategy in this dissertation: I analyze questionnaire data for this study on the individual level. But if the analysis contains variables on visiting behavior – which are only available on dyadic level – I analyze data on the dyadic level, as Kenny and colleagues (2006) suggest.

6 Aims of this Research Project

The central aim of this research project is to empirical test the two approaches described in chapters 3.4 and 4.2, namely setting learning goals and supporting deep information processing, in a virtual and a real exhibition; whether or not they can enhance learning in museums as was postulated in chapter 2.4. To test this assumption I integrate the theoretical part presented so far in a model on collaborative learning in museums. In this chapter, I present the main research questions of my dissertation and delineate assumptions from literature.

6.1 Collaborative learning in museums – A research model

In chapter 3, I introduced *learning goals* as an important driver of information processing during a museum visit. In visitor groups, shared goals which are aware to all members of the group are powerful for guiding information processing (Hinsz et al., 1997; Tindale & Kameda, 2000) and shared regulation processes (Hadwin & Oshige, 2007; Volet et al., 2009). With respect to these goals, information is selected, evaluated as (ir)relevant, enriched with elaborations – in visitor groups for example in conversation (Leinhardt & Knutson, 2004) –, and embedded in existing memory structures (cp. Figure 2).

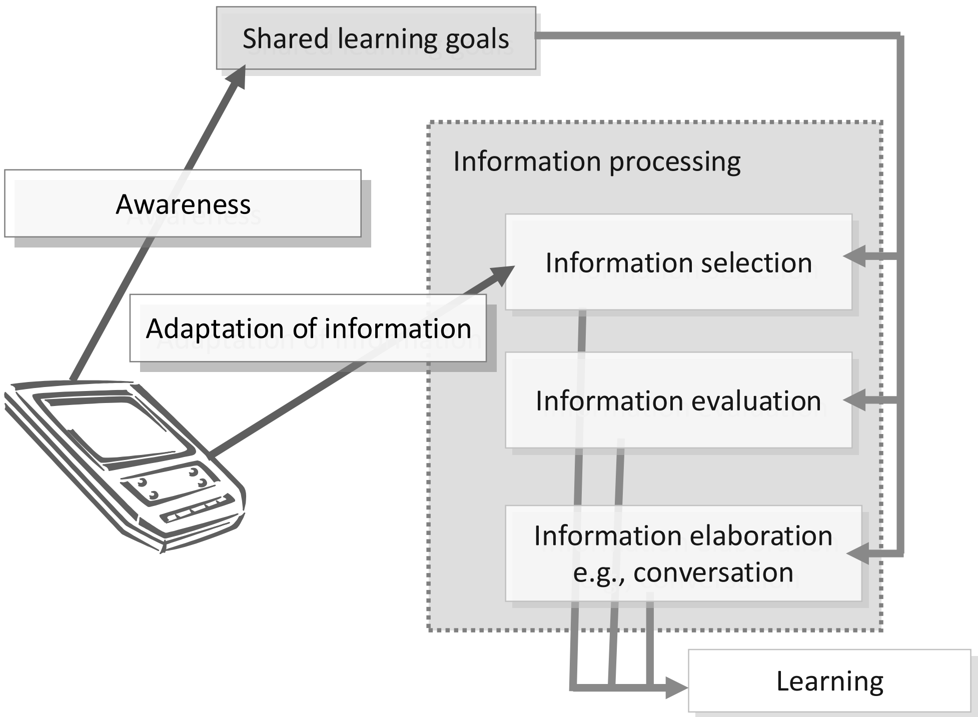


Figure 2. Integrated model of goal-oriented collaborative learning in museums

In museums, the awareness of a goal can be disrupted by attractive exhibits that are not related to this goal (Briseño-Garzón et al., 2007). By *adaptation of information* to this goal, the awareness of this goal can be maintained throughout the visit. In addition, less effort has to be invested in selection of information based on high-level cues (i.e., goal-relevance), but rather low-level cues (i.e., attractiveness of exhibits) can guide the choice of exhibits. Adapted additional information relates selected exhibits to the aware goal (Brusilovsky, 2003), reduces requirements for self-regulation (Leutner, 2004), and frees cognitive resources for deep processing and elaboration of information.

6.2 Research questions

This dissertation wants to empirically prove the two ideas how information processing and learning in museums can be supported, namely awareness of a shared learning goal and adaptation of information to this goal. As a third question, I want to compare their effects in a virtual and a real exhibition.

Question 1: Can awareness of a shared learning goal support information processing and learning in an exhibition?

Whereas Rothkopf and Billington (1979) observed overall shorter processing of information, other studies (e.g., Schnotz & Zink, 1997) especially in the museum context (Falk et al., 1998; Zueck, 1988) report longer processing of information of visitors with a learning goal. Especially, they take more time on goal-relevant content (Corredor, 2006; Rothkopf & Billington, 1979; Schnotz & Zink, 1997). Therefore, it can be assumed that visitor dyads with awareness of a shared learning goal will select more goal-relevant exhibits and will explore them longer than goal-irrelevant exhibits.

Learning goals lead to deeper processing of information (Shapiro & Niederhauser, 2004, p. 615) and more elaboration of relevant content (Corredor, 2006; Leinhardt & Knutson, 2004). Therefore, it is assumed that with awareness of shared learning goals visitors subjectively report deeper processing than visitors without awareness.

Research on learning goals and knowledge acquisition shows a positive effect of goals on learning (Zumbach & Reimann, 2002), especially on goal-relevant knowledge (Rothkopf & Billington, 1979). Also in museums visitors with a more focused visiting strategy were found to gain higher mastery knowledge (Falk et al., 1998). Only Zueck (1988) did not find any difference in knowledge acquisition. I assume that this is due to the fact that she cued the visitors that a knowledge test will follow; thereby, she formalized the research setting. Therefore, I assume with respect to learning that with awareness of a shared learning goal visitors gain more goal-relevant and more knowledge overall than visitors without awareness of a shared learning goal.

***Question 2:* Can adaptation of information to a shared learning goal further support information processing and learning in an exhibition?**

Adaptive hypermedia adjust the presentation of information to the needs, for example, goals, of visitors (Brusilovsky, 2003). Therefore, it reduces the requirements to search for goal-relevant information and supports visitors' self-regulatory processes (Leutner, 2004). Consequently more uniform selection and processing of information can be expected, visitors should select goal-relevant and goal-irrelevant exhibits alike and process them to a similar extent.

With learning goals goal-relevant content is processed more deeply (Corredor, 2006; Leinhardt & Knutson, 2004; Shapiro & Niederhauser, 2004, p. 615). As adaptation increases the amount of goal-relevant information, it is assumed that these visitors subjectively experience deeper processing than visitors without adaptation.

Adaptation of information leads to a more coherent presentation of information and, thereby, can support visitors in building a more coherent mental model of the exhibition (Oberlander, Mellish, O'Donnell, & Knott, 1997). Thereby, it further supports the acquisition of goal-relevant knowledge. At the same time, visitors also process goal-irrelevant information, which is linked to their goal by the adapted information. Therefore, visitors who receive adapted information should gain a similar amount of goal-relevant and goal-irrelevant knowledge. Additionally they should acquire more knowledge than visitors without adaptation.

Question 3: Is information processing with respect to questions 1 and 2 similar in a virtual exhibition and in a laboratory exhibition?

Research shows that real exhibitions are in favor of virtual exhibitions with respect to the exhibit experience (Eberbach & Crowley, 2005; Frost, 2002; Lincoln, 2006; Schweibenz, 2004). However, virtual exhibits promote different kinds of questions and reflections than real exhibits (Eberbach & Crowley, 2005). Visitors to a virtual exhibition do acquire more knowledge than visitors to a real exhibition (Lincoln, 2006). An explanation could be that a virtual exhibition activates more learning associations whereas a real exhibition activates more leisure associations. Therefore, I assume that visitors to a virtual exhibition do process information more deeply than in a real exhibition and more similar to formal learning settings. As a consequence, visitors to the virtual exhibition should also acquire more knowledge.

In the following two chapters I present the empirical studies which aim to answer these research questions, first a study in a virtual exhibition and second a study in a real exhibition.

7 Study 1: Virtual Museum

This study addressed the question, whether awareness of a shared learning goal and adaptation of information to this goal can support collaborative information processing in a virtual exhibition on Nanotechnology and consequently learning from this exhibition.

7.1 Hypothesis

Based on the research questions and the assumptions presented in chapter 6.2, the following hypotheses[7] were formulated with respect to **awareness of a shared learning goal**:

Hypothesis AwI1: With awareness of shared learning goals visitors select more goal-relevant than goal-irrelevant exhibits.

Hypothesis AwI2: With awareness of shared learning goals visitors take more time to process goal-relevant information than to process goal-irrelevant information.

Hypothesis AwD1: With awareness of shared learning goals visitors report deeper processing than visitors without awareness.

Hypothesis AwL1: With awareness of shared learning goals visitors gain more goal-relevant than goal-irrelevant knowledge.

Hypothesis AwL2: With awareness of shared learning goals visitors gain more knowledge than visitors without awareness of shared learning goals.

The following hypotheses were formulated for **adaptation of information**:

Hypothesis AdI1: With adaptation of information visitors are equally likely to select goal-relevant and goal-irrelevant exhibits.

Hypothesis AdI2: With adaptation of information visitors process goal-relevant exhibits as long as goal-irrelevant exhibits.

Hypothesis AdD1: With adaptation of information visitors report deeper processing than visitors without adaptation.

Hypothesis AdL1: With adaptation of information visitors gain a similar amount of goal-relevant and goal-irrelevant knowledge.

Hypothesis AdL2: With adaptation of information visitors gain more knowledge than without adaptation.

[7] The code of the hypotheses was generated to make it easier to associate them with the research questions. The first two letters refer to the manipulation (Aw … awareness, Ad … adaptation), the third letter refers to the dependent variable (I … information processing, D … depth of processing, L … learning), and the number is an index within this category.

7.2 *Methods*

As outlined in chapter 5, the methods of this study were carefully designed to provide a setting that is as informal as possible. The study was conducted in February and March 2006 in Tübingen (Germany).

7.2.1 Research design

In this study, I used a nested design[8] (see Table 4). In condition 1 information is adapted explicitly to user input; visitors are asked to state a shared learning goal and are presented information that matches this goal. In condition 2 visitors are made aware of their shared goal in the same way, but information is not adapted to this goal. In a control condition (condition 3) neither goals are made aware nor is information adapted.

Table 4. Research design of study 1

	Condition 1	Condition 2	Condition 3 (Control)
Awareness of shared goals	Yes	Yes	No
Adaptation of information	Yes	No	No

Awareness of shared goals is manipulated by asking visitor dyads to find or negotiate a shared learning goal for the following visit of the exhibition. Adaptation of information is manipulated via the presentation of additional information that matched the visitor dyad's shared goal. To make sure that effects of adaptation are not due to the presentation of additional information, dyads in conditions 2 and 3 (without adaptation of information) receive additional information as well. However, this information is not related to their goal but is rather random.

Comparison of conditions 2 and 3 provides information on the effects of awareness of a shared goal. Conditions 1 and 2 are compared for information on the effect of adapting information, when shared goals are aware to visitor dyads.

7.2.2 Sample

Dyads of acquainted subjects were recruited for a study on communication in museums. This cover story is used to reduce expectations of a learning-related study, because a pilot study showed that subjects participate with a learning intention otherwise. As participants with a learning intention would act more similar to formal learning and would reduce the size of the expected effect, a learning-unrelated-instruction and study title are used.

Participants receive 8 Euros per hour ($M = 1.8$ h or 14.02 €) or study credits for their participation in this study.

[8] A full 2x2 design cannot be realized, because adaptation of information requires the presence of goals.

Overall, 94 participants in 47 dyads[9] took part and were randomized to the three conditions (16 dyads in each, condition 1 and 2, 15 dyads in condition 3). Most dyads were same sex (63 %, 8 male, 22 female). Relationships included friends (31 %), flat mates (27 %), couples (26 %), fellow students (10 %), and siblings (6 %). Nearly all dyads reported to know each other well (96 %) and their answers on the relationship were significantly correlated indicating a close relationship (ICC = .30, $F[46,47] = 1.86$, $p = .02$).

Many dyads (41 %) visited an exhibition together the first time; another 44 % went to an exhibition with their study co-visitor only seldom or occasionally; only a small proportion reported that they visited exhibitions together often (13 %) or very often (3 %). Still, most study participants visit a museum regularly: once a year (35 %), several times a year (44 %), once a month (12 %), or several times a month (6 %).

The participants were between 18 and 56 years old ($M = 23.68$, $SD = 5.36$). Most hold at least a high school diploma (96 %).

7.2.3 Material and technology

A small exhibition on Nanotechnology ("Nanodialogue", by the European Commission) serves as research setting in this project. A virtual version of the exhibition – identical in content and complexity – was created and is presented in the form of a graphical hypertext (with imagemaps). The hypertext contains four layers (see Figure 3a-d): the whole exhibition on layer 1, 7 exhibition parts (walls, tables) on layer 2, 44 exhibits and 20 texts on layer 3, and 44 exhibit-related texts on layer 4. Visitors can navigate by clicking on the selected part of the exhibition (highlighted by red borders) to go to the next layer or by using the small navigation images in the left column to go back to a higher layer. The whole hypertext consists of 116 pages. The exhibition's size enables research on this exhibition in a research laboratory under controlled conditions; but it is still complex enough to require information selection by visitors.

For all exhibits and texts on level 3, four parallel text sets with according images have been created from literature on nanotechnology, providing information serving four different learning goals (cp. chapter 4.3): chances & risks of nanotechnology, influences on society, impact in daily life, and background information. The information is adaptively presented to dyads according to their shared learning goal in condition 1, whereas dyads in conditions 2 and 3 receive random text versions for each exhibit serving different learning goals. This additional information is presented on the representation of a Pocket PC on the right side of the screen (see Figure 3e) when a visitor selects an exhibit on level 3.

[9] A meta-analysis on the effect of group goals on group performance by O'Leary-Kelly and colleagues (1994) indicates an effect size of d = 0.92. A power analysis with G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) revealed that 32 participants are required to find an effect of this size. As a second independent variable – the adaptation of information – was introduced I planned additional participants for the third condition. A minimal sample size of 48 participants emerged. As this study is conducted in an informal learning environment and focuses on groups rather than on individuals I planned to recruit twice as many participants to be able to conduct analyses on the individual and dyadic level.

Figure 3. Design of the virtual exhibition Nanodialogue: layer 1 (a), 2 (b), 3 (c), and 4 (d) and pocket PC (e)

For the interaction with this exhibition visitors do not use a standard monitor and a mouse, but a smartboard: This allows, on the one hand, a bigger visual presentation of the exhibition accessible to more people and, on the other hand, input by touch from both participants alike, though not at the same time.

7.2.4 Procedure

Participants go through this experiment as a dyad, without other participants present. Before receiving a microphone each, they are told that they participate in a study on communication in museums and that they are going to visit a virtual exhibition on the smart board. To familiarize participants with navigation on the smartboard they explore a small graphical hypertext based on a zoo map first.

Before exploration of the exhibition, dyads in conditions 1 and 2 are made aware of a shared goal: They are asked to select a learning goal first of individual and then of shared interest from the list of four topics. All topics are addressed in the exhibition but each one by some exhibits only. Dyads in the control condition (condition 3) receive a small introductory text providing the same information that the exhibition addresses these four topics.

Dyads visit the laboratory exhibition without time constraints. During the visit they receive additional information on the PDA-image on the right side of the screen: in condition 1 information adapted to the dyad's shared interests and in conditions 2 and 3 random information matching any of the four topics.

After the visit, participants fill out a questionnaire on their visiting experience and knowledge gains. This questionnaire is answered by each participant individually.

In the end, participants are debriefed with regard to the aim of the study and are rewarded for participation.

7.2.5 Measures

Logfiles of the hypertext and the Pocket PC provide different measures of users' exploration behavior: Besides the overall visit duration, the mean time of processing for each layer in the virtual exhibition and for the PDA is calculated. Also the overall number of exhibits visited is derived from the logfiles. In a second step, the exploration duration and the number of explored exhibits were differentiated with respect to the exhibit's and the additional information's goal-relevance.

To assess depth of processing, the self-report-measures by Salomon (1984) were adapted to the setting of visiting a museum (see Figure 4). Additionally, subjects were asked to compare the mental effort they invested to process information in the virtual exhibition with the mental effort usually required to process information in seven other everyday situations (reading a newspaper, visiting other exhibitions, learning, reading a contract, watching news on TV, thematic conversation with friends, visiting a cinema). Further indicators for depth of processing were retrieved from the logfiles (exploration duration) and knowledge test (see chapter 5.2.1).

How much effort did you need to understand the exhibition content?

very much ❍ ❍ ❍ ❍ ❍ absolutely not

Did the exhibition content stimulate further thought?

very much ❍ ❍ ❍ ❍ ❍ absolutely not

How much did you concentrate on the content while visiting the exhibition?

very much ❍ ❍ ❍ ❍ ❍ absolutely not

Figure 4. Self-report measures for depth of processing

Learning was assessed by a knowledge test. As many researchers in the museum context criticize the use of formal assessment methods like knowledge tests (e.g., Allen, 2002; Donald, 1991; Griffin & Symington, 1998) participants could also indicate for each question partial or full knowledge (Ben-Simon et al., 1997, see chapter 5.2.2) and absence of knowledge (see Figure 5 for an example). Right and wrong answers were weighted with 1 for full and with 0.5 for partial knowledge. By summing up these values, a weighted knowledge score was calculated. The ratio of full to partial knowledge serves also as an outcome measure of depth of processing.

The influences of nanotechnology on the environment …

	definitely right	probably right	probably wrong	definitely wrong	I don't know
... can be neglected, nothing will change.	❍	❍	❍	❍	❍
... are serious, existing elements can change.	❍	❍	❍	❍	❍
... are positive as well as negative.	❍	❍	❍	❍	❍
... are examined insufficiently until now.	❍	❍	❍	❍	❍

Figure 5. Exemplary multiple choice question

Before answering the knowledge test, visitors reported their prior knowledge on nanotechnology on a single self-report question: "Please, think back prior to visiting the exhibition. How many knowledge on nanotechnology did you have beforehand?"

7.3 Results and discussion

First, I present and discuss the effects of awareness of shared learning goals; then those of information adaptation.

7.3.1 Awareness of shared goals

To analyze the effects of awareness of shared goals I compared the visiting behavior, depth of processing, and knowledge gains of conditions 2 and 3. Both conditions received random information, but in condition 2 dyads were made aware of a shared learning goal prior to visiting the exhibition.

Visiting behavior

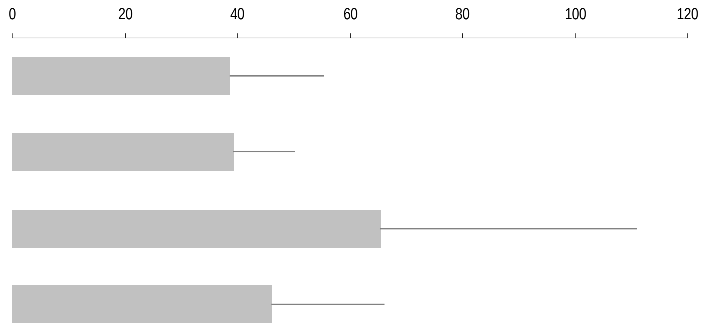
An overview on the visiting behavior of dyads with awareness of shared goals (condition 2) and without (condition 3) is given in the appendix (Table A1). I assumed that participants with awareness of a shared learning goal would select more goal-relevant than goal-irrelevant exhibits (hypothesis AwI1) and process goal-relevant information longer than goal-irrelevant information (hypothesis AwI2). One-sided comparisons were computed to test these hypotheses.

With awareness of a shared learning goal, dyads explored as many goal-relevant as goal-irrelevant exhibits ($M_{goal\text{-}relevant}$ = 26.38, SD = 12.80, $M_{goal\text{-}irrelevant}$ = 26.73, SD = 10.99; t = 0.99, df = 15, p = .170). Therefore, hypotheses AwI1 stating that goal-relevant exhibits are selected more frequently has to be rejected. Even though this result indicates that dyads did not select exhibits in a goal-directed manner, a different explanation is that it was difficult to identify the goal-relevance of exhibits on layer 2 in the virtual exhibition due to the display size and the graphical resolution. If this is the case, visitors have to select an exhibit first and scan the information on layers 3 and 4 to identify the goal-relevance of an exhibit. If this explanation is true, goal-relevant information should be explored longer than goal-irrelevant information.

With respect to the exploration duration visitors with awareness of shared goals tended to process goal-irrelevant exhibits longer than goal-relevant exhibits ($M_{goal\text{-}relevant}$ = 38.02 seconds, SD = 13.52, $M_{goal\text{-}irrelevant}$ = 39.76, SD = 14.32; t = -1.57, df = 15, p = .069). At first sight, this result contradicts hypotheses AwI2 which assumes that with awareness of shared learning goals dyads explore goal-relevant information longer. However, conditions 2 and 3 differed significantly in the variance of the overall duration of exploration on layers 3 (F = 7.76, p = .009) and 4 (F = 4.41, p = .045): Dyads with awareness of a shared learning goal acted more heterogeneous than dyads without awareness. Therefore, a more differentiated analysis was conducted: As participants randomly received additional information on the PDA, in condition 2 this information sometimes matched the dyad's shared goal (M = 21 %, SD = 3 %) and sometimes it did not (M = 79 %, SD = 3 %). Therefore, it can be compared how long participants in this condition explored goal-irrelevant sites with goal-relevant additional information on the PDA and how long participants explored goal-relevant sites with goal-relevant additional information on the PDA. If goal-irrelevant sites required more mental effort to process, they should be explored longer – especially if the additional information is goal-relevant. Results confirmed this assumption: When the additional information was goal-relevant, goal-relevant sites were explored significantly shorter than goal-irrelevant sites (see Table 5; t = -2.35, df = 13, p = .035). But this holds only for goal-relevant information: If the additional information is goal-irrelevant, no significant difference between the exploration duration of goal-relevant and goal-irrelevant exhibits is found (see Table 5; t = 1.37, df = 13, p = .098). This result partially confirms hypothesis AwI2 which assumed that visitors explore goal-relevant information longer than goal-irrelevant information as in other studies on goals and learning with hypermedia (Corredor, 2006; Schnotz & Zink, 1997). However, this effect was only found for goal-irrelevant exhibits. This is a reasonable pattern as the value of goal-relevant additional information is highest, when the exhibit per se does not convey similar information. In this case the additional information is more deeply elaborated on and, therefore, explored longer. The effect cannot be explained by "conflicting" information alone (serving the goal on the PDA, but not at the exhibit), as it does not appear for the opposite pattern, that is, goal-relevant exhibits with goal-irrelevant information on the PDA: In this case, similar "conflicting" information is presented but the main information of the exhibits already conveys goal-relevance and the information on the PDA can be neglected, resulting in shorter exploration duration.

Table 5. Average exploration duration in dependence of exhibits' and additional information's goal relevance (seconds)

Exhibit	PDA
goal-relevant	goal-relevant
	goal-irrelevant
goal-irrelevant	goal-relevant
	goal-irrelevant



Overall, visitors with awareness of a shared goal in comparison to visitors without awareness visited significantly less pages on layer 4, that is, the textual information on the exhibits (M_2 = 33.63, SD_2 = 17.28, M_3 = 46.47, SD_3 = 14.07; t = -2.26, df = 29, p = .032). This is another indicator for more selective visiting behavior. Rounds (2004) assumes that quitting rules are applied in museums by strategic visitors (e.g., quit after a certain amount of interesting information or after a certain time). The observed visiting behavior of dyads with awareness of a shared goal indicates that they acted like such strategic visitors and engaged in dyadic self-regulation.

Self-reported depth of information processing

As they engage in more strategic visiting behavior, it was assumed that with awareness of shared learning goals visitors report deeper processing than visitors without awareness (hypothesis AwD1). In contrast to this assumption no differences between participants in conditions 2 and 3 emerged (M_2 = 3.72, SD_2 = 0.45, M_3 = 3.71, SD_3 = 0.55; t = 0.09, df = 60, p = .463). This finding contradicts also results from other studies on learning goals and hypermedia (Corredor, 2006; Shapiro & Niederhauser, 2004). When I took a closer look at the reported depth of processing in this virtual exhibition, I found that participants in both conditions processed the information deeper than in other exhibitions (M_2 = 3.47, SD_2 = 0.80, t_2 = 3.30, df_2 = 31, p_2 = .002; M_2 = 3.53, SD_2 = 0.73, t_3 = 4.00, df_3 = 29, p_3 < .001)[10]. An explanation can be that visitors in condition 3 without awareness of shared learning goals already processed information deeper than in physical exhibitions, indicating that visiting a virtual museum is indeed a more formal situation than a normal museum visit, as the findings by Lincoln (2006) suggest. Therefore, the additional effect of learning goals might be reduced in a virtual exhibition.

[10] A value of 3.00 means similar deep processing in this and other exhibitions, higher values deeper processing in this exhibition. An overview on depth of information processing in the virtual exhibition in comparison to other daily activities can be found in the appendix (Figure A1).

Learning

With awareness of a shared learning goal, I assumed that visitors gain more goal-relevant than goal-irrelevant knowledge (hypothesis AwL1) and that they gain more knowledge than visitors without an aware goal (hypothesis AwL2). However, with awareness of a shared learning goal, participants in condition 2 did gain a similar amount of goal-relevant and goal-irrelevant knowledge ($t = -0.50$, $df = 31$, $p = .310$). They answered 60 % of the knowledge test correctly for goal-relevant ($M = 60.62$ %, $SD = 14.56$) and goal-irrelevant questions ($M = 59.63$ %, $SD = 13.86$). Therefore, hypotheses AwL1 which assumed higher acquisition of goal-relevant knowledge has to be rejected. An explanation for the similar amount of goal-relevant and goal-irrelevant knowledge acquired are the results found on processing of goal-relevant and goal-irrelevant information: No differences in amount of goal-relevant and -irrelevant information explored could be found. Dyads explored goal-irrelevant exhibits even longer when accompanied with goal-relevant information.

Visitors with awareness of shared goals did not differ from learners without awareness in their knowledge acquisition ($M_2 = 57$ %, $SD_2 = 12$ %; $M_3 = 59$ %, $SD_3 = 9$ %; $t = -0.69$, $df = 60$, $p = .246$). Even though this result contradicts hypothesis AwL2, it is in line with the study by Zueck (1988) on learning goals in museums which did not find an effect of specific learning goals on learning outcomes. But still, some research exists that supports the link between learning goals and learning in museums: Falk and colleagues (1998) found an effect of a focused visiting strategy (in the sense of specific goals) on learning outcomes, when they used a mind-mapping technique to assess learning. Similarly, correlations between visitors' learning motivation and their subjective learning experience (Packer & Ballantyne, 2002) and conversational elaboration (Leinhardt & Knutson, 2004) are reported. It seems as if only studies which assessed learning with a knowledge test found no effects (Zueck, 1988).

To sum up, awareness of a shared goal leads to more goal-directed processing of information: Goal-relevant information on goal-irrelevant exhibits is processed longest indicating deep processing of this information. However, no effect on learning was found: Visitors acquired a similar amount of goal-relevant and goal-irrelevant knowledge. Overall, the amount of knowledge acquired was similar for visitors with and without awareness of shared goals. A possible explanation for the missing effect of awareness of a shared goal on knowledge acquisition is that the exhibits only partially satisfied the different learning goals. A huge part of the exhibition is not related to the goal chosen. Therefore, adaptation of information should increase the effect of goals on learning.

7.3.2 Adaptation of information

To analyze the effects of information adaptation, I compared the visiting behavior, depth of processing, and knowledge gains of visitors in conditions 1 and 2. Both conditions were aware of a shared learning goal but while visitors in condition 1 received adapted additional information on the PDA-display visitors in condition 2 received random additional information on the PDA-display.

Visiting behavior

An overview on the visiting behavior of dyads in conditions 1 and 2 is given in the appendix (Table A2). It was assumed that adaptation of information leads to a similar selection (hypothesis AdI1) and processing (hypothesis AdI2) of goal-relevant and goal-irrelevant exhibits.

With respect to the number of exhibits visited, with awareness of a shared learning goal and additional adaptation of information, dyads in condition 1 explored as many goal-relevant as goal-irrelevant exhibits ($M_{goal\text{-}relevant} = 35.00$, $SD = 12.26$, $M_{goal\text{-}irrelevant} = 34.77$, $SD = 10.61$; $t = 0.48$, $df = 15$, $p = .637$). Therefore, hypotheses AdI1 was supported: With additional information which re-contextualizes an exhibit in the context of an aware shared learning goal all exhibits are equally likely to be explored. As these dyads also explored a higher proportion of the exhibition ($M_1 = 69.69$ %, $SD_1 = 17.78$; $M_2 = 54.32$ %, $SD_2 = 21.29$; $t = 2.22$, $df = 30$, $p = .034$, see appendix Table A2), this is an indicator that adaptation reduced requirements for selective behavior: Each selected exhibit relates to a dyad's shared goal and, thereby, reinforces awareness of the shared goal, but also allows a selection behavior that is not based on the criterion of the exhibit's goal-relevance. In contrast, without adaptation of information (condition 2) visitors with an aware learning goal are more selective and explore less information. Strategic visitors to exhibitions apply quitting rules (Rounds, 2004), for example, when their goal is satisfied or no more goal-relevant information seems to be present. With adaptation of information this requirement is reduced, as all information relates to a dyad's shared goal.

However, visitors with adaptation of information did not process all information equally long, but rather explored goal-irrelevant exhibits longer ($M = 38.68$ seconds, $SD = 11.41$) than goal-relevant exhibits ($M = 30.07$ seconds, $SD = 9.73$; $t = -1.80$, $df = 15$, $p = .046$). This result contradicts the hypothesis AdI2 formulated a-priori, but is consistent with the result found for condition 2 with awareness of a shared learning goal but without adaptation: When exhibits are goal-irrelevant, but presented with additional goal-relevant information they are processed longer than goal-relevant exhibits with goal-relevant information. Interestingly, dyads in condition 2 process goal-irrelevant exhibits with goal-relevant information even longer ($M = 65.34$, $SD = 45.64$) than dyads in condition 1 ($M = 38.68$, $SD = 11.41$; $t = -2.13$, $df = 14.42$, $p = .051$). This might be explained by the partial reinforcement in condition 2: Because only at some exhibits the additional information serves the dyad's goal, the value of goal-relevant information for goal-oriented information processing is higher in these dyads. Therefore, they make use of this information more thoroughly in elaboration and take more time on it. This pattern is similar to the one found in Corredor's (2006) study on goal setting on museum websites in which effective goal setters visited less content pages but took more time to explore them and produced more elaborating comments on the content during thinking aloud.

Self-reported depth of information processing

I assumed that with adaptation of information visitors report deeper processing than visitors without adaptation (hypothesis AdD1). But visitors with and without adaptation of information did not differ significantly from each other in their reported depth of information processing ($M_1 = 3.55$, $SD_1 = 0.61$, $M_2 = 3.72$, $SD_2 = 0.45$; $t = -1.30$, $df = 62$, $p = .099$). This result is in contrast to hypothesis AdD1 which assumed deeper processing in condition 1 with adaptation of information.

As in the other two conditions, participants in condition 1, that is, with adaptation of content, report to concentrate more in the virtual exhibition than in other exhibitions ($t = 2.08$, $df = 31$, $p = .023$; cp. appendix, Figure A2). As visitors in all three conditions reported to process information deeper than in other exhibitions the virtual exhibition setting seemingly was more formal and learning-related.

A more detailed analysis within condition 2, that is, with awareness of a shared goal but without adaptation, revealed that those dyads who processed the information deeper received more goal-relevant additional information on the PDA ($r = .70$, $p = .005$). It can be concluded that – when not all information relates to the goal – more goal-relevant information elicits deeper processing. But this effect disappears when all information is adapted to the goal.

Learning

With respect to learning, I assumed that with adaptation of information visitors acquire a similar amount of goal-relevant and goal-irrelevant knowledge (hypothesis AdL1) and that they gain more knowledge than without adaptation (hypothesis AdL2). When additional information was adapted to participants' shared learning goals, they achieved a marginally higher knowledge score overall in comparison to participants receiving random information ($M_1 = 28.28$, $SD_1 = 6.05$, $M_2 = 25.98$, $SD_2 = 6.40$; $t = 1.48$, $df = 62$, $p = .072$). Additionally, they are significantly better able to answer transfer questions ($M_1 = 13.81$, $SD_1 = 2.09$, $M_2 = 12.47$, $SD_2 = 3.44$; $t = 1.89$, $df = 51.12$, $p = .032$). They also feel more confident about their knowledge (relation full knowledge / partial knowledge: $M_1 = 1.39$, $SD_1 = 0.99$, $M_2 = 1.00$, $SD_2 = 0.58$; $t = 1.94$, $df = 62$, $p = .023$). These results confirm hypothesis AdL2 that adaptation of information increases knowledge gains. Visitors with adaptation report more full knowledge, whereas visitors who randomly receive additional information on the PDA indicate more partial knowledge. As I assumed full knowledge to be associated with deeper processing of information (Mayr, Tibus, et al., 2007) this result indicates deeper processing of information in condition 1.

Similar to the results reported above for dyads with awareness of shared goals but without adaptation, dyads who received adapted information gained a comparable amount of goal-relevant and goal-irrelevant knowledge ($M_{goal\text{-}relevant}$ = 62.52 %, SD = 12.49, $M_{goal\text{-}irrelevant}$ = 61.37, SD = 11.05; t = -0.67, df = 31, p = .253, hypothesis AdL1 confirmed). As visitors who received adapted information on the PDA explored goal-irrelevant exhibits longer it is not surprising that they gained a high amount of goal-irrelevant knowledge. But also no differences were found in comparison to visitors in condition 2 for the amount of goal-relevant knowledge acquired (t = 0.84, df = 62, p = .201) as well as for the amount of goal-irrelevant knowledge acquired (t = 0.63, df = 62, p = .266). As dyads in both conditions engaged with a similar amount of goal-relevant and goal-irrelevant exhibits, the similar extent of goal-relevant and goal-irrelevant knowledge acquisition can be explained by their visiting behavior.

7.4 Conclusion

This study showed that awareness of shared goals can elicit a more selective and more goal-directed behavior in dyads visiting a virtual museum: Pairs of acquaintances explored exhibits longest if the exhibits per se were not relevant for the shared goal but were accompanied by goal-relevant information on a PDA. In this case additional information on a PDA can really unfold its benefits: It satisfies visitors' goals and thereby induces deep processing. Especially those visitors, who received goal-relevant additional information only occasionally, explored this information with goal-irrelevant exhibits very long.

However, visitor dyads who were aware of a shared goal also visited less exhibits in comparison to those visitors who were not aware. On the one hand, this behavior can be interpreted as more strategic and socially self-regulated; but on the other hand, this behavior can be interpreted as disappointment as their goals were not satisfied by the information, their expectations were not fulfilled in the exhibition. Indeed, visitors who did not receive goal-relevant information reported their goal to be less fulfilled in the exhibition than visitors who received information adapted to their goal (M_1 = 4.06, SD_1 = 1.29, M_2 = 3.38, SD_2 = 1.41; t = 2.03, df = 62, p = .023). Additionally, dyads under awareness of shared goals reported the deeper processing the more goal-relevant information on the PDA they randomly received. Though no deeper processing of information was self-reported by visitors who received fully adapted information on the PDA, higher knowledge acquisition and more full knowledge of these visitors indicate that adaptation of information led to deeper processing of information.

Therefore, it can be concluded that awareness of a shared learning goal can elicit more strategic and goal-directed processing of information in a virtual exhibition. But if the presented information and exhibits do not satisfy this goal, visitor dyads will explore less information and visitors will acquire less knowledge. Even though visitor dyads, who received random information explored parts of the exhibition more deeply, namely goal-irrelevant exhibits associated with goal-relevant information on the PDA, overall deeper processing of the information happened, when visitors always received adapted information. These visitors had to invest less effort in the evaluation of information and, therefore, could invest more cognitive resources in deep elaboration of content – throughout the whole visit – resulting in better learning outcomes.

An interesting result found in all conditions is that participants reported a similar depth of information processing as in learning and a higher depth of information processing than in other exhibitions. Lincoln (2006) found higher knowledge acquisition in visitors to a virtual exhibition than visitors to a real exhibition. This is an indicator that virtual exhibitions are more learning-related and formal environments than real exhibitions. Consequently, I assume that dyads in my study did not explore the virtual exhibition as they would normally explore an exhibition in the real museum context: It seems that participants in study 1 behaved more like learners and less like visitors to a real exhibition. This behavior results in higher learning outcomes, in deeper processing of information, but also in less efficiency of the manipulations than could be expected in a more informal setting. Therefore, one might question the similarity of behavior, processing, and learning in a virtual and a real exhibition. To further explore this question I conducted a second laboratory study with a similar research design, but in a real exhibition that was displayed at our research institute.

8 Study 2: Laboratory Exhibition

Results on the amount of invested mental effort in study 1 indicate that a virtual exhibition made participants invest more cognitive resources than in conventional exhibitions. This might be due to the fact that the hypermedia setting activated more learning associations and less leisure associations like a normal museum. To explore this hypothesis I conducted a second study in a real exhibition. This aim was feasible by the possibility to transfer the actual exhibition, which was used as a model for the virtual exhibition in study 1, from the Deutsches Museum in Munich to the Knowledge Media Research Center in Tübingen. Thus, I had the opportunity to conduct research in a conventional exhibition but under controlled conditions and without confounding factors.

8.1 Hypotheses

Study 2 addressed the same research questions as study 1 (see chapter 6.2): Can awareness of a shared learning goal and adaptation of information to this goal support collaborative information processing in an exhibition on Nanotechnology and can they consequently foster learning from this exhibition? The following hypotheses were formulated for **awareness of shared learning goals**:

Hypothesis AwI1: With awareness of shared learning goals visitors select more goal-relevant than goal-irrelevant exhibits.

Hypothesis AwI2: With awareness of shared learning goals visitors take more time to process goal-relevant information than to process goal-irrelevant information.

Hypothesis AwD1: With awareness of shared learning goals visitors report deeper processing than visitors without awareness.

Hypothesis AwL1: With awareness of shared learning goals visitors gain more goal-relevant than goal-irrelevant knowledge.

Hypothesis AwL2: With awareness of shared learning goals visitors gain more knowledge than visitors without awareness of shared learning goals.

The following hypotheses were formulated for **adaptation of information**:

Hypothesis AdI1: With adaptation of information visitors are equally likely to select goal-relevant and goal-irrelevant exhibits.

Hypothesis AdI2: With adaptation of information visitors process goal-relevant exhibits as long as goal-irrelevant exhibits.

Hypothesis AdD1: With adaptation of information visitors report deeper processing than visitors without adaptation.

Hypothesis AdL1: With adaptation of information visitors gain a similar amount of goal-relevant and goal-irrelevant knowledge.

Hypothesis AdL2: With adaptation of information visitors gain more knowledge than without adaptation.

8.2 Methods

As outlined in chapter 5, the methods of this study were carefully designed to provide a setting that is as informal as possible. The study was conducted from April to June 2006 in Tübingen (Germany).

8.2.1 Research design

The same research design as in study 1 was implemented (see Table 4, p. 50). Participants in condition 1 were made aware of a shared learning goal and received additional information adapted to this goal. Participants in condition 2 were also made aware of a shared learning goal but received additional information that randomly served different learning goals. Condition 3 served as control condition; these participants were not made aware of a shared goal and received random additional information as in condition 2.

Awareness of shared goals in conditions 1 and 2 was realized by asking visitor dyads to find or negotiate a shared learning goal for the following visit of the exhibition. This decision was inserted into a mobile device. Adaptation of information was manipulated by means of presenting additional information on this mobile device; the information either matched the visitor dyad's shared goal (condition 1) or was random (conditions 2, 3).

8.2.2 Sample

As in study 1, the sample size was selected based on a power analysis according to the effect size reported by O'Leary-Kelly and colleagues (1994). Again, the minimal sample size of 48 participants was increased due to informal character of the experimental learning setting and the higher variance expected (Griffin & Symington, 1998).

As in study 1, dyads of acquainted subjects from Tübingen (Germany) were recruited for a study on communication in museums to reduce expectations of a learning-related study. Participants received 12 Euros or study credits for their participation in this study.

Overall, 60 participants in 30 dyads took part and were randomized to the three conditions (11 dyads in condition 1, 10 dyads in condition 2, and 9 dyads in condition 3). Most dyads were of same sex (67 %, 2 male, 18 female). Relationships included friends (53 %), flat mates (10 %), couples (23 %), fellow students (10 %), and siblings (3 %). Nearly all dyads reported to know each other well (97 %) and their answers on their relationship were significantly correlated (ICC = .66, $F(29,30) = 4.83$, $p < .001$).

Many dyads (40 %) visited an exhibition together the first time. Another 33 % went to an exhibition with their study co-visitor only seldom or occasionally. Around a forth has visited exhibitions together regularly (27 %). Still, most study participants visited a museum regularly: Once a year (37 %), several times a year (43 %), or one or more times a month (18 %).

Participants were between 20 and 49 years old (M = 23.12, SD = 4.45). Most had at least a high school diploma (87 %).

8.2.3 Material and technology

The same exhibition about nanotechnology ("Nanodialogue" by the European Commission) as in study 1 serves as research setting in this project. In contrast to study 1, the real exhibition was displayed at the Knowledge Media Research Center in Tübingen (see Figure **6**, right). Therefore, research in a real exhibition but under controlled conditions (e.g., no other visitors present) was possible.

Figure 6. Elevation of the exhibition Nanodialogue (left) and the physical exhibition at the Knowledge Media Research Center (right)

The same four text sets as in study 1 served as additional information. The information was presented to dyads according to their shared learning goal in condition 1, whereas dyads in conditions 2 and 3 received random text versions for each exhibit serving different learning goals. The exhibit information could be retrieved from a Personal Digital Assistance (PDA, Fujitsu Siemens Pocket LOOX 720). In contrast to study 1, in which the additional information was displayed for each exhibit on the right side of the screen, in study 2, participants had to retrieve the additional information actively. Therefore, they did not receive additional information for each explored exhibit– as in study 1 – but only for those selected.

To observe the visiting behavior as unobtrusively as possible, four cameras were installed and directed towards the four exhibition walls. Via LAN the video could be watched in real-time in an adjacent room. This observation possibility was used to simulate a location-sensitive mobile device: If a visitor dyad was in front of a given exhibition part, the PDA showed the according image of this exhibition part (layer 2 in study 1). The display of the according image was controlled remotely by the experimenter (Figure 7). The PDA communicated with the remote control via WLAN[11].

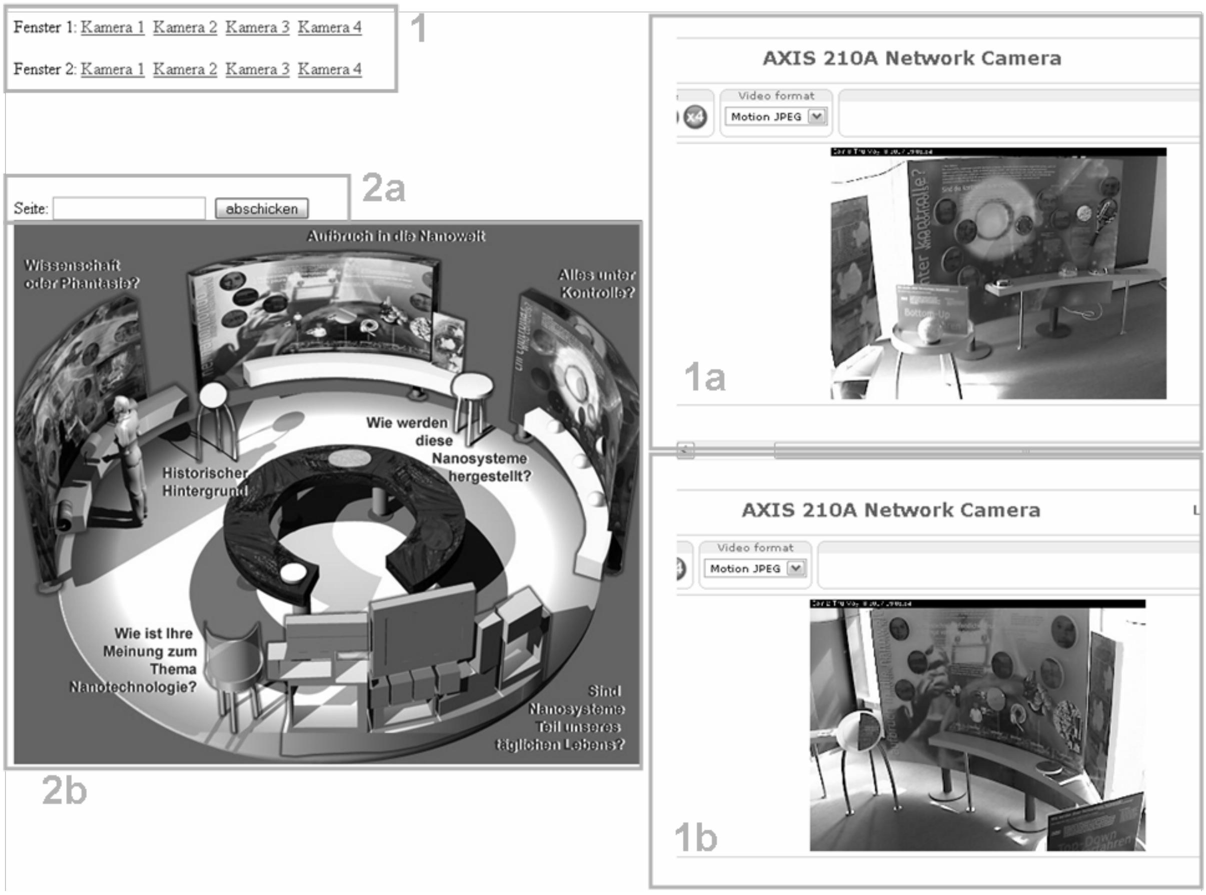


Figure 7. Remote control of additional information displayed on the PDA: Videos from two cameras were displayed (1a, 1b) that could be selected by the experimenter (1). Content was sent either via graphical selection of the exhibition wall on mouse click (2b) or via textual input (2a). Below field 2b the last loggings of the PDA were displayed

8.2.4 Procedure

Participants went through this procedure as a dyad, without other participants present. They were informed that they participated in a study on communication in museums and that they were going to visit an exhibition on Nanotechnology together. Then they received a microphone that recorded their conversation.

Before visiting the exhibition, dyads in conditions 1 and 2 were asked to select a learning goal of individual and then shared interest from a list of four goals. Their selection was logged into a PDA. Dyads in the control condition 3 were verbally introduced to the exhibition's theme and thereby were also informed that these four topics were addressed in the exhibition.

[11] Due to instability of the wireless LAN network, data from three dyads (not counted in the description of the sample) could not be used for analyses. A stable communication mode of the mobile device or independence from communication via networks (e.g., by storing all information on the PDA directly) seems to be crucial for future studies on – but even more important for the introduction of – mobile devices in museums.

Then, dyads received one PDA and were told that they could retrieve additional information for each exhibit. They were instructed how to interact with the PDA via touch screen or stylus. In condition 1 the additional information on the PDA was adapted to the dyad's shared learning goal and in conditions 2 and 3 the information randomly matched any of the four topics. Dyads in condition 1 were not informed that content on the PDA will be adapted to their shared learning goal. Still, as the selected shared goal was logged into the same device that they received for their visit, this information was communicated implicitly.

Dyads explored the laboratory exhibition without time constraints.

After the visit participants individually filled out a questionnaire on their visiting experience and knowledge gains. In the end, participants were debriefed on the aim of the study and received payment or study credits.

8.2.5 Measures

Log files of the PDA provide different measures of users' visiting behavior: the exhibits at which visitors searched for additional information and how long they explored this information. Also the overall number of exhibits, for which additional information was retrieved, was derived from the log files. As dyads saw on the PDA the exhibition wall that was currently in front of them, the log files served additionally as an observation protocol of the dyads' visits: How long they attended to each exhibition wall, in which order they explored the walls, and how often they returned to walls. In addition, the overall duration of the visit was timed and noted down.

The questionnaire was the same as in study 1 and assessed participants' self-reported depth of information processing, knowledge gains, and descriptive information (cp. chapter 7.2.5).

8.2.6 Analysis

As in study 1 visiting behavior measures were assessed on a dyadic level only and participants answered the questionnaire individually. Therefore, again statistical analyses have to take into account the nonindependence in the data. I proceed as in study 1 and analyze behavioral data on the dyadic and questionnaire data on the individual level (see chapter 5.3).

In addition to the nonindependence, in this study the behavioral measures differ hugely between the dyads, with a number of extreme values (cp. Figure 8). Thus, nonparametric analyses are conducted regarding visiting behavior.

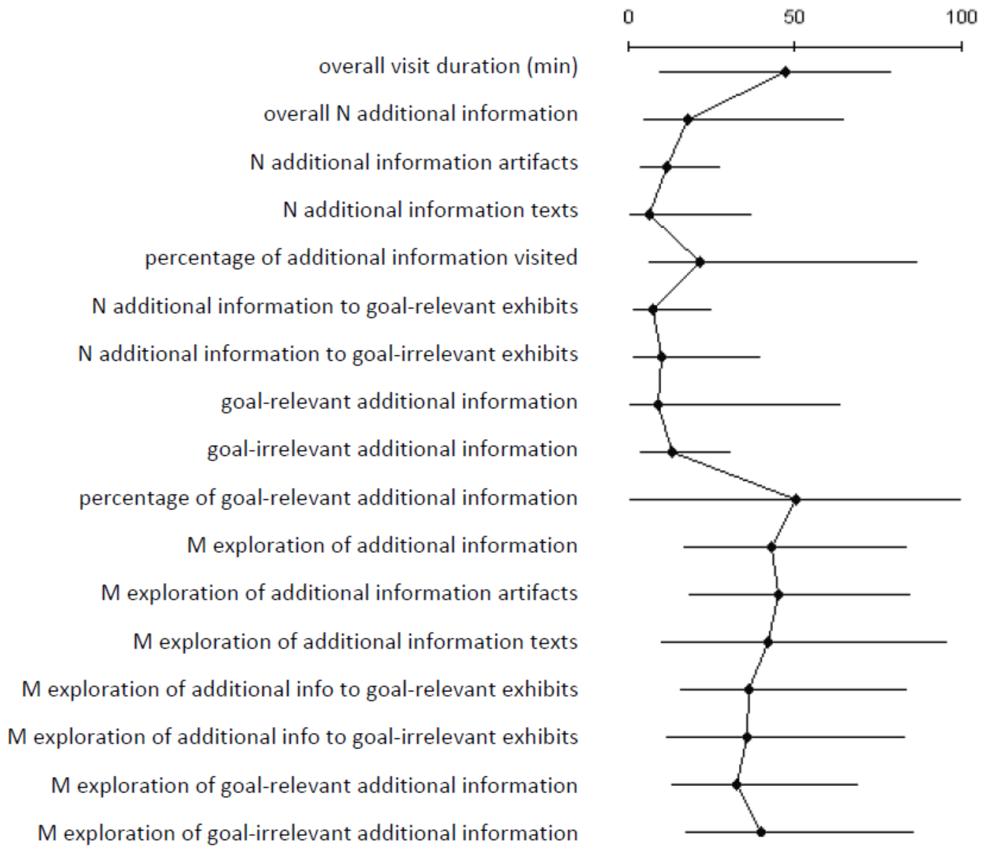


Figure 8. Range of behavioral measures: minimum, mean, and maximum

8.3 Results and discussion

As for the virtual exhibition study the results are presented for both manipulations separately: first, awareness of shared goals, then, adaptation of information.

8.3.1 Awareness of shared learning goals

To analyze the effects of awareness of shared goals I compared the visiting behavior, depth of processing, and knowledge gains of conditions 2 and 3. In both conditions dyads received random information on the PDA, but in condition 2 dyads were made aware of a shared learning goal prior to exploring the exhibition.

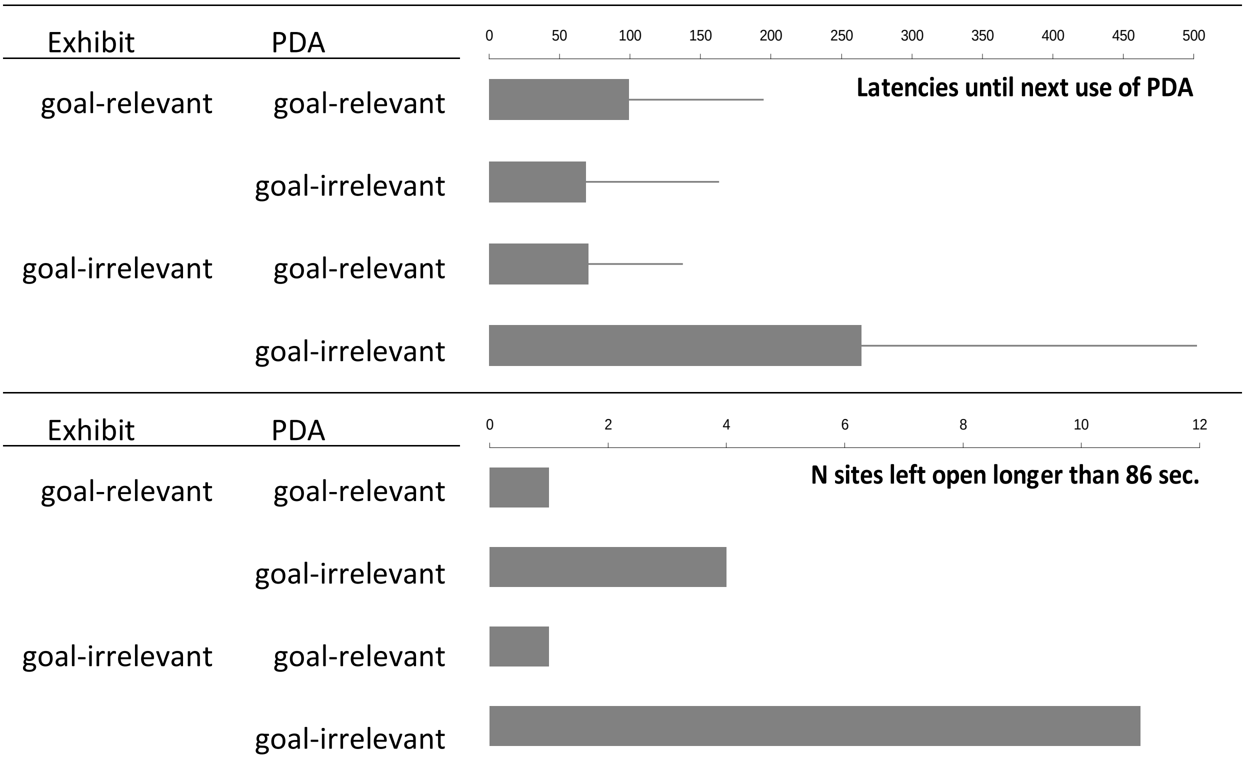
Visiting behavior

An overview on the visiting behavior of dyads in conditions 2 and 3 can be found in the appendix (Table A3). Dyads in condition 2 retrieved less additional information for exhibited artifacts compared to dyads in condition 3 ($M_2 = 9.00$, $SD_2 = 3.50$; $M_3 = 14.00$, $SD_3 = 5.17$; $U = 18.50$, $Z = -2.20$, $p = .029$). This might be due to the fact that, in condition 2 visits tended to last shorter than in condition 3 ($M_2 = 39.17$, $SD_2 = 16.69$; $M_3 = 53.24$, $SD_3 = 16.85$; $U = 23.00$, $Z = 1.80$, $p = .072$). This finding is interesting, as other studies (Falk et al., 1998; Zueck, 1988) on the contrary report that visitors with a specific goal spent more time in an exhibition. But it is similar to study 1 where visitors’ expectations were disappointed by the information in the exhibition.

To further understand how information was processed, one-sided comparisons were computed to test the hypotheses. I assumed that participants with awareness of a shared learning goal would search for more goal-relevant than goal-irrelevant information (hypothesis AwI1) and would explore goal-relevant information longer (hypothesis AwI2). To answer these hypotheses I analyzed the requests on the PDA with respect to the goal-relevance of the related exhibit. The likelihood to retrieve additional information on the PDA was similar for goal-relevant (22 %) and goal-irrelevant (20 %) exhibits (Wilcoxon $Z = -0.56$, $p = .282$). In a next step, I compared the exploration behavior in dependence of the information's goal-relevance. In contrast to hypothesis AwI2, participants explored goal-relevant additional information shorter than goal-irrelevant additional information ($Md_{goal\text{-}relevant} = 30.63$ seconds, $IQR_{goal\text{-}relevant} = 21.05$, $Md_{goal\text{-}irrelevant} = 37.12$ seconds, $IQR_{goal\text{-}irrelevant} = 25.43$; Wilcoxon $Z = -1.72$, $p = .043$). A closer look at the log files revealed that many outliers exist in the exploration duration: Approximately 10 % of the exploration durations are longer than the maximum duration found in study 1 (86 seconds). This finding can be explained by the fact that participants sometimes did not close a page after exploring it but rather left it open until their next request. When the analysis is repeated without these outliers, visitors explore goal-relevant additional information as long as goal-irrelevant additional information ($Md_{goal\text{-}relevant} = 27.67$ sec, $IQR_{goal\text{-}relevant} = 16.23$, $Md_{goal\text{-}irrelevant} = 28.04$ sec, $IQR_{goal\text{-}irrelevant} = 16.48$; Wilcoxon $Z = -0.30$, $p = .384$). This result contradicts other research that found goal-relevant content to be explored longer than goal-irrelevant content (Corredor, 2006; Rothkopf & Billington, 1979; Schnotz & Zink, 1997). However, until now no studies on the exploration duration of goal-relevant information in real museums was conducted. It seems that this finding cannot be transferred to a real museum setting.

Despite this findings, a further, more detailed analysis of the logfiles showed that visitors with an aware goal used the PDA in a goal-directed manner: When the participants with awareness of shared goals received goal-irrelevant information for goal-irrelevant exhibits they more often left the site on the PDA open for more than 86 seconds in comparison to those events, when they received goal-relevant information or visited a goal-relevant exhibit ($\chi^2 = 15.71$, $df = 3$, $p = .001$, see Table 6). Additionally, after goal-irrelevant information on a goal-irrelevant exhibit participants waited longer until they used the PDA again (in comparison to goal-irrelevant exhibits with goal-relevant information: Wilcoxon $Z = -1.57$, $p = .065$; in comparison to goal-relevant exhibits with goal-irrelevant information: Wilcoxon $Z = -2.43$, $p = .008$; see Table 6). This result is an indicator that dyads with awareness of a shared goal processed the information on the PDA in a goal-directed manner: If they requested additional information on goal-irrelevant exhibits and received goal-irrelevant information, they were more likely to leave the site opened very long or to wait a long time before they used the PDA again. This finding can be interpreted as an indicator that they searched for goal-relevant information on the PDA but were disappointed by the result of their request. If they received goal-relevant information which re-contextualizes the goal-irrelevant exhibit in the context of their shared learning goal they were more likely to request information on another exhibit within the next minute. This differential behavior was not found for goal-relevant exhibits. This result partially confirms hypothesis AwI1 stating that visitors did indeed value goal-relevant information higher than goal-irrelevant information. As in study 1, this is especially true, when an exhibit is goal-irrelevant.

Table 6. Information evaluation in condition 2 (with awareness of a shared goal)



These findings indicate that visitors with an aware goal – like in study 1 in a virtual museum – did engage in selective behavior (Rounds, 2004).

Self-reported depth of information processing

I assumed that with awareness of shared learning goals visitors report deeper processing than visitors without awareness (hypothesis AwD1). With respect to the self-reported depth of information processing, participants in condition 2 and 3 did not differ from each other significantly (Pillai's Trace = 0.42, $F = 1.95$, $df_1 = 10$, $df_2 = 27$, $p = .082$, $\eta^2 = .419$, see appendix Figure A3). This result contradicts hypothesis AwD1. Dyads in both conditions invested a similar amount of mental effort as in other exhibitions. This result contrasts findings from virtual museums that effective goal setters elaborate deeper on relevant content (Corredor, 2006). It seems that in a real exhibition visitors with awareness of a shared learning goal for itself do not report deeper processing of information, but further support – like adaptation of information – is required.

Learning

With awareness of a shared learning goal, I assumed that visitors gain more goal-relevant than goal-irrelevant knowledge (hypothesis AwL1) and more knowledge overall than visitors without awareness (hypothesis AwL2). Participants in condition 2 did not gain more goal-relevant knowledge than goal-irrelevant knowledge ($t = -0.75$; $df = 19$, $p = .231$). They answered about 62 % of the knowledge test correctly for goal-relevant and goal-irrelevant questions. Therefore, hypotheses AwL1 has to be rejected. Like in study 1 visitors acquired a similar amount of goal-relevant and goal-irrelevant knowledge with and without awareness of shared goals. The results on information processing provide an explanation for this similarity: No differences in amount of goal-relevant and goal-irrelevant information explored were found and dyads explored goal-relevant information as long as goal-irrelevant information. Therefore, they seem to have processed both kinds of information in a similar depth.

But in line with hypothesis AwL2, dyads in conditions 2 and 3 differed in their overall knowledge acquisition ($M_2 = 27.50$, $SD_2 = 5.86$, $M_3 = 23.89$, $SD_3 = 4.67$; $t = 2.09$, $df = 36$, $p = .044$). Participants who are aware of a shared goal gain more knowledge than participants without awareness. This finding is in line with other studies on hypertext (Zumbach & Reimann, 2002) and museum learning (Falk et al., 1998). However, this difference cannot be attributed to a higher number of correct answers ($M_2 = 58.75$ %, $SD_2 = 9.82$, $M_3 = 56.16$ %, $SD_3 = 9.21$; $t = 0.84$, $df = 36$, $p = .409$) but rather has to be attributed to a tendency towards more full knowledge with awareness of shared goals (ratio full / partial knowledge: $M_2 = 1.33$, $SD_2 = 1.07$, $M_3 = 0.90$, $SD_3 = 0.74$; $t = 1.77$, $df = 36$, $p = .084$). Similarly, Falk and colleagues (1998) found a difference only in the mastery of the topic. The result of this study can explain why Zueck (1988) did not find any differences when she used multiple choice questions: Participants gain a similar amount of factual knowledge, but with awareness of a shared goal they process information deeper and are, therefore, more confident in their knowledge.

To sum up, visitors who are aware of shared goals evaluate additional information in a very goal-directed way; especially for goal-irrelevant exhibits they neglect the PDA if it does not fulfill their goal. This is an indicator that these visitors evaluate the PDA by the goal-directedness of the information presented. It could also be shown that visitors gain more knowledge with awareness of shared goals. Still, the actual exploration behavior of this visitor groups remains somewhat fuzzy. To further shed light on visiting strategy in this group, I conducted a case study with one dyad in condition 2 and further explored their visual exploration of the exhibition.

8.3.2 Case study: Re-viewing the visitor's view

To gain a more complete picture of information processing with awareness of shared goals, I equipped one member of a dyad in condition 2 with an ASL MobileEye eye tracker. A mobile eye tracker uses two cameras to record viewing behavior on the move (see Mayr et al., 2009, for a discussion of mobile eye tracking as research method for mobile learning in museums). One camera records one eye of the participant, while the other camera records the scene from the subject's perspective. After individual calibration, both images can be combined in a video of the scene with the fixation position marked by a small red cross. The methodology provides insight into the perspective and the viewing behavior of the participant.

Method

The participants in this case study were a couple, Anna and Christian[12]. Christian was 23 years old, Sylvia 22. They knew each other very well, though they had never visited an exhibition together.

First, the purpose and the function of the eye tracker were explained to the dyad. Christian volunteered to visit the exhibition with the mobile eye tracker, he was normally sighted. Then, the eye tracker was calibrated to a distance that Christian normally keeps while looking at exhibits (around 60 cm). Christian and Anna were instructed to explore the exhibition as they would normally do in a science museum. Otherwise the procedure followed the procedure for all participants in condition 2.

For the purpose of analysis, eye movement recordings were transformed to .avi-files and analyzed with the video analysis software Videograph©. I did not analyze eye movements based on xy-coordinates (examining which points on a wall are fixated independent of their denotation), but based on elements and categories (examining which exhibits on a wall are fixated, cp. Turano, Geruschat, & Baker, 2003). For my purposes, fixations of similar elements or within the same object category were of higher interest than proximity of fixations. The categories were developed according to information elements of the exhibition (exhibits, text units, labels, see Figure 9).

[12] Names changed by the author.

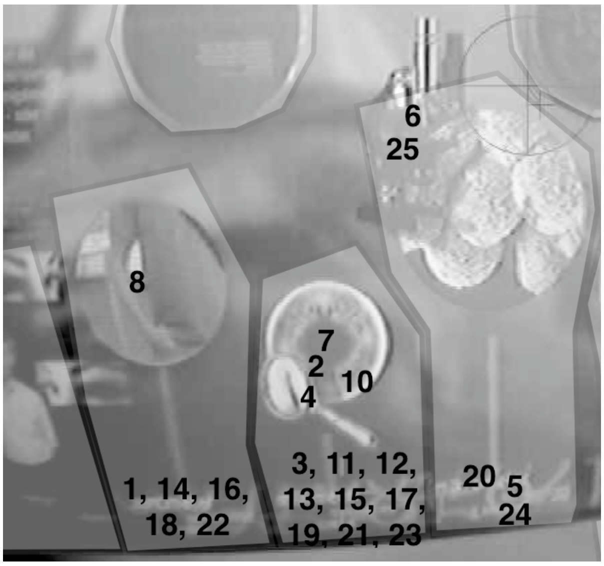


Figure 9. Part of the exhibition wall „Into the Nanoworlds“: Bordered areas show coding categories, numbers the order of fixations

Results and discussion

Christian and Anna explored the exhibition for 58 minutes. During their visit they made use of the PDA quite frequently: They requested additional information 34 times and explored the information on average for 29 seconds. In the verbal feedback on the PDA Christian evaluated it rather positive: “interesting, easier to process, faster to take in than other media”. Anna rated it more negative: “positive: easy to use, negative: not much additional information”; maybe this negative rating can be explained by the random presentation of goal-relevant information.

Christian and Anna started their visit with silently watching the film and exploring wall 4. Then Christian started off around the exhibition counterclockwise and explored each wall once and then started a second round (cp. appendix Figure A5). When exploring the first wall (wall 4), he frequently used the PDA (13 % of the looks) and visually interacted with Anna (14 % of the looks). However, during the remaining first round, he explored the exhibition rather individually (4 % of the looks towards Anna) and without the PDA (0 %). During the second round he changed his visiting strategy: He used the PDA often (14 %) and visually interacted with Anna frequently (25 %).

To better understand Christian’s visiting behavior I looked at intraindividual differences in the visual exploration of goal-relevant and goal-irrelevant exhibits. As found for all participants in study 2, no difference was found in the average fixation duration of goal-relevant and goal-irrelevant exhibits ($M_{goal\text{-}relevant} = 25$ sec, $M_{goal\text{-}irrelevant} = 20$ sec; $t = -0.53$, $df = 62$, $p = .602$) or number of fixations ($N_{goal\text{-}relevant} = 27$, $N_{goal\text{-}irelevant} = 37$; $\chi^2 = 1.56$, $df = 1$, $p = .211$). However, the scan patterns following goal-relevant and goal-irrelevant exhibits reveal clear differences ($\chi^2 = 11.44$, $df = 1$, $p = .001$, see Figure 10): After exploring goal-relevant exhibits Christian was more likely to look towards Anna, after exploring goal-irrelevant exhibits he was more likely to look at the PDA.

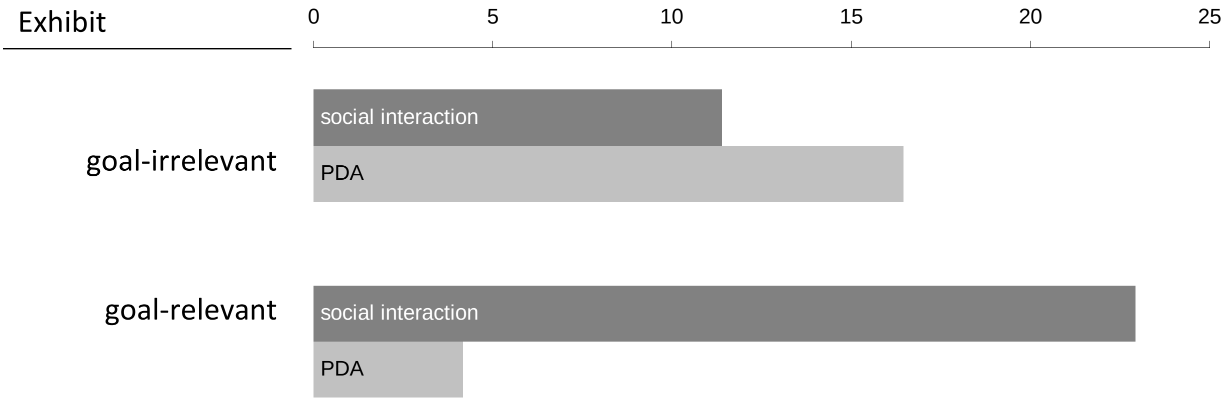


Figure 10. Scan patterns after goal-relevant and goal-irrelevant exhibits

This viewing pattern indicates that goal-relevant information indeed lead to social interaction. The social character of the shared learning goal activates social referencing and conversation (Clark & Brennan, 1991; Leinhardt & Knutson, 2004), when goal-relevant information was processed visually. If a goal-irrelevant exhibit was perceived, it was not neglected – as was found in studies on text processing and hypertext learning (e.g., Rothkopf & Billington, 1979; Schnotz & Zink, 1997) – but rather the PDA is sought as a resource that can relate this exhibit to the shared goal. This finding confirms and further explains the overall result of participants in condition 2, that is, with awareness of a shared goal but without adaptation of information; why they neglected the PDA more often when it did present goal-irrelevant information: They strategically used the PDA to search for goal-relevant information on goal-irrelevant exhibits. When the information did not comply with their search they ignored it. This finding further supports the relevance of adaptation of information on the PDA so that their search for goal-relevant information will be successful.

8.3.3 Adaptation of information

To analyze the effects of adaptation of information, I compared the visiting behavior, depth of processing, and knowledge gains of participants in conditions 1 and 2. Dyads in both conditions were aware of a shared learning goal, but during the exploration of the exhibition dyads in condition 1 could retrieve adapted information on the PDA whereas dyads in condition 2 could retrieve random information only.

Visiting behavior

An overview on the visiting behavior of dyads in conditions 1 and 2 is given in the appendix (Table A4). I assumed that adaptation of information leads to similar selection (hypothesis AdI1) and processing (hypothesis AdI2) of goal-relevant and goal-irrelevant exhibits.

With respect to the requests for additional information, with awareness of a shared learning goal and additional adaptation of information (condition 1) dyads as often requested additional information for goal-relevant (Md = 19 %) as for goal-irrelevant exhibits (Md = 20 %; Wilcoxon $Z = -0.62$, $p = .534$). Therefore, hypothesis AdI1 is confirmed: With additional information which re-contextualizes an exhibit in the context of an aware shared learning goal the goal-relevance of the exhibit is no indicator for the use of additional information. Also, no differences were found with respect to exploration duration: When information was adapted to participants' shared goals, they processed it as long if it referred to goal-irrelevant exhibits (Md = 29.25 sec, IQR = 19.33) as if it referred to goal-relevant exhibits (Md = 28.25 sec, IQR = 31.25; Wilcoxon $Z = -1.42$, $p = .155$; after exclusion of outliers: Wilcoxon $Z = -0.27$, $p = .790$). But as discussed earlier, also visitors who are aware of a shared goal and do not receive adapted, but rather random information explore goal-relevant and goal-irrelevant information similarly.

As reported above, dyads with shared goals but random information (condition 2) had outliers more frequently (leaving the PDA open longer than 86 seconds) and longer latencies until the next use of the PDA, if the additional information on a goal-irrelevant exhibit was not goal-relevant (cp. Table 6). In contrast, in condition 1 in which additional information on the PDA was adapted to participants' shared goals outliers were evenly distributed across goal-relevant and goal-irrelevant exhibits ($\chi^2 = 0.88$, $p = .346$) and latencies were similar for goal-relevant and goal-irrelevant exhibits (Wilcoxon $Z = -1.07$, $p = .285$). However, in comparison to dyads who received random additional information, the latencies of dyads who received adapted additional information were rather long (see Table 7): They waited on average 202.32 seconds (SD = 97.32) until their next request. With random information, in contrast, latencies after receiving goal-relevant information were on average 95.79 seconds (SD = 88.61). This difference is even higher for goal-irrelevant exhibits, for which after receiving goal-relevant information on the PDA dyads with adapted information waited on average 209.74 seconds (SD = 132.95) and dyads with random information waited on average only 70.68 seconds (SD = 66.38). Therefore, the short latencies in condition 2 which were observed when the exhibit, the additional information on the PDA, or both were goal-relevant can be interpreted as reinforcement of PDA use: If at least one source supports goal-related information processing, visitors are rewarded in their goal-oriented information processing and might be more motivated to search for further goal-relevant information (cp. Csikszentmihalyi & Hermanson, 1995) than they are if the PDA presents always goal-relevant information.

Table 7. Latencies for participants with awareness of shared goals with adapted (condition 1) or random (condition 2) additional information

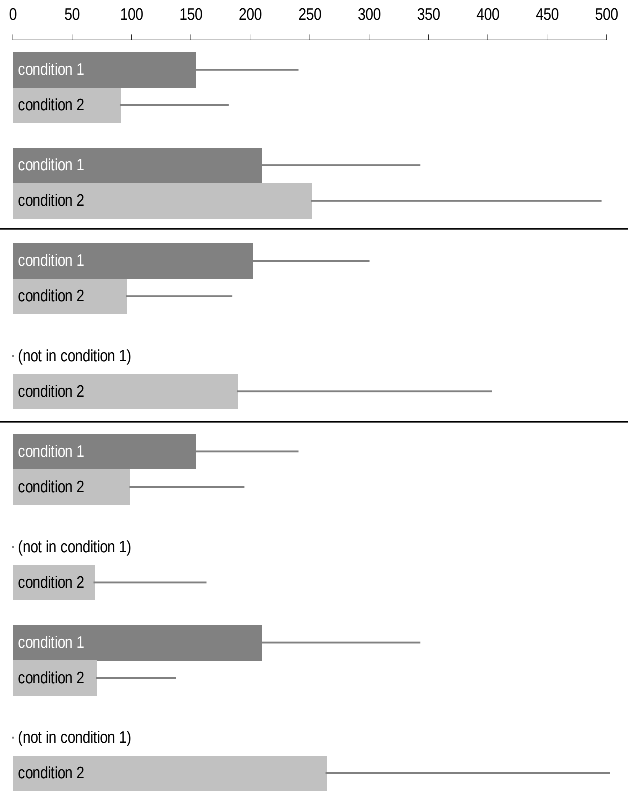


Exhibit	PDA	U	Z	p
Relevant		25.00	-1.89	.059
Irrelevant		55.00	0.00	1.00
	relevant	21.00	-2.17	.030
	irrelevant			
relevant	relevant	20.00	-1.46	.143
Relevant	irrelevant			
Irrelevant	relevant	11.00	-2.21	.027
Irrelevant	irrelevant			

Self-reported depth of information processing

Hypothesis AdD1 states that with adaptation of information visitors report deeper processing. In a direct comparison, visitors with and without adaptation of information did not differ significantly from each other in their depth of processing (Pillai's Trace = 0.20, $F = 0.78$, $df_1 = 10$, $df_2 = 31$, $p = .645$, $\eta^2 = .202$). But in relation to visiting other exhibitions, depth of processing in the laboratory exhibitions was reported to be deeper in condition 1 ($t = 3.17$, $df = 21$, $p = .005$) but similar in condition 2 ($t = 1.23$, $df = 19$, $p = .234$)[13]. This result confirms hypothesis AdD1 and is an indicator that adaptation of information can elicit deeper processing in an informal learning setting. This is in line with other studies who found deeper processing with higher goal-orientation (Corredor, 2006; Leinhardt & Knutson, 2004; Shapiro & Niederhauser, 2004, p. 615) which is elicited by a higher amount of goal-relevant information.

Learning

With respect to learning, I assumed that with adaptation of information visitors acquire a similar amount of goal-relevant and goal-irrelevant information (hypothesis AdL1) and that they gain more knowledge than without adaptation (hypothesis AdL2). When information

[13] An overview on depth of processing in the laboratory exhibition in relation to other daily activities is provided in the appendix.

was adapted to participants' shared learning goals they gained a similar amount of knowledge as visitors without adaptation (M_1 = 27.09, SD_1 = 5.57, M_2 = 27.50, SD_2 = 5.86; t = -0.23, df = 40, p = .409). Also no differences existed with respect to the confidence into their own knowledge (ratio full / partial knowledge: M_1 = 1.25, SD_1 = 0.87, M_2 = 1.33, SD_2 = 0.07; t = -0.26, df = 40, p = .399). These results contradict hypothesis AdL2 that adaptation of information further increases learning. However, the ratios between full and partial knowledge shows that participants in both conditions did acquire more full knowledge. This is an indicator for deeper processing of information with awareness of a shared learning goal as discussed earlier. Adaptation of information cannot further increase the effect of goal-orientation on learning.

Similar to the results reported above for dyads with awareness of shared goals but without adaptation, dyads who received adapted information gained a comparable amount of goal-relevant (M = 60.78 %, SD = 14.59) and goal-irrelevant knowledge (M = 60.05 %, SD = 13.89; t = 0.341, df = 21, p = .736, confirms hypothesis AdL1). When goal-relevant and goal-irrelevant knowledge acquisition was compared across conditions 1 and 2, no difference was found for goal-relevant knowledge (t = -0.47, df = 40, p = .319) and for goal-irrelevant knowledge (t = -1.28, df = 40, p = .103). Again, this is in line with the finding that goal-relevant and goal-irrelevant information was explored to a similar extent.

8.4 Conclusion

Participants in both conditions which were aware of a shared goal did acquire more full knowledge than participants without awareness. More full knowledge is an indicator for deeper processing. This result is in line with prior studies on museum related research (Falk et al., 1998) and can, therefore, be regarded as robust. In contrast to my assumptions, I did not find an additional positive effect of adaptation on learning. However, with adaptation visitors experienced deeper processing than in other exhibitions resulting in higher self-reports.

Awareness of shared goals did elicit in dyads visiting a small exhibition a more selective and more goal-directed use of a mobile device providing additional information: Pairs of acquaintances who received goal-relevant information on a goal-irrelevant exhibit from the PDA were fast to use the mobile device again. In contrast, when the PDA did not present the sought goal-relevant, but rather goal-irrelevant information on a goal-irrelevant exhibit the device was likely to be neglected for a longer period. This pattern was found especially for goal-irrelevant exhibits: For these a PDA providing additional goal-relevant information is most beneficial. A case study on one dyad which was aware of a shared goal revealed that whereas goal-irrelevant exhibits lead to search for goal-relevant information on the PDA, goal-relevant exhibits lead to social interaction (at least visually). This finding is an indicator that socially shared regulation (e.g., Volet et al., 2009) was elicited by awareness of shared goals.

Additionally, visitor dyads who were aware of a shared learning goal explored the exhibition shorter than visitors who were not aware. This again is an indicator for disappointment; that their goals were not satisfied by the information and their expectations were not fulfilled in the exhibition. Another explanation could be that they acted more strategically and applied quitting rules when they did not find further goal-relevant information (cp. Rounds, 2004). In contrast, dyads who received adapted information on the PDA acted more uniformly; but they did not retrieve more information from the PDA overall.

These results imply that making visitors aware of a shared learning goal is a promising strategy to support more goal-directed deep information processing and learning in a museum. A PDA providing additional goal-relevant information leads to more uniform visiting behavior which is similar to “normal” dyads without any goals. But in contrast to these normal visitors, they acquire as much knowledge as other visitors who are aware of a shared learning goal. While awareness of shared goals induces strategic behavior and higher knowledge acquisition, adaptation of information reduces requirements of self-regulation and socially shared regulation.

9 General Discussion

Based on a review of literature on informal learning and behavior of museum visitors I derived two approaches how learning in museums can be supported: Making visitor dyads aware of a shared learning goal was assumed to help them visit a museum in a more focused way, regulate their information processing socially, process information deeper, and thereby acquire more knowledge. As normally information processing in informal settings is rather superficial, a second support was implemented to help visitor dyads in maintaining deep, goal-oriented processing throughout their visit: They received additional information on a PDA that re-contextualized an exhibit in the context of the shared learning goal which was made aware to the dyad. Adaptation of information reduces the requirements to search for goal-relevant information and thereby it frees cognitive capacities to invest in elaboration on the information. Additionally, awareness of the shared goal is reinforced by each goal-relevant information received and can be maintained throughout the visit with less effort.

Two studies should empirically verify whether these two ways of support can enhance deep, goal-oriented information processing and learning in an exhibition (research questions 1 and 2). The studies differed in their learning setting: Study 1 was conducted in a virtual exhibition, and study 2 in a laboratory exhibition. These two settings differ in their formality: Virtual exhibitions are more formal and elicit more learning-related behavior, whereas real exhibitions should activate more leisurely concepts. Therefore, the effectiveness of both support approaches can be compared across the two studies and allows drawing conclusions about the influence of the setting's formality (research question 3).

Despite the differences in the setting of studies 1 and 2 they address the same experimental manipulations, that is, (1) awareness of a shared learning goal (conditions 1 and 2) or not (condition 3) and (2) adapted (condition 1) or random additional information (conditions 2 and 3), and their influence on the same dependent variables, visiting behavior, depth of information processing, and learning. Therefore, in the following results from both studies will be compared to answer research question 3 before a general discussion of the results and methodology is undertaken. In the end of this chapter consequences for further research and media in museums are derived.

9.1 Comparison of studies 1 and 2

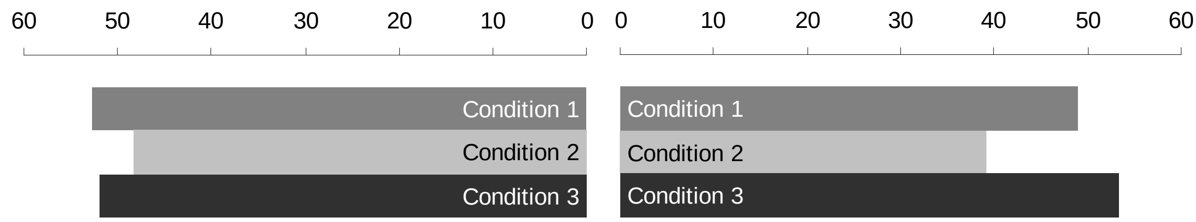
The *visit* duration of dyads in condition 1 and condition 3 is similar in both conditions and in both studies (cp. Table 8). In contrast, dyads in condition 2 took less time to visit the exhibition: Though this effect is significant only in study 2, a trend can be observed also in study 1.

In line with the shorter overall visit duration, in comparison to conditions 1 and 3 dyads in condition 2 also explored fewer exhibits in study 1 and retrieved additional information less often in study 2 (see Table 8). The difference in numbers between study 1 and study 2 has to be attributed to the changed display of additional information: Whereas in study 1 dyads received additional information for each exhibit automatically, it had to be retrieved actively in study 2. Therefore, less additional information was explored. In relation to the number of exhibits visited in study 1, they asked for additional information at every fifth exhibit in study 2.

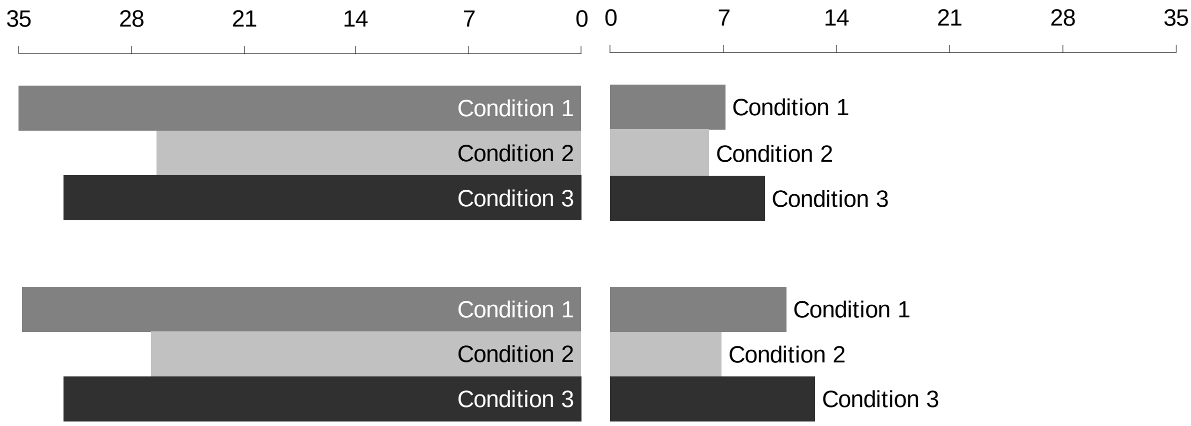
Table 8. Comparison of visiting behavior in studies 1 and 2

Study 1	Study 2

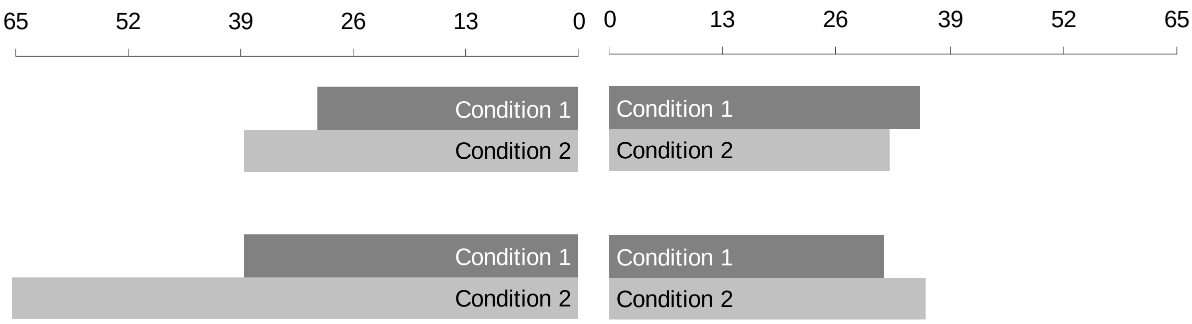
Visit duration



Number of goal-relevant (row 1) and goal-irrelevant (row 2) exhibits explored



Average exploration duration of goal-relevant (row 1) and goal-irrelevant (row 2) exhibits with goal-relevant additional information on the PDA

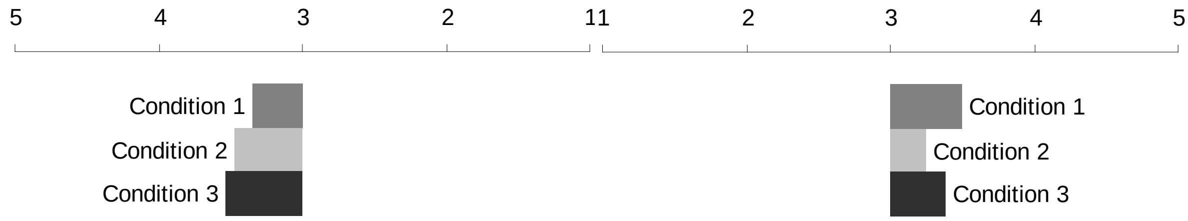


In addition, in study 1 visitors with awareness of shared goals explored goal-irrelevant exhibits longer than goal-relevant exhibits when they received goal-relevant additional information (see Table 8). This pattern was especially evident for dyads in condition 2. I assume that this pattern emerges due to a higher goal-value of goal-relevant additional information if the exhibit per se does not carry goal-relevant information. In study 2 this pattern was not found with respect to the exploration duration. However, exploration duration in study 1 did compass the exploration of the exhibit and of the information on the PDA, but in study 2 only the exploration of the information on the PDA was measured. Also, the additional information might contain a high value for all requested exhibits due to their aura (Valdecasas et al., 2006) – regardless of their goal-relevance. Still, a similar pattern as in study 1 emerged when the latencies until the next use of the PDA were analyzed: If the PDA presented goal-irrelevant information for a goal-irrelevant exhibit, dyads in condition 2 neglected the PDA in the following more often and longer than if the PDA presented goal-relevant information for a goal-irrelevant exhibit. Additionally, eye movement analysis of one visitor's visual exploration behavior in this condition revealed that he was more likely to request additional information on the PDA when he explored a goal-irrelevant exhibit. In contrast, for goal-relevant exhibits he more often turned towards his visit companion. Therefore, the results of both studies present the same picture: Visitors in condition 2, that is, with awareness of a shared goal but with random additional information on the PDA, engaged in more selective visiting behavior and did value goal-relevant information on the PDA about goal-irrelevant exhibits most.

Self-reported depth of information processing in study 1 was higher in the virtual exhibition than during other museum visits (cp. Table 9). In contrast, in study 2 visitors in the control condition (condition 3) and with awareness of shared goals (condition 2) reported more similar depth of information processing compared to other museum visits. Only visitors who were aware of a shared goal and received adapted additional information on the PDA processed the information deeper than during other museum visits. This result indicates that a virtual exhibition setting does elicit deeper processing than a real exhibition.

Table 9. Comparison of self-reported depth of information processing in studies 1 and 2

Study 1	Study 2
Self-reported depth of processing in comparison to processing of a real exhibition	



Study 1	Study 2
Order of daily activities with respect to depth of information processing (descending)	
1. Watching news on TV	1. Reading a contract
2. Learning (school, university)	2. Learning (school, university)
3. Visiting the cinema	3. Visiting another exhibition
4. Visiting another exhibition	4. Conversation with friends about a topic
5. Reading a newspaper	5. Reading a newspaper
6. Conversation with friends about a topic	6. Watching news on TV
7. Reading a contract	7. Visiting the cinema

Another astonishing finding is the different order of daily activities with respect to self-reported depth of processing in the two studies (see Table 9). Whereas Salomon (1984) found that television is perceived as “easy” to process and print in contrast as “tough”, the results in study 1 show a completely opposite pattern: Television is regarded as most demanding whereas reading a newspaper is regarded as less demanding than visiting the virtual exhibition. But in study 2 both, newspaper and television, rank quite low in depth of processing. Another puzzling result is the shallow depth of processing associated with reading a contract in study 1, whereas in study 2 this activity ranks highest. An explanation could be that the virtual environment in study 1 activated the concept of an online contract (Do you ever attend to these contracts?), whereas in study 2 a “real” contract was associated. Therefore, it must be assumed on the one hand that the developed scale is not suitable to be transferred from one setting to another. On the other hand the finding is an indicator that different concepts were activated in the two studies: in study 1 a computer-context with passive reception, like watching a film; in study 2 a more active context, like having a conversation with friends.

Visitors who were not made aware of a shared learning goal (condition 3) seemed to engage in quite deep processing in the virtual exhibition as they acquired more full knowledge (cp. Table 10). In contrast, these visitors acquired more partial than full knowledge in study 2. This result is in line with the finding by Lincoln (2006) that learning is higher in a virtual exhibition. Without the implementation of any support (awareness of shared learning goals, adaptation) visitors to a virtual exhibition do process information deeper and gain more knowledge than visitors to a real exhibition.

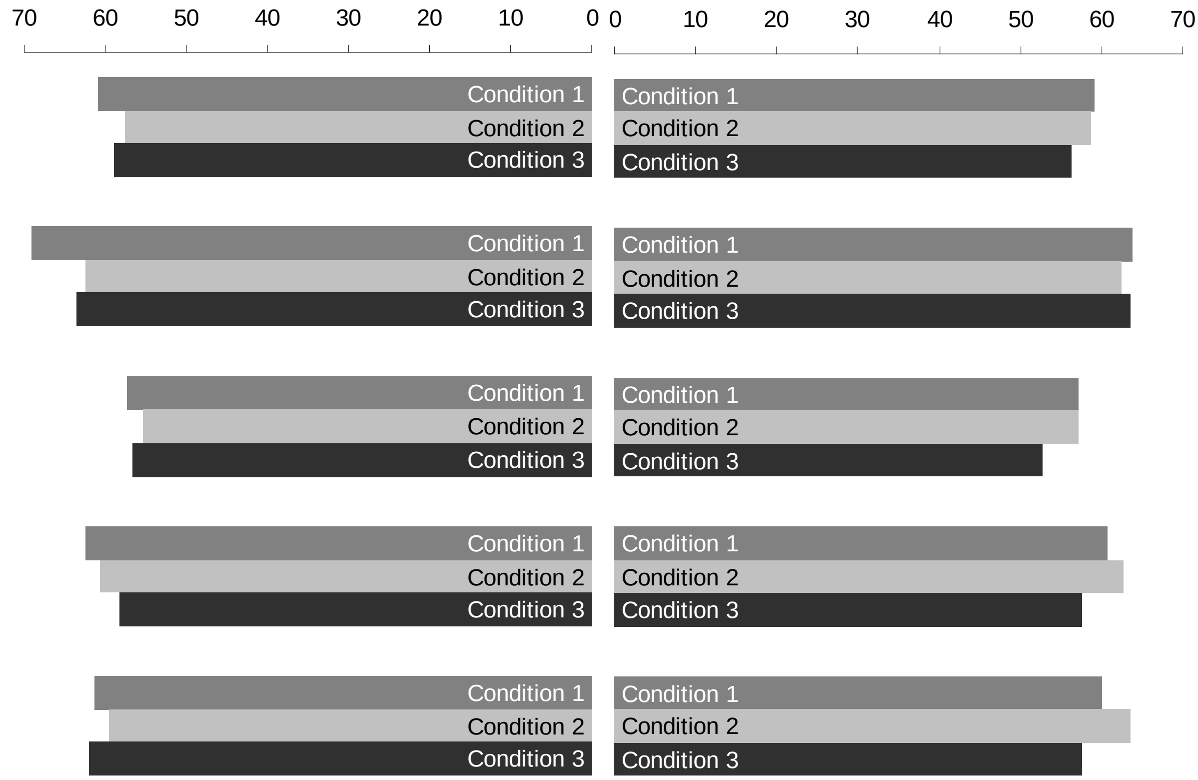
With awareness of shared goals those visitors to a virtual exhibition who received additional information adapted to their shared learning goal (condition 1) acquired more *knowledge* in general and more full knowledge in comparison to visitors who received additional information that randomly served different learning goals (condition 2, see Table 10). In the real exhibition, visitors who were made aware of a shared learning goal – independent of the adaptation or random presentation of information – showed evidence of more full knowledge and also acquired more knowledge in general. This is an indicator that in the real exhibition visitors in conditions 1 and 2 engaged in deeper processing, even though this assumption contradicts the lower self-reports on depth of processing by visitors in condition 2. Whereas in the real exhibition awareness of shared goals alone already led to higher knowledge acquisition, in the virtual exhibition additional adaptation of information was necessary for this effect to unfold.

In both studies no differences emerged with respect to the acquisition of goal-relevant and goal-irrelevant knowledge: All participants acquired a similar amount of both kinds of knowledge.

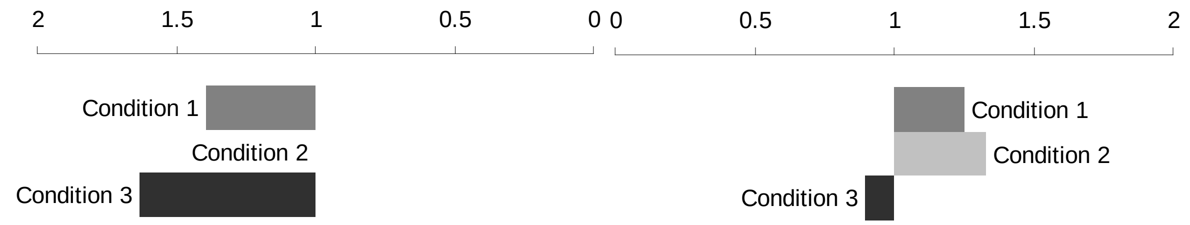
Table 10. Comparison of learning in studies 1 and 2

Study 1	Study 2

Percentage of right answers in the knowledge test: overall (row 1), transfer (row 2), facts (row 3), goal-relevant (row 4), and goal-irrelevant (row 5)



Ratio full knowledge / partial knowledge



9.2 Discussion

Visitors' self reported *depth of information processing* indicates that the experimental setting in study 1, a virtual exhibition, was more formal and more similar to hypertext learning than to informal learning in a real science exhibition. Visitors in the control condition, without awareness of a shared learning goal, reported quite deep processing and also acquired a high amount of full knowledge in the virtual exhibition. In contrast, the real exhibition in study 2 was less associated with learning: Visitors in the control condition reported similar depth of processing compared to other exhibitions and acquired a higher amount of partial knowledge. Both are indicators of more informal learning and more superficial processing. Therefore, it can be concluded with respect to research question 3 that visiting a virtual exhibition is more formal than visiting a real exhibition and that different levels of depth of information processing are associated with the two settings:

deeper processing and the acquisition of more full knowledge in a virtual exhibition in contrast to more superficial processing and the acquisition of more partial knowledge in a real exhibition.

The *visiting behavior* of dyads who were made aware of a shared learning goal indicates goal-oriented information processing. In both studies I observed a selective evaluation of information in condition 2 with aware shared goals but random additional information: In study 1 information was elaborated longer if the PDA-frame presented goal-relevant information that the exhibit did not convey. In study 2 dyads used the PDA as a resource that compensates for missing goal-relevance of exhibit. This selective use of exhibits is an indicator of self-regulation processes (Boekaerts & Minnaert, 1999) and can be interpreted as highly strategic behavior. Rounds (2004) argues that a selective use of exhibits enables visitors to focus only on exhibit elements that interest them, thereby minimizing time and effort. He states that "partial use of exhibitions is an intelligent and effective strategy for the visitor whose goal is to have curiosity piqued and satisfied" (p.389). In line with such a strategy, dyads with an aware shared learning goal who received random information terminated their visit earlier in the real exhibition and explored less information overall in the virtual exhibition. In contrast, dyads in condition 1 who received additional information adapted to their shared learning goal behaved similar to the dyads in the control condition: They explored the real exhibition longer and requested more information in the virtual exhibition. Still one indicator of goal-oriented processing was found in condition 1, too: In study 1 they explored goal-irrelevant exhibits longer than goal-relevant exhibits. For goal-irrelevant exhibits it is necessary to additionally explore and elaborate the information on the PDA to process the exhibit in a goal-oriented way. More effort and more time have to be invested by the learners – as was found.

An important finding of the case study conducted within study 2 is the relevance of the social situation for this goal-oriented processing of information: After exploring goal-relevant exhibits the visitor was more likely to turn towards his visit companion. This is an indicator that the shared goal indeed served as shared frame of reference (cp. Clark & Brennan, 1991; Clark et al., 1983) and that the dyad engaged in socially shared regulation (cp. Järvelä & Volet, 2004; Volet et al., 2009) of the visiting behavior and information processing in the real exhibition. Further research should focus on the question what the social context in this study did contribute to the effects observed and whether individual visitors engage in similar strategic processing if they are made aware of a learning goal and receive adapted goal-relevant information.

On an individual level, awareness of a shared learning goal also led to higher *learning* in a real exhibition: In study 2, dyads from both conditions that were made aware of a shared learning goal acquired more knowledge than dyads from the control condition. This is in line with other studies on learning goals in museums which report higher learning when a learning motivation is present (Falk et al., 1998; Leinhardt & Knutson, 2004; Packer &

Ballantyne, 2002). Interestingly, none of these studies used a knowledge test to assess learning: higher mastery of the topic in Personal Meaning Mapping (Falk et al., 1998), a higher subjective learning experience (Packer & Ballantyne, 2002), or more indicators of learning during conversational elaboration (Leinhardt & Knutson, 2004). The only study that also used a knowledge test to assess learning did not find an effect of specific learning goals on learning outcomes (Zueck, 1988). In contrast in this dissertation, visitors could also indicate their confidence into the correctness of their answers (cp. Ben-Simon et al., 1997). I assume that partial knowledge emerges from superficial information processing but full knowledge emerges from deep processing. In line with this assumption, visitors with and without awareness of shared goals did not differ from one another in the number of correct answers – similar to Zueck's (1988) findings. Rather, visitors who were made aware of a shared learning goal acquired more full knowledge. Similarly, Falk and colleagues (1998) found no differences in the extent of knowledge between focused and unfocused visitors but only in their mastery of the topic. This result, again, is an indicator for deeper processing of information by visitors with learning goals.

According to Schnotz and Zink (1997) goal-oriented hypertext learners do acquire more goal-relevant knowledge than learners without goals. I assumed to find a similar effect in studies 1 and 2. Contrary to this hypothesis, no differences in the amount of goal-relevant and goal-irrelevant knowledge acquired were found intraindividually and between conditions with and without awareness of a shared learning goal. Why might this be the case? Briseño-Garzón and colleagues (2007) assume that environmental factors distract visitors – independent from their entry agenda. Some exhibits intuitively call visitors' attention towards them (Rounds, 2004). A factor that might be relevant here is the aura of an exhibit (Benjamin, 1936; Valdecasas et al., 2006) that attracts visitors and guides exhibit selection. The similar amount of goal-relevant and goal-irrelevant exhibits explored in both studies is an indicator that the mere goal-relevance of an exhibit is not the central criterion for selecting and exploring an exhibit. Goal-relevance might lead to deeper elaboration whereas missing goal-relevance might lead to search for additional information or to sweeping to another exhibit. But as exhibits are selected independent from their goal-relevance the acquisition of a similar amount of knowledge with respect to goal-relevant and goal-irrelevant information can be expected. Maybe this finding is typically for informal learning in museums, where the attractiveness and the aura of exhibits steer visitor engagement? Currently, no study on learning goals in museums was published that reports effects on visitors' selection of exhibits. But the findings of this dissertation suggest that goal-relevance does not influence exhibit selection.

Because in the laboratory exhibition study conditions 1 and 2 show similar outcomes in terms of learning, the question can be raised whether *awareness of shared goals* is enough *or additional adaptation of content* is needed for effective informal learning? Awareness of shared goals induces goal-oriented evaluation and deep processing of information. Both are indicators of self-regulation processes (Boekaerts & Minnaert, 1999). These visitors can be compared to the effective goal-setters in Corredor's (2006) study, who selectively engaged in deeper processing of relevant content only. Adaptation of information has a comparable benefit with respect to the learning outcome (in the virtual exhibition even learning outcomes were higher with adaptation of information than without), but visitor dyads in this condition show less goal-oriented processing of information, as the requirements of self-regulation were reduced by adaptation of information (Leutner, 2004). Rather they explore the exhibition similar to dyads in the control condition that are not aware of a shared learning goal and receive random information. Why is adaptation of information beneficial for museum visitors? As outlined above information selection during a museum visit normally is not goal-directed but rather builds upon the salience and attractiveness of exhibits. Additional information can recontextualize exhibits that attract visitors' attention in the context of their goals, interests, or prior knowledge. The visual exploration behavior in the case study showed that such an expectation was raised in visitors who were made aware of a shared learning goal; they were more likely to ask for additional information on goal-irrelevant exhibits. If the additional information on the PDA met the dyads' goals, they more often retrieved additional information from the PDA again afterwards. By satisfying visitors' learning goal its awareness is maintained throughout the visit and visitors will be less distracted by goal-irrelevant but attractive exhibits as they relate to their goals – by means of the additional information on the mobile device.

To conclude, awareness of shared learning goal can induce self- and socially shared regulation of visiting behavior, deep processing of goal-relevant information, and acquisition of full rather than partial knowledge. But to ensure that awareness of the shared learning goal is maintained throughout the visit and that visitors are free to choose any exhibit adaptation of additional information on a PDA is beneficial.

9.3 Conclusions for further research

In this dissertation I used a nested *research design*. Therefore, the effect of adaptation of information could not be studied independently from awareness of shared learning goals. How could these effects be separated? Next to explicit adaptation of information –the form of adaptation I used in these studies by providing information adapted to users' explicitly stated goals – also implicit adaptation of information is possible (cp. chapter 4.3); for example, information could be adapted to visitors' prior exhibit selection (cp. Not et al., 1997; Petrelli & Not, 2005). Even though such an implicit adaptation requires a technically more advanced media application, it would allow to conduct a study with a complete 2 x 2 research design and to differentiate between the main effects and the interaction of both factors. A prerequisite of this design would be that visitors implicitly base their information selection on unconscious learning goals, which remains to be proven. Until now too little knowledge exists on the factors that contribute to the selection of exhibits – Is it the mere salience, the aura of an exhibit? Is it the position of an exhibit within the exhibition? The studies presented here suggest that relevance of the exhibits for a learning goal is not relevant for information selection but rather for exploration duration and successive behavior. More research on the factors that guide exhibit selection and on the influences of learning goals on visiting behavior is needed.

One open methodological question remains: How can *depth of information processing* be assessed best? In this dissertation I used three different measures: exploration behavior, self-reports, and full versus partial knowledge acquisition. The subjective reports seem to be of little validity, as they show a different picture than the outcome measures and the visiting behavior. Knowledge acquisition as an outcome indicator could be successfully applied in this study: Partial knowledge seems to be an indicator of more superficial processing, full knowledge of deeper processing. But a more interesting question is how depth of information processing can be assessed in the actual process? Other researcher suggest eye movements (number of fixations, Rothkopf & Billington, 1978), conversation (Leinhardt & Knutson, 2004), or processing time (Corredor, 2006; Schnotz & Zink, 1997). In study 1, longer processing of information was observed for goal-relevant additional information accompanying goal-irrelevant exhibits. In study 2 another indicator of deep processing was found, namely the behavior following deep processing of goal-relevant information: When the visitor in the case study explored goal-relevant information he was likely to visually engage in social interaction. When he visually explored goal-irrelevant information he sought for additional information on the PDA afterwards. If other dyads with awareness of shared goals received goal-irrelevant information upon such a request, they ignored the PDA longer and more often than in other cases. These behavioral patterns can be interpreted as an indicator of deep or shallow processing respectively. Further research is needed to address the reliability of these measures in other learning settings and to assess their validity in relation to other measures found in literature.

Griffin and Symington (1998, p. 2) stated about *learning assessment* in museums:

> To expect many similarities between the learning of individual visitors may not be productive. The very personal nature of learning in a museum, the short time students are involved in these distinct experiences, and the broader, but individual contexts in which it occurs make it meaningless to attempt to measure museum-based learning with the same degree of reliability as classroom learning.

I agree with them that the assessment of learning outcomes in museums requires other methods than research in formal educational settings. The approach presented here relies on the work of Ben-Simon and colleagues (1997) to differentiate between partial and full knowledge. By applying this methodology, I could replicate the finding from museum research that learning motivations enhance learning in museums (Falk et al., 1998; Leinhardt & Knutson, 2004; Packer & Ballantyne, 2002) using a knowledge test – a methodology which did not reveal such an effect until now (Zueck, 1988). Therefore, I think the assessment of partial and full knowledge is a promising way to measure informal learning outcomes in museums with high reliability, though further refinement of this methodology might be necessary.

The finding that participants in study 1 reported deeper information processing than in other exhibitions raises the question whether research from *virtual museums* can be transferred to real museums, as suggested for example by Corredor (2006). Comparison of results from the virtual and the laboratory exhibition study shows some common patterns with respect to information processing but also some differences: For example, awareness of a shared learning goal led to higher learning outcomes in study 2, whereas in study 1 it did so only with additional adaptation of information. Also, in the virtual exhibition participants in the control condition reported very deep processing of information and acquired more full than partial knowledge. These results indicate that some form of learning association was activated in the virtual exhibition and that the setting might be more formal than visiting a real exhibition. Therefore, research findings from virtual museums should be transferred to real museums with caution only.

9.4 Conclusions for media in museums

The results of this dissertation show that it is not enough to just make learners aware of a shared learning goal. An important prerequisite for the influence of this goal on information processing and learning is that the goal is in some way met by the exhibits and information in the exhibition (see also Zueck, 1988). As a possible support I suggested adaptive mobile media which can recontextualize exhibits; for example with respect to visitors' goals. In this study I manipulated awareness of a shared goal by providing visitors a list of possible learning goals for the exhibition and encouraging them to select one goal of shared interest. The benefit of this manipulation is that adaptation of information is made easy as the number of necessary text sets is restricted. However, I think that the success of this manipulation was in some parts due to the little prior knowledge of participants on the topic of nanotechnology. If visitors normally explore an exhibition (especially one on a different topic) they come with more prior knowledge and stronger interests than was the case here. As this leads to more heterogeneous visitor expectations the provision of a list of goals might not be successful in such exhibitions. But at the same time, it is not possible to provide a guiding system that can relate each exhibit in an exhibition to each goal a visitor might possibly have. A possible solution is to conduct an evaluation study with a representative sample of visitors to assess their interests and learning goals in relation to an exhibition (topic). In a second step, it would be possible to develop and provide adaptive information for the most frequent learning goals and expectations found. Otherwise also a technically more powerful system could be developed which analyzes visitors' stated learning goals semantically and generates relevant texts from a huge information pool. In comparison to such an application, the mobile device used in this dissertation was rather simple: Learning goals and adaptation were predefined and restricted to four, user's location awareness was simulated in study 2, and a graphical hypertext was used for information selection in both studies. However, the purpose of this study was a proof of the underlying concept. The results of the conducted studies show that awareness of a shared learning goal and adaptation of information can support deep processing and learning in an exhibition. Awareness of shared goals induces deeper processing and additional adaptation of content ensures that these goals are met by the information presented and thereby further supports goal-directed behavior. These two ways of support successfully build upon characteristics of the learning setting of visiting an exhibition. This dissertation provides an example how a museum can take the informal visiting situation seriously and support visitors in self-regulated processing and learning.

To conclude, I want to return to Blühm (2008, p. 9) who said about a museum visit: "How exciting it gets, you determine by yourself; because the artifacts in a museum mirror whatever you want to see within". Sometimes the museum has to support the visitors to discover what they want to find out about the exhibits and to present an adapted mirror image.

10 Summary

In informal learning visitor often do not pursue any learning goals and normally do not process information in a deep manner. From these characteristics of the learning setting two approaches were derived how learning in museums can be supported: (1) Making visitor dyads aware of a shared learning goal helps them to visit a museum in a more focused way, regulate their information processing socially, process information deeper, and thereby acquire more knowledge. (2) As normally information processing in informal settings is rather superficial, a second support is needed which helps visitor dyads to maintain deep, goal-oriented processing throughout their visit: An adaptive mobile device displays additional information that re-contextualize an exhibit in the context of a dyad's shared learning goal. Adaptation of content reduces requirements to search for goal-relevant information and thereby frees cognitive resources for elaborating the information. As a side effect, awareness of a shared goal is reinforced by each goal-relevant information that is received on the device and can be maintained throughout the visit with less effort.

Two studies were conducted to test whether these two ways of support can enhance deep, goal-oriented information processing and learning in an exhibition. Study 1 was conducted in a virtual exhibition and study 2 in a laboratory exhibition. These two settings differ with respect to their formality and allow analyzing effects of the learning environment's formality on the efficiency of the two approaches.

In the virtual exhibition (study 1) visitors with awareness of shared goals processed goal-irrelevant exhibits longer if they were accompanied by goal-relevant additional information. Adaptation of information led to higher learning outcomes and more full knowledge, indicating deeper processing of information with adaptation.

In the real exhibition (study 2) visitors with awareness of shared goals acquired more full knowledge than visitors without awareness – independent from adaptation of information. Awareness did not effect exploration duration, but a goal-directed use of the mobile device: Without adaptation visitors especially requested additional information on goal-irrelevant exhibits. If in this case the device presented goal-relevant information they were fast to use it again; but if the device presented goal-irrelevant information is was more likely to be neglected in the following.

Results from both studies indicate that awareness of shared goals elicits goal-directed behavior (exploration duration, evaluation of information) and self- / socially shared regulation processes. But if the exhibits do not meet the visitors' activated goals they are likely to be disappointed and terminate their visit earlier. Adaptive mobile devices can help to satisfy their search for goal-relevant information. Additionally, they reduce requirements of exhibit selection and maintain and even reinforce the awareness of the shared learning goal. Combining both ways of support seems to be a promising way how museums might assist their visitors in self-directed, deep processing of information.

11 Zusammenfassung

Beim informellen Lernen im Museum verfolgen BesucherInnen vielfach keine Lernziele und verarbeiten Information oft nur oberflächlich. Ausgehend von diesen Merkmalen der Lernsituation wurden zwei Möglichkeiten abgeleitet, wie Lernen im Museum unterstützt werden kann: (1) Die Bewusstmachung von geteilten Lernzielen unterstützt Besucherdyaden in zielgerichteterem Besuchsverhalten; in der gemeinsamen (Selbst-)Steuerung der Informationsverarbeitung, in der tieferen Verarbeitung von Information und letztendlich im Lernen. (2) Da Informationsverarbeitung in informellen Lernumgebungen normalerweise eher oberflächlich ist, bedarf es einer zweiten Unterstützung, die den Besucherdyaden hilft ihre zielgerichtete Informationsverarbeitung während des gesamten Besuchs aufrechtzuerhalten: Eine Lösung bieten adaptive mobile Medien, die den BenutzerInnen Zusatzinformationen präsentieren, welche die Exponate im Bezug zu deren Lernzielen setzen und so re-kontextualisieren. Dadurch werden die Anforderungen zur Suche nach zielrelevanten Exponaten und Information reduziert und es stehen mehr kognitive Ressourcen zur tiefen Verarbeitung und Elaboration der Informationen zur Verfügung. Daneben verstärkt die adaptive zielrelevante Zusatzinformation die Bewusstheit des geteilten Lernziels und erhält diese während des gesamten Besuchs aufrecht.

Diese beiden Unterstützungsansätze für tiefe, zielorientierte Informationsverarbeitung und Lernen in Museen wurden in zwei Studien empirisch überprüft. Studie 1 wurde in einer virtuellen Ausstellung durchgeführt, Studie 2 in einer Laborausstellung. Diese beiden Settings unterscheiden sich hinsichtlich ihres formalen Charakters und erlauben es den Einfluss der Formalität einer Lernumgebung auf die Effektivität der beiden Unterstützungsansätze zu untersuchen.

Durch die Bewusstmachung geteilter Ziele verarbeiteten Besucherdyaden in der virtuellen Ausstellung (Studie 1) zielirrelevante Exponate länger, wenn diese von zielrelevanter Zusatzinformation am mobilen Medium begleitet wurden. Die zusätzliche Adaptation der Zusatzinformation führte zu einem höherem Lernerfolg der BesucherInnen und mehr Sicherheit in ihr eigenes Wissen (Vollwissen), einem Indikator für tiefere Informationsverarbeitung.

In der Laborausstellung (Studie 2) erwarben alle BesucherInnen mit bewussten geteilten Lernzielen (unabhängig von der Adaptation) mehr Vollwissen. Bewusste Ziele hatten keinen Effekt auf die Dauer der Exploration, jedoch auf eine zielgerichtete Nutzung der mobilen Medien: Ohne Adaptation fragten die Besucherdyaden im speziellen Zusatzinformation zu zielirrelevanten Exponaten an. Erhielten die BenutzerInnen auf ihre Anfrage zielrelevante Information nutzten sie in der Folge das mobile Endgerät verstärkt; erhielten die BenutzerInnen jedoch zielirrelevante Information wurde es in der Folge eher ignoriert.

Die Ergebnisse der beiden Studien zeigen, dass die Bewusstmachung geteilter Lernziele ein zielgerichteteres Besuchsverhalten und die (gemeinsame) Selbststeuerung des

Lernprozesses hervorrufen kann. Wenn jedoch die Information nicht mit dem aktivierten Ziel übereinstimmt, werden die Erwartungen der BesucherInnen enttäuscht und der Besuch früher abgebrochen. Adaptive mobile Medien können dem entgegensteuern, indem sie die Suche der BenutzerInnen nach zielrelevanter Information befriedigen. Sie reduzieren die Anforderungen für die Informationsselektion und können sogar die Bewusstheit der geteilten Lernziele während des Besuchs verstärken. Die Kombination beider Ansätze scheint ein viel versprechender Weg zu sein, wie Museen ihre BesucherInnen in selbstgesteuerter, tiefer Informationsverarbeitung unterstützen können.

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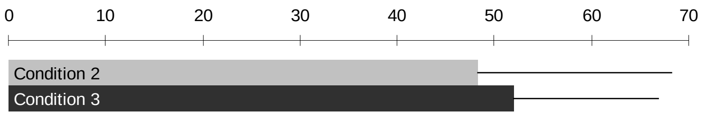
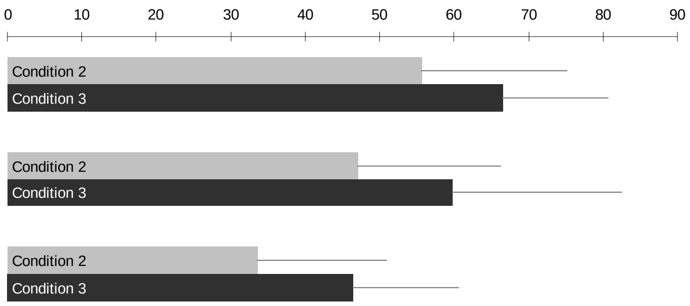
Appendix

Table A1. Study 1: visiting behavior of dyads in conditions 2 (awareness of shared goals) and 3 (no awareness) for each layer of the virtual exhibition



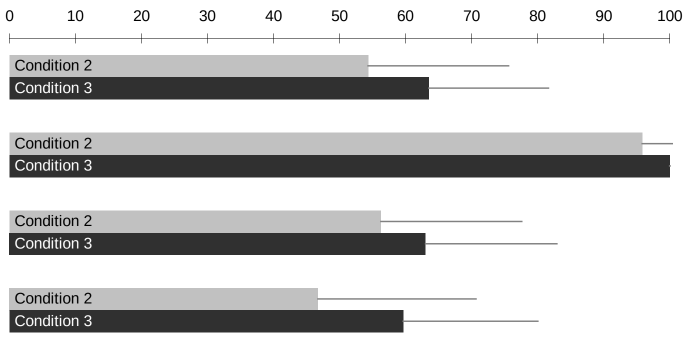
	t	df	p
Visit duration	-0.59	29	.561

N of pages visited



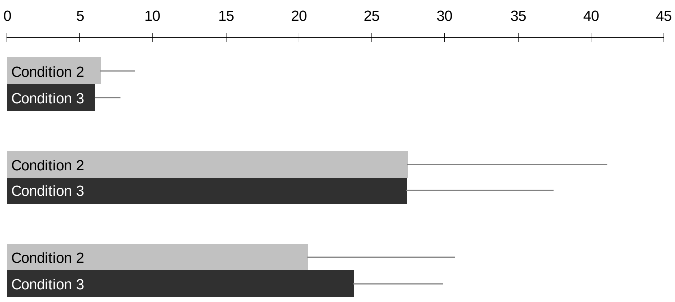
	t	df	p
Layer 2	-1.77	29	.087
Layer 3	-1.71	29	.099
Layer 4	-2.26	29	.032

% of exhibition visited



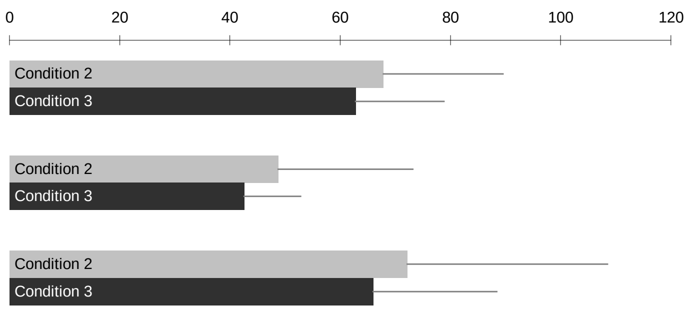
	t	df	p
Overall	-1.29	29	.208
Layer 2	-2.24	15.0	.043[a]
Layer 3	-0.91	29	.369
Layer 4	-1.61	29	.117

Overall minutes on layer



	t	df	p
Layer 2	0.56	29	.578
Layer 3	0.01	29	.993
Layer 4	-1.07	24.8	.296

Average seconds per page



	t	df	p
Layer 2	0.74	29	.467
Layer 3	0.93	20.4	.362
Layer 4	0.57	29	.574

[a] Due to the small overall number (7 exhibition parts) and no variance in condition 3 (everybody visited each wall), this significance should not be interpreted.

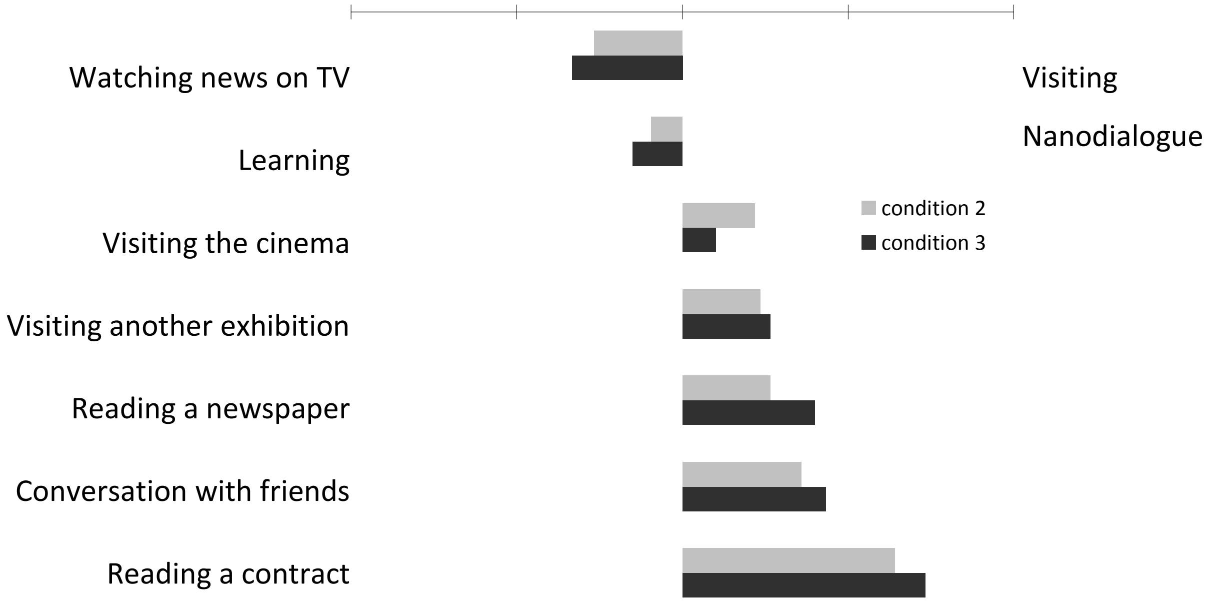
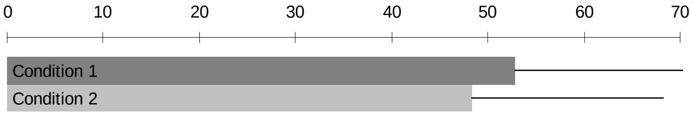
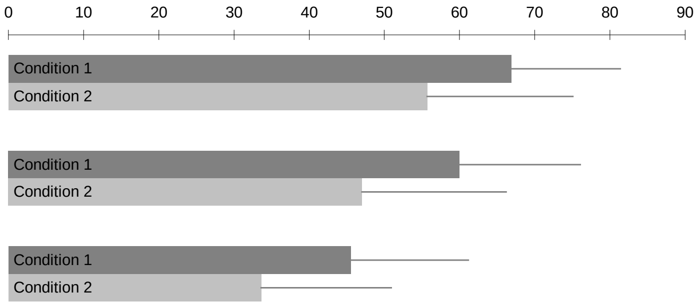
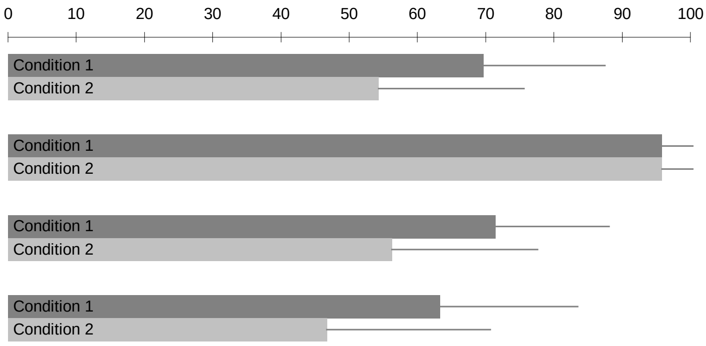
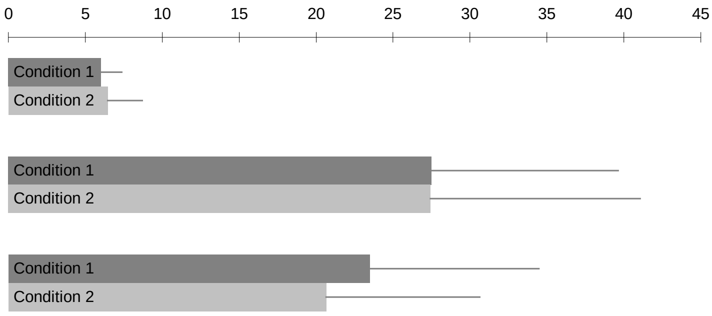
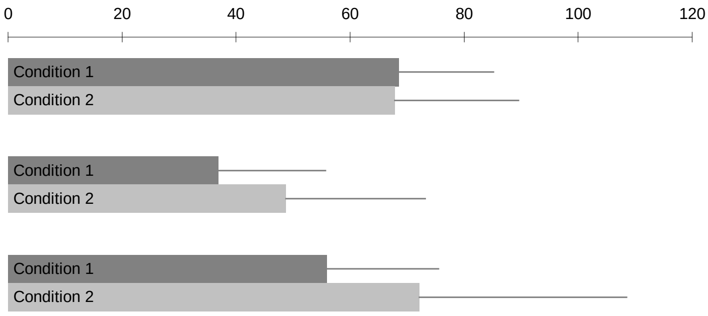


Figure A1. Study 1: self-reported depth of information processing in the virtual exhibition Nanodialogue in comparison to other daily situations in conditions 2 (awareness of shared goals) and 3 (no awareness)

Table A2. Study 1: visiting behavior of dyads in conditions 1 (adapted information) and 2 (random information) for each layer of the hypertext

Measure	Layer	Chart	t	df	p
Visit duration			0.67	30	.509
N of pages visited	Layer 2		1.85	30	.074
	Layer 3		2.08	30	.046
	Layer 4		2.05	30	.049
% of exhibition visited	Overall		2.22	30	.034
	Layer 2		0.00	30	1.00
	Layer 3		2.24	30	.033
	Layer 4		2.11	30	.043
Overall minutes on layer	Layer 2		-0.67	30	.509
	Layer 3		0.01	30	.989
	Layer 4		0.76	30	.451
Average seconds per page	Layer 2		0.10	30	.924
	Layer 3		-1.54	30	.134
	Layer 4		-1.58	30	.124

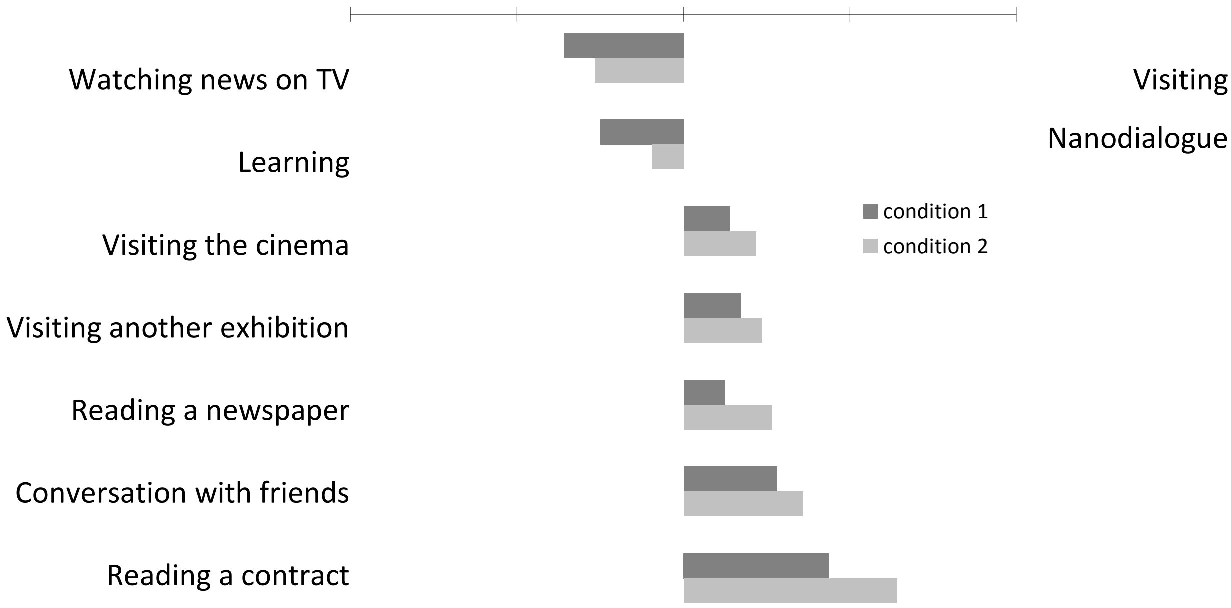
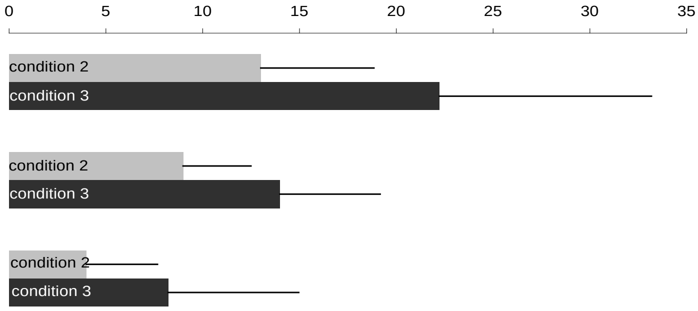
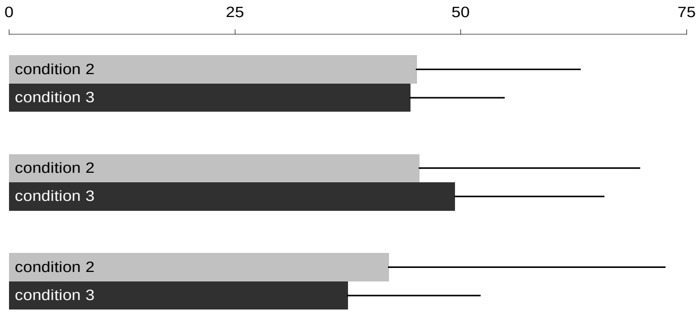
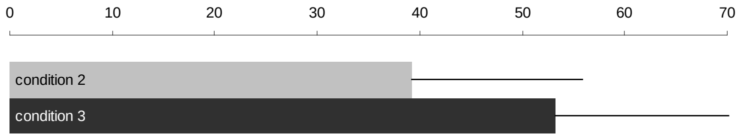


Figure A2. Study 1: self-reported depth of information processing in the virtual exhibition Nanodialogue in comparison to other daily situations in conditions 1 (adapted information) and 2 (random information)

Table A3. Study 2: visiting behavior of dyads in conditions 2 (awareness of shared learning goals) and 3 (no awareness)







		U	Z	P
N additional information	Overall	22.00	-1.88	.060
	Artifacts	18.50	-2.20	.029
	Texts	28.50	-1.36	.175
Average seconds per site	Overall	43.00	-0.16	.870
	Artifacts	40.00	-0.41	.683
	Texts	34.00	-0.19	.847
	Visit duration	23.00	1.80	.072

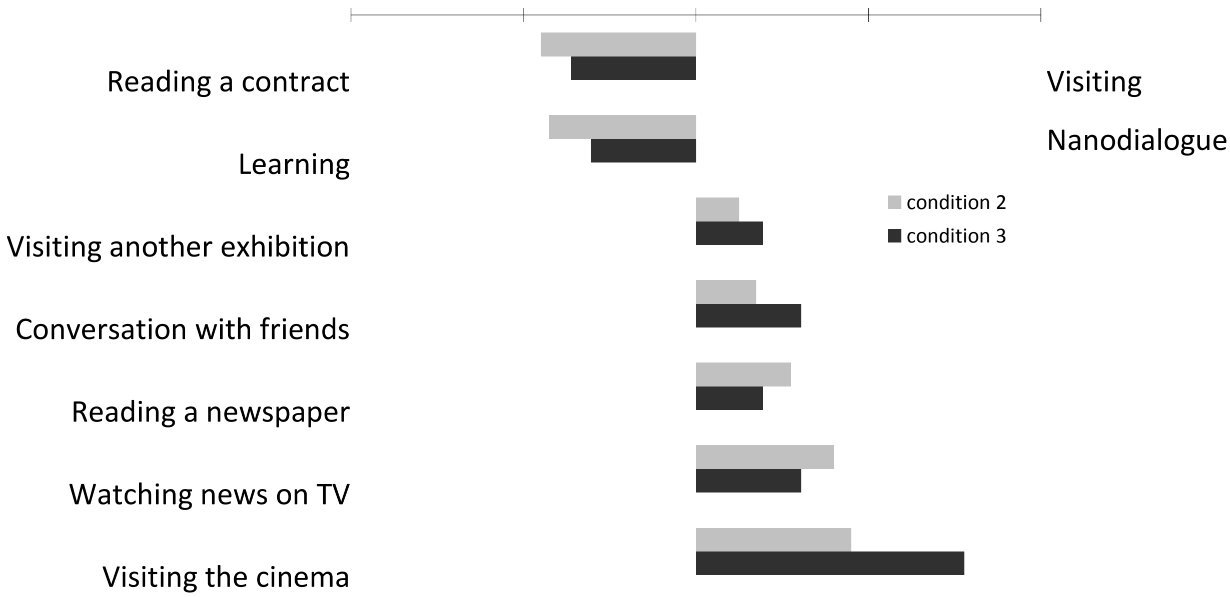
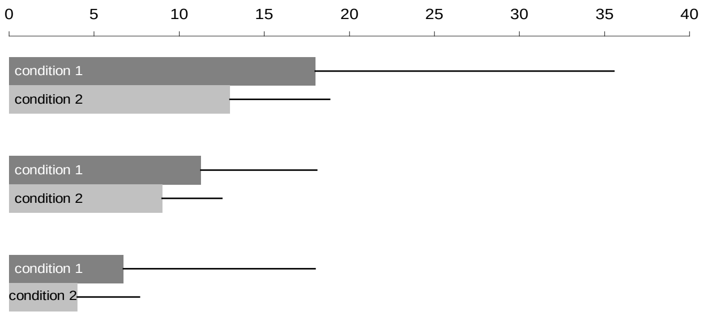


Figure A3. Study 2: self-reported depth of information processing in the laboratory exhibition Nanodialogue in comparison to other daily situations in conditions 2 (awareness of a shared goal) and 3 (without awareness)

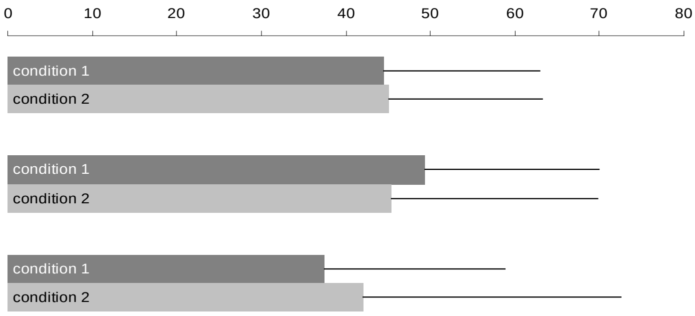
Table A4. Study 2: Visiting behavior of dyads in conditions 1 (adapted information) and 2 (random information)

N additional information

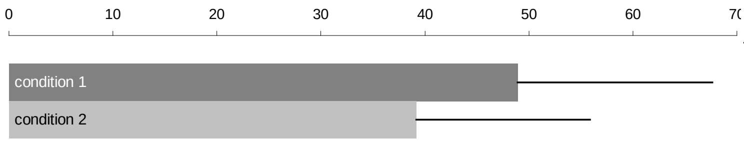


N additional information	U	Z	P
Overall	53.00	-0.14	.888
Artifacts	46.50	-0.60	.548
Texts	50.00	-0.36	.721

Average seconds per site



Average seconds per site	U	Z	P
Overall	42.00	-0.92	.360
Artifacts	52.00	-0.21	.833
Texts	35.00	-0.49	.627



	U	Z	P
Visit duration	38.00	-1.20	.231

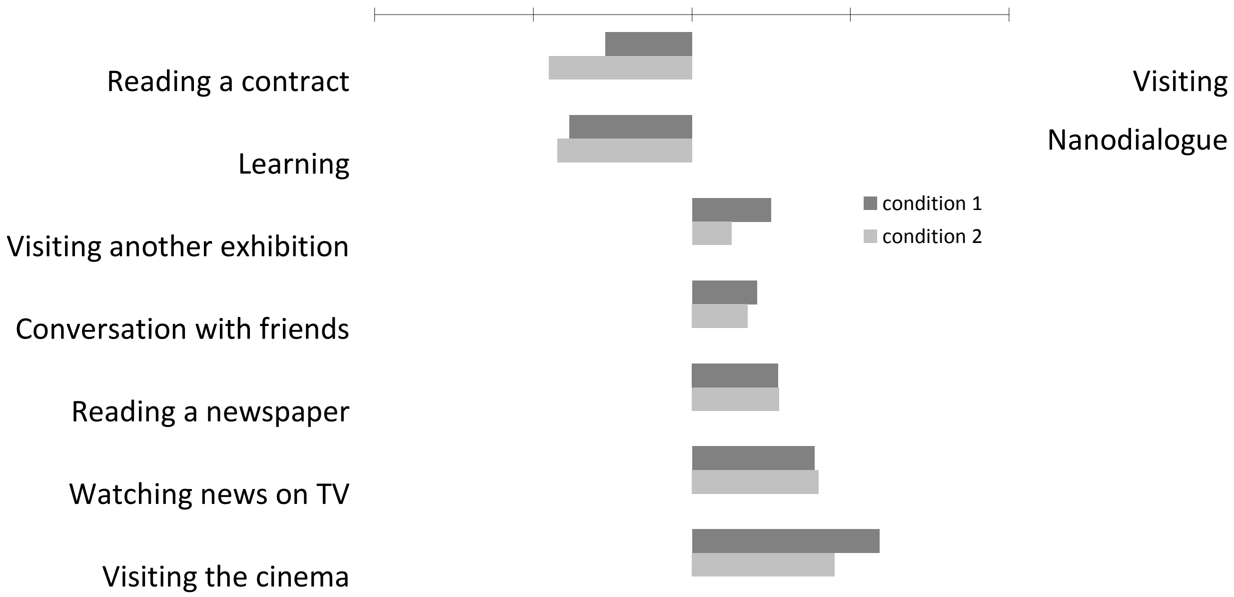


Figure A4. Study 2: Self-reported depth of information processing in the laboratory exhibition Nanodialogue in comparison to other daily situations in conditions 1 and 2

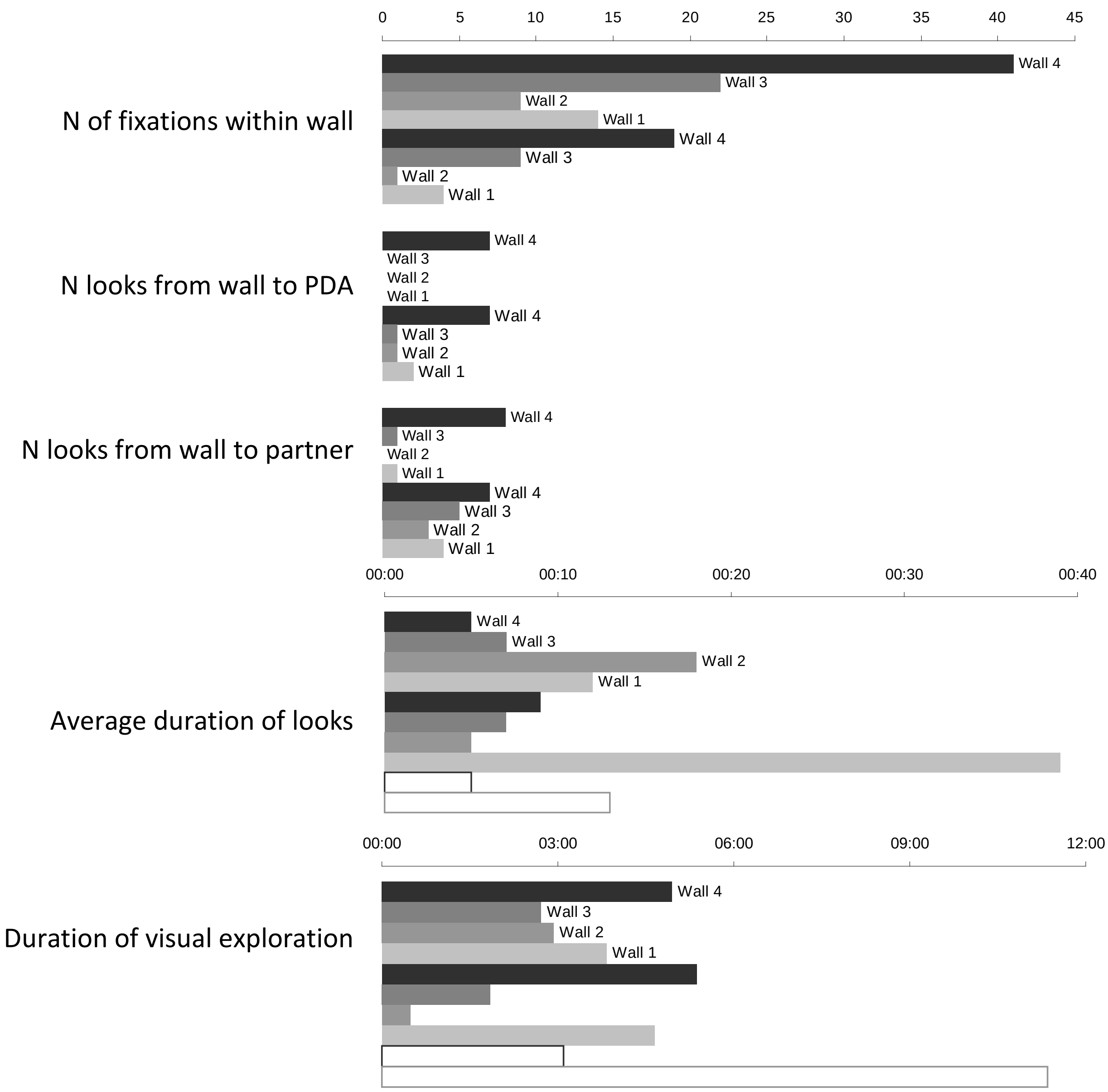


Figure A5. Study 2: visual explorations of exhibition walls in the case dyad