SMART HOME CONTROL VIA PDA

An Example of Multi-Device User Interface Design

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Abstract: Smart home systems must be controlled comfortably and securely by a broad range of users and in diverse contexts of use. One possibility to meet the requirements deriving from these diversities is to provide multiple devices to control the system. When a smart home application is used by one person on different devices, the user interface concepts should support an easy transition between devices. This article describes the development and result of a multi-device user interface to control a smart home system with focus on usability issues. The target devices are touch screen display and PDA. The design principles for inter-usability proposed by Denis & Karsenty 2004 are discussed and adapted with respect to a balance of inter-usability and usability of the specific device interface. The refined PDA user interface is described in detail.

Key words: smart homes, PDA, control applications, HCI.

1. INTRODUCTION

Developing smart home solutions, we have to face a remarkable diversity in user and context characteristics. Within a household typically different social roles exist and accordingly household resources are used in a different way. The user characteristics may differ in gender, age, and experience - the latter two also change over time. The context of use of household appliances also differs quite a lot. A user interface has to support hectic and unfocussed behavior as well as effective task completion. The challenge is to fulfill these requirements from the user interface side and to provide a usable interface to system control and interaction. An example of multi-device user

A. Sloane (ed.), *Home-Oriented Informatics and Telematics*

interface design (Seffah & Javahery, 2004) with focus on usability issues developed in the research project LIVEfutura[8] is described here.

2. USABILITY ISSUES OF MULTI-DEVICE SYSTEMS

The usability of a multi-device system comprises the usability of a concrete implementation of an application on the target device and the usability of the multi-device system as such.

There are many styleguides that provide principles for UI design for different platforms and devices (Lynch & Horton, 2001; Microsoft Corporation, 2001; Sun Microsystems, 2001; palmsource™, 2004; Windows 2004). Therefore this paper concentrates more on inter-usability issues (Denis & Karsenty 2004), i.e. usability issues that arise when an application is used via different types of devices.

Denis & Karsenty (2004) provide a conceptual framework for inter-usability of multi-device systems. They propose two dimensions that have to be fulfilled by a multi-device system to be usable given inter-device transitions: *knowledge continuity* and *task continuity*. Knowledge continuity means that what the user has learnt from the usage of an application via one device also holds for another device in the multi-device system. Task continuity has to do with a shared memory of user actions with the system that allows a user to continue tasks begun via one device via another.

To ensure task continuity when a device transition is made, all devices have to have the same information status and have therefore to be "always on". This is also a requirement coming from the fact that a smart home system is normally a multi-user-system. The first precondition to avoid problems with conflicting actions of different users and conflicting system- and user-actions is to provide real-time information on the status of the house on all devices (Ringbauer & Hofvenschiöld, 2004). In our study described here we did not develop a solution on the technical side for our user interfaces[9]. Therefore this article concentrates on knowledge continuity.

Denis & Karsenty (2004) suggest three main design principles constituing the basis of inter-usability:

[8] LIVEfutura (www.livefutura.de) was funded by the German Ministry for Education and Research, funding no. 01AK931.

[9] The touch screen display user interface was prototypically implemented as one user interface of an integrated smart home demonstrator from Fraunhofer FOKUS and Fraunhofer IMS in the project LIVEfutura.

- Inter-device consistency (perceptual, lexical, syntactical, and semantic consistency)
- Transparency what the system can do and how it works
- Adaptability, e.g. to the user profile

The principle *inter-device consistency* takes up aspects of the dialogue principles four and seven of the ISO 9241-10 (ISO, 1996) "conformity with user expectations" and "suitability for learning". The user expectations in the case of a multi-device system in the context of smart living environments are built upon:

- experience with non-technical applications and services in real life (e.g. pin board as communication centre in the home, experience with temperature setting on the radiator)
- expectations on the use of technology derived from prior experiences with information technology (e.g. office software, mobile phone, remote control)
- expectations on the interaction with one service provided by the smart home application from the usage of another service (e.g. remotely controlling the coffee machine and retrieve the fuel level of the car)
- expectations on the functioning of an application because of experience with other applications via the same device (e.g. a regular PDA user would expect an application for integrated home control to work similar to his organizer application on the PDA)
- prior experience with other devices of the same system (inter-usability)

The claim for transparency has to be fulfilled with a sound user interface concept on the respective device. In our study we focused on the issue of *inter-device consistency* and its relationship to "suitability for the task" (ISO 1996). Especially the points *semantical consisteny* and *syntactical consistency* may contradict the aim of efficient task completion on a particular device sometimes.

3. DEVELOPMENT OF THE USER INTERFACE CONCEPT

Most of the results presented here were achieved in the research project LIVEfutura. It was a project dealing with the specification and prototypical implementation of an integrated overall home control concept covering all relevant application areas: home automation, audio/video control, home appliances, home computer network, home telecommunication network, and even the private car. LIVEfutura covered both, the interconnection of the different subnetworks via gateways and proxies and the realization of

integrating user interfaces for overall home control. The goal was to provide an easy, secure and satisfying access to smart home services for all.

For the development of the smart home control a user-centred design process (ISO, 1999) was adopted. The methods and results are described in more detail in Ringbauer et al., 2003.

3.1 Development of the information structure, and the basic interaction steps

The first step in the development process was to collect the functional and non-functional requirements through interviews with potential users. We were also living in the INHAUS Duisburg[10] for a two day period. The INHAUS is a fully connected home run by our project partners and the industry and is probably the most known smart home in Germany. Diary methods were used to capture the use of technology in the real living context (Ringbauer & Hofvenschiöld, 2004). In the requirements analysis it turned out that the user group is very heterogeneous and that we have to cope with a broad range of usage needs (e.g. activate the setting "leaving home" and remote access to security settings) and contexts of use (e.g. cosy Sunday morning vs. quick breakfast on a weekday). Therefore we decided to develop two types of interaction devices for the integrated smart home environment: a stationary device as a main control device and a mobile device that might be personalized.

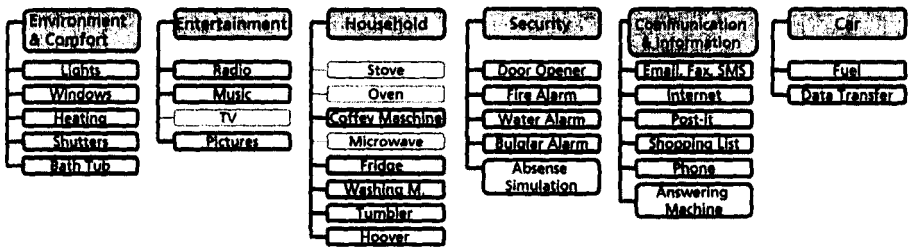

Figure 1. Functionally oriented information architecture on the basis of the card sorting (the appliances in the gray boxes have not been networked at the time of development)

For the stationary input device we chose a rectangular touch screen display. A touch screen display has the advantage to enable direct interaction with the finger being the pointing device. Having a pointing device makes it easier for inexperienced users. A touch screen display ideally placed in the

[10] www.inhaus-duisburg.de (English version available)

kitchen or the hall has been widely accepted in several studies (Kalmer, 2001; Meyer, 2002). Especially to fulfil the need of exchange of household information the kitchen seems to be a good place for a stationary device (Harper & Shatwell 2003).

In the first concept step we described the interface at a very general level. With the information collected and structured by scenarios (Carrol, 2000), extant systems analysis, task analysis (Kirwan & Ainsworth 1992), card sorting (Usability Net, 2003) and wording tests we built the basic information architecture, defined main screens and which steps are necessary to fulfill a task. Then we added the wording to application categories and services. The first information architecture is shown in fig. 1.

As in the *Unified User Interface Development* presented by Stephanidis & Savidis (2003) this basic interface structure with elements and actions stays the same for all device user interface concepts. In contrast to Stephanidis & Savidis we did not specify all possible interface artefacts with adaptation rules to enable an (automated) adaptation to all possible user and context variables. We chose two promising devices, touch screen display and PDA and adapted the user interface to them.

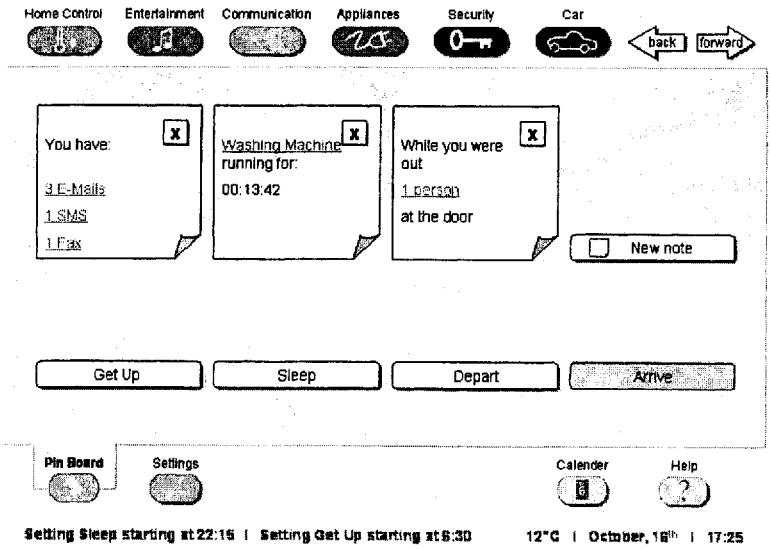

Figure 2. Touch Screen Prototype – Pin Board (starting screen)

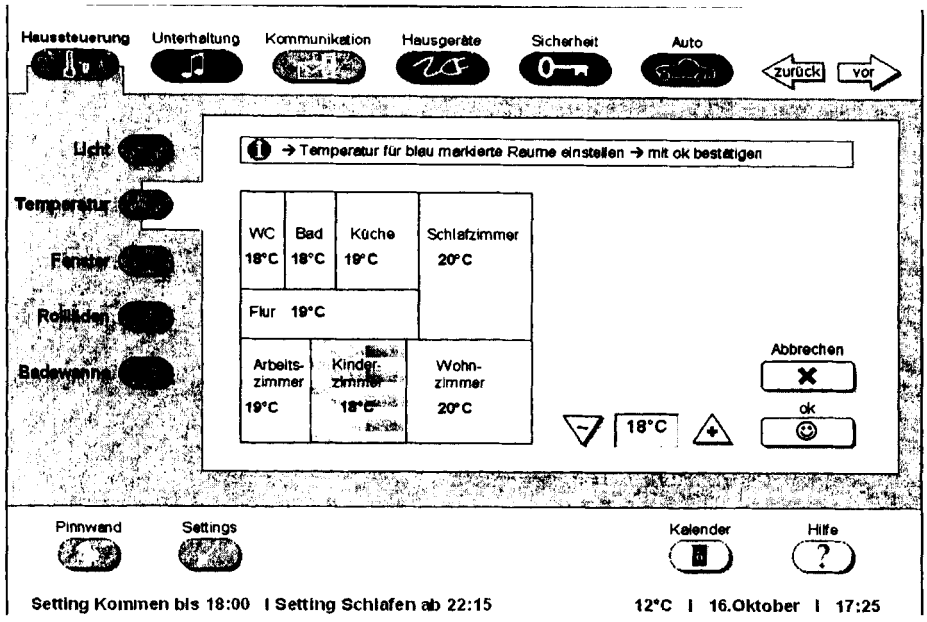

Figure 3. Touch Screen Prototype – Heating control screen with instruction, floor plan, parameter change and cancel/ok button

3.2 Adaptation to device

3.2.1 User interface concept Touch Screen

The touch screen display user interface was developed first. With this development an iterative optimization of the initial information structure and wording was achieved. The touch screen display user interface underwent a layout review, and two usability tests (Ringbauer et al., 2003). A third usability test was made with the final version to test it with elderly users (Wiebelt & Ringbauer, 2004).

The prototype is displayed in fig. 2 and fig. 3. You can see a pin board screen serving as a home screen for the smart home control. The pin board is the central place for information exchange between household members and between people and system. The settings (combined functions) are situated on that main screen to enable easy and quick access (e.g. when leaving the house).

The main navigation on the top is organized in functionally oriented tabs. Orientation is supported by visual clues like colors and icons.

The navigation steps to take a control action are:

1. Select application domain (particular tab in the top navigation, e.g. home control)
2. Select specific application (e.g. heating)
3. Optionally: Read the instruction
4. Optionally: Judge on the basis of the overview provided if a control action should be taken
5. Select a room for parameter adjustment (e.g. children room)
6. Adjust parameter (e.g. from 18 ° C to 20 ° C)
7. Confirm or cancel the action

3.2.2 User interface concept PDA

The PDA user interface prototype was implemented in flash on a Compaq iPaq PDA. In our prototype we did not include the hard keys of the PDA in the interaction concept because we assume that the PDA is not only used for home control but also as a personal digital organizer. Therefore the default hard key functions "address book", "calendar", "tasks" and "memos" were not overruled by smart home functions. The use hard keys to control smart home appliances, e.g. one-click access to the pin board screen was not in the scope of this study but should be subject of future research. The keyboard symbol in the prototype (see fig. 4 and fig. 11) simulated the inclusion of the PDA on-screen keyboard in the interaction concept (e.g. to write a notice).

A PDA-specific adaptation was made to the contents provided. The PDA offers less functions and services than the touch screen display does: there is no opportunity to build a complex setting (e.g. to define what the smart home system should do when the family is going asleep) or to change a complex setting but to activate it (e.g. press the icon "Sleep/Schlafen" in fig. 4 resp. fig. 11). I.e. the semantic consistency Denis & Karsenty (2004) claim for inter-usability of multi-device-systems is not given - touch screen display and PDA are complementary devices (Denis & Karsenty, 2004). On the other hand a PDA user interface gets clustered and complex quite easily when to many functions are provided. Here the inter-usability of the multi-device system has to be balanced to the usability of the respective device.

Having defined the PDA as an additional user interface to the main user interface touch screen display, the PDA does not have to be used by everyone in the household but is probably used together with the main device for a household member owning a PDA and needing remote access.

For the PDA user interface concept this means that we have to face device transitions and we have expectations on the one device because of the other one. In addition a PDA is normally used as personal device for other applications and services than house control as well. So we have an

experience background of the person using the PDA with these applications (see section 2).

Several user interface decisions on the balance of inter-usability and handheld usability had to be taken for the PDA concept:

a) Is it more important to have a *perceptual consistency* between touch screen display and PDA concept or to allow a combination of icon and textual description of the functions in the top navigation?
b) Is it more convenient to work with floor plans like in the touch screen prototype or more efficient to work with lists and dialogues on the small screen size of the PDA?
c) PDAs work mainly with the concept of auto-save (Weiss 2002) in contrast to a dialogue pattern with ok/cancel. Because of better results in the usability test the dialogue concept was implemented for the touch screen display instead of the auto-save concept. What should be adopted for the PDA?
d) Do the preferences depend on experiences made with the touch screen device or with other mobile devices before?

The low-fidelity prototype to investigate these questions is shown in figure 4 - figure 9.

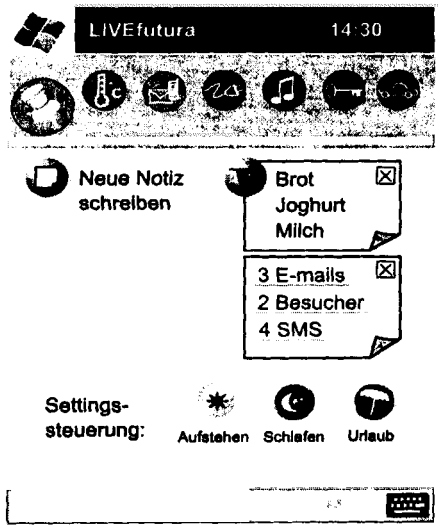

Figure 4. PDA lo-fi prototype - top navigation with icons in a row

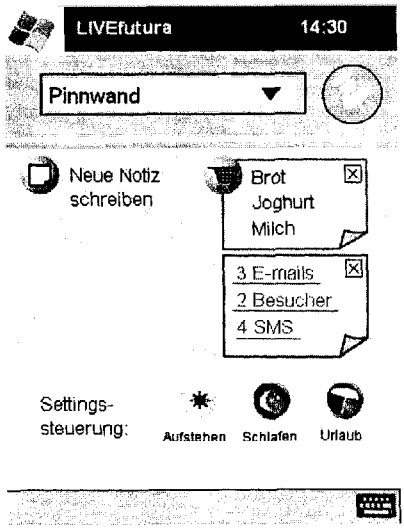

Figure 5. PDA lo-fi prototype - top navigation with icon and additional label with drop-down box navigation

Figure 6. PDA lo-fi prototype - list-type overview on the application domain home control; parameter change is achieved via choice of room or function

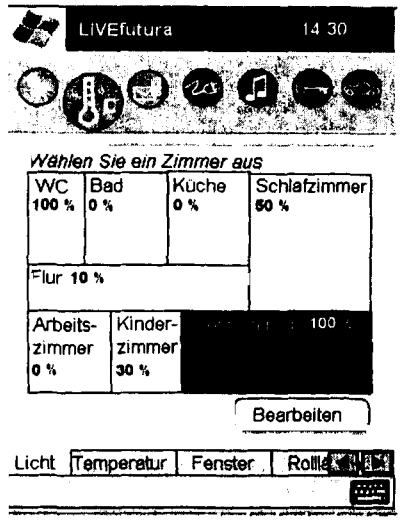

Figure 7. PDA lo-fi prototype - floor plan navigation with one function on a single tab

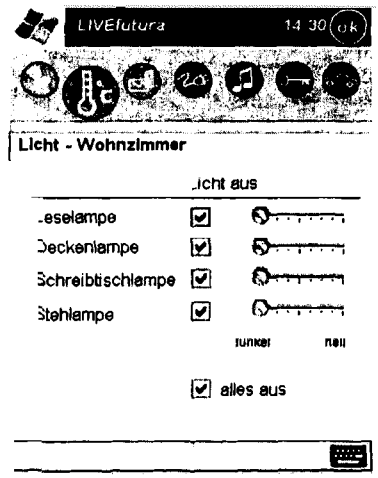

Figure 8. : PDA lo-fi prototype - auto-save concept in the style of the Pocket PC

Figure 9. PDA lo-fi prototype - dialogue concept with "cancel" and "ok"

3.3 Results of the usability tests with the PDA prototypes

The usability test was done in august 2003 with ten test persons from whom four had participated in the usability test with the touch screen display prototype as well (this was done to get an idea of an answer to question d). Half of the test persons used a PDA in everyday life and gender was balanced.

a) *Perceptual consistency vs. Icon plus Wording*: The answer to this question is very clear: the versions with the icons in a row were highly preferred to the drop-down box. This stated also for the group who did not know the touch screen prototype. Some persons said, they would like some additional wording to the icon but all said that they would get used to the icon without wording as well because of the colour. There was no usability problem with either version but test persons said that the version with the icons in a row would support the transparency of the application as a permanent overview of functions.

b) *Floor plans vs. lists and dialogues*: The answer to this question is not obvious. The overview on the status of the house concerning a specific application domain was better supported by the list - some test persons did not note being on a particular tab (e.g. light or heating) at all (again no noticeable difference between touch screen and naïve group). On the other hand people were annoyed by having to step through the dialogues. They wanted to change the parameters in the list directly.

c) *Auto-save vs. dialogue confirmation* : We saw a preference for the confirmation buttons by most of the test participants - it seemed to be the

more secure type of interaction. One reason was that the Pocket PC-style "ok" to close the parameter-change-window was overlooked by most test participants and that "ok" without the opportunity to "cancel" seems to cause discomfort. On the other hand the users being more experienced with mobile devices said one would easily get used to that. We also saw a learning effect concerning the use of the "ok" in the upper right corner in the course of the test.

d) *Previous user experience*: We did not see a strong effect of either having tested the touch screen display prototype before or of using a PDA in everyday life.

3.4 Acceptance of devices

After the usability test with the PDA we had an interview about which device would be the best for interacting with an integrated home environment.

Seven out of ten people said a PDA would be the best control device followed by a stationary touch screen display (five out of ten). Even four out of the five people who also tested the touch screen display preferred the PDA[11]. The main reasons were that a PDA was said to be cute in size and provides an easier feedback than a remote control without integrated display (e.g. the standard remote control of the TV). Negative comments to the PDA use were that having to use a stylus for every action is uncomfortable (as described in section 3.2.2 there was no hard key interaction for the prototype).

This might be an important point: happily using a PDA as an input device in a usability test does not guarantee it being a suitable input device in every day use in the home. Living in the smart home test environment *INHAUS* in Duisburg we found out that a PDA is not suitable for many contexts of living like sleepiness, wet hands etc. (Ringbauer & Hofvenschiöld, 2004).

4. REDESIGN OF PDA PROTOTYPE

On the basis of the test results the PDA user interface concept was redesigned and extended. We streamlined the PDA on more efficient task completion. The main navigation at the top with the icons in a row was kept

[11] The test device for he touch screen display was a big web pad. The touch sensitivity of the web pad was not optimal. So we could have an effect on the preference of device for this reason.

but the style of the application was harmonized within the application and to other applications used on a PDA (e.g. standard tabs in contrast to the button-like tabs we used in the touch screen display to avoid a "desktop-style").

The note on the pin board of the low-fidelity prototype has been limited to the number of three. Working with the notes in the usability test was straightforward. Therefore for the redesign we decided to display a list with icons but to keep the note-metaphor when reading a note.

To face the display limitations of the PDA without forcing the user to take too many steps to complete a task we decided to add specific navigation for the refined PDA user interface concept. E.g. there are "previous/next note" buttons for the PDA when a note is read to compensate for the note overview on the touch screen display.

The pin board screen with the list of notes is shown in fig. 10. You can see an open note in fig. 11. The buttons "vorherige/nächste" translates to "previous/next".

Figure 10. PDA user interface - pin board screen with a list of notes and the most important settings (waking up, sleep, holiday)

As status information displayed in a list (e.g. the status information of lightning, heating, windows, shutter) was appreciated in the test, the refined PDA user interface concept offers list-type overviews with the opportunity to directly change parameters on the same screen on the first tab. This

supports the important use case of remote access and respects the less space a PDA offers. On the other hand we decided to redundantly provide floor plan navigation on the other tabs to support a visually easy to grasp overview on a single application, e.g. lightning. The interaction opportunity to zoom in a specific room from a floor plan could be a future starting point for a better context-driven task support, given the user is situated in that room.

Figure 11. PDA user interface - open note with "previous/next" buttons on the bottom

Figure 12. PDA user interface - list-type overview on home control services; lightning in Max' room selected, direct change of the parameter setting possible

Figure 13. PDA user interface - floor plan with an overview on lightning

Figure 14. DA user interface - coffee machine screen with dialogue to order coffee; "cancel" and "ok" provided

We found a compromise to deal with the findings that the dialogue-style interaction concept that requires an "ok" or "cancel" to terminate each action was preferred but an efficient task completion was also claimed (e.g. an adjustment of temperature directly in the list-table would have been appreciated). The refined PDA user interface concept forces "ok" or "cancel" only when an "action" is performed in contrast to a "parameter change". E.g. editing of a note or ordering a cup of coffee leads in a dialogue and requires a confirmation whereas the change of temperature in a room or closing of a window works with auto-save. To avoid usability problems

arising from the mixture of auto-save and dialogue-style we provide clearly visible and real-time feedback on the parameter change.

Figure 15. PDA user interface - shutter control in the overview list; auto-save concept

5. CONCLUSION

We suggest that in future the interaction with a smart home environment is accomplished with a family of devices, depending on task, situation and actual user. These devices will be complementary devices (Denis & Karsenty 2004) in the sense of being tailored to respective user and usage scenarios. One important device will still be some manual control as this is a type of interaction people still feel secure with and want to keep (Ringbauer et al., 2003).

What turned out to be important for a usable multi-device user interface is a good balance of inter-usability and usability of the respective device. Here consistency-issues have to be balanced with task effectiveness. In our study some principles of inter-device consistency were overruled by device-specific requirements.

Perceptual consistency: we suggest that perceptual consistency is important for a common branding and from a usability side concerning the recognition of main interface elements and principles. The type of interaction element should be the same but the visual appearance can be adapted to what is expected on the respective device.

Lexical consistency: if there are labels, they should be the same across devices. So requirements of all possible devices or interaction means for the whole multiple user interface has to be taken into account from the beginning. This might be even more complex having a voice user interface to develop.

Syntactical consistency: if there is no reason to change the order of steps to take to accomplish a task on different devices, keep it. Otherwise it is important to keep transparency of the interface to make clear why steps are different. E.g. one could provide a personal mobile device to control the smart home environment as some kind of "personal remote control in the house". Then the user interface should take into account that it is more likely that the user wants to control the lights in the living room being in the living room than controlling the lights in the cellar.

Semantic consistency: services provided should only be the same if that is suitable for the scenario the device is meant for. One rule should be that there is no function grouped into another category for different devices (e.g. if there are the application domains "communication" and "security" the cameras in the house with the option to leave a message are either grouped in communication or in security - this does not depend on the device.

A smart home interface does not have to be able to show the actions of the actual user but the actions of the system (e.g. rule-based control the heating system) and the actions of others users of the house.

6. LIMITATIONS OF THE STUDY

In our study we collected data on the usability of multi-device systems mainly in the laboratory on the basis of our requirements analysis in the field. For the future it is important to extend the studies on multi-device systems to real living and testing environments to acquire more knowledge on context and habituation effects. Especially the systematic investigation of device changes and on user characteristics determining device use will be of interest.

7. FUTURE CHALLENGES

On the technical side the provision of task continuity on all devices in a system will be a future challenge. On the user interface side, one interesting challenge will be how to profit from adaptation and context-awareness without causing the feeling of loosing control over the system. Another challenge will be to find a balance between automated generation of

interfaces for different devices and manual tuning to enhance usability. Concerning the development process of a multiple user interface there will be a challenge to plan for interaction options that are not available yet and to manage the multi-device development: nowadays the companies are often organisationally structured on the basis of the service types and devices they offer - they all have to work together and synchronize their activities on multiple channels for a usable multi-device user interface.

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