Supporting Information Processing in Museums with Adaptive Technology

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Abstract

When people visit informal learning settings like museums, they often do not give priority to learning and knowledge building. This could be due to a leisure orientation or due reduced cognitive capacities available for information processing. To enhance collaborative and individual elaboration of information presented and individual as well as collaborative learning in museums it is assumed that information presentation should be adaptive and match visitors' shared interests. Additionally, when a visitor dyad is aware of their shared goals more goal-orientated information processing and knowledge communication should result and thereby learning should be enhanced. To address the effect of goal-awareness and adaptive information presentation an experimental study is conducted. Shared goals are made aware to visitor dyads and information is presented adaptively on a Pocket PC during their museum visit. Visitors, who are aware of their goal, but do not receive adaptive information, look at fewer exhibits than others. Visitors, who are aware of their shared goals and are provided with adaptive information additionally, are better in solving transfer problems. Impact for design of adaptive technology for informal learning is discussed.

Keywords: Informal Learning; Mobile Learning; Computer-Supported Collaborative Learning; Cognitive Capacity

Information Processing in Informal Settings

Informal learning settings like museums provide rich resources for individual and collaborative knowledge building: Visitors have to choose from a huge pool of information according to their personal interest (*free-choice-learning*, Dierking, Ellenbogen, & Falk, 2004) and elaborate on the selected information. Therefore, visitor interests and learning goals have an even greater value in informal than in formal learning settings (Boekaerts & Minnaert, 1999) as they guide information selection and elaboration.

Unfortunately, informal learning is often inferior to formal learning with regard to knowledge acquisition. Different explanations for this phenomenon are possible: First, visitors might have no learning but only recreational and social intentions when visiting a museum (leisure hypothesis). Second, presented information might be too complex to process with the cognitive capacities available in this setting (capacity hypothesis). Both hypotheses will be explored with regard to theories of information processing and existing results of psychological and museum research.

Leisure Hypothesis

Studies on visitors' 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 some general interest (Black, 2005). Interestingly, different results emerge when visitors are given a list of different motivations to indicate how much they agree with each of them (Falk, Moussouri, & Coulson, 1998; Packer, 2006): Most people indicate that learning is an important part of their visiting experience, but also entertainment. 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 had a learning experience. According to Falk et al. (1998) visitors with education or entertainment agendas have higher learning outcomes than visitors with other agendas (place, life cycle, social event, and practical issues). Thus, differences in visiting agendas do not fully explain differences in learning: Visitors with learning goals as well as visitors with leisure goals have learning experiences in informal settings (Falk et al., 1998; Packer, 2006).

Subjective concepts about and attitudes towards the learning setting and learning within this setting (Packer, 2006; Salomon, 1984) might explain the similar power of learning goals and leisure goals for knowledge acquisition: Packer (2006) showed that learning in museums has an important enjoyment characteristic in visitors' subjective concepts. According to the work of Salomon (1984), the subjective attitudes towards a medium determine how information is processed: As American children have higher leisure attitudes towards television they process information with less mental effort than Israeli children. As visitors regard learning in museums as easy and effortless (Packer, 2006), Salomon's (1984) results should be valid for the museum setting, too.

As descriptive museum studies (e.g., Black, 2005, p. 16) showed that around 80% of museum visitors come in groups, it could be assumed that many visitors come with a social intention instead of a learning intention. However, Packer and Ballantyne (2005) found that the social experience is subjectively not an important agenda for a collaborative visit. Anderson (2003) on the other hand found that especially the social aspects of a visit are remembered in the long term. Co-visitors are also important for knowledge processing in the museum (Packer & Ballantyne, 2005): Dyads share opinions about the exhibits, explain them to each other and relate information to prior experiences in their conversations. These observations are similar to results in formal learning, where social influences were shown to be important for information processing (Hinsz, Tindale, & Vollrath, 1997; Levine, Resnick, & Higgins, 1993; Salomon & Perkins, 1998). However, it remains to be proven, that these processes and influences are equivalent. Nevertheless, the social situation of a museum visit can assist knowledge acquisition in the individual and should be taken into account when designing technological support for informal learning.

As studies showed the relevance of a focused visiting strategy for learning in museums (Falk et al., 1998), learning could be improved, when a museum is visited in a more focused way. Studies in formal learning contexts showed 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 can raise curiosity, intrinsic motivation and attention towards reaching this goal (Boekarts & Minnaert, 1999; Csikszentmihalyi & Hermanson, 1995; Loewenstein, 1994). Therefore making shared goals aware to a visitor dyad prior to a museum visit might enhance their goal orientation and thereby informal learning.

Capacity Hypothesis

Museum studies on visitors' attention and cognitive capacity are quite rare. One of the best documented concepts in museum research is "museum fatigue" (Evans, 1995; Petrelli, Not, & Zancanaro, 1999): Museum visitors experience physical and mental fatigue after some time of exploration. According to Serrell (1997) there is only a limited time available to hold visitors' attention. The average visitor spent 19 minutes in an exhibition and 51% of visitors looked at less than half the exhibits available. If visitors are provided with advanced organizers more mental effort is available to process the information presented: When homogenous exhibit clusters were labeled accordingly by Falk (1997) visitors' concept development was enhanced. This effect could be explained by a higher amount of mental effort available for information processing. Research by Salomon (1984) indicates that different amounts of mental effort are invested in informal / leisure and in formal / educational settings. An analysis of differences between informal and formal learning shows that self-regulation of the learning behavior differs (Boekaerts & Minnaert, 1999): In an informal learning setting goals have to be set by the learner himself, he has to select appropriate information, and process it with respect to his prior knowledge. Maybe an even higher amount of mental resources is needed in informal learning settings to process information at the same depth as in formal settings.

The social situation can reduce the needed mental resources by providing some kind of structure: Agendas are often implicitly inhered in an existing visitor group (e.g., school classes: learning intention, parent-child groups: exploration intention) and shared interests guide their visiting behavior. Other visitors serve as model for information selection (*social navigation*, Höök, 2003). Exhibit information is elaborated in conversation (*conversational elaboration*, Allen, 2002; Leinhardt, Crowley, & Knutson, 2002). Studies in the context of formal learning for example show that under specific conditions (e.g., high trust, familiarity) dyads are superior to individual learners regarding memory capacity (Hinsz et al., 1997; Hollingshead & Brandon, 2003).

But not only other visitors, also the museum as a learning environment can structure the visit and guide visitors in a way that reduces mental resources needed to process the information. Following this rationale, principles for object organization (e.g., Falk, 1997) and label design (e.g., Bitgood, 2000) are broadly used in museums. But these actions do not serve all visitor groups in the same way: They have different interests, prior knowledge, time resources, to name only some differences. New media applications can adapt information to visitors' needs (cp. Goren-Bar et al., 2006). Adaptive systems build a model of the visitor and use this model for further interaction (Brusilovsky, 2003). An exemplary application is a PDA guide suggesting tours based on visitors' interests and time budget (e.g., Singapore Science Centre; Teo, 2005). Next to an explicit adaptation of information based on user input (e.g., Teo, 2005) implicit adaptation based on user behavior is possible (e.g., Not et al., 1997). As information that matches a visitor dyad's shared interests reduces the amount of mental effort needed to relate this information to existing knowledge structures, more cognitive capacities are available to process the information. Thereby, informal learning could be increased.

Research Questions

The appropriateness of both hypotheses for learning in museums is studied in this experiment. First, visitor dyads are made aware of a shared goal. It is assumed that availability of shared goals in working memory would increase motivation and learning orientation in informal learning.

Second, information is presented adaptively to a visitor dyad's shared goal. Thereby the need to relate a selected object to this goal is reduced. Other ways of adaptation like

adapted navigation or adaptive guided tours were considered, too. The advantage of adaptive information to every exhibit is that visitors' free-choice is maintained. As free-choice is an important feature of informal learning (Dierking et al., 2004) a less invasive technology seems more appropriate for a museum setting.

It is studied whether visitor dyads, who are aware of their shared goals or who are presented information adaptively, select objects differently, elaborate information in their conversation in different ways, and finally learn more than visitors provided with none of these two ways of support.

Methods

A 2 (goal-awareness) x 2 (goal-adaptive information) experimental design is used in this study (see table 1). In condition 1 information is adapted explicitly on user input; visitors are asked to state their shared goal. In condition 2 visitors are made aware of their shared goal, too, but information is not adapted to this goal. In a third condition information is adapted implicitly on visitors' prior exhibit selection. In a control condition (condition 4) neither goals are made aware nor is information adapted.

Table 1: Research design.

Goal-awareness	Goal-adaptive information	
	Yes	No
Yes	condition 1, N = 16	condition 2, N = 16
No	condition 3, N = 15	condition 4, N = 15

Subjects

15 dyads of acquainted subjects from Tuebingen (Germany) are recruited per condition. Relationships include fellow students (10%), flat mates (27%), friends (31%), siblings (6%), and partners (26%). Most dyads are same sex (63%) and have at least a high school diploma (87%) or university degree (9%). 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 first subjects are randomized to conditions 1, 2, and 4. Condition 3 is assessed subsequently, as behavioral data from other participants serves as data base for implicit adaptation in condition 3.

Material

A small exhibition about nanotechnology ("Nanodialogue" by the European Commission) serves as research setting in this project. A virtual version of the exhibition was created and is presented in the form of a graphical hypertext (imagemaps) on a smartboard, allowing input from both participants alike. The size of the exhibition allows research on this exhibition in a research laboratory under controlled conditions. Validation studies in the real exhibition are planned.

For all exhibits five parallel text sets have been created, providing adequate information serving five different interests (chances & risks, societal impact, impact on daily life, background information, oddities). The information is presented to dyads according to their shared interests in condition 1 or prior exhibit selection in condition 3, whereas dyads in conditions 2 and 4 receive random text versions for each exhibit. Exhibit information is presented on a Pocket PC.

Next to a video camera and PDA log files, microphones were used to record the visiting behavior of a dyad. Communication was recorded as an indicator of cognitive processing and collaborative elaboration of information.

To assess mental effort the self-report-measures by Salomon (1984) were adapted. Additionally, subjects were asked to compare the mental effort needed to process information in the exhibition with mental effort needed to process information in seven other everyday situations (e.g., visiting other exhibitions, watching news on TV, reading a contract).

Learning is assessed with a knowledge test. To find an appropriate measure for informal learning, three different types of questions are used: Open questions that allow assessment of broader and deeper knowledge, multiple-choice (MC) factual knowledge questions, and MC transfer knowledge questions. For all MC questions partial and full knowledge could be indicated by the participant (Ben-Simon, Budescu, & Nevo, 1997). Partial knowledge seems more appropriate as learning outcome for informal learning settings than full knowledge. Prior knowledge on nanotechnology is controlled.

Procedure

Participants are asked to participate in a study on communication in museums. This cover story is used to reduce expectations of a learning-related study, as a pilot study showed that subjects participate with a learning intention otherwise. As subjects with learning intentions would act more similar to formal learning and would reduce the size of the expected effect, a learning-unrelated-instruction and study title was used.

At the beginning, participants are familiarized with navigation in the virtual exhibition and the use of a PDA. Then, dyads in condition 1 and 2 are asked to select a topic of shared interest from a list of topics, which are satisfied in the exhibition. In condition 1 information about the exhibits is then adapted to these interests. In condition 3 exhibit selection in the first minutes is analyzed with respect to the behavior of participants in conditions 1, 2, and 4, and information is then presented adaptively based on this behavior.

Dyads visit the laboratory exhibition without time constraints. After the visit participants are asked to fill out a questionnaire on their knowledge, satisfaction with the visit, experienced mental effort, prior knowledge, interest in the topic, and acceptance of the technology.

Participants received 12 € for their participation in this study.

Results

To compare *visiting behavior* across the experimental conditions, overall visiting time, number of selected exhibits and mean time at exhibits were analyzed. Preliminary data analysis[1] indicates that subjects have similar overall visiting times in all conditions and spend similar amounts of time at exhibits on the average. Subjects in condition 2 tended to look at less exhibits than subjects in conditions 1 and 4 ($df = 2$, $F = 2.33$, $p = .10$; cp. figure 1).

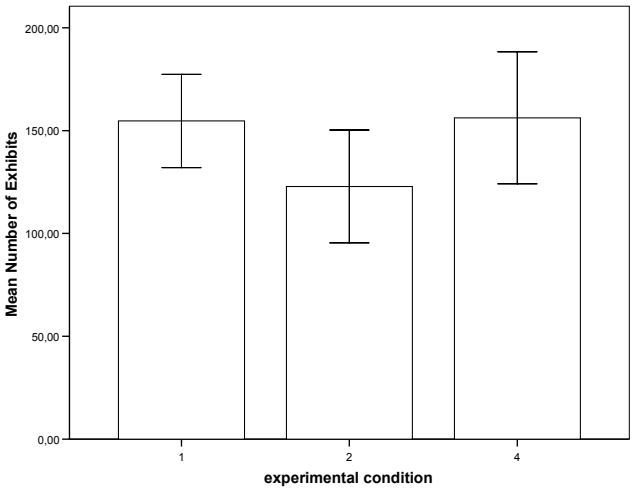

Figure 1: Mean number of exhibits visited

Conversational data have not been analyzed so far. Communication will be categorized with respect to negotiation processes, evidence of goal-orientation in exhibit selection and elaboration on information, and depth of processing. However, similarity of data within dyads is a first indicator that social processes during the visit lead to convergence of dyads (e.g., subjective knowledge acquisition $ICC = 0.39$, $F = 2.26$, $p = .003$, however prior knowledge $ICC = 0.03$, $F = 1.07$, $p = 0.41$, cp. Kenny, Kashy, & Cook, 2006).

With respect to *knowledge acquisition*, dyads, who received information that matched their shared interests, tended to be better able to answer transfer questions ($df = 2$, $F = 2.17$, $p = .10$). No differences were found with respect to factual knowledge.

First analysis did not show different *amounts of invested mental effort* between groups, but more sophisticated data analyses are still in progress.

Discussion

Other studies found that visitors focused on a specific interest stay longer in a museum (Doering & Pekarik, 1997; Falk et al., 1998). In contrast, this study found similar overall visiting time in all conditions. As subjects to a laboratory experiment can not be compared to visitors with respect to their agendas, interindividual differences might be reduced. Additionally, as subjects visited only this exhibition, they are more likely to spend much time on this exhibition in contrast to visitors to a large museum, where many different exhibitions are explored during one visit.

Visitors in condition 2, who were aware of their shared goals, but did not receive adaptive information, visited less exhibits than visitors in other conditions. This might be due to expectations, raised by the awareness of shared goals, but not satisfied with the random texts these visitors received. More detailed data analysis will show if there exist differences in attendance to additional information, if more conversational elaboration on exhibits within the dyad takes place in conditions 1 and 2, or both is the case. By making available relevant information for visitors' shared interests by adaptation it is assumed that a deeper processing strategy can be induced. Rothkopf and Billington (1979) found in an eye-tracking-study on text-processing, that goal-relevant information received more attention than goal-irrelevant information, when a specific goal was available.

With a focus on a specific interest visitors were shown to learn more (Falk et al., 1998). In this study dyads with adaptive information were better able to use their newly acquired knowledge to answer transfer questions. This is in line with the assumption that subjects in this condition elaborated higher on the content. The similar amounts of factual knowledge in all conditions shows that even without aware goals and adaptive information some knowledge is acquired in informal settings. This emphasizes the importance of non-strategic information acquisition (cp. Berger, 2002) in informal settings like museums.

Analysis of conversational data is still missing, but the influence of aware goals on conversation could be shown in other studies (Higgins, McCann, & Fondacaro, 1982; Russell & Schober, 1999). As the awareness of shared interests or goals adds to a dyad's common ground (Clark & Brennan, 1991) it thereby influences conversation. Furthermore, more thorough elaboration of information in dyadic conversation is assumed when information is adapted to a dyad's shared interest, as the amount of needed mental effort to relate the information to this shared interest is reduced.

An open question still is, whether the awareness of a specific interest also induces a learning orientation in visitors. A preliminary study showed an influence of learning orientation on the visiting behavior (more information and exhibits examined, higher scores in the knowledge test). These patterns are similar to preliminary results of the main study. Detailed analysis of the conversational data might answer the question whether a dyad's awareness of shared goals led to a more focused visiting strategy.

Studies on invested mental effort reported that less mental effort is invested in leisure settings (Salomon, 1984). These results show that adaptation of information and awareness of shared goals are two powerful ways to elicit deeper

[1] Data collection of condition 3 and data analysis is still in progress. Therefore, only tendencies are described and no numbers are reported. Results of the whole sample will be presented at the conference.

elaboration in leisure settings. However, no differences in amounts of invested mental effort were found between the experimental conditions so far. Studies on adaptive systems in formal (Brusilovsky, 2003) and informal contexts (Goren-Bar et al., 2006) show interindividual differences in acceptance and effect of adaptive systems depending on personality and prior knowledge. Maybe analysis of conversational data will give further insight into this question.

Overall, this study showed that both support systems – goal-awareness and adaptation – had an impact on visiting behavior and learning in the exhibition Nanodialogue: As adaptive technology provides the visitor with goal-relevant information, free-choice in the informal setting is maintained and less mental effort is needed to find appropriate information. With adaptive technology visitors seem to gain knowledge more flexible for transfer. Additionally, an informal setting like a museum emphasizes not only learning, but also enjoyment and development of interest and public understanding of science and humanities (PUSH, Durant, 1992) as outcomes of a museum visit. Influences of adaptive technologies on PUSH, visiting enjoyment, and interest development are important topics to be addressed in future studies.

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