Potentials and Challenges of Mobile Media in Museums

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***Abstract*—In this article we discuss potential scenarios of use for mobile media in museums and the challenges they pose. We examine how the characteristics of mobile technology suit the specific characteristics of a museum setting. Based on these considerations different ways to support visitors with mobile devices are put forward: attentional focus and guidance; satisfaction of situational interest; information adaptation to a specific visitor and to a specific location; information elaboration through facilitation of knowledge exchange and externalized memory support, as well as assistance in exhibition evaluation. Implications for the development of mobile applications in museums are derived.**

***Index Terms*—Adaptive systems, informal learning, information retrieval, mobile communication, museums, unsupervised learning.**

I. INTRODUCTION

In recent years museums became objects of increasing interest in the context of life-long learning as well as in the field of mobile learning. In Europe up to 183.124 visits per 100.000 inhabitants were counted [1] and up to 52 percent of the population visit a museum at least once a year. These numbers show that museums have the potential to be an important contributor to life-long learning of children, students, families, single visitors, and groups. At the same time, advances in mobile technology make it possible to provide information and connectivity on the move, enriching the museum setting in unprecedented ways. But as implementations of mobile technologies in museums increase in number, there is doubt if the implementation of mobile devices makes sense in this setting. Daniel Molitor [2] concisely asks the question "why are we doing this? Is it just because the stuff is out there and we're hip and cutting edge, or is this adding something fundamentally?"

In this article, we analyze how mobile devices can be used in exhibition contexts to improve the visiting experience, increase learning, and satisfy interests. We will look at potentials and challenges of mobile technologies for museums from a psychological point of view. This viewpoint leads to insights for the development and design of new mobile technologies as well, but technical aspects are not at the center of our article[1]. Rather, we want to raise the question in which way mobile technologies can assist a museum visitor.

[1] For the technical potentials and challenges of mobile devices in museums see [3], [4], [5], [6], [7], [8], [9], [10], and [11].

First, we introduce the museum setting: what characterizes museums, what constitutes exhibitions, and how visitors behave in this context. In the second part we identify different characteristics of mobile devices. The main part of this article will deal with the question how these technological characteristics can be used to enrich the museum visit. We conclude with implications for the development of mobile applications in museums.

A. Museums, Exhibits, and Visitors

The International Council of Museums (ICOM, [12]) defines *museums* as

> a non-profit making permanent institution in the service of society and of its development, open to the public, which acquires, conserves, researches, communicates and exhibits, for purposes of study, education and enjoyment, the tangible and intangible evidence of people and their environment.

This definition encompasses the high heterogeneity of museums. Museums display arts, science and technology, (local) history, natural science, ethnography, and much more. For the purpose of this article and in accordance to ICOM's definition, museums may also be botanic gardens, aquariums, zoos, and science centers. They can be indoor, open-air, or mixed.

Museums are typical examples of informal learning settings that are distinct from formal learning settings like schools by their leisure focus [14]. Learning in such a setting includes not only cognitive, but also motivational and emotional development. Usually museum visitors are rather autonomous, they often come in groups, and information selection and learning depends on intrinsic motivation and interest of the visitor to a great extent. Visiting behavior seldom is externally controlled, but is self-regulated by the visitor [15].

Exhibits are usually of great cultural or scientific value or extremely rare. Their uniqueness and authenticity is a main characteristic of museums and their greatest asset. They can be displayed in many different ways, from a "classic", neutral style in front of a white wall or in a display case without any or minimal information (especially in art museums) to a highly interactive, media dominated style (especially in science centers). Often different kinds of visualizations are mixed which increases the complexity of exhibitions.

Visitors across and within different exhibitions are usually very heterogeneous (e.g., regarding age, gender, prior knowledge, interests, goals, cp. [13]) and visitor characteristics vary between different types of museums. It is important to keep in mind that there is no "typical visitor" of a "typical exhibition" in a "typical museum". Since most visitors come in pairs or groups and are rarely

alone in an exhibition, a museum visit is a social situation and event. Other visitors serve as model for information selection (social navigation, [16]) and to elaborate on information in conversation (conversational elaboration, [17]). Visitors often treat exhibitions like an "all you can eat buffet" [18]. They try to see as much as possible but invest only little time for an individual exhibit ("window-shopping", [19]), making it difficult to fully understand single exhibits.

The museum setting is very complex, mostly consisting of many exhibits with high attraction power and placing high demands on visitors' cognitive resources. Despite interindividual differences, museum visitors commonly show signs of "museum fatigue" after about 30 minutes: Their interest decreases, they are more selective in choosing exhibits for further exploration, and they process information less deeply [20].

If we consider these aspects of the setting and the visitor, we draw the following conclusions: (1) Visitors and their visiting behavior are very heterogeneous. (2) The visitors decide what they want to see and for how long and what is considered to be worthy of further elaboration. (3) There is a time limit to get visitors' attention due to museum fatigue. (4) The selection of information and exhibits is very important. (5) The social environment influences the visit.

B. Mobile Technology

If we now look at mobile media, there are some key characteristics of mobile devices which are promising for their use in museums [21]:

Made to be mobile. Mobile devices like handheld computers or smartphones, are powerful technologies that are small and lightweight and can easily be carried around. As a museum visit is an experience on the move (in contrast to static ones like watching TV or sitting in a classroom), the mobility of the devices is a key potential for the museum. Information can be accessed on the move - the "anytime, anywhere"-argument for mobile devices. While portability is seen as main advantage, it also comes with a price, especially considering the heterogeneity of visitors: The small overall size of the device demands an equally small screen size and reduced input keys, making it difficult to display much information on the screen, to enter information, and to handle the device (especially for the visually impaired or persons with reduced motor control, like small children or elderly people). Also, while the device may be potentially available all the time on the move, the mere availability of mobile devices does not guarantee their actual use.

Made for connectivity. Mobile devices usually have numerous interfaces for data exchange, for example WiFi, UMTS, Bluetooth, IR, and RFID. This allows real time update of content (e.g., exhibit information, guided tours, special event notification) and great flexibility of information. The content provided can be dependent on a visitor's spatial position (location awareness) as a passive map or active guide leading visitors to interesting exhibits or providing location specific information. Additionally, connectivity allows communication with other visitors in different parts of the museum, enabling groups to explore the museum separately but remain in constant contact.

Made for a personal experience. Due to their small screen size mobile devices are made for a single user (taking personal in "personal digital assistant" seriously). Adaptive programming and personalized content for a visitor allow to tailor information to the interests and capabilities of a specific visitor, using information about self-reported interests, age, prior knowledge, or time constraints [8]. If user-awareness is combined with location-awareness, fully context-sensitive applications can present the "right information, at the right time, in the right way" [22]. While it is at least possible for a group of visitors to share the screen of a computer terminal or projection [6], the small screen size and frequent use of headphones in mobile devices makes sharing a single mobile device difficult or impractical.

II. POTENTIALS AND CHALLENGES OF MOBILE DEVICES IN MUSEUMS

If we look at these three main characteristics of mobile devices and at the characteristics of the museum setting, we come to the conclusion that mobile devices have the potential to offer museum visitors a personalized experience and assist them during their visits. How are mobile devices currently used in museums? The main applications appear to be to provide additional information and guidance. While the classic audio-guide is common, more and more museums begin to use PDA-like devices. They still provide audio information, but can also include visual information (static and animated) and can be flexibly configured (e.g., regarding user interface or functionality). However, mobile devices can not only assist visitors, they often impede visitor-exhibit and visitor-visitor-interaction: (1) *Visitor-exhibit-interaction*. Visitor studies as [23] show that mobile devices can distract visitors from exhibits. Thereby the interaction with the authentic objects, the main characteristic of museums, diminishes. (2) *Visitor-visitor-interaction*. Interaction between visitors might be reduced due to the use of mobile devices. This impairs the museum experience because social interaction strongly influences elaboration of information during conversation [17] and information selection [16]. These two problems must be overcome to use mobile devices in a purposeful way.

But mobile devices should not only overcome problems inherent to mobile technology. They should also add fundamentally to the museum visit [2]. Given the outlined characteristics of a museum visit and of mobile devices, we propose that mobile devices have the potential to enhance the visit by providing and assisting visitors in

a) attentional focus and guidance,
b) satisfaction of situational interest,
c) information adaptation to a specific visitor,
d) information adaptation to a specific location,
e) information elaboration through facilitation of knowledge exchange, and
f) information elaboration through externalized memory support.

If mobile applications come up to these potentials, they should result in higher visitor satisfaction, motivation, interest, and learning.

In addition to the benefit for visitors, mobile devices can

g) assist the museum in exhibition evaluation/visitor studies.

We will now discuss each of these points in detail, present their specific potentials, prototypical examples, challenges, and possible solutions.

A. Attentional Focus & Guidance

Potentials. Reference [24] defines attention as "expenditure of psychic resources" (p. 1). Attention towards an exhibit can be seen as prerequisite for learning and is also an indicator of interest and personal relevance of the exhibit.

Additional information (e.g., labels) might distract from the exhibits themselves: Some people argue that mobile devices support the "aura" of exhibits, a feeling of awe created by unique or remarkable objects [25], as no additional labels at the exhibits are necessary. Information can be presented in an unobtrusive way without destroying the visitors' feeling of wonder [26]. Visitors can experience emotional feelings of being impressed, amazed, or even touched (which is an important reason why people visit museums) before they consult their mobile device to learn something about the exhibit. However, it was observed that mobile devices distract visitors and redirect their attention from the exhibit to the mobile device [23]. Thereby, the central part of a museum visit – the interaction with the exhibit – is lost or at least reduced to a great extent. Therefore, the purpose of a mobile device should be to selectively direct visitors' attention to important aspects of an exhibit and enhance their interaction with exhibits. This preserves the tension between "letting the exhibit speak for itself" and giving additional information by directing attention towards specific features of the exhibit. This combination allows visitors to establish a meaningful relationship to the object.

Prototypical example. A handheld prototype based on a PDA was used at the Museum of Anthropology in Vancouver, Canada. It provided a video clip that broke down a complex artwork in its elements [27]. This mobile application directed visitors' attention towards specific parts of the exhibit. Thereby, it allows visitors to better understand the artwork.

Challenges. Changing the visitor-exhibit relationship not only provides focus and guidance, it lures the visitor's attention to the screen. For example, the introduction of mobile guides to an ancient Roman bath resulted in less interaction with exhibits [23]. This is commonly known as "lure of the screen" or "heads down" phenomenon.

A complicating factor is the heterogeneity of visitors regarding their (mobile) computer literacy[2] and their acceptance of (mobile) technology in museums. For these visitors a mobile guide will impede engagement with the exhibits if it is necessarily required.

Possible solutions. If textual output is given via audio, visitors' visual attention is free to take in the exhibits [10]. However, in this case software is needed that transfers text to speech in decent quality and maintains the advantage of easy changes in content of digital texts. In this somehow old-fashioned scenario screens should be used to a minimum only, mostly to allow selection of exhibits and display of pictures and videos which cannot be given per audio. Visual media can also use explicit relations to the exhibit, as suggested by [23]: Presented information can only be decoded if the visitor frequently looks at the exhibit to include important but missing points in the video or picture ("back and forthing", [28]). A technically sophisticated way to enhance attention to the exhibit is the use of mobile devices as "magic lenses": Visitors see the exhibit on the screen via a camera attached to the device. The device recognizes what is displayed via markers and augments the displayed image by additional information on the screen (as conceptualized in [29]).

Mobile guides should be as easy as possible so that they can be used by most visitors. Applications need to be self-explanatory and specifically designed for the specific exhibition. In contrast to personal organizers it cannot be expected that visitors have the time to learn new programs and functions, but the application must be obvious on a single glance.

B. Satisfaction of Situational Interest

Potentials. Authentic exhibits in an exhibition can stimulate curiosity and situational interest, a fleeting desire for more and deeper information (cp. [26] and [30]). Intrinsically motivated visitors get engaged with exhibits more and elaborate information more deeply [31]. Mobile devices can help to meet these interests and satisfy curiosity: With high storage capabilities and internet connection, mobile devices can provide access to diverse, interest fulfilling information according to his choices. The device can work as a digital, mobile label which contains sufficient information to satisfy visitors' situational interests on the spot and at any time [10]. In contrast, a media station has to be shared with others and draws the visitor's attention away from the exhibit. Mobile devices expand the physical exhibition space into a virtually augmented information space – beyond size restricted labels. Situational interest can lead to acquisition of deeper knowledge through more elaborate information processing strategies [32]. This is of high relevance in museums since the setting provides little extrinsic motivational factors as formal settings like schools do.

Prototypical example. In an empirical study by [33], visitors to an exhibition could retrieve additional information about the exhibits on their PDAs including articles from Wikipedia. Even though this study was done in a laboratory exhibition, first results are promising: Availability of information leads to more positive evaluations of the exhibition and to higher self-reports of engagement with the topic after the visit.

Challenges. Sufficient additional information to satisfy a high variety of visitor interests has to be created or collected and verified. Existing texts (e.g., labels, internet sources, scientific databases) are often unsuitable in length and content.

An additional problem is navigation through such a huge knowledge base, since visitors should be "quickly rewarded with a success experience and provided with simple and short amounts of information" [34].

Possible solutions. If the amount of necessary information cannot be provided by museum staff alone it is possible to include others – visitors and non-visitors alike – in the provision of knowledge. Allowing access to an online encyclopedia like Wikipedia provides necessary information in breadth and depth [33]. Additionally, as the content is licensed under the GPL, no copyright conflict

[2] For an overview how often visitors do "get it wrong" regarding media installations see [3] and [4].

arises. However, misuse and quality control become an issue. Museums can also involve visitors to create their own content, for example by letting visitors contribute to exhibit information via social tagging or entries in a local wiki. However, this requires a change in museums' (and curators') identity from providers of expert information to providers of a knowledge exchange platform.

Adaptive navigation systems can especially support learners with higher knowledge [35]. If we transfer these results to the museum setting it makes sense to give basic information about exhibits first and adapt hyperlinks and navigation on a PDA when a learner proceeds to deeper knowledge levels. Complexity of information should increase only with continuing engagement [34]. Structure of the content should be easy to identify even for inexperienced visitors.

C. Information Adaptation to a Specific Visitor

Potentials. Mobile devices can provide highly personalized information that is adapted to a visitor's characteristics (e.g., age, impairments, media preferences, prior knowledge, language). This adaptation can either be explicit or implicit: For explicit adaptation visitors provide information about their interests first and are presented information, which matches these interests. For examples, see [36] and [37]. Implicit adaptation uses inferences based on visitor behavior (e.g., prior visited exhibits) to create a visitor profile without visitors explicitly providing information [38]. Adaptation can concern selection of information about exhibits, recommendations of interesting exhibits, or presentation format. Visitors should gain most from adapted information since individual adaptation facilitates information elaboration and integration into existing knowledge structures which are necessary to learning. Cognitive affordances are reduced since visitors have to invest less mental effort to integrate new information to their existing knowledge structures [39]. An additional advantage is the addressee-only way, in which information can be provided: Via the small screen and headphones information reaches only the visitor who requests this information. In this way other visitors are not disturbed and can discover the exhibit in their personal way.

Prototypical examples. Reference [9] describes a mobile system that implicitly adapts exhibit descriptions to a visitor's prior interaction with the system and to his prior movements. This application establishes connections between exhibits by providing information on an exhibit with relations to previously visited exhibits. Thereby it enables a coherent visiting experience that can also result in a more coherent mental representation of different exhibits.

The Mercedes-Benz Museum in Stuttgart, Germany, is a good example for addressee-only provision of information [40]. Audio guides with headphones are used for all audio transmission, even from installed, large screen videos. This allows visitors to access specific information (e.g., basic facts) without distracting other visitors who are engaged in a "silent dialogue" with the exhibits or are requesting other information (e.g., technical information or information for children).

Challenges. To provide personalized information additional and specified content is needed. An intelligent system is needed that delivers the right content to the right person based on the user model. This is especially complicated by the high heterogeneity of visitors.

Some studies, for example [41], 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 adaptive mobile guides to a different extent.

Possible solutions. While online dictionaries and encyclopedias like Wikipedia are comprehensively built they lack the necessary adaptability to visitors' interest. The creation of specific texts considering prototypical interests is a possible low-tech-solution [37]. An intelligent indirect adaptive system can be built with feedback from the visitors themselves after retrieving the information, as it is known from technical help sites on the internet ("Was this information helpful for you?") paired with personal information of the visitor (e.g., age, interests, prior knowledge). For practical purposes explicit adaptation is probably easier.

The highest acceptance of adaptively was found for adaptation of content based on prior interaction with the mobile device and prior information requested [41]. As acceptance of such an adaptation was high despite individual personality characteristics it seems to suit a variety of visitor groups. Therefore, implicit adaptation should only build on prior interaction with a mobile device. Additionally, modes of adaptation should be made explicit to make visitors feel comfortable with the device.

D. Information Adaptation to a Specific Location

Potentials. Especially in big museums orientation is an issue for some visitors. But also in smaller museums, the amount of information displayed cannot be fully processed by visitors. This information richness requires visitors to make many selections. If spatial information was available for mobile devices it would be possible to suggest tours, as in [42] and [43], display the current location, or provide recommendations of exhibits and events in the vicinity. This improves orientation, navigation through the museum, and selection of exhibits. Thereby, affordances of the complex setting are reduced and more cognitive resources are available to attend to and elaborate on exhibits.

Prototypical example. The Singapore Science Centre, Singapore, used a mobile application called "Science Alive" where visitors could specify their interests and the amount of available time [43]. The guide then led visitors through the science center, providing them with a tour to specific locations that matched their interests and time budget.

Challenges. Adaptation based on location has low acceptance within most visitors [41]. This could hinder implementation of location-aware mobile technologies in museums.

From a technical viewpoint, location awareness is still not possible inside museums with sufficient accuracy. See [21] and [34] for further discussion of this problem.

Possible solution. The low acceptance of location-aware technology found by [41] may be due to missing controllability. Mechanisms of location-awareness have to be explained to visitors to make them feel comfortable. Additionally, controllability by the visitor should be

maintained. Then, acceptance of such technologies should rise.

E. Information Elaboration through Facilitation of Knowledge Exchange

Potentials. One of the problems noticed in the use of mobile devices in museums is the reduction of visitor-visitor-interaction [23]. This is especially problematic as "visiting a museum is a social occasion. Hardly anyone visits a museum alone" [5]. Shared experiences provide common ground for communication and discussion, which in turn enhances elaboration of information and the visiting experience as a whole (cp. [17] and [44]). Therefore it seems important to use mobile devices in a way that does not impede social processes but supports them. For example, mobile devices – if they are connected and messaging is possible – can maintain communication in a group, even when group members split up during their visit [43].

Another important social aspect of museum visits is what is called “social navigation” [16]: Others influence information processing to a great extent [45]. For example, visitors usually determine exhibits as interesting that attract a lot of attention from others. To expand social interaction beyond existing visitor groups two possibilities of social navigation are suggested [16]: collaborative annotations to embed an existing object socially [46] and social awareness systems similar to those used by amazon.com ("Other persons who visited this exhibit also visited ..."). If mobile devices could track a visitor’s behavior and information selection, they could compare this behavior to behavior of other visitors and accordingly recommend exhibits and information based on similar visiting patterns. Additionally, votes and polls are suggested to extend social interaction beyond existing groups [10].

Another possibility to extend social interaction beyond existing groups is to expand individual design activities by boundary objects. Boundary objects are “evolving artifacts that become understandable and meaningful as they are used, discussed, and refined [...]. It is interaction around a boundary object, not the object itself, that creates and communicates knowledge” [47]. A museum specific wiki can serve as a boundary object as it allows visitors to share knowledge about the displayed exhibits and tap the available expertise of the visitors who have extensive background knowledge or personal experience with the issue at hand. Thereby, even single visitors can elaborate on the content socially, getting engaged with the exhibit to a greater extent.

Prototypical examples. Reference [37] developed an application that supports face-to-face social interaction: She provided dyads of visitors with adaptive information that matched their shared goals. A dyads’ shared goal becomes part of their common ground. Exhibit information was adapted in a way, that it connected exhibits with these shared goals. As this adapted exhibit information builds on a dyad’s common ground conversational elaboration is made easy and enriches the visiting experience.

Two applications addressing social navigation are ArtTraces and VideoTraces [46]. Visitors can leave their opinions, questions, and interpretations of exhibits. Other visitors can retrieve these annotations and thereby make meaning out of exhibits socially.

Challenges. Facilitating knowledge exchange via mobile devices in museums is a problem as mobile devices can impair existing knowledge exchange between visitors [48]. As a personal device reduces visitor-visitor-interaction shared experiences are rare. Headphones which improve the visitor-exhibit-relationship further increase this problem. The visit becomes a very individual experience and the mobile device cuts down social interaction [11]. It is important to decrease these negative effects first and to address the question afterwards how the beneficial effects of communication between visitors can be increased.

Especially the described mobile application using social navigation might demand too much from some visitors: Reference [49] found that some persons prefer visiting a museum alone to visiting in a group. This could also hold for a quasi-social situation and would result in systematic rejection of “social” mobile applications by this visitor group.

Possible solutions. Solutions to enhance exchange between visitors are: giving visitors the ability to eavesdrop on a companion’s audio guide or equipping visitors with only a single-ear-phone to enable shared and individual activity [50]; providing only one device per group and adapting information to shared interests and shared characteristics of a group to support common ground [37]; providing each group member with different content and encouraging them to share their information with each other [36]; implementing a communication function in mobile guides to enable electronic communication within or across visitor groups [43]; providing multi-player games as a playful approach to a museum visit supported by use of mobile devices, for example treasure hunts [51] or role plays [52].

As some visitors might reject social or quasi-social interactions via mobile devices it is important to provide them with choice: They should be able to visit the museum individually (without mobile device or with a personal mobile application as described above) but also with direct social interaction (without mediation through mobile devices).

F. Information Elaboration through Externalized Memory Support

Potentials. Mobile devices can help to use the limited time in exhibitions more efficiently and allow pre- and post-visit engagement with exhibition content. The preparation of a museum visit can be supported before a visitor enters the museum by providing an overview of available topics, exhibits, and the museum layout on a website. Normally, visitors need to orientate themselves when they enter an exhibition to get an overview of the exhibits and identify the exhibits that are interesting for them. If this is done on the web at home prior to the visit, more time in the exhibition is available for actual engagement with exhibits. Bookmarking can be used to compile interesting exhibits to a personal tour which can be accessed in the museum itself. At the museum, mobile devices help visitors to selectively find and thereby focus on personally interesting objects. Such a more focused visiting strategy can enhance learning [53].

Post-visit engagement with an exhibition is uncommon, but could enrich a museum experience by prolonged engagement with exhibits. Such activities can be facilitated with mobile devices [33]: Interesting exhibits can be bookmarked at the device while exploring the exhibition and accessed later via internet. The bookmarks provide a connection point for further post-visit exploration and serve as a thread for later knowledge exchange. In comparison with catalogues containing full information about the exhibition these personal solutions have the advantage to be tailored: Visitors do not have to find the respective exhibits again and can engage with them at home – individually and socially. Reference [19] points out that for learning to occur museum visits have to become a symbolic reference point for later conversations.

Another interesting possibility would be the use of a visit-documentation for school classes. Integration of field trips with classroom activity is often difficult [54] and could be assisted by pre- and post-visit-activity.

Prototypical examples. On the website of the Ueberseemuseum, Bremen, Germany, visitors can bookmark interesting exhibits in advance. During the visit they can access this information on their mobile devices, which will show them their bookmarked exhibits on the exhibition map.

A prototypical solution for post-visit-engagement was designed for the Exploratorium in San Francisco [18]. Visitors could bookmark objects and trigger photos that showed themselves interacting with the exhibits. The information could be accessed on a personal webpage. This personal pictures served as memory of the visit and as starting point for individual and social elaboration after the visit.

Challenges. While pre- and post-visit- engagement with the exhibition is certainly wanted by the visitors [56], actual use of these features is probably the greatest challenge. If bookmarks before the visit were possible, visitors would need to know about this feature before they enter the museum. However, few visitors prepare their visit in advance. For bookmarking during the visit there is little evidence that it is actually used to the extent to which it was planned, mostly due to "lack of interest and time" and lack of visibility of this option for the visitors [57].

Copyright of the content is another problem. Museums might see the availability of material on a website as loss of a source for income (postcards/catalogues in museum shops) or asset of the museum (material is only available for paying on-site museum visitors).

Possible solutions. Since visit preparation is uncommon it will take strong advertising and word-of-mouth-recommendations to make creating a personal tour a fixed part in advance of a museum visit. Increases in bookmarking rates in "The Tech Museum of Innovation" in San Jose from 28 to 54 percent within three years were found after better advertising, staff training measures and improved organization were implemented [57].

To facilitate usage of documentation after the visit the bookmarks should be personalized. When not only objects and information texts selected by the visitor are included, but also photos of visitors themselves or photos which were triggered by themselves as in [18] and [58], post-visit-access of personal webpages might increase.

A free access to copyrighted material on museums' webpages comes with a change in museums' strategy: Pictures of museums' artworks in the hand of visitors are no longer seen as copyright infringement but as free advertising: They can stimulate people to visit the museum and facilitate word-of-mouth advertising.

G. Exhibition Evaluation

Potentials. A common problem with mobile devices in museums and with exhibitions in general is evaluation or rather lack thereof. This is an interesting phenomenon since mobile devices allow tracking of visiting behavior in real time and thus would make a continuous formative evaluation possible.

Questions like "which exhibits gain most attention", "which information do visitors retrieve from the mobile device", "how many visitors come", "how long do they stay", and "how do they like the exhibition" can easily be assessed on a continuous basis. Each visitor who receives a mobile device or logs onto the website of the museum could automatically become a participant in a visitor study, providing a base for long-term visitor statistics at previously unprecedented levels of detail, continuity, and accuracy. This information can be used to improve exhibitions and mobile devices until they match visitors' needs more properly. Additionally, since exhibit information is available in digital form for presentation on a mobile device, it becomes easier to change than fixed labels or installations.

Prototypical example. Reference [6] used smartcards (giving only location information) to find out which exhibits gain most attention and why. They confirmed the importance of layering that allows visitors different levels of engagement.

Challenge. Continuous evaluation requires close cooperation between museum staff (mainly curators) and developers of the mobile device to create the infrastructure necessary for automated data gathering and preparation. The data has to be analyzed and the implications have to be implemented.

Visitors privacy concerns need to be addressed and data protection measures implemented.

Possible Solutions. Feedback from visitors to curators, directly via interviews and indirectly via log files, should be considered already when a mobile application is planned in a museum. Reference [9] gives a good overview how user evaluation can be used to improve a mobile application.

Visitors need to receive information which data is stored and used. They must have the choice to opt-out, having their data deleted after the visit.

III. CONCLUSIONS

If we consider Daniel Molitor's [2] quotation again and the described potentials and challenges of mobile devices in museums, we come to the conclusion that, yes, mobile devices can add fundamentally to the museum visit. They can enhance attention towards exhibits, provide personal information, help in navigation, enrich social interaction, and extend a visit before and after the actual stay at the museum. But they will not do this automatically, as the described problems show, which were found after implementations of mobile devices [23]. Comparable with the early days of computers in classrooms it is not sufficient to provide a device and a program and expect everything to work well. Implementations of mobile

devices in museums need to be designed carefully. Museums are not test-beds for new mobile technology that is forced into this setting, even if the heterogeneity of the visitors and the diverse content are inviting to do so. During our field research we met a lot of implementations which were introduced more for testing technology than for assistance of the visitor. This practice might give interesting results for technological developments but places unnecessary stress on museum visitors' and on staffs' patience and enjoyment, salting the ground for future use of mobile technology in this setting.

Regarding the implementations, sometimes less is more, as the described examples show. It is important that the device and the application are kept as simple as possible. Each option should be carefully considered if it really makes sense and can be used by the variety of the visitors, since too many options might confuse visitors. If the device requires a visitor's full attention, it costs valuable time and mental resources, which would otherwise be invested for exploration of exhibits. The device should subtly assist visitors, not become the main part of the visit.

We also would like to stress that mobile devices are no money makers. They require a lot of effort (e.g., restructuring, increasing security, training and convincing the staff), a high initial and continuous investment of money (e.g., buying the devices, development of software, maintenance/replacement), and very detailed planning of design, implementation, and changeability. For further discussion see [10], [11], and [34].

Implementation of mobile devices in a museum demands (1) a clear intention what is supposed to be achieved by the device, (2) a close cooperation between the museum and the developers, and (3) a lot of effort on all parts. 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. In the field of mobile devices in museums interdisciplinary research and development projects are needed between museology, visitor research, computer science, and psychology to the benefit of all parties. Then a mobile device can add something fundamentally beneficial to the museum experience.

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