Södertörns högskola | Institutionen för kommunikation, medier och it
Magisteruppsats 15 hp | Medieteknik | Vårterminen 2010
Magisterprogrammet Interactive Media Design

Exploring the effects of different fidelities in an early design process of mobile prototyping

Av: Pehr-Henric Danielsson
Handledare: Maria Normark

södertörns högskola
SÖDERTÖRN UNIVERSITY

Exploring the effects of different fidelities in an early design process of mobile prototyping

Pehr-Henric Danielsson
Södertörns Högskola
ph.danielsson@gmail.com

Abstract. There are a vast number of research and studies undertaken within the domain of user-centered design concerning the design process of an artifact, but still there are questions being raised of the relatively new and successful field of mobile design. During recent years mobile technology have surpassed the standardized thoughts of how to prototype and evaluate such a ubiquitous device. The paper addresses this predicament by discussing aspects of fidelity differences in an early design process of a mobile design. The example being presented refers to a design study of an iPhone-application, where two different types of prototypes were created and user tested, a low-fidelity paper prototype and a mixed-fidelity interactive prototype. The paper sets focus on the various differences between these fidelities closely related to the case. It also reflects on how mobile design approaches can mature during the early stages of a design process.

Introduction

Within the field of interaction design and much like other design principles, the prototyping phase has been an integral part of the design process of artifacts. The reason for this is mainly because a prototype helps defining an idea not only by the look and feel, but also by communication with both users, clients or fellow designers. In the past the way of prototyping and testing an interactive artifact for a PC was usually a straightforward and standardized procedure. But with the continuing success of mobile devices these traditional prototyping methods needs to be questioned (Krauß and Krannich, 2006). The ever-growing diversity of mobile technology and the wide range of usage paradigms such as *contextual* and *ubiquitous nature, small size factors, touch-screens, features* and *functionality* can generate great problems for designers, each trying to find their own solution (de Sá and Carriço, 2008; Säde, 2002). Because of this, designing for mobile devices must be looked upon as a challenge of its own, where new design approaches have to be discussed.

What kind of novel challenges and problems can be encountered during the early design process of a mobile phone? In this paper I will problematize the aspects of mobile prototyping and its evaluation stages by referring to my own design study of an iPhone-application where two different types of prototypes were created and tested. The assorted aspects from the case will be put into specific issues and analyzed into generic terms. The purpose of the paper is to emphasize the fidelity differences and its effects during the early creation of such mobile design, mainly by focusing on low- and mixed-fidelity from a prototyping and evaluation perspective. The paper summarizes and concludes five major points, which are especially important to take into consideration from these fidelity perspectives when designing prototypes of a mobile phone and its applications.

Background

Developments in mobile technology during recent years have changed the way we communicate and in many ways surpassed the current user-centered design (UCD) methodology. As an example, applications (“apps”) written for the smartphone of iPhone exceeds 85, 000 in just over two years since the release of the device (Rogers, 2010). In respect to this, new approaches need to be adopted and introduced for the design process of mobile artifacts and applications specifically when it comes to the phases of prototyping and evaluation (de Sá and Carriço, 2006).

UCD-methodology is a commonly used method in the field of interaction design and could be defined as an approach to involve users into the design

increasing the understanding of the user tasks and needs (Mao et al., 2005). The method of participatory design is a commonly used approach in UCD and mobile prototyping. It represents a way of enabling the users of a computer system to play a more active and critical role in the design of developing it further (Schuler and Namioka, 1993). Another similar approach is cooperative design, were users become lay designers and develop mock-ups of design together with the professional designer using familiar tools (Sidhavatula and Wendt, 2007). Jones and Marsden (2006) points yet to another technique of collaboration, were the initial step of a design is first singled out by the designer or amongst a team of expert designers. Usability methods and techniques within UCD can be classified into three groups in the design process defined as *data gathering*, *prototyping* and *evaluation* (de Sá and Carriço, 2008). Another study by Säde (2002) points to similar stages. These are usually practiced in chronological order even though the designing process of the artifact is often iterative with parallel tasks going on at the same time. As discussed, the scope within this paper will concentrate on the two latter parts in the design process, namely *prototyping* and *evaluation*.

Prototyping

Prototyping could be seen as a way of representing an artifact's idea, behavior and interaction (Säde, ibid.). According to Lim et al. (2008), there are three values to consider when manifesting a design idea known as the *materials*, *resolution* and *scope* of the prototype. Houde and Hill (1997) present a similar model, which correspond to the important aspects of an interactive artifact known as the *role*, *look and feel* and *implementation*. Elucidating what values or aspects the designed prototype should be compatible with is a central part of successful prototyping.

The degree of fidelity is another dimension to discriminate prototypes. Houde and Hill (ibid.) define fidelity as *'closeness to an eventual design'* (p369) whereas Rudd et al. (1996) identifies fidelity as *'the degree to which the prototype accurately represents the appearance and interaction of the product'* (p78). The range of prototyping methodologies generally describes fidelities of low and high, even though examples also exist of mid-fidelity. According to Rudd et al. (ibid.), are positive aspects of low-fidelity e.g. *quick* and *inexpensive design*, *multiple design concepts*, *useful for communicating* and *finding screen layout issues*. On the negative side there are factors such as *little use of usability tests, navigation* and *interactivity limitations, facilitator driven* and *poor detail of design and specification*. Positive aspects of high-fidelity are *interactivity, complete functionality, look and feel of final product, user-driven, use for test and exploration* and *a clearly definition of the navigational scheme*. Disadvantages from a high-fidelity perspective include *time-consuming, costly to develop, blinds users to major flaws, not effective for requirement gathering* and *risk of users think the prototype is 'real'* (Rudd et al., ibid.).

The study by McCurdy et al. (2006) introduced a new fidelity known as mixed-fidelity, which contained certain aspects of high-fidelity and low-fidelity in others. McCurdy et al. (ibid.) presented five dimensions characterizing the prototype and much like the definitions by Houde and Hill (1997) and Lim et al. (2008), these dimensions puts the focus on what to prototype and evaluate during the design process of an artifact. These thoughts go hand in hand with the point of the levels of fidelities in mobile prototyping, which will be adopted and discussed during this paper.

Evaluation

The evaluation part in the UCD-design process is usually classified into two approaches, the first method often involving end-users and the second variant including experts and fellow designers. Evaluations made with users can provide empirical data, compared to expert reviews, which is usually based on a more subjective manner (Säde, 2002). There are several generic UCD-design and evaluation methods applicable for prototyping and developed for desktop systems such as *interviews, user testing, questionnaires, heuristic evaluation* and *cognitive walkthrough* (Jones and Marsden, 2006) but very few are suited for the unique features of a mobile device and its contextual usage (de Sá and Carriço, 2008). In fact, the study by de Sá and Carriço (ibid.) point to this evaluation stage of mobile design as being frequently discarded. Because of this, there is no sound compromise when it comes to validate evaluation results during mobile prototyping tests, especially when it comes to usability evaluation out of the lab. How to choose the right prototyping technique, which is also most valuable from an evaluation standpoint, is therefore highly debated (de Sá and Carriço, ibid.). According to Jones and Marsden (2006), mobile testing and evaluation requires both lab-based evaluations and contextual testing complementing each other in order to collect reliable results, thereby allowing the high-fidelity as the only true option. In contrast, the low-fidelity prototypes are often seen as insufficient and subjective from an evaluation perspective. Closely related to this is the method Wizard-of-Oz, often used in low-fidelity prototyping, where some or all functionality of the prototype is simulated behind-the-scenes by a human appearing to be the functioning system (Reilly et al., 2005). Even though this can be an effective method, it is often viewed as non-objective from an evaluation perspective (Jones and Marsden, 2006).

The research conducted by Lim et al. (2006) focused on the specific issue of validity between low- and high-fidelity prototypes of mobile devices. The major findings from the study claimed that it is important to determine what aspects to evaluate when it comes to usability before building a low-fidelity prototype. The study by Reilly et al. (2005), which concerned early prototyping evaluations, points to the same conclusion emphasizing the need of determining the

appropriate levels of granularity and fidelity of a prototype before developing and evaluating it.

Another classification similar to the idea of what to evaluate is vertical and horizontal prototyping, often used when time is a factor. The point of a vertical prototype is to include only a subset of an artifacts function but in a higher fidelity manner, whereas a horizontal prototype does not represent all the details of a specific function but contains an increased level of functionality instead (Rudd et al., 1996). Even though these types of prototypes seem to contain limited range, they can be extremely efficient not only providing user-interface interactivity but also and foremost when it comes to evaluate design decisions in an early stage of design.

Mobile prototyping in the right direction

It should be pointed out that there are extensive studies and work by researchers and developers focusing on PC-emulated software and specialist platforms and devices combining desktop systems and physical devices, but this lies not within the scope of this study and have been discussed elsewhere (Jones and Marsden, 2006; Pering, 2002). Instead there are some examples in literature that stand out and utilize the possibilities of the mobile behavior and its usage paradigms being discussed above. During the last years research projects by Bolchini et al. (2009); de Sá et al. (2008); Krauß and Krannich (2006); Pfleging et al. (2010) have tried to incorporate these mobile aspects into the end-device focusing on various degrees of fidelities. The study by Bolchini et al. (2009) pointed to the fact that by implementing the prototype into the end-device on an early basis enabled an important cognitive and emotional experience, which would not be possible to generate otherwise. The three levels of cognition defined by Norman (2004) as *visceral*, *behavioral* and *reflective design* must therefore be considered as especially important when it comes to influencing the human-interface interaction. When designing a mobile artifact or application, several perspectives should be taken under consideration such as the *usability, physicality* and *aesthetics* of the product (Bolchini et al., 2009). Based on these reflections, the cognitive aspects are emphasized during the case study and analysis of the designs. This concerns especially the visceral design, which in regard to handheld devices focus on the physicality of how e.g. the interface looks and feels when using it (Bolchini et al., ibid.).

This being said, it must be emphasized that designing for a mobile device often goes beyond these concrete sensory feelings, since the experience of a prototype also have to consider contextual factors and circumstances. Because of this Buchenau and Suri (2000) introduced experience prototyping, which term could be defined as highlighting *'the experiental aspect of whatever representations are needed to successfully (re)live or convey an experience with a product, space or*

system' (p424). To meet this demand a designer or a user often has to explore by doing in an active participation. And by practicing experience prototyping it will not only include engagement with the intended artifact, but also with the intended environment. Applying these ideas makes it even more interesting when it comes to point in the right direction of designing mobile artifacts and applications. In fact the study by Hennipman et al. (2008) refers to mixed-fidelity prototyping as being the most efficient solution of experience prototyping when focusing on the front-end of a prototype since it enables to test a design as 'real' as possible.

As discussed, the importance and need of changing the way we look upon mobile prototyping is highly relevant. By reflecting at the examples, which tries to apply the new usage paradigms such as the ones of contextual and ubiquitous nature, or the intended mobile's physicality and functionality, it seems that the consciousness of the problem is starting to be recognized. But even though these examples point to interesting results, there is a need of more case studies, which includes the mixed-fidelity into the debate during early stages of mobile design. Based on this background an analysis will be conducted differencing the pros and cons of the low- and mixed fidelities in my design study of an iPhone-solution.

Design stages of an iPhone-solution

The design study concerns a mobile design project of an iPhone-application being redesigned from a web-based time management system called Primula used at the Linnaeus University in Sweden. The web-based interface of Primula handles the overall administrative functions for the personnel and their daily routines. The purpose of the mobile version of the application was not only to enable the users a new and improved design and usability, but also by making it mobile and efficient to use, thereby increasing the usage of the system.

Two prototypes of the iPhone-solution were developed and evaluated during the early stage of the design. Because of this, vertical prototyping was applied and different tasks for each function were decided before starting out with the sketching of the first prototype. This design was created and formed as a paper prototype, one of the most commonly used materials and way of prototyping concerning low-fidelity (Lim et al., 2006). This prototype was sketched out and colorized on different paper cards similar to the graphical interface of the iPhone. Using cardboard, a mock-up of an iPhone was cut out made to hold the sketched cards during the user tests. The second prototype was created using the software application of Adobe Fireworks where static digital cards were designed partly from snapshots of the iPhone and graphical elements, which became linked together and exported to a webpage. By adding a bookmark of the webpage to the homescreen of the iPhone, a simulation of the application within the end-device was possible to use during the second user test and evaluation.

The user tests were performed applying the method of think aloud, which is frequently implemented in usability studies gaining insight into how users think and work with an artifact during the design process (Ramey et al., 2006). The user tests were performed in the working environment of the informants and governed by a facilitator. During the user test, the informants were asked to verbalize their task at hand, how they experienced and thought about the design. The user tests were video recorded which made it possible to analyze the data and evaluate what happened after the event. The analyses led to new changes, which were applied in the second prototype. The user tests that followed only served as reflections and thoughts for future work. The design project ended after this second evaluation but still it generated interesting outcomes. Functions and features were added and removed, prioritized and redesigned which in the end turned the mobile design towards a more personal and user-based application.

Design study

As discussed, the main intention of the design study was to develop an iPhone-solution of the web-based time management system of Primula and to iterate and refine the design in several versions. This being said it is important to note that the initial phase of the design process, the data gathering, which led to the requirements of the prototype, was also a great part of the design project even though it will not be in focus during this specific case study. By using various methods such as focus group discussions and participatory interviews regarding what the mobile solution should contain, it served as a ground for the thematic analysis of the data being collected. This phase resulted in a specific requirement for the mobile solution, where many of the original features and functions of the web-application were removed. The hierarchy was flattened and several functions were prioritized because of its frequently usage in the existing web-application. Besides this, a completely new function was applied and named “Flex-clock” which was supposed to implement the function of clocking in and out the staff at the Linnaeus University. The final requirement of the first prototype involved two types of functions, *main* and *supplementary*. The main functions were “Flex-clock”, “Amount of working hours”, “Travel expense”, “Expense”, “Vacation application”, “Wage statement” and “My cases”. The supplementary functions, “Personal information” and “Settings” were intended to enable a more common, quick and helpful information for the user.

Five informants of the staff were recruited and interviewed during the whole design project, two women and three men. The informants were chosen deliberately because they use an iPhone. This helped them to be aware of its characteristics in which the design was aimed towards from the start. One of the men is a teacher and was interviewed because of his somewhat different and less frequent usage of the Primula-system compared to the other four informants

working as administrators at various departments at the university. The administrators use the web-based application of Primula more often than a teacher, which was the main reason for the considerate number of administrators in the study. All informants had the role as an end-user during the design project and were part of the user tests.

Low-fidelity paper prototype

The first step in the ideation phase was to come up with ideas of what the intended design could look like and how the functions were supposed to work. Because of this, design ideas were sketched out on paper with the requirements in mind. Working as a single designer, it was hard to distinguish whether the design in fact could work for its intended users. Another thing was the number of finalized ideas. Because of the tight timeline, one version was chosen to continue with and implemented into the first prototype. Even though this could be seen as a great risk of limiting creative solutions, it was on the other hand an advantage to very quickly produce something without no one to question or disturb the idea of the design.

The first prototype became a low-fidelity paper prototype with the intention of enabling a fast and inexpensive way to assess and communicate design ideas from the users and evaluate their reactions without using functional solutions. Another point of using such a prototype was to try and prevent major design errors from the very beginning. Starting out and applying the sketches into a prototype, the next challenge was to find a way to design the cards and nodes of the functions so that the users could get an insight of the intended application and understand how it was supposed to work. Because of this, different tasks for each function were created which placed the user in a specific scenario to solve for each function. But since this was not a high-fidelity prototype it was not possible to cover all the functionality, instead general features of each function was chosen to pinpoint each task. By applying this idea, a structure started to take form of all the functions and features that would be included in the first prototype. These cards included in the tasks were then created and painted on separate paper notes.

Since the paper prototype was intended for a real-life setting, rigid material was utilized in the form of cardboard to quickly create a mock-up of an iPhone-solution with the goal of designing the prototype as close to the original as possible. The point of doing this was the intention of generating a greater understanding and experience, not only by handling the prototype as a ‘normal’ mobile but to also invoke a sensation of look and feel in an early stage of prototyping. Because of this a printed picture of an iPhone was glued on top of the mock-up and a frame cut out in order to easily insert and remove the cards during the user tests.

Figure 1. The final low-fidelity paper prototype and its usage during a user test

When the low-fidelity prototype was finally constructed, the usability evaluation session was prepared by constructing a questionnaire, which contained all the tasks the informant was supposed to perform during the user test. Each of these tests of the prototype took place in the informant's own working place/office. Because of this it could be said that the setting was partly controlled but also in-situ, performed at a location where the user normally would use the intended mobile solution of Primula. Even though it could be an advantage to evaluate the prototype in various contexts such as walking, driving or commuting by train, the limited study was not able to encompass these alternatives as well. On the other hand much of the interaction would probably be done during office hours and in similar environments. During the user tests the method of think aloud was applied with the intention of encourage the informants to explore the paper prototype and its sketched out tasks for every function in the intended graphical user interface (GUI) of the application. The tests, which usually lasted around an hour, were video recorded for detailed analysis. Apart from being the facilitator, I also played role of the computer and switched to the next card in the GUI when the user e.g. pressed a certain button. Because the prototype was sketched out by hand, there were some confusion regarding certain words and buttons, which the user had a problem to understand. Even though the intention of the elements in the prototype was explained, this was something that appeared to inflict negatively on the users and seemed to constrain their actions and thoughts to some degree.

When the user tests were finished, each test was analyzed by transcribing the thoughts from each user, the notes written from the session and the user's action collected from the video recording. This being done, the next step was to look for similar patterns from the tests in order to find out how well the prototype met the demands and experience of the user. By assembling the most urgent and recurring

data, certain ideas about what needed to be changed in the next iteration became clearer. After a final revision it was obvious that a number of changes had to be made in order to meet the requirements of a mobile solution of Primula.

Mixed-fidelity interactive prototype

When the changes were finally decided, the next step was to apply them into a new prototype that made use of the intended device in the intended context. By doing so the goal was to retrieve more important data during the next user test. Once more paper sketches were used in order to create a mixed-fidelity version as the next iteration. For this purpose an interactive prototype had to be partly developed using real characteristics, which concentrated exactly on what needed to be tested but at the same time clearly resembled the intended end product. In other words the focus was on the front-end of the application and not the back-end. Having the mixed-fidelity method in mind, it would expectantly allow the users to appreciate the high-fidelity of the GUI and its simulated interactivity. And by implement it into the iPhone, it would hopefully result in new ideas and changes from the users. After this initial phase, conceptual screen cards were created using the software application of Adobe Fireworks. These static cards were formed partly from snapshots of the iPhone and graphical elements from the web. Because of this it was possible to reuse the appearance of commonly used buttons, menus and features of the iPhone. When finished, the cards were linked together by hotspots in Adobe Fireworks and exported to a webpage using the Javascript library of jQuery and scripting language PHP. When applying these steps, the prototype could be read within the intended device and by finally adding the link to the homescreen of the iPhone, a simulation of an application was possible to use during the second user test.

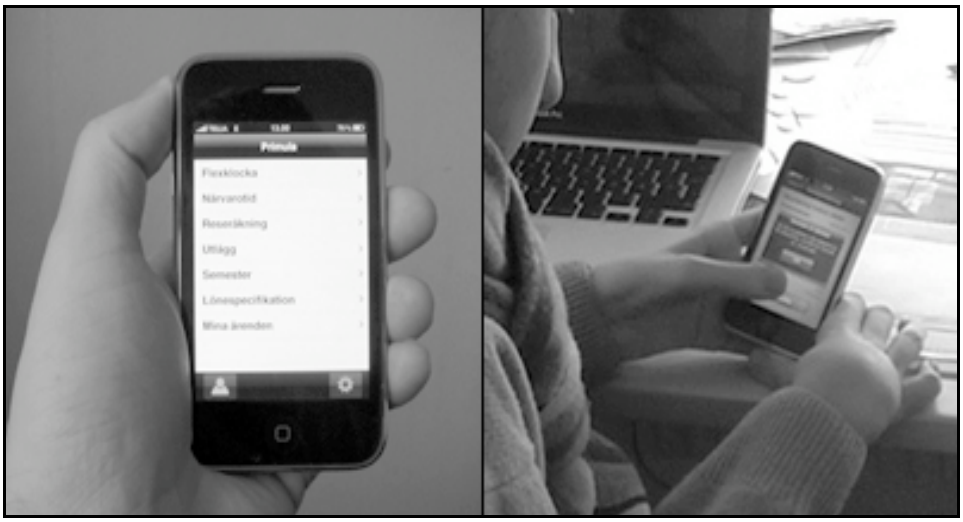

Figure 2. The final mixed-fidelity interactive prototype and its usage during a user test

The second user test contained the same tasks and was performed in the same context as the first evaluation. But this time the experience of using the intended device in combination with the interactivity of the touch screen seemed to generate a more instantaneous immersion. This immediate response and reaction became very clear from the users. When using the existing end-device, the users motivation of being part of the study seemed to increase during the user test. By taking the role of a facilitator for the second time, the informants had to think aloud in front of the video camera once again in order to more comprehensively retrieve interesting and useful data. In comparison to the previous prototype, I did not have to be part of the interaction, which not only increased the ability to focus more on the users reactions, but also minimized the disturbance during the tests. Besides this, there were almost no questions regarding the GUI of the simulated application, which also helped improve the data collection.

When the second round of user tests were finished, each test was analyzed by viewing the video recording. The ideas and reflections were also transcribed including the notes taken during the tests. When this phase was finished, a new investigation was undertaken in order to see how well the prototype met the expectations of the end-users. After several analyses, it was clear that a number of improvements and changes had to be made. Interestingly, the data showed that there were some completely new flaws with the interface, which was referring to the interactivity of the functions. This was something that had not been possible to detect in the first paper-based prototype. Since the second prototype was simulated in the intended device, other errors related to the physicality of the device could also be found. One example of this was the big buttons applied in the function of the “Flex clock”. No one had in the previous version thought about how easy it was to activate these by mistake on a touch screen until it actually was implemented into the intended device. One solution to solve this was to constrain the buttons by redesigning them as slide buttons instead, which would require a more deliberate action from the user. Overall both new and old flaws were found and experienced in a completely new way, which had not been possible if a second paper-based version had been created instead of the mixed-fidelity interactive prototype.

As discussed, the design project was ended after this second evaluation and the discovered changes only served for future work, but still it helped turn the iPhone-solution of Primula into a real and efficient working tool in comparison to the administrative instrument of Primula that exists today on the web. With the help from the prototypes the new ideas and design became externalized into something the users could control, understand and experience. Because of this, most of the users became eager to implement it in their own working routine if it were to exist.

Fidelity issues

This investigation has deliberatively been focusing on explicit needs and problems of the case being described. This being said there are several general aspects concerning the fidelities, which can be found during the analysis of the case. When discussing the issues between the iterations of the iPhone-solution, the main stages of the design process *prototyping* and *evaluation* divide the designed artifact enabling the pros and cons of the fidelities to be more clearly defined and encapsulated. These issues are discussed below.

The prototyping stage

The *issue of ideation* could be found in an early stage during the creation of the low-fidelity paper prototype. Working alone as a designer, the first problematic situation occurred when sketching out the ideas from the very beginning. Even though the ideas were quick and easy to create and helped to focus on the aspects of the design, the one thing lacking was the important feedback and ideas from others. One of the main possibilities when using a low-fidelity prototype in general is not only to create several ideas, but also to have a dialogue and communication between other expert designers or users. Participatory and cooperative designs emphasize this need in an early stage, which became particularly clear during the ideation process (Schuler and Namioka, 1993; Sidhavatula and Wendt, 2007). Having fellow designers and/or users brainstorming and discussing several designs, invokes a higher degree of creation and helps to correct initial errors and wrongfully ideas from the very beginning. These possibilities which is a strength from a low-fidelity perspective, was on the other hand much more constrained when it came to the creation of ideas regarding the mixed-fidelity prototype. Even if this prototype became looked upon as the next iteration of the designed idea and thereby excluding other design concepts, the way of ideation is much more complex. It would still be possible to brainstorm and create several design concepts using a prototyping application such as Adobe Fireworks, but the effectiveness of learning and collaborating with such a tool, would simply be inefficient to initialize a design with. From the perspective of ideation, a mixed-fidelity prototype serves its purpose best when the design is being narrowed down into a single design proposal.

Closely related to this is *the issue of cost*, which is highly important as well during the early stages of the design process. In order to produce an interactive design using the prototyping tool of Adobe Fireworks, it did not only include the cost of the application per say but also the number of working hours it took to learn how to apply all the graphical elements and to present the interactive solution in the correct platform. The cost of the mixed-fidelity can therefore be said to rely not only on expensive prototyping programs, but also on the amount

of hours it takes to obtain this skill in order to create a design concept using this method. Even though there was no need of a programmer/engineer to help finalize the designed idea in this specific case, it's not comparable to the cost efficient paper prototype created in the first proposal. By using pencils, paper and cardboard it required very little skill and time to complete the first design, once decided what it should contain. Again, seen from a bigger perspective with larger design projects, this would allow a team of designer or users to go through a number of alternatives without the risk of great investment in money and time (Rudd et al., 1996).

The *issue of design* is another matter where the two fidelities differentiate themselves in an early design process. Producing design concepts rapidly and at a low-cost is one thing using low-fidelity, but when it comes to focusing on a design reflecting the intended GUI of the application it is harder to comply with. With the described case in mind, several problematic situations occurred during the first user tests because of this, which e.g. generated questions about words and buttons that the users had a hard time to understand in the sketched out GUI. Even though these problems weren't many, they inflicted on the usability evaluation and disturbed the intended test to some extent (Lim et al., 2006). This being said it should be noted that one of the main ideas of a low-fidelity prototype is to depict concept and not to focus on details. Even so, when it comes to unnecessary errors due to a bad sketch, this could lead to serious effects in a longer perspective. In contrast during the user test of the mixed-fidelity prototype, this type of confusion was almost non-existing. This had much to do with the usage of existing elements of the GUI of the iPhone, such as fonts and buttons, which the end-user already was familiar with. Applying these elements it also helped improving the chances to create a design, which not only reflected the front-end of the intended iPhone-application but also enhanced the certainty from a designer perspective knowing that the users would recognize the elements extremely fast and with little errors.

The *issue of interactivity* also concerns interesting aspects, which in many ways goes hand in hand with the aesthetics of the design. When constructing the interactive prototype, the main intention was to enable a higher degree of understanding not only by presenting what the application would look like, but also how it would be explored and interacted with from the users perspective. Since the designed GUI was task-oriented it was not intended to be operated as a final product, since it was merely a mixed-fidelity focusing on specific features. Despite this the buttons and features that had been activated as hotspots based on the task-based scenarios, received in general a much more positive response than the paper cards during the test of the low-fidelity prototype. The non-functionality of a paper prototype as described in the case is typical for low-fidelity, since it's meant to show design direction and not respond by input (Rudd et al., 1996). In contrast, when testing the mixed-fidelity interactive prototype and its focused

interactivity, increased this understanding of how the nodes and cards were connected in the GUI. Because of this, it helped the users to get a better acceptance by experiencing it for themselves and not having a facilitator changing the cards for every click and action they wanted to perform. In return, this lead to new data where completely new flaws were found, which referred to the interactivity of the functions. As stated, this was something that simply not had been possible to detect in the low-fidelity paper prototype, pointing to yet another difference between the two fidelities.

The *issue of look and feel* concerns the differences between the cognitive aspects of the prototypes being described. During the creation of the first low-fidelity paper prototype, much effort was put into creating a design which resembled the intended device in order to invoke a sensation of look and feel closely related to visceral design (Norman, 2004). But even with such an attempt it still only became a mock-up in the eyes of the end-users and thereby handled as such. By using the mixed-fidelity method on the other hand, it enabled an extremely easy way to incorporate the aspects of look and feel. Since this characteristic already existed in the smartphone, the only concern was to simulate the GUI using graphical elements and linking them together using hotspots. The quick and painless way of enabling this important issue when using a mixed-fidelity prototype is a great advantage over the low-fidelity prototype in an early design process. By making it possible to quickly anticipate the mobile experience in as many aspects as possible, generates not only the valuable user feedback, but also efficiency in time and energy (Bolchini et al., 2009).

The evaluation stage

The *issue of distinguishing errors* during the user tests is something highly debated when it comes to mobile design. In this specific case, the low-fidelity paper prototype was particularly useful for discovering vital errors based on the user test. Several screen layout issues were quickly found by the users and thereby changed in the next iteration of the design. This result is synonymous to what is customary with a low-fidelity evaluation, solving major interface problems in the initial stage of a prototype both efficiently and inexpensive (Rudd et al., 1996). From this perspective, the mixed-fidelity prototype is not as economical and rapid to generate such outcome, instead it had a different advantage over its predecessor in the specific case. Apart from some errors found in the screen layout, there were completely new problems that occurred during the second user test relating to the interactivity of the artifact. These errors were not possible to foresee in the paper prototype. The described example of the “Flex clock” and its buttons that could be activated by mistake should be seen as a generic illustration of how important it can be to implement a mixed-fidelity prototype into the end-device.

The *issue of vertical prototyping* is another interesting difference, which becomes vividly clear when performing the user test and evaluation. Even though this method is applicable on both prototypes in the case (Rudd et al., ibid.), an obvious dissimilarity could be found concerning the functionality. Enabling interactivity into the mixed-fidelity prototype, the users quickly understood how the product would operate. And by following the same instructions as with the low-fidelity paper prototype, the users could experience an instantaneous feedback due to their actions, which was impossible to simulate during the first iteration. This second user test seemed to motivate the users in a completely new way, leading to a much higher degree of participation, which generated several innovative ideas on how the iPhone-solution could be improved. Because of this it could be said that the users became constructive members and active thinkers and not only evaluators and passive users of the tool (Hennipman et al., 2008).

The *issue of evaluation bias* is a very important part to emphasize as well when it comes to the user test and evaluations of the low- and mixed-fidelities. As described in the case, the user tests of each fidelity were performed almost in an identical way. The main difference between the user tests was the role I took as a facilitator. The paper prototype invoked a greater deal of involvement, not only because the explanations of what certain parts meant in the sketches as discussed, but also since I played the role of the computer as well. Even though this behavior increased the communication and response from the users, which is one of the main ideas of low-fidelity, it cannot be accepted as valid results (Lim et al., 2006). By taking this role much similar to the Wizard-of-Oz, it also meant that the first user test could not be objective at all (Jones and Marsden, 2006). When performing the second user tests of the mixed-fidelity on the other hand, the evaluation bias decreased. Since I did not have to play the role as a computer, the end-users could appreciate the prototype and its action on their own, leading to fewer disturbances and higher degree of validity. This being said, the mixed-fidelity prototype described here cannot compete with formal usability testing and collecting user reaction to the system, which requires high-fidelity prototypes (Jones and Marsden, ibid.). But as discussed, one of the main points of using the mixed-fidelity is to focus on what to prototype and evaluate. With this in mind, a design team could instead choose to focus on the user interaction and logging of the clicks and actions, making the back-end high-fidelity instead of the front-end as in my case (McCurdy et al., 2006). Again this is a point, which puts the focus on what to prototype and evaluate and generates great advantage when choosing the mixed-fidelity.

The *issue of experience prototyping* is another way to look upon the users interaction and experiences with a mobile artifact and/or its application. Even though experience prototyping implies that it can be applied using any material as long as it's possible to interact with, it can have its disadvantages concerning the evaluation part. This goes hand in hand with the low-fidelity paper prototype,

being evaluated during the first user test. Since there were several questions regarding the unfinished look during this test, it was difficult to claim that all of the findings concerned the design proposal and not the natural characteristics of the prototype (Hennipman et al., 2008). This type of hesitation did no occur when evaluating the mixed-fidelity prototype at all because the front-end of the design was as close to reality as possible and included in the intended device. Since this is encouraged in experience prototyping, i.e. the part visible to the users should be as real as possible, this was straighten out as yet another difference between the two prototypes in the case. From this point of view, it turns mixed-fidelity into a great approach of performing experience prototyping (Hennipman et al., ibid.).

Finally, the *issue of context* is increasingly interesting when it comes to mobile design and its evaluation, still highly debated amongst researchers and developers because the lack of widely agreed methods (Jones and Marsden, 2006). As mentioned, even though there are several generic evaluation methods used in the field of UCD, these are often applied using desktop systems and not specifically suited for the contextual testing as well (de Sá et al., 2008). In the described case the goal was not to find the ultimate solution of evaluation of a mobile design, but to localize important errors encountered in the beginning of the design process of the iPhone-solution. When it came to the question of context and where the user tests should take place, it seemed to matter very little to the evaluation of the low-fidelity paper prototype. Closely related to the thoughts of experience prototyping, it had very much to with the low resolution and unfinished look of the designed cards and mock-up. Even though it could be possible to perform the user test in various contexts, the errors found during the vertical prototyping and task based scenarios would be more or less the same. It must be remembered that one of the main intentions with the low-fidelity paper prototype is to show design direction and conceptual approaches, not enable cognitive aspects such as visceral design or e.g. interactivity and functionality (Bolchini et al., 2009). This was on the other hand quite applicable when it came to the mixed-fidelity prototype. From this viewpoint, it would instead be more motivated to perform an advanced user test in various contexts during the second evaluation with all intended characteristics included in the prototype. This would most likely lead to new interesting data and experiences fruitful for the design. But as being described, this was not possible during the design study, mainly because the time and cost did not enable such arrangement of logistics required for contextual testing. This being said, the issue of context is a most interesting aspect when it comes to differencing mixed-fidelity and low-fidelity, and must be kept in mind during future studies of contextual evaluations and mobile designs.

Conclusions

In this research various differences and problems have been discussed between the low- and mixed-fidelities of a mobile design. An effort has also been made to extend the discussion by exemplify a specific design study concerning application prototypes in iPhone. As discussed, the findings have been design specific but also put into general terms, where the outcome to some extent supports previous research within the field of mobile prototyping. This being said there are especially five main conclusions possible to draw from this study.

Firstly, using low-fidelity to initialize a design concept is highly efficient, quick and inexpensive. Its strength lies in the possibilities of communicating and sharing ideas with other stakeholders, not in the focus of design and interactivity. Because of this it should not try to compete with all the aspects of coming iterations of the design, since it serves a different purpose. *Secondly*, when a low-fidelity prototype is being user tested, the very same advantages in the creation of the prototyping stage becomes its disadvantage during the evaluation. The unfinished look and lack of functionality demands a greater need of a facilitator and/or Wizard-of-Oz conducting the test, which leads to subjective data and invalid results. Still it's a very effective way to solve major errors in the interface, likely to be encountered independently of context and evaluation method. *Thirdly*, the mixed-fidelity cannot compete with the efficiency of the low-fidelity advantages when it comes to create, participate and brainstorm around the first design concepts. The logistics of applications and computers needed and the knowledge and time it takes to produce a design, constraints this possibility in a high degree. Instead it serves its purpose best when a single design is decided. The real strength using mixed-fidelity is the ability to concentrate on what to prototype by pinpointing low- or high-fidelity on either the front-end or the back-end of a design. *Fourthly*, the evaluation of a mixed-fidelity can very efficiently focus on the area of interest. Because mixed-fidelity enables a quick and inexpensive way to generate interesting result, it makes it highly interesting to use in various types of contexts and evaluations appropriate for mobile design. *Fifthly*, by enabling the possibility to implement a mixed-fidelity prototype into the intended device focusing on the front-end of a design as the described case, it takes the design and user experiences a step further. Fulfilling the purpose of experience prototyping and allowing a realistic feeling of how the product is supposed to work, derives completely new and important errors and ideas, which turns the user into a more active and beneficial member and the designer even further enlightened.

During this study a goal has been to apply several usage paradigms, which is part of the diversity of mobile technology. And it appears to be within the differences between the fidelities one can find a way forward in the mobile design and its prototyping. As well as it seems to be an increasingly need of a

standardized way of conducting and evaluating mobile design, the important role of the intended end-device must also be accepted and included in the way we look upon prototyping today. But in order to continue and develop these methods and ideas, more studies and research regarding this area is needed. As mentioned throughout the study, incorporating the thoughts of mixed-fidelity during the early stage of the design process would most likely evolve and mature the mobile prototyping, increasing the experience and understanding for all stakeholders.

Acknowledgments

First of all I would like to thank Anna Fridh and Kamil Kozuch for all the ideas and support, which made this paper possible. I also would like to thank my supervisor Maria Normark for her insights during the writing process. Apart from this, I would like to express my gratitude to all my informants for giving me such valuable ideas and inspiration during the design project.

References

Bolchini, D., Pulido, D., and Faiola, A. (2009). FEATURE "*Paper in screen" prototyping: an agile technique to anticipate the mobile experience*. interactions 16, 4 (Jul. 2009), 29-33.

Buchenau, M. and Suri, J. F. (2000). *Experience prototyping*. In Proceedings of the 3rd Conference on Designing interactive Systems: Processes, Practices, Methods, and Techniques (New York City, New York, United States, August 17 - 19, 2000). D. Boyarski and W. A. Kellogg, Eds. DIS '00. ACM, New York, NY, 424-433.

de Sá, M. and Carriço, L. (2008). *Lessons from early stages design of mobile applications*. In Proceedings of the 10th international Conference on Human Computer interaction with Mobile Devices and Services (Amsterdam, The Netherlands, September 02 - 05, 2008). MobileHCI '08. ACM, New York, NY, 127-136.

de Sá, M. and Carriço, L. (2006). *Low-fi prototyping for mobile devices*. In CHI '06 Extended Abstracts on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006). CHI '06. ACM, New York, NY, 694-699.

de Sá, M., Carriço, L., Duarte, L., and Reis, T. (2008). *A mixed-fidelity prototyping tool for mobile devices*. In Proceedings of the Working Conference on Advanced Visual interfaces (Napoli, Italy, May 28 - 30, 2008). AVI '08. ACM, New York, NY, 225-232.

Hennipman, E., Oppelaar, E. R., van der Veer, G. C., and Bongers, B. (2008). *Rapid and rich prototyping: proof of concepts for experience*. In Proceedings of the 15th European Conference on Cognitive Ergonomics: the Ergonomics of Cool interaction (Funchal, Portugal, September 16 - 19, 2008). J. Abascal, I. Fajardo, and I. Oakley, Eds. ECCE '08, vol. 369. ACM, New York, NY, 1-6.

Houde, S. and Hill, C. (1997). *What Do Prototypes Prototype?* In M. Helander, L. T. & P. Prabhu (Eds.), Handbook of Human-Computer Interaction (2nd ed.). Amsterdam: Elsevier Science.

Jones, M. and Marsden, G. (2006). *Mobile interaction design*. Chichester, England: Wiley.

Krauß, M. and Krannich, D. (2006). *ripcord: rapid interface prototyping for cordless devices*. In Proceedings of the 8th Conference on Human-Computer interaction with Mobile Devices and Services (Helsinki, Finland, September 12 - 15, 2006). MobileHCI '06, vol. 159. ACM, New York, NY, 187-190.

Lim, Y., Pangam, A., Periyasami, S., and Aneja, S. (2006). *Comparative analysis of high- and low-fidelity prototypes for more valid usability evaluations of mobile devices*. In Proceedings of the 4th Nordic Conference on Human-Computer interaction: Changing Roles (Oslo, Norway, October 14 - 18, 2006). A. Mørch, K. Morgan, T. Bratteteig, G. Ghosh, and D. Svanaes, Eds. NordiCHI '06, vol. 189. ACM, New York, NY, 291-300.

Lim, Y., Stolterman, E., and Tenenberg, J. (2008). *The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas*. ACM Trans. Comput.-Hum. Interact. 15, 2 (Jul. 2008), 1-27.

Mao, J., Vredenburg, K., Smith, P. W., & Carey, T. (2005). *The state of user-centered design practice*. Commun. ACM 48, 3 (Mar. 2005), 105-109.

McCurdy, M., Connors, C., Pyrzak, G., Kanefsky, B., and Vera, A. (2006). *Breaking the fidelity barrier: an examination of our current characterization of prototypes and an example of a mixed-fidelity success*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006). R. Grinter, T. Rodden, P. Aoki, E. Cutrell, R. Jeffries, and G. Olson, Eds. CHI '06. ACM, New York, NY, 1233-1242.

Norman, D. A. (2004). *Emotional design: why we love (or hate) everyday things*. New York: Basic Books.

Pering, C. (2002). *Interaction design prototyping of communicator devices: towards meeting the hardware-software challenge*. interactions 9, 6 (Nov. 2002), 36-46.

Pfleging, B., Valderrama Bahamondez, E. d., Schmidt, A., Hermes, M., and Nolte, J. (2010). *MobiDev: a mobile development kit for combined paper-based and in-situ programming on the mobile phone*. In Proceedings of the 28th of the international Conference Extended Abstracts on Human Factors in Computing Systems (Atlanta, Georgia, USA, April 10 - 15, 2010). CHI EA '10. ACM, New York, NY, 3733-3738.

Ramey, J., Boren, T., Cuddihy, E., Dumas, J., Guan, Z., van den Haak, M. J., and De Jong, M. D. (2006). *Does think aloud work?: how do we know?*. In CHI '06 Extended Abstracts on Human Factors in Computing Systems (Montréal, Québec, Canada, April 22 - 27, 2006). CHI '06. ACM, New York, NY, 45-48.

Reilly, D., Dearman, D., Welsman-Dinelle, M., and Inkpen, K. (2005). *Evaluating Early Prototypes in Context: Trade-offs, Challenges, and Successes*. IEEE Pervasive Computing 4, 4 (Oct. 2005), 42-50.

Rogers, M. P. (2010). *Wrong number: avoiding the hidden perils in iPhone development*. J. Comput. Small Coll. 25, 5 (May. 2010), 300-305.

Rudd, J., Stern, K., and Isensee, S. (1996). *Low vs. high-fidelity prototyping debate*. interactions 3, 1 (Jan. 1996), 76-85.

Schuler, D. and Namioka, A. (1993). Preface. In: D. Schuler & A. Namioka, eds. 1993. *Participatory design : principles and practices*. Hillsdale, N.J.: L. Erlbaum Associates.

Sidhavatula, V and Wendt, B. Sc. A. (2007). *Using mock-ups, a feature of the scandinavian approach to user involvement in design*. Scandinavian Student Interaction Design Research Conference. (March 8- 9, 2007). BTH.

Säde, S. (2002). *Mobile ease-of-use and desirability through user-centered design*. SSGRR 20022w L'Aquila. (Jan. 2002).