# Usability Trade-offs for Adaptive User Interfaces: Ease of Use and Learnability

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**ABSTRACT**

An analysis of context-aware user interfaces shows that adaptation mechanisms have a cost-benefit trade-off for usability. Unpredictable autonomous interface adaptations can easily reduce a system's usability. To reduce this negative effect of adaptive behaviour, we have attempted to help users building adequate mental models of such systems. A user support concept was developed and applied to a context-aware mobile device with an adaptive user interface. The approach was evaluated with users and as expected, the user support improved ease of use, but unexpectedly it reduced learnability. This shows that an increase of ease of use can be realised without actually improving the user's mental model of adaptive systems.

**Categories and Subject Descriptors**

H.5.2 [Information Interfaces and Presentation]: User Interfaces – Auditory (non-speech) feedback, Ergonomics, Evaluation/methodology, Graphical user interfaces, Input devices and strategies, Prototyping, Voice I/O.

**General Terms**

Measurement, Experimentation, Human Factors.

**Keywords**

Usability, adaptive user interfaces, context awareness, cognitive support, evaluation.

## INTRODUCTION

Current developments in ICT related research are leading to a growing diversity of mobile devices, smart environments, and mobile services. Adaptive user interfaces are often pointed at as a mechanism to fit this diversity of devices and services to the users' requirements, goals and contexts of use [6]. Although adaptation, personalisation and customisation are considered the buzzwords of HCI research in the era of ubiquitous and mobile computing (for instance: [1,4,5,9,10,14]), successful adaptive user interfaces are still hard to find in practice [11]. An explanation for this relative unsuccessfulness might be that adaptive user interfaces are unpredictable, incomprehensible and fail to provide users with a feeling of control (for example: [3,11,12,13]). We assumed that an important cause of these issues is that users experience difficulty in building adequate mental models of such systems. We investigated if the negative aspects of adaptive user interfaces can be overcome by supporting users in their mental model construction process.

We have chosen Norman's [7] theory on mental models, design models and systems images as a starting point for the development of a user support concept. Unfortunately, Norman does not describe how to translate his approach to actual system design practices. We complemented Norman's theory with aspects of Rasmussen's [8] framework on human information processing, which led to the following synthesis: "The system's design model should be made visible through the system image, be it on multiple levels and in causal and functional terms". In this way users will develop adequate mental models, enabling better learning and providing more ease of use.

In the following, a limited description of the experimental method that we used to assess the approach and the corresponding results are discussed.

## METHOD

To evaluate our approach we have built a prototype of a mobile device that adapts its user interface to its current context. We also equipped it with user support based on the synthesis described above. We aimed to test if supported participants' mental models would differ from those of unsupported participants.

### Prototype

Dey and Abowd's [2] framework on context and context-information was used to specify the functionality of the prototype. We developed a prototype that: (a) can be used to view video content with audio and subtitles via a wireless network (service), (b) can be aware of: its battery level, the available network bandwidth, the level of surround noise, the intensity of surround light, the level of movement and the required discretion (context awareness), and (c) can adapt its input and output modalities (adaptive behaviour). This means that the device can autonomously switch on and off its: pen/touch input, speech input, video output, audio output and text output (subtitles).



*IUI'04*, Jan. 13–16, 2004, Madeira, Funchal, Portugal.
ACM 1-58113-815-6/04/0001.

### User Support

We assumed that users should be able to check at all times how they were supposed to communicate with the device, and how the device would communicate with them. We developed a two-level support concept that provides the user with real-time information about the active modality (the top row of icons in Figure 1) and on demand the contextual factors determining why certain modalities are not available (bottom row of icons in Figure 1).

Figure 1 – User support: explaining why the system has switched off audio output in the current context: due to loud surrounding noise and the required discretion level.

### Experimental Setup

#### *Participants and procedure*

Seventeen students of Utrecht University (The Netherlands) participated in the study. Eight participants were male and nine were female. Their ages ranged from 18 to 27 years. Each experimental session had a maximum duration of 4 hours. Participants were assigned to either one of two groups. One group was supported, the other group was unsupported.

Each participant was asked to view two 30 minutes video streams with the device (respectively task 1 and task 2), and to complete a questionnaire before and after the viewing of the video streams. The first video stream was a tourist video about the Dutch city of Delft and had to be viewed in TNO's 'homelab', a laboratory equipped as a living room. The second stream was a business related talk show named 'Business Class', and had to be watched outside at a bus stop near TNO.

During the viewing of a video stream, a number of changes in the context were simulated to which the mobile device reacted. In the homelab, for instance, the level of surround noise was manipulated by adjusting the volume of the background music. At the bus stop, for instance, changes in battery level and available network bandwidth were simulated.

#### *Measurements*

We intended to measure the 'learnability' and the 'easy of use' of the device. To measure learnability, we developed a mental model test. The same test was conducted before (pre-test) and after (post-test) the two tasks. The test consisted of 10 short scenarios. In each scenario, participants were given a description of the context in terms of the 6 context factors (battery, bandwidth, noise, light, movement and required discretion). Participants had to indicate for each scenario which one of the 5 alternative combinations of modalities they thought would be active in the scenario (see Figure 2 for an example scenario)

Ease of use was measured by asking a similar set of questions 6 times during each video stream. In addition, subjects had to complete a usability questionnaire after the video streams.

**Example question mental model test**

You have taken the bus home. You decide to use your device to check if there are any good movies on tonight. You decide to watch the trailers of 2 of them.

**Context description**

Battery=high; Bandwidth=low; Noise=medium;
Light=normal; Movement=medium; required discretion=high.

Please indicate what behaviour you would expect from your device in the scenario and context described above:

| | Input | | Output | | |
|---|---|---|---|---|---|
| | Touch | Speech | Video | Audio | Text |
| 1 ☐ | On | On | On | Normal | On |
| 2 ☐ | On | On | On | Normal | On |
| 3 ☐ | On | Off | Off | Off | On |
| 4 ☐ | Off | Off | Off | Off | On |
| 5 ☐ | On | On | Off | Low | On |

Figure 2 – Example question of the pre and post-test

#### *Hypotheses*

We expected the learnability of the device with user support to be better than without user support, therefore the supported group was expected to perform better on the post-test than on the pre-test. Additionally, we expected the supported group to perform better on the post-test than the unsupported group.

With respect to ease of use, we hypothesised that the device would be easier to use for the supported participants. During the video streams we expected the supported group to perform better than the unsupported group, and we expected the supported group to score higher on the usability questionnaire.

## RESULTS

As can be seen in Figure 3, the hypotheses regarding learnability were not supported. Not only did the supported group score lower on the post-test (mean 3.50, sd. 1.92) than on the pre-test (mean 5.38, sd. 1.92), but it also scored lower on the post-test (mean 3.50, sd. 1.92) than the unsupported group (mean 4.22, sd. 1.20)

Hypotheses regarding ease of use were partly supported (Figure 4). First, supported participants understood their device significantly better during the first task ($N=17$, $t(15)=2.119$, $p<.05$). Mean scores on the second task seem to show the same trend. Second, results on the usability questionnaire showed that supported participants trusted the device significantly more than unsupported participants (1-sided Fisher exact, sig. 0.36).

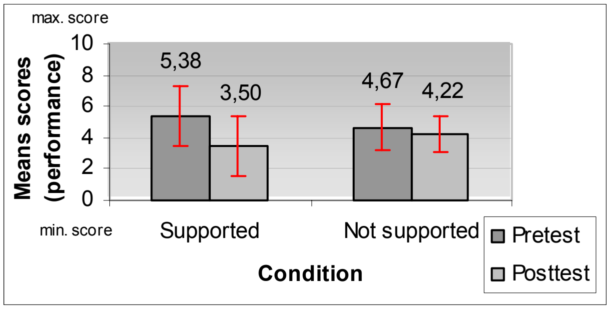


Figure 3 – Performance on pre and post-test, per condition

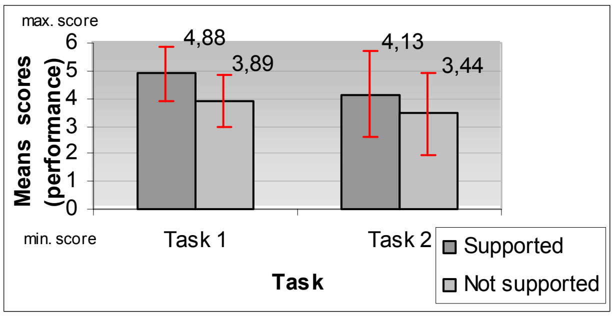


Figure 4 – Performance during the two tasks, per condition

## DISCUSSION AND CONCLUSION

The research shows that the negative aspects of adaptive user interfaces can be overcome without actually improving the user's mental model of the adaptive system. This raises the question whether Norman's model is actually valid for highly adaptive systems. It might turn out that for certain domains an adequate understanding of the system's design model is not required to reach sufficient ease of use.

Although adaptive user interfaces seem to be the solution able to deal with the growing diversity of usage contexts, devices and users there is also downside. Adequate support can be developed to improve the benefits and reduce the costs. However, further research is necessary to determine the factors influencing the exact cost-benefit trade-offs for usability of adaptive user interfaces.

## ACKNOWLEDGMENTS

This research was supported by the Towards Freeband Communication Impulse of the technology programme of the Dutch Ministry of Economic Affairs (The CACTUS Project). The research was carried out at TNO Human Factors, Soesterberg. We thank Robert de Hoog (University of Amsterdam, Department of Social Science Informatics) for his comments and suggestions during this study.

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