Electronic Communications of the EASST
Volume 56 (2013)

Proceedings of the Combined workshop on
Self-organizing, Adaptive, and Context-Sensitive Distributed Systems
and
Self-organized Communication in Disaster Scenarios
(SACS/SoCoDiS 2013)

Challenging the Need for Transparency, Controllability, and Consistency in Usable Adaptation Design

Romy Kniewel, Christoph Evers, Ludger Schmidt and Kurt Geihs

12 Pages

Guest Editors: Michael Zapf, Florian Evers
Managing Editors: Tiziana Margaria, Julia Padberg, Gabriele Taentzer
ECEASST Home Page: http://www.easst.org/eceasst/ ISSN 1863-2122

Challenging the Need for Transparency, Controllability, and Consistency in Usable Adaptation Design

Romy Kniewel[1], Christoph Evers[2], Ludger Schmidt[1] and Kurt Geihs[2]

[1]Human-Machine Systems Engineering, University of Kassel
[2]Distributed Systems Group, University of Kassel

Abstract: Adaptive applications constitute the basis for many ubiquitous computing scenarios as they can dynamically adapt to changing contexts. The usability design principles transparency, controllability, and consistency have been recommended for the design of adaptive interfaces. However, designing self-adaptive applications that may act completely autonomous is still a challenging task because there is no set of usability design guidelines. Applying the three principles in the design of the five different adaptations of the mobile adaptive application Meet-U revealed as difficult. Based on an analysis of the design problem space, we elaborate an approach for the design of usable adaptations. Our approach is based on a notification design concept which calculates the attention costs and utility benefits of notified adaptations by varying the design aspects transparency and controllability. We present several designs for the adaptations of Meet-U. The results of a user study shows that the notification design approach is beneficial for the design of adaptations. Varying transparency and controllability is necessary to adjust an adaptation's design to the particular context of use. This leads to a partially inconsistent design for adaptations within an application.

Keywords: Usable adaptations, controllability, transparency, consistency, notification design approach, context of use, use case study

1 Introduction

Traditionally, adaptive software tries to support the user by performing autonomic adaptation actions based on information about its environmental context provided by sensors or other data sources. The user is not asked for confirmation nor is he otherwise involved in the reconfiguration of the software. For example, an adaptive mobile application could integrate an indoor map service and would change from a less-detailed outdoor map to a detailed indoor map about the building so the user finds his way more easily.

Usability has become an established and necessary feature for IT and argues to support the user to reach his goals in an effective, efficient, and satisfying manner in a particular context of use. However, usability and adaptivity are not as easy to be combined. Adaptive applications continuously adjust their state and change their behavior at runtime, particularly in highly volatile and heterogeneous environments to provide the best utility. As soon as there is a high degree of user interaction in the software, an adaptation action that is carried out autonomously might not meet the user's expectations. Also the user might become confused, when being directly confronted with a visible change of the application or its behavior.

There are general usability design principles; however, there are none for adaptive software. Only the usability principles transparency, controllability, and consistency have been stated to be relevant for adaptive applications which change their displays and available actions to the user's current goals and physical abilities, so called Adaptive User Interfaces (AUI) [2][5][16][22]. We questioned the general applicability of these principles to the design of adaptive applications when we designed the adaptations for Meet-U. Meet-U supports its users with different adaptations in several contexts: for planning private or public events with friends, to timely navigate to these events, and to employ services provided by the environment of public events. To reach usability for every adaptation each context of use needs to be considered for the design of a particular adaptation.

In this paper, we first give a short introduction to adaptivity, usability, and the usability principles transparency, controllability, and consistency. Then we analyze the design problem space of usable adaptive applications and discuss the general applicability of the three usability principles. We elaborate our design approach for Meet-U's adaptations which is based on a framework for notification design. It considers the attention cost and utility benefits of interactions like transparent and controllable adaptation processes. The framework provides the three critical parameters interruption, comprehension, and reaction that can be varied in order to change the level of the attention that a notified adaptation would cost. We demonstrate our approach by designing different variations for Meet-U's adaptations. The design variations feature different levels of transparency and controllability. In order to evaluate our approach and the adaptation designs, we conducted a user study and present its results.

2 Background

Usable adaptation design is a research field which is investigated little. However, usability is a relevant aspect for adaptive applications.

2.1 Adaptivity

Application adaptivity is rooted in the field of autonomic computing research. The aim of autonomic computing has been to achieve the best desirable service for the user without actually incorporating the user in the machine's decision. Applications should act completely autonomic [15]. The ability to autonomously perform changes in parameterization or configuration is based on sensory inputs and associated rules. Sensors deliver information about the environmental state. Situations like the presence of certain people, services, or environmental conditions like location or temperature may affect the application's behavior. A common approach to achieve such application-level adaptation is the use of a feedback loop in combination with component-based software design [10]. From the technical perspective, we differentiate between four types of adaptation:

- Parametric Adaptation: An application usually has parameters or properties which can be adjusted to achieve some change in behavior or functionality. Parametric adaptation does usually not require any architectural changes.
- Compositional Adaptation: Software developed in a modular fashion facilitates the composition of different sub-components realizing a complex component. Such components can be exchanged at runtime allowing different application variants.
- Deployment Adaptation: Distributed systems and mobile applications interacting with their environment, may substitute local components by components that are available on other entities within the environment.
- Adaptation by Service Integration: A more flexible way is the integration of external services which is the preferred choice when dealing with dynamic and heterogeneous environments whose exact characteristics cannot be foreseen at design time.

2.2 Usability

Usability has become an established feature of technologies in the domain of human-computer interaction. In this field, technologies are understood as a kind of tools, which people utilize to solve their tasks in order to reach their higher-level goals. Usability is a characteristic of the technology's user interface. It is defined as "[...] the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." [6] The context of use is composed of four elements: the user, the tasks he wants to accomplish, the means for work, and the physical and social environment the user is interacting in to reach his goals. Understanding the context of use is fundamental to design usable software because the characteristics of each component influence how the interface should be designed best in order to be usable for the user.

As seen in the previous subsection, adaptive applications actually strive for being usable on a general level. They want to provide the best service for the user. But an application action that is carried out autonomously might not meet the user's needs and expectations. Also an adaptation that disrupts the user from solving his tasks makes the application less usable.

There are several established usability guidelines that describe different design principles which are to be considered in the development of usable applications. They support to make the right design decisions and prevent from making the same mistakes over and over again. There are guidelines such as norms, heuristics, and claims.

In the context of adaptive applications, where it is undesirable to incorporate the user for the adaptation's decision, the design principles for usable dialogues from the norm EN ISO 9241-210 [6] are particularly relevant to mention. A dialogue is defined as the interactions between a user and a system to achieve a particular user goal. Interaction includes all input and output steps. So any adaptation that has any output causes a dialogue with the user. This guideline for usable dialogues recommends any dialog to be controllable. "A dialogue is controllable when the user is able to initiate and control the direction and pace of the interaction until the point at which the goal has been met." [6]. Furthermore, the design principle consistency that can be found in several guidelines [19][20] can be described as: "Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens; and consistent commands should be employed throughout." [21]. It can relate to the interactivity, the visual design, the language, the structure of an interface. It supports to achieve the usability principles conformity with user expectations and self-descriptiveness from the mentioned norm [6].

Adaptivity can have effects on the application's user interface. When being confronted with adaptivity changes, the user may become disrupted [16]. The possible usability shortcomings of software that changes its user interface during run-time have been discussed in the field of adaptive user interfaces (AUI). Unlike adaptive software incorporating architectural adaptation, AUIs only adapt the user interface according to context changes in order to make it more suitable and usable. For example, an AUI would change to interaction by voice when a visually impaired user wanted to use the application. One usability shortcoming with AUIs is that end users might become disrupted when the interface behavior is unexpected and cognitive perturbation can be caused. Further, users may perceive a loss of control over the processes, a loss of transparency, and a loss of predictability respectively [12][14][16]. Three usability recommendations for this type of adaptive application have been found, these are: transparency, controllability, and consistency [2][5][16][22].

Transparency, sometimes also referred to as comprehensibility, is the extent to which the user can understand actions of the system, and to which he has an understanding of how the system works [14]. As soon as the underlying principle of adaptations in an application is transparent, any adaptation would become predictable.
Controllability specifies to which extend the user can enable or prevent particular actions or states of the system if the user has the intention of doing so [14]. This can be done in different granularity and way. There have been suggestions by Evers et al. [8] on how to improve controllability for adaptive applications. They differentiate between implicit and explicit control of an adaptive application. Whereas implicit control describes all types of influence where the user modifies the current structure and behavior of the application ad-hoc, explicit control allows the user to change the adaptive behavior of the application by either changing adaptation preferences or toggling the adaptive behavior prior to adaptation.
Consistency for the adaptations of AUIs was favored by Peissner and Sellner [22]. Also it is stated that internal consistency (e.g. layout, terminology, color, etc.) of the user interface is a crucial issue in the usability of software with a high level of interactivity [19][23][24].

3 Analysis of the Design Problem Space

When we were confronted with the task to design the adaptations for the mobile adaptive application Meet-U, we had problems with simply applying the usability principles transparency, controllability, and consistency. One single and consistent design for all adaptations would not take into account the particular user needs in each context of use. For example, in a few contexts the user might be involved in other tasks in the environment and would want the adaptation anyway. If the adaptation design would not consider the needs from each context the adaption would become less usable. Thus, we analyzed the design problem in order to find an alternative design approach, which we found in the area of notification design.

3.1 The Use Case Meet-U

Meet-U is a mobile adaptive application that enables its user to organize meetings that take place at public or private events, e.g., concerts, films at the cinema, or birthday parties [3]. Meet-U provides support to users in every situation. Starting with the general planning phase of such events Meet-U is also capable of timely navigating the user to the event while using different navigation and map providers. Being at the event location Meet-U may integrate (software) services provided by the event organizer to improve user experience. Depending on the type of event the Meet-U application can autonomously change the device's audio settings, e.g. muting the phone. The requirements for the design of Meet-U were elaborated in a multidisciplinary development approach for socio-technical technology [4].

3.2 Meet-U's Adaptations

From the technical point of view Meet-U supports the adaptation types presented in Section 2.1. Depending on time, location, and user preferences Meet-U switches from the planning mode to the navigation mode, requiring changes in the architectural composition of the software components. Depending on the location, Meet-U automatically selects the best provider for an indoor or outdoor map. When driving, Meet-U may swap the displaying component to the car's navigational device. To integrate local services at the event location Meet-U determines location and time and compares the provided with the required services features. The service alternative providing the best Quality of Services (QoS) will be integrated. Depending on the event type and the individual user preferences Meet-U may perform changes in parameterization of the device's audio settings, such as to mute the device.

3.3 Problems with Applying the Three Usability Principles

The usability principles transparency, controllability, and consistency could not be simply applied when designing Meet-U's adaptations. According to the design principles transparency, Meet-U's user should be informed when an adaptation happens. The principle controllability would demand that the user is always in control and thus always being asked for approval. This design would reinforce multitasking. Each adaptation would cause an interruption in the user's ongoing activity. Especially in the mobile context, the user's attention is occupied with activities far away from interacting with the device. A transparent and controllable adaptation would capture the user's attention. But attention is a limited resource in human-computer interaction [13]. So interruptions can become disruptions and distractions from solving tasks [1]. In this case, the user is hindered reaching his goals and the application turns less usable. Additionally, the design principle consistency would argue for one design for all adaptations within Meet-U. But usable interface design always considers the particular context of use. In each context of use, the user's attention is differently occupied. So, in order to provide usable adaptations only, each of Meet-U's adaptations should be designed accordingly the user needs in the particular context in which the adaptation happens.

These problems of applying usability principles have been stated by several other authors, such as [7][9][25]. One of the reasons for the problems is that most guidelines suggest a general absolute validity but in fact, they can only be applied in a specific context. Additionally, it is difficult to select the guidelines that apply to a particular design problem. However, there are no particular design principles for the design of usable adaptations. In contrast to guidelines, user interface design patterns have been favored as design tools because they are less abstract and easier to interpret which makes them easier to apply for design. User interface design patterns capture proven design knowledge described in terms of a problem, context, and solution [25]. However there is no particular design pattern for adaptations of adaptive applications.

3.4 Proposal for a Notification Design Approach

Transparent and controllable adaptations create multitasking divided-attention situations. This is not completely negative, especially if the user highly desires to be informed and to be in control. The issues of interface design for multitasking, divided-attention situations have been treated in the field of notification design. Notifications deliver valued information to users in an efficient and effective way while they are engaged in other tasks [17]. To be informed about an adaptation can be of low or high value depending on the context of use or how much attention the user wants to pay respectively. According to McCrickard [18] notifications can be designed regarding the tradeoffs between the user notification goals and attention costs of the notification. The three parameters which can be varied are interruption, comprehension, and reaction. For example, if the user has a high interruption goal, high reaction goal, and low comprehension goal, as it is typical to alarm situations, the notification should be designed to cause a transition from the primary task (parameter interruption is high) and a prompt for an immediate response (parameter reaction is high). In this example, information does not need to be memorized for longer periods of time (parameter comprehension is low). The parameters can also be designed in a way that they create a monitoring situation which does not interrupt the user much from his activities. The three parameters relate to the principles transparency and controllability but allow more detailed design considerations.

4 Notification Design Approach

To design Meet-U's adaptations we applied a notification design approach based on a notification design pattern for smartphones from Hoober and Berkman [11] that we analyzed and modified regarding the critical parameters interruption, comprehension, and reaction.

4.1 Notification Design Pattern Fundament

The pattern Notification is described as a solution to notify the user of any notifications of any priority without unnecessarily disturbing current processes [11]. The pattern does not refer to functionality changes such as done by adaptations. Three design variations are mentioned: Notification Strip, Annunciator Row, and Pop-Up. They are described as one solution. None information is provided to support the choice of a design variation regarding its attention cost. Below, we explain the three variations and summarize the design recommendations given as far as they were relevant for the design of Meet-U's adaptations. Further, we state the expected transparency and controllability.

4.1.1 Notification Strip

A Notification Strip is a separate area on a fixed location of the viewport which is dedicated to notifications. To differentiate it from the Annunciator Row and the Title of a view, it should be placed at the viewport's bottom. It only appears when notifications are present. When the user selects a single notification the item in the application that housed the notification is displayed. The information presented in the strip should not scroll. Multiple notifications may be grouped by category with counters indicating the number of notifications for each category.

4.1.2 Annunciator Row

The notification may be included in the Annunciator Row. It is also referred to as status bar, and provides an easy to discover display of the status of important hardware features, such as sound settings, network connections, or battery level. It may house notifications icons, too. The application initiating the notification should be stated, e. g. with an appropriate icon. Information and settings should be accessed through interacting with the row. A complete list of notifications is shown when the Annunciator Row is opened by tapping or dragging the row.

4.1.3 Pop-Up

A Pop-Up is a separate dialog box. It should be used if there is no good place for a notification area or if the annunciator row of the operating system is unsuitable for repurposing. The Pop-Up may appear over the current context whenever a notification appears. Further, it should offer adequate actions, not too many options and necessitate as few as possible steps to react.

4.2 Additional General Recommendations

Hoober and Berkman [11] give further recommendations for notifications which are applicable to all three variations, for example: one consistent notification method should be provided and must not conflict with system wide notifications. However, this consistency recommendation conflicts with our previous statement providing an adequate design for each context of use. Therefore, we have investigated this in our user study (see Section 6). Furthermore, the user should be encouraged to act on or dismiss a notification easily. Multiple notifications must not obscure each other, must not be displayed serially, and should never be displayed to external displays. Only very-high-priority notifications may interrupt media-centric activities, current operations or actions should be suspended and data needs to be saved. A customizable acoustic and vibration signal at a notification can enhance the intensity of a notification.

5 Designing Meet-U's Adaptations

The design of Meet-U's adaptations was based on scenarios, personas, and requirements elaborated in a multidisciplinary development approach for socio-technical technology [4]. After identifying the required adaptations to support the user, the chosen platform standard as well as an interface pattern for notification design was applied in the design of the adaptations.

5.1 Meet-U's Adaptations

According to the user's goal, the different tasks the user must solve to reach the goal and the difficulties that might occur, several supportive adaptations could have been identified:

- A1 Initiate a timely navigation to an event and display navigational information (Navigation Initiation)
- A2 Transfer the display of navigational information to an external device for car navigation (External Device)
- A3 Enhance navigational information by indoor information (Indoor Map)
- A4 Enhance event participation through services provided at the event or event environment (At Event Service)
- A5 Switch to silent mode during the event (Mute Device)

5.2 Employing the User Interface Design Patterns for Notifications

The four design variations for Meet-U's adaptations are based on the design recommendations described in Section 4. Further, the visual design of any interface element follows the platform standard of the Android operating system.

5.2.1 Design Variation 1 – Autonomous Adaptation without Notification

The design variation (V1) aims at verification. In this variation, the adaptation is automatically carried out without notifying the user beforehand or afterwards, and without giving a direct opportunity for the user to control the adaptation. The system acts autonomously. Transparency and controllability of this variation are low. When adaptation A1 is carried out, in this variation, the application displays a map for navigating to an event automatically.

5.2.2 Design Variation 2 – Adaptation Strip with Undo

In the design variation (V2) the adaptation is also carried out autonomously without notifying the user beforehand. The user is informed afterwards and an undo button is provided. In this

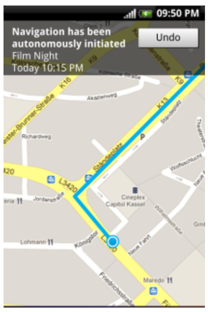

Figure 1. Design variation Adaptation Strip with Undo (V2) for adaptation Navigation Initiation (A1).

variation, transparency of the adaptation is low, but the adaptation is controllable. The interface design follows the Notification Strip pattern but is placed on the top of the viewport (see Figure 1). It only appears when an adaptation has been carried out. The interruption by this adaptation design is low, the reaction aspect is high, and the comprehension aspect is low.

5.2.3 Design Variation 3 – Adaptation Pop-Up with Countdown

In the third design variation (V3) a pop-up indicates beforehand that an adaptation will be carried out after a countdown of ten seconds. A cancel button gives the user the chance to stop the adaptation (see Figure 2). Transparency is high and the adaptation is controllable.

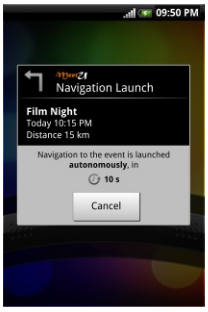

Figure 1. Design variation Pop-Up with Countdown (V3) for adaptation Navigation Initiation (A1).

5.2.4 Design Variation 4 – Adaptation Pop-Up with Acceptance

In the fourth design variation (V4) the user is asked by a pop-up if the adaptation should be carried out. The user is informed about the reason for notification and gives control over the adaptation through the display of an OK button and a Cancel button (see Figure 3). Transparency and controllability of this adaptation design is high.

Figure 2. Design variation Pop-Up (V4) for adaptation Navigation Initiation (A1).

6 User Study

A user study with ten potential users was conducted. Every participant is experienced in using mobile devices and mobile applications.

6.1 Hypotheses

We formulate the following hypotheses based on the summarized usability recommendations for adaptations which are explained in Section 2.2:

- All adaptations will be accepted as they support reaching the user's goal.
- The design variation with high transparency and high controllability will not be chosen for all adaptations.
- The design variation with the lowest transparency and controllability will not be chosen for any adaptation.
- A participant will not choose only one design variation for all adaptations.

6.2 Method

First, the idea of Meet-U and the tasks it supports were described to the participants. Then the adaptations were explained and the participants were asked on each adaptation if they would like to have this adaptation when they were using Meet U. Further, all design variations were verbally explained and the participants were asked to rank all four variations for every adaptation. The ranking score of a design variation results from summing up all values reached for each position in the ranking. The value is the product of the count of nominations with an adequate position's weight (position 1: weight = 4, position 2: weight = 3, position 3: weight = 2, position 4: weight = 1). The score is calculated by:

$$score = \sum_{i=1}^{4} position_i * weight_i$$

Finally, all design variations were shown on a screen to the participants and they were asked to answer several questions regarding different design aspects of the preferred design variations. These questions were:

1. Is the information displayed in the design clearly understandable?
2. Does the adaptation deliver enough information which explains what reaction is permitted and required?
3. Is the status of adaptation apparently designed?
4. Is the trigger of adaptation apparently designed?
5. How is the style of reaction designed?
6. How well can the adaptation be perceived and how well does it interrupt current activities?

The answers were ranked on a 7-point Likert-scale (values +++, ++, +, +/-, -, --, ---). Afterwards, each participant was asked open questions regarding the quality of the four design variations and the perceived purpose of the adaptations.

7 Results and Discussion

The adaptations Navigation Initiation (A1), Indoor Map (A3), and At Event Service (A4) were liked by all participants. The adaptation External Device (A2) was refused by three people. Regarding the adaptation Mute Device (A5) the participants had quite differing opinions: Six answered they would like this adaptation and four refused it. The ranking scores of the design variations for every adaptation are shown in Table 1. The highest scores are marked bold. They show that different design variations for particular adaptations were preferred.

Table 1. Scores of the design Variations (V1-V4) for every adaptation (A1-A5)

	V1	V2	V3	V4
A1	12	21	29	**38**
A2	21	26	25	**28**
A3	26	**27**	26	21
A4	18	**28**	**28**	26
A5	22	26	22	**30**

For the adaptation Navigation Initiation (A1) the participants clearly liked to be informed beforehand and most accept the adaptation variation V4. The design variation V4 was also preferably chosen for A2. It also has the highest score for the adaptation of Mute Device (A4). However, since the meanings about V4 varied a lot, no definitive recommendation can be made. Six participants put design variation V4 on rank 1, and four participants put design variation V1 on rank 1. Design variation V2 was put on rank 2 by six participants. The different preferences were also expressed in the interviews. Two participants explicitly preferred the design variation V4, which allows total control of the adaptation. This might be a phenomenon which is specific to particular user personalities. The adaptation that enhances the navigation by an indoor map (A3) has its highest score for design variation V2 (Adaptation Strip with Undo). The similar score shows, that there is no explicitly preferred variant. Design variation V1 scored on position 1 for five participants and V2 for only one person. However, design variation V2 was on second position for five people. Regarding the adaptation for integrating the event service (A4), the design variations V2 and V3 have reached the same score. However, seven participants put design variation V3 on position 1 and 2, which is an argument in favor for this variation.

All questions of the questionnaire were rated above-average. So the interface design of the adaptations was evaluated usable. This was confirmed in the interviews. All participants positively rated the idea of Meet-U, endorsed the presented adaptations and favored the overall design. Moreover, the notification design approach appears to be beneficial for the design of usable adaptations. However, we consider the fact that the laboratory evaluation was conducted on static designs and the number of participants was few. In particular, in real situations, adaptations would be executed more frequently and condensed at the event place. A few suggestions for improving details of the adaptations were made: the adaptation that launches the navigation should additionally ask whether the user wants to walk or go by car. The adaptation A5 should additionally allow a silent mode. Also the application should know the event type and adapt the sound settings adequately. One participant asked for a 30 seconds lasting countdown. A vibration signal was stressed to be useful.

8 Conclusion

In this paper, we first exposed the need for usability guidelines and tools for the design of usable adaptive applications. The usability recommendations transparency, controllability, and consistency that were found for adaptive user interfaces were described. We analyzed the problem space of usable adaptive applications. We then expressed our doubts about a general applicability of the usability recommendations for all adaptive applications.

In reference to our analysis of the problem space, we reasoned a notification design approach for the design of usable adaptations. We applied this approach in the design of the adaptations for the mobile and adaptive application Meet-U. Based on a design pattern for notifications we designed four different design variations which feature transparency and controllability differently. These variations are Autonomous Adaptation without Notification, Adaptation Strip with Undo, Adaptation Pop-Up with Countdown, and Adaptation Pop-Up with Request. We applied these design variations to five adaptations of Meet-U and conducted a user study with subsequent interviews. Regarding the results, we conclude:

- The concept of consistency cannot be generally applied for adaptations. Depending on the context of use, the design of the adaptation that is carried out should be designed differently concerning transparency and controllability.
- High controllability of an adaptation is not always desired, for example for the adaptation that enhances navigational information by an indoor map, and the adaptation that provides an event service to the user.
- Transparency of an adaptation does not compulsory mean that the user wants to experience every single adaptation. Especially for the adaptation that mutes the device, many participants voted for Autonomous Adaptation without Notification.
- The suggestions for design optimizations from the interviews strengthen our recommendation to consider the context of use, the user experiences, and not just the context the application senses, to design usable adaptations.

9 Future Work

Field studies with a larger number of participants will reveal more details on the usability of the four design variations for particular adaptations. Dynamic aspects such as the frequency of visible adaptation processes or the effects of missing a controllable adaptation will be considered. Applying the adaptation design variations to further adaptive applications will output design patterns for particular adaptations in certain contexts of use.

10 References

[1] Arroyo, E. and Selker, T. 2011. Attention and Intention Goals Can Mediate Disruption in Human-Computer Interaction. INTERACT (2), 454–470.

[2] Bunt, A., Conati, C., and McGrenere, J. 2009. A Mixed-Initiative Approach to Interface Personalization. AI Magazine 30 (4).

[3] Comes, D., Evers, C., Geihs, K., Saur, D., Witsch, A., and Zapf, M. 2011. Adaptive applications are smart applications. In 1st International Workshop on Smart Mobile Applications, San Francisco, CA, USA.

[4] Comes, D.; Evers, C.; Geihs, K.; Hoffmann, A.; Kniewel, R.; Leimeister, J. M.; Niemczyk, S.; Roßnagel, A.; Schmidt, L.; Schulz, T.; Söllner, M. & Witsch, A.: Designing Socio-Technical Applications for Ubiquitous Computing - Results from a Multidisciplinary Case Study. In: Distributed Applications and Interoperable Systems (DAIS 2012), Stockholm, Sweden, 2012. Berlin / Heidelberg: Lecture Notes in Computer Science. Springer, 2012, S. 194-201

[5] Dessart, C.-E., Motti, V. G., and Vanderdonckt, J. 2011. Showing user interface adaptivity by animated transitions. In Proceedings of the 13th international ACM SIGACCESS conference on Computers and accessibility (ASSETS'11). ACM, New York, 131-138.

[6] DIN EN ISO 9241. 2006. Ergonomics of Human System Interaction.

[7] Dix, A., Abowd, G., Beale, R. and Finlay, J., 1998. Human-Computer Interaction. Prentice Hall, Europe.
[8] Evers, C., Kniewel, R. Geihs, K., and L. Schmidt. 2012. Achieving User Participation for Adaptive Applications. In 6th International Conference on Ubiquitous Computing & Ambient Intelligence. Vitoria-Gasteiz, Spain.
[9] Fitts, P.M., 1954. The information capacity of the human motor system in controlling the amplitude of movement. Journal of Motor Behavior. Vol. 47, 381–391
[10] Geihs, K., et al. 2009. A comprehensive solution for application-level adaptation. Software: Practice and Experience, 39, 385-422.
[11] Hoober, S. and Berkman, E. 2011. Designing Mobile Interfaces, O'Reilly Media.
[12] Hook, K. 2000. Steps to take before intelligent user interfaces become real. Interacting with Computers, 12, 409-426.
[13] Horvitz, E., Kadie, C. M., Paek, T., and D. Hovel. 2003. Models of Attention in Computing and Communications: From Principles to Applications, Communications of the ACM 46(3) 52-59.
[14] Jameson, A. 2003. Adaptive interfaces and agents. In Human-Computer Interaction Handbook, Erlbaum, 305-330.
[15] Kephart, J. and Chess, D. 2003. The vision of autonomic computing. Computer, 36(1), 41-50.
[16] Lavie, T. and Meyer, J. 2010. Benefits and costs of adaptive user interfaces. Int. J. of Hum.-Comp. Stud., 68, 508-524
[17] McCrickard, D. S., Chewar, C., Somervell, J., and Ndiwalana, A. 2002. A Model for Notification Systems Evaluation—Assessing User Goals for Multitasking Activity. ACM Transactions on CHI 10(4), 312–338.
[18] McCrickard, D. S. and Chewar, C., 2003. Attuning notification design to user goals and attention costs. Communications of the ACM, 45(3), 67-72.
[19] Nielsen, J., 1989. Executive Summary: Coordinating User Interfaces for Consistency, in Nielsen, Jakob (editor), Coordinating User Interfaces for Consistency, Academic Press, San Diego, 1-7.
[20] Norman, D. A. 1988. The design of everyday things. Basic Books, New York, 1st basic paperback edition 2002.
[21] Shneiderman, B. and Plaisant, C. 2005. Designing the user interface: Strategies for effective human-computer interaction. Addison Wesley, 4th edition.
[22] Peissner, M. and Sellner, T. 2012. Transparency and controllability in user interfaces that adapt during run-time. CHI Workshop.
[23] Reisner, P. 1990. What is Inconsistency? Proceedings of the IFIP Third International Conference on Human-Computer Interaction, Interact '90. Elsevier Science Publishers B.V., North-Holland, 175-181.
[24] Rothrock, L., Koubek, R., Fuchs, F., Haas, M., and Salvendy, G., 2002. Review and reappraisal of adaptive interfaces: toward biologically inspired paradigms. Theoretical Issues in Ergonomics Science 6(2), 157-172.
[25] van Welie, M., van der Veer, G. and Eliens, A. 2000. Patterns as Tools for User Interface Design. In International Workshop on Tools for Working with Guidelines, Biarritz, France, 313-324.