

# Empirical Evaluation of User Experience in Two Adaptive Mobile Application Prototypes

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## Abstract

Today's applications such as ubiquitous systems are more and more aware of user's habits and the context of use. The features of products and the context of use will affect the human's experiences and preferences about the use of device. Thus, user experience in user-product interaction has been regarded as an important research topic in the mobile application design area. The purpose of this paper is to clarify how user experience can be evaluated in adaptive mobile applications. The user experience evaluations were performed through interviews and observation while test users were using PDA-based adaptive mobile application prototypes. As a result, this paper presents the analysis of the test methods for further user experience evaluations.

**CR Categories:** J.m [Computer Applications]: Miscellaneous; Experimentation; Human Factors

**Keywords:** Adaptation, HCI, mobile device, user experience evaluation

## 1 Introduction

In the recent years, the use of different mobile products such as mobile phones and Personal Digital Assistant (PDA) devices has increased rapidly. Moreover, ubiquitous computing has become a popular topic in research and design areas. Nowadays, systems are more and more aware of their context of use. [Dey and Abowd 1999; Weiser 1991]

In order to be useful, ubiquitous applications need to be designed so that the user's needs and preferences and the context of use have been taken into account [Consolvo et al. 2002]. However, the evaluation of pervasive computing systems and their influences on users is quite difficult because the evaluation will require analysis of real users in a real context [Bellotti et al. 2002]. In addition, in continuous interaction research, test users should have a fully operational, reliable, and robust tool [Bellotti et al. 2002]. Evaluation with an incomplete prototype will not give a realistic test result. Nevertheless, preliminary tests in early phases of product development are necessary to perform in order to achieve information about the end user's preferences and needs.

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In the recent years, in the Human-Computer Interaction (HCI) research area the capturing of user experience has been seen as an important and interesting research issue. In general, user experience has been captured with techniques like interviews, observations, surveys, storytelling, and diaries among others [Johanson et al. 2002; Nikkanen 2001]. However, in the HCI research area the understanding of user experience and its evaluation has not been established. One reason for this may be shortcomings in the definition of user experience and its relation to usability issues. Also, future proactive environments and adaptive mobile devices bring new aspects to the field of user experience research.

The aim of the paper is to study how user experience can be evaluated in adaptive mobile applications. User experience research and its methods are briefly presented in Chapter 2. Adaptive mobile prototypes and user experience evaluations are described and methods analyzed in Chapter 3. The results of the paper are presented in Chapter 4. Finally, the research is concluded and further work discussed in Chapter 5.

## 2 User Experience and Research Methods

Basically, user experience refers to the experience that a person gets when he/she interacts with a product in particular conditions. In practice, there are numerous different kinds of people, products and environments that influence the experience that interaction evokes (Figure 1). The user and the product interact in the particular context of use that social and cultural factors are influencing. The user has the following aspects: values, emotions, expectations and prior experiences, among others. Also, the product has influential factors, for example, mobility and adaptivity. All these factors influence the experience that user-product interaction evokes. [Dewey 1980; Forlizzi and Ford 2000; Hiltunen et al. 2002]

Moreover, in order to investigate user-product interaction, researchers need to determine the nature of a product. The type of the product will affect the research methods and targets. For example, user experience studies of web sites [Garrett 2002] emphasize visual issues whereas research of hand-held devices needs more attention on issues such as size, weight and mobility. Likewise, the evaluation of ubiquitous computing environments emphasizes different factors of a product and may thus require different methods for investigating user experience. In addition, the target use group needs to be defined before developing or testing prototypes; for instance, if the device will be put to public use and the users are not very familiar with computers, the interface should be simple and clear [Bellotti et al. 2002].

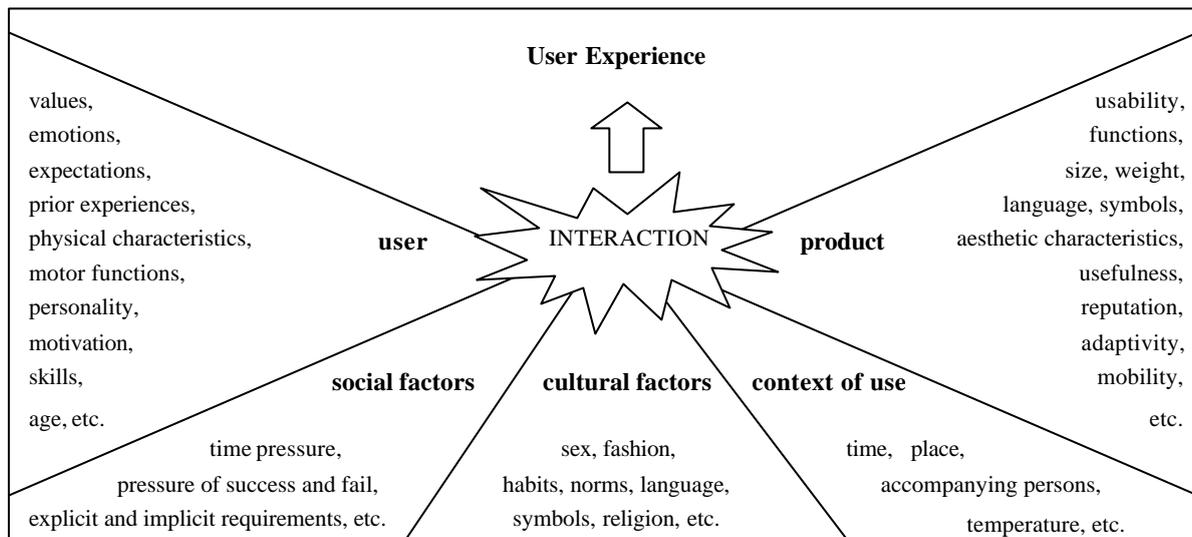


Figure 1. User experience forms in interaction with user and product in the particular context including social and cultural factors

There are several methods in the user experience research area that have been used for capturing experiences, for instance interviews, observation, surveys, diaries, storytelling and prototyping [Nikkanen 2001]. In long-term use, surveys, diaries [Palen and Salzman 2002] and storytelling have been regarded as an effective way to get information about user experience. That is because the user can express some of his/her experiences in a written form. Stories are ways to organize and remember experiences and they enable humans to communicate experiences in different situations to the particular people involved [Forlizzi and Ford 2000]. On the other hand, observation is a suitable method to gather user experience from non-verbal expressions. This is important, because the user may not be aware of his/her experiences or be capable to express them verbally. Buchenau and Fulton Suri [2000] have developed a method called Experience Prototyping for simulating experiences of different situations. The method allows designers, clients or users to “experience it themselves” rather than just witness a demonstration of someone else’s experience. [Buchenau and Fulton Suri 2000]

Ubiquitous environments bring new aspects to user experience research. One reason for that is that environments and systems, according to Mark Weiser’s vision [1991], should be invisible to the user; however, it should be possible to evaluate the interaction with the system. User experience in this kind of challenging environments and systems have been evaluated by interviews and observations in different ways [Bellotti et al. 2002; Johanson et al. 2002; Fleck et al. 2002].

Bellotti et al. [2002] have utilized different methods in their evaluations. In the first evaluation, they used two different questionnaires: a complete version and a short version. One year later, in the second evaluation, they performed ethnographic observation and qualitative and quantitative measurements [Bellotti et al. 2002]. Johanson et al. [2002] have developed interactive workspaces (iRoom) and performed some experiments of human-computer interaction. In these

experiments they have utilized open participatory meetings with different sets of groups, e.g. expert and student project groups [Johanson et al. 2002]. Fleck et al. [2002] have developed an electronic guidebook for an interactive museum, called Exploration. In this museum, they have performed informal user studies by observing users with and without technology. Moreover, subjects were interviewed after the use of the prototype [Fleck et al. 2002].

### 3 User Experience Evaluations

In this study, user experience has been evaluated in two different adaptive mobile applications. Both the evaluation cases are presented and their weaknesses and strengths are discussed. Interview was selected as the method, because the amount of test users was quite small; this made it possible to observe user during the interview, and gave an opportunity to make the evaluation flexible. Observation was selected for gathering user experience from non-verbal expressions because the user may not be aware of his/her experiences, or be capable to express them verbally. Also, these methods were well suited for the test situation and resources. The interviews and observations have been analyzed from the user experience point of view, i.e. how well these methods suit user experience research.

#### 3.1 The First Evaluation

The first evaluated prototype (Figure 2) is a context-adaptive application and it runs in a Personal Digital Assistant (PDA). This mobile device can localize the user by using WLAN (Wireless Local Area Network) positioning. In addition, the application can learn the user’s habits on choosing the phone profile (normal, silent, loud) in a particular room by using routine learning algorithms.



Figure 2. The first adaptive mobile application prototype.

The context-aware application prototype can ask the user if he/she wants the profile to adapt automatically. The user can set the profile of his device and can make notes, for example mark a location of the meeting in the calendar of the prototype. Based on the context information of the user's location, the device can remind the user of the appointed meeting so that the user has enough time to get there, for example five minutes before the meeting. In addition, the user can add notes to the meeting place, and thus the prototype will give reminders of those notes in the meeting.

### 3.1.1 Test Scenario

The user experience of these applications' features was evaluated with the following predefined scenario:

- The user is using his/her mobile device in a corridor at his/her workplace. The application reminds the user that he/she has a meeting in one minute in a particular meeting room.
- The user enters the meeting place and the application automatically adapts into silent mode.
- When the user is in the meeting room, the application reminds him/her about any notes that he/she has made earlier. The note can be for example that the user must remember to bring forward some important things in the meeting.

This test scenario was created so that it enabled testing of the main adaptive features of the prototype. Moreover, it made it possible to evaluate user experience in the real environment. The first evaluation was conducted in an office-type environment. The test environment consisted of one big corridor and several rooms along it. One of the rooms was the meeting room where the user was going. The test was performed during the workday, and consequently there were some passers-by.

### 3.1.2 Test Methods

In this case study, the user experience evaluation techniques were interviews before and after the use of the prototype and observation during the use and the interviews. Users were asked to "think aloud" during the test. Interviews and observations were tape-recorded. The interview questions were developed on the basis of literature reviews [Bellotti et al. 2002; Dewey 1980; Forlizzi and Ford 2000; Hiltunen et al. 2002]. The questions concerned the user's prior experiences and present emotions, the prototype's mobility and adaptivity, context of use, and social and cultural factors. The interviews were organized so that one of the researchers asked questions and the other made notes, even though the interview was also recorded. The clerk also asked additional questions. Both of the researchers observed the test user during the interviews.

The observation was selected in order to get some information about the user's emotions and experiences, which he/she may

not be able to describe him/herself. The observation focused on the user's facial expressions and behavior in general. During the test the observations about the user's gestures and behavior were written down. The whole evaluation including interviews took between 20 and 30 minutes.

The prototype was tested with three test users. The aim was to collect different user experiences, so two of the test users were familiar with computers and they had some background in information processing science. One of the users was quite inexperienced with computers and had a background in the humanities. No more test users were used because the aim of the first evaluation session was to collect preliminary information of the suitability of interviews and observations for user experience research.

### 3.1.3 Analysis of Test Methods

The study illustrated that interviews and observations are appropriate methods for evaluating user experience in user-product interaction. The documenting of the gestures and facial expressions during the test was slow and hard to combine with the particular action. In addition, perhaps some of the gestures were missed. Thus, in order to catch user experience from emotions and facial expressions, observations as well as interviews are better to record onto videotape.

**Goal definition.** The user experience evaluation elicited several improvements for the further tests. For example, a goal for the test has to be predefined, because user experience includes so many different aspects. In the test plan these factors have to be defined and a decision made about which information is needed to be captured; for example, whether experience relating to mobility issues is needed to be gathered, or also adaptivity and the context of use. Moreover, the test situation and atmosphere have to be as natural as possible for the test user because it will affect the kind of user experience that is formed.

**Interview.** It is important that the questions related to user experience are very simple so that the interviewee can understand them easily. Questions should not be strictly directed to user experience issues; for example, the interviewer should not ask, "Did the context of use affect the experiences that arose with the use of the application?" Instead, a better way is to ask "Can you tell something about this test situation? How did you feel about it?" In addition, the order of questions may affect how the interviewees understand the questions and this will influence user experience. For example, the interviewee should not be prompted by asking some questions about user experience before it is a topical issue. This is quite a challenge for user experience researchers because they have to find a balance for when to ask questions and when to expect the user to tell about his/her experiences freely. Nevertheless, it could be difficult for the user to express his/her personal experience verbally.

One of the interesting findings was that if the user was handling the product during interviews he/she may play with the product and not concentrate carefully on the interview questions. On the other hand, when the user has got a product in his/her hands he/she is more interested in discussing it and can perhaps express his/her opinions and experiences about the device better, because after familiarization he/she knows the device better.

### 3.2 The Second Evaluation

In the second evaluation, the adaptive application is implemented into a PDA-based prototype and it has an adaptive map-based interface (Figure 3). In this application, the map can be positioned according to the user's present location by using WLAN positioning.



Figure 3. The second adaptive mobile application prototype [Rantakokko 2003].

Via the compass feature, the map can be rotated automatically according to a user's orientation. The user can zoom in and out on the map by moving his/her hand under the prototype's proximity sensor. The prototype zooms in when the user puts his/her hand closer to the sensor and vice versa. Scrolling the map is implemented by utilizing an accelerometer. Thus, the user can scroll the map by tilting his/her hand in four directions (forward, backward, left and right). In addition, the prototype's map includes objects and halos the aim of which is to help the user in finding different places and objects faster and more easily. With the halos the user can estimate the distance to a destination. [Rantakokko 2003]

#### 3.2.1 Test Scenario

The test scenario was developed so that it was appropriate for the test environment. The environment was a home laboratory, which consisted of a kitchen, a living room, an office room and a hall. However, it was not appropriate to use the map-based prototype in the home environment. Instead, it is more sensible to evaluate the features of the prototype in some bigger context, for instance a health centre. So, we renamed the test environment more appropriately, e.g. living room was now waiting room.

The tests were performed with the following predefined scenario and test cases:

- **Test case 1:** The user is in the health centre and is given the gesture- and context-sensitive control device for finding the necessary places and objects. The user gets acquainted with the features of the prototype:
  - Positioning: the user identifies him/herself from the screen of the prototype.
  - Compass: The user uses the compass by holding the prototype in front of him/her and turning simultaneously.
  - Zooming: The user zooms by altering the distance from the bottom of the device to other objects.
  - Scrolling: The user tilts the prototype.
  - Service selection: The user clicks the icons and recognizes objects.

- Halo: The user identifies the distance of objects through the arcs of halo circles.
- **Test case 2** The user is sitting in the living room and waiting to see a doctor. He/she needs to go to the toilet and will use the prototype's feature to find out where the toilet is located.
- **Test case 3:** After going to the toilet, the user needs to wait for the doctor for a moment. He/she wants to change the channel on the TV, but first he/she has to find the remote control. He/she will use the prototype for that.

#### 3.2.2 Test methods

The improvement ideas from the first evaluation were taken into account in this second evaluation. Hence, interviews and observations were recorded with a video recorder. Before the actual tests a pilot test was performed and it confirmed that the test scenario and cases are appropriate.

At the beginning of the test, the users' backgrounds as well as their familiarity with mobile applications were determined. Interview questions were updated from the first evaluation and they concerned the user's prior experiences and expectations, the prototype's mobility and adaptivity, context of use and social factors.

This evaluation was conducted in a laboratory, because the tested prototype required a particular WLAN environment in order to operate. The user experience evaluation was carried out with ten test users. The purpose was to get user experiences from different kind of users. Thus, half of the users were experienced and had been using PDA devices a lot or at least a little, or they had a background in technology. The other half had never used a device like that and came from different fields of occupation. In each evaluation, the whole test situation including interviews took approximately an hour.

In addition to the interview and observation, the questionnaire and user instructions for the prototype were sent to the test users afterwards (a few days later). The purpose of the questionnaire was to clarify the user's experiences about the prototype and its features as well as the whole test situation. This gave the users the possibility to think about the test more carefully than just in the test situation.

#### 3.2.3 Analysis of test methods

The second study also supports the view that interviews and observations are methods that can be used for evaluating user experience, because a lot of the user's thoughts, experiences and emotions can be captured. Nevertheless, these methods are not enough in order to get a deeper knowledge of the user's emotions and experiences. The evaluation of user experience will need more capable ways to catch user experience.

**Video recording.** Although the selected methods seemed to be good, some observations and problems arose. For example, tests were videotaped in front of the users, and this perspective gave information about the user's facial expressions such as eyebrow movements. However, when the user's head was down while he/she was watching the device, it was difficult to see all the facial expressions (Figure 4). Another problem was videotaping when the user has to move between different rooms (Figure 4). He/she could turn his/her back to the camera. The biggest problem in the video recording was that the screen of the device was not recorded at all. Information about what happened on the

screen was captured via the user's "thinking aloud" and the moderator standing alongside the test user and watching the screen.

The use of video recording elicited some new questions for user experience research: Does video recording have an influence on the user's behavior and user experience formation? Do these possible impacts influence user experience? Can we collect all emotions only by using video recording? For example, one test user said that she is very nervous, but that was impossible to interpret from her facial expression and gestures. So, this user experience (emotion) was captured via interview – not by observing.

**Interview.** The first evaluation showed that user experience questions should be formulated in a particular way, so that that the user can understand them easily. In this second evaluation,

interview questions were made easier and "the user's language" was used. However, some of the test users regarded the questions as difficult. Does this mean that it is difficult for the user to verbally express his/her experiences? Is some visual expression an easier way for the user to express his/her emotions and thoughts?

**Test situation.** Organizing the test elicited several problems as well. Firstly, the test premises were too small in order to test some features of the prototype, for instance the benefit of positioning. Secondly, the test included too many features for the users to use the prototype and learn all functionalities. The test could be organized so that it is divided into two sessions where a part of the features will be tested first and the rest of them a little later (a week or two). Thus, the learning of the use

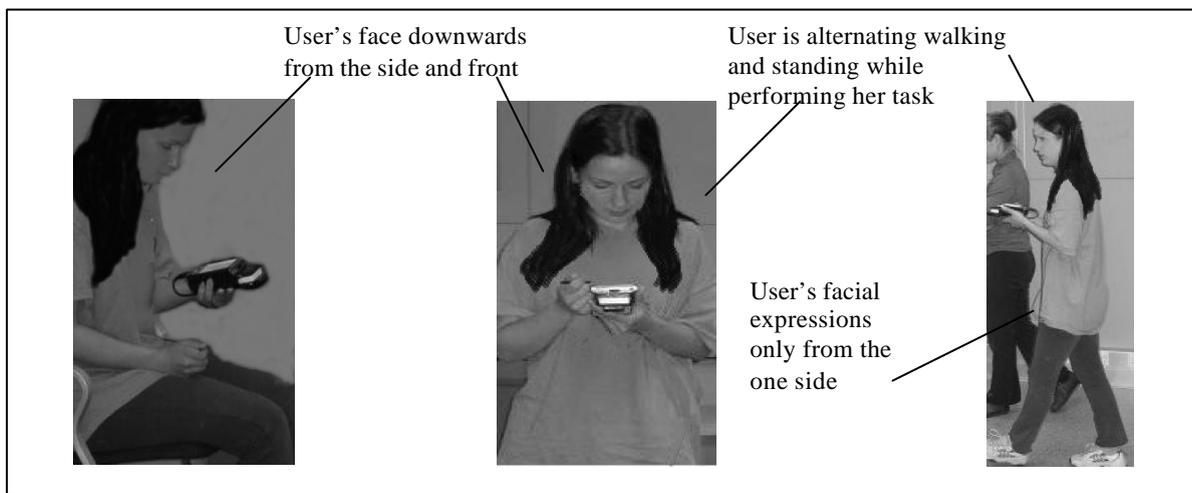


Figure 4. Capturing the user's facial expressions, gestures and body movements in interaction with the prototype.

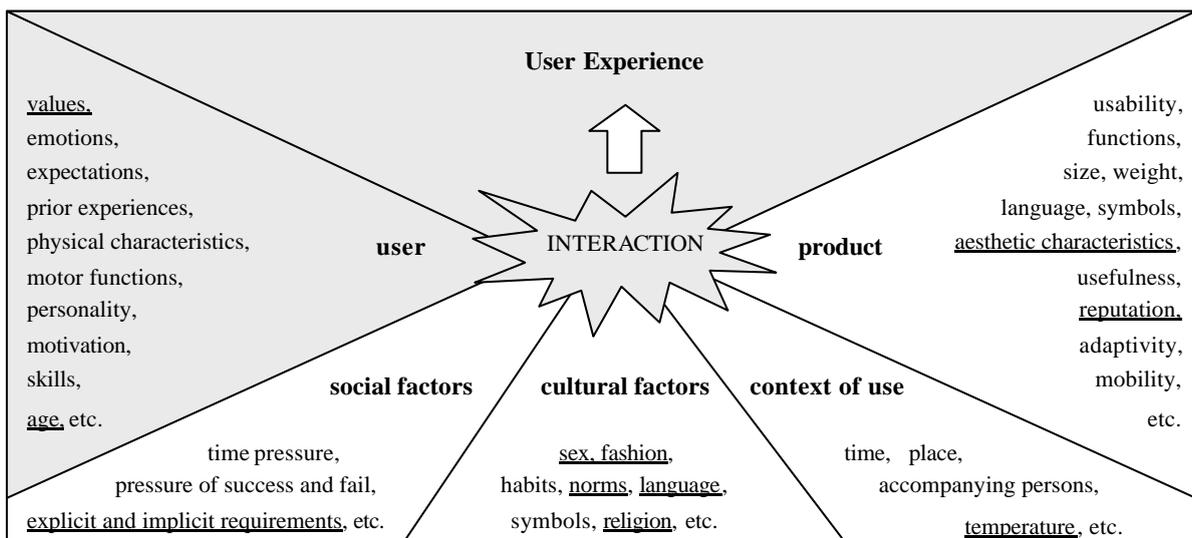


Figure 5. User experience factors captured via interviews and observations.

of the application can be also evaluated. From the viewpoint of user experience research, there were too many (five) tests in one day. Thus, researchers had to keep a schedule in order to be ready for the next test person. The tests were planned to be conducted one after the other. This strict schedule may have certain influences on user behavior and thus user experiences.

## 4 Results

This chapter is divided into two parts. Firstly, the benefits and challenges of the interview and observation methods from the viewpoint of user experience research are summarized.

Secondly, the suitability of interviews and observations for user experience research is discussed.

### 4.1 Benefits and Challenges

Interview is a good method for user experience evaluation, because then the test situation can be like a “chat session” with the test user. It gives the possibility to create a calm and nice atmosphere in test situation. This is also an easy way to get information about the user’s background (age, education), prior experiences, expectations and motivation, etc.

Table 1. User experience factors captured via interviews and observations.

Factor	Int.	Obs.	Comment
<b>User</b>			
values,	<input type="checkbox"/>	<input type="checkbox"/>	NE
emotions,	<input type="checkbox"/>	<input checked="" type="checkbox"/>	- Difficult for user to express emotions verbally.
expectations,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Interview gave this information very well, also observation gave information about user’s appearance (shy, enthusiastic)
prior experiences,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Good and bad experiences about technical devices. - Use of device and understanding of symbols.
physical characteristics,	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Small hand vs. big device.
motor functions,	<input type="checkbox"/>	<input checked="" type="checkbox"/>	- Affected user experience (how well can use the product)
personality,	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Personality affects storytelling (-> user experience results as well). It also affects observation (gestures).
motivation,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Motivation and lack of motivation were noticed.
skills,	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Skills influenced user experience (use of different equipments like compass).
age	<input type="checkbox"/>	<input type="checkbox"/>	NE
<b>Product</b>			
usability,	<input type="checkbox"/>	<input checked="" type="checkbox"/>	- Usability issues were not interviewed/tested, however observation elicited that it affects user experience.
functions,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Interviews and observation gave a lot of information about the functions of the device.
size,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Size of device vs. size of user’s hand and use of both hands.
weight,	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Weight affected use and thus user experience.
language,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Affected understanding of the device, and thus user experience in a negative or positive way.
symbols,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Affected understanding of the device, and thus user experience in a negative or positive way.
aesthetic characteristics,	<input type="checkbox"/>	<input type="checkbox"/>	NE
usefulness,	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Affected user experience in a positive way.
reputation,	<input type="checkbox"/>	<input type="checkbox"/>	NE
adaptivity,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Hard for the user to explain this factor, so the observation gave more information about it.
mobility	<input checked="" type="checkbox"/>	<input type="checkbox"/>	- Was regarded as an obvious and positive aspect.
<b>Social factors</b>			
time pressure,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Users leaned on the moderator a lot.
pressure of success and fail,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Users explained a lot why they cannot use the device.
explicit and implicit req.	<input type="checkbox"/>	<input type="checkbox"/>	NE
<b>Cultural factors</b>			
sex,	<input type="checkbox"/>	<input type="checkbox"/>	NE
fashion,	<input type="checkbox"/>	<input type="checkbox"/>	NE
habits,	<input type="checkbox"/>	<input checked="" type="checkbox"/>	- Users compared features to a magnifier (zooming) and a glass of water (scrolling).
norms,	<input type="checkbox"/>	<input type="checkbox"/>	NE
language,	<input type="checkbox"/>	<input type="checkbox"/>	NE
symbols,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Symbols were familiar from other contexts.
religion	<input type="checkbox"/>	<input type="checkbox"/>	NE
<b>Context of use</b>			
time,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Influenced user experience.
place,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- Interview and observation gave different information about its influences on user experience.
accompanying persons,	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	- No influence on user experience.
temperature	<input type="checkbox"/>	<input type="checkbox"/>	NE

However, there are some interesting challenges for the interviewers to clarify. Firstly, questions related to user experience should be formulated very carefully so that the users can understand them easily. Secondly, usually the user can express his/her opinions about a device and its characteristics, but verbally describing his/her feelings about the device is more difficult. In that kind of a situation, the interviewer can try to “read between the lines” when the user speaks about his/her experiences. Nevertheless, this challenge may require using some other methods as well.

Observation also gave information about user experience. However, researchers need to interpret the user’s facial expression, body movements and gestures carefully, because the personality of the user will affect how they behave. For example, one test person said that she is very nervous, but her outward appearance was really calm. Moreover, humans make gestures very differently, for instance while one moves his or her eyebrows a lot, the other can move his/her eyes only a little.

These two user experience evaluations elicited that a comprehensive observation will require video recording. In the first evaluation, video recording was not used, and thus only some facial expression was captured. However, the second evaluation was video recorded but still some challenges occurred. The first thing in video recording in user experience research is that it must not influence the user and his/her experiences. This is an interesting challenge. However, in order to collect the user’s facial expressions, gestures and actions on the screen, the video recording should be organized from different perspectives, for instance, from the front of the user’s face, the top of the screen and a little bit farther away so that the user is in the picture. In order for the observation to be reliable, a tool or a method for interpreting different gestures and emotions is required.

## 4.2 Suitability for user experience research

The picture (Figure 1) presented in Chapter 2 illustrates what different factors affect user experience in user-product interaction. In evaluations, some factors can change; for instance, in the user experience evaluation presented in this paper, the user was one part that changed. The device, social and cultural factors and the context of use were the same. Consequently, when the user changes, interaction and user experience change as well (grey areas) (Figure 5).

User experience factors can be captured via interviews or observations on a particular level. Factors, which did not appear in the evaluations, are underlined in the picture (Figure 5) and marked as NE (Not Emerged in the evaluations) in the table (Table 1). However, this paper does not deny that those factors could not be captured via interviews and observations.

The evaluations elicited that some user experience factors can be gathered via both of the methods. For example, the user can comment on the product’s functions and say that they are easy to understand and learn. However, when he/she uses product, the observer can perceive that he/she uses it in the wrong way. On the other hand, observation does not always bring out the user’s emotions properly, and thus interview can reveal the true emotions more easily. Hence, interviews and observations can give different information about the same factor, and thus give a more comprehensive view to user experience. This paper

presents what user experience factors were captured via interviews and observations (Table 1).

## 5 Conclusion

The purpose of this paper was to define how user experience can be evaluated in adaptive mobile applications. In general, the capturing of user experience is quite difficult, because there are so many different factors in user-product interaction (Figure 1). For the evaluation, those factors should be clarified and a goal for the test defined in a test plan. This may help make the evaluation more systematic.

Both the examinations illustrated that interviews and observations are appropriate methods for capturing user experience (Table 1). However, this study confirmed that several methods need to be used in order to evaluate user experience. In addition to the interviews and observations, researchers will need more efficient ways to get information about the user’s emotions and experiences, concerning for example collection and interpretation of body gestures and facial expressions. In order to collect authentic emotions, the test situation should be organized so that is as natural as possible. As further research, more user experience evaluations will be done for different adaptive mobile devices, using different methods.

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