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Reducing Complexity of Interaction with Advanced Bathroom Lighting at Home

Reduktion der Interaktionskomplexität bei hochentwickelten Badezimmerbeleuchtungssystemen für die Heimanwendung

User Interface Development_Usability Evaluation_Home

Summary. Developments in lighting technology provide a wide range of new opportunities for domestic use which have been demonstrated in several interior design projects. At the same time, available user interfaces providing full control over these systems are too cumbersome to use and are not acceptable for the majority of consumers. To reduce this complexity, we aimed at creating an intuitive user interface control for advanced multi-source lighting systems. Based on participatory design techniques, we invited end-users to help us design and evaluate the new interaction concept. In the final evaluation the user interface design was rated highly with regard to its perceived usefulness and "ease of use". New designs for advanced lighting systems should aim at user-friendly interfaces that make the transition from ordinary light switches to these new interfaces as simple and natural as possible.

Zusammenfassung. Die Entwicklungen in der Beleuchtungstechnik eröffnen zahlreiche neue Möglichkeiten für die Nutzung im Haushalt, was in vielen Innenarchitekturprojekten veranschaulicht wurde. Gleichzeitig sind aber die Benutzungsoberfläche, die zwar eine komplette Kontrolle über diese Systeme bieten, schwierig zu handhaben und für die Mehrheit der Benutzer nicht annehmbar. Zur Verringerung von Komplexität haben wir uns das Ziel gesetzt, eine intuitive Benutzungsoberfläche für moderne Multi-Source Lichtsysteme zu entwickeln. Basierend auf partizipativen Gestaltungsmethoden baten wir Benutzer, uns bei der Gestaltung zu unterstützen und das neue Interaktionskonzept zu bewerten. In der abschließenden Evaluation wurde die Gestaltung der Benutzungsoberfläche in Bezug auf die wahrgenommene Benutzbarkeit positiv eingeschätzt. Neue Gestaltungsmöglichkeiten moderner Lichtsysteme benötigen auf benutzerfreundliche Schnittstellen, die den Wechsel von herkömmlichen Lichtschaltern zu neuen Benutzungsoberflächen so leicht und natürlich wie möglich machen.

1. Introduction

Developments in lighting technology provide a wide range of new opportunities for domestic use which have been demonstrated in several interior design projects of which the Vos Pad (Price 2003; Vos 2003) and our own HomeLab (Aarts 2003) bathroom lighting demonstrator are two illustrative examples. In the HomeLab demonstrator, in order to control each of its 50 different light sources, users need to manually drag sliders of a software interface to define the intensity of light for each lamp. Similar complex controls were used to manually control 135 groups of LEDs (light emitting diodes) in the Vos Pad installation. Therefore, available user interfaces providing full control over these systems are too cumbersome to use and are not acceptable for the majority of bathroom users. To reduce this complexity in our design, we aimed at creating an intuitive user interface control for advanced multi-source lighting systems. In our work, we focused on controlling lighting in the context of the bathroom due to the rich mix between different types of activities that require the support of both functional and atmospheric lighting. Functional lighting is required for short functional activities that occur frequently, and demand good visibility conditions, namely, hygiene, quasi-medical and grooming activities (Kira 1976). Atmospheric lighting is required for creating a pleasant ambiance, where hedonic qualities are more important than just visibility. Such is the case for Relaxation activities, for example when taking a relaxing bath after work.

2. User Study

The goal of this study was to gain insight into whether people would want atmospheric and functional lighting to support their daily activities in the bathroom and if yes, how. To answer this question, we conducted a user study using Cultural Probes (Gaver 1999) and later inviting users to participate in interactive Workshops in HomeLab. The first part of the study was focused on gathering knowledge on bathroom activities, activity-associated areas and objects used, and identifying needs related to the use of lighting in the bathroom. As such, participants worked on the probes in their homes for a period of one week. The second part of the study was conducted in HomeLab where we had semi-structured interviews with participants after they had experienced the bathroom lighting demonstrator.

One specific question we were interested in was how bathroom activities and the associated needs for lighting would be different in a multi-user setting, e.g. in a household where several family members use the same bathroom. This was the reason to involve five couples (families living in one household) to participate in our study, constituting a total of 10 participants. We did not involve children in this study since working with children would require a different methodological approach. However, wherever it was relevant, we discussed usage situations involving children with parents.

The Cultural Probes consisted of a Diary, which contained questions, a timeline for tracking their activities and assignments such as to draw and describe what their ideal bathroom would be like. The probes also included a disposable camera as a means to visually support and highlight some of the experiences of the participants while filling-in the diaries.

In the Workshops, the bathroom lighting demonstrator was presented in a sequence of modes that include a Night Mode, a Wake-Up Mode, a Day Mode, and a Relax Mode. Scenarios (Carrol 2000) were used to provide participants with a context when each mode would most probably be used. We gathered feedback from participants and analysed their reactions to the demonstrator, as well as collected new ideas triggered by their imagi-
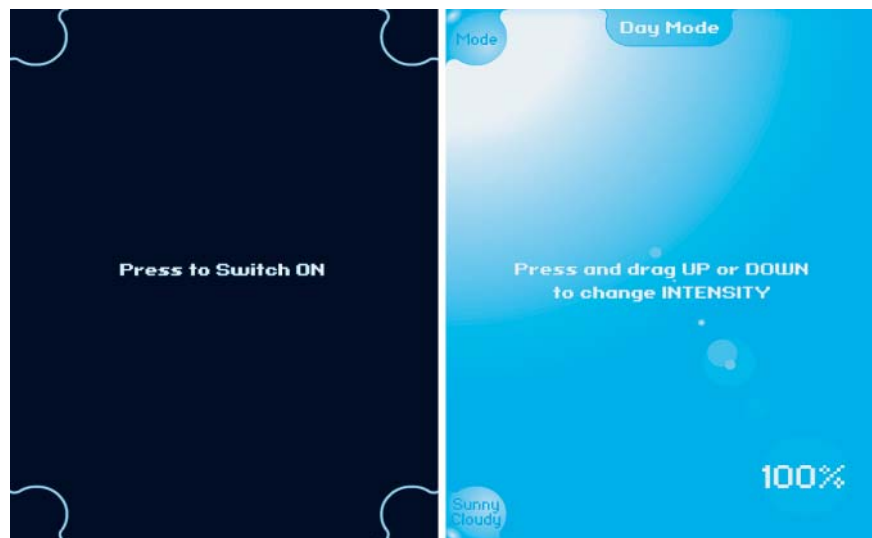

Figure 1: Light Switch off (left) and on (right)

Figure 2: Natural Light – Sunny sky corresponding to warm white light (left) and cloudy sky corresponding to cold white light (right)
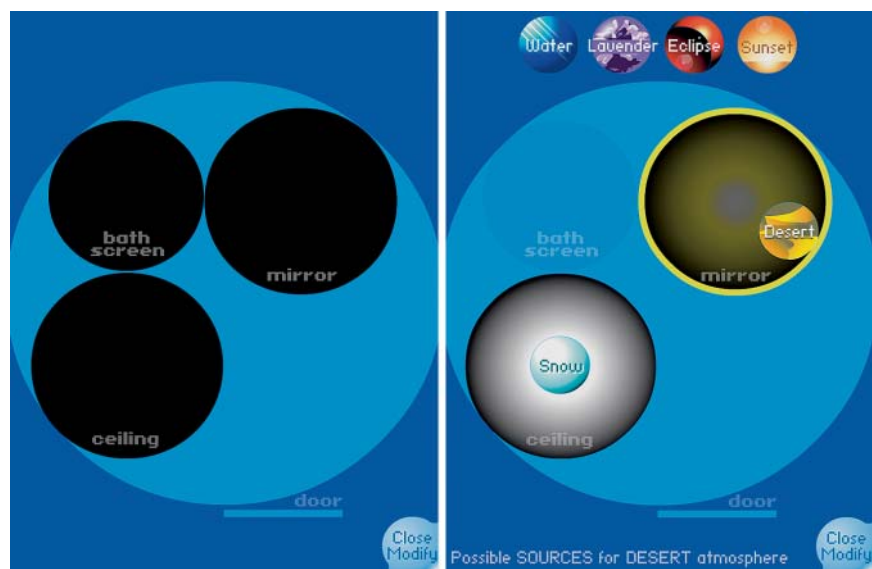

Figure 3: Fish-eye View – Lighting areas and the door as a reference point (left). Coloured Marbles and changes in intensity (right)

nation. We encouraged participants to modify settings to fit their specific needs and tastes in order to understand how personal preference for colours in lighting may play a role in such systems.

Initially, during the Cultural Probes, participants were reluctant about the idea of having coloured lighting in their bathrooms. However, after witnessing the bathroom lighting demonstrator during the workshops, there was a sudden shift in their opinion which can be explained by the difference between being asked to imagine what a given system can do and to actually experience it (Lucero 2004). During the workshops the majority of our participants expressed their concerns about the potential complexity of the interaction with the system. They indicated that, preferably, controlling the system should be as simple as how they currently control lighting in their homes. Therefore, our main goal was to create an intuitive user interface control for advanced multi source lighting systems that would help reduce the potential complexity of interaction.

3. Design

General design guidelines were formulated to help us make the lighting control simple to interact with. In our problem analysis, we identified two types of tasks, those used frequently and those only used sporadically. Frequent-use functions include switching the lights on and off, changing the intensity of light and activating the different modes. Sporadic-use functions include creating new presets for relaxation or modifying existing presets. In order to avoid the use of several function-specific controls, we aimed at creating a unique type of controller integrating all functions (i.e. frequent and sporadic). Furthermore, users needed to control functions from the location where the activity was taking place (i.e. changing lighting conditions of the Relax Mode from the bathtub). Therefore, ideally several controllers had to be located in strategically chosen activity-related areas in the bathroom. Finally, in order to keep the interaction as simple as possible, we encouraged controlling the system through familiar interaction styles used for interacting with ordinary light switches and dimmers.

3.1 Usability Goals

Usability goals were defined to serve as selection criteria for our design ideas and as acceptance criteria for the evaluation. Qualitative usability goals and measurable objectives were defined for each of the following items:

- The system should be easy to use: Switching the lights on and off, changing the intensity of light and activating modes should be achieved in a simple way.
- The system should be easy to learn: First, our participants told us in the user study that they did not want to spend significant time learning how to set up or modify existing functions. Second, from our own experience in setting-up the bathroom system, we knew users would be overwhelmed by the prospect of having to control a large number of lights individually. Therefore, simplifications representing groups of lights had to be easy to interpret.
- Users should feel in control: Users should be able to override the system at any time, especially in case of emergency. Therefore, the system should respond to the users' actions in a fast and reliable way.
- The interaction with the system should lead to "joy of use": Users' perceptual-motor and emotional skills should be taken into account for the new interaction concept. Perceptual-motor skills are closely related to how people interact nowadays with light switches. Emotional skills are connected with creating an aesthetically pleasing experience (Overbeeke 2000).

3.2 Conceptual Design

There were three main issues that needed to be addressed when designing a control for such a complex lighting system. We wanted to find appropriate metaphors that were simple and clear enough to users to address them.

"Light Switch"

First, we needed to provide a familiar interaction style that would consider the perceptual-motor skills of users. Based on our design guidelines and usability goals, we proposed a "Light Switch" metaphor. Thus, users control lighting via an object that is familiar to them. The interface resembles an ordinary light switch in its size

and in providing an equivalent interaction style (i.e. press plus the extension of press-and-drag). These interfaces are located in activity-related areas, namely by the bathroom entrance, by the mirror and near the bathtub.

We analysed how people interact with light switches at home in order to define the interaction with our "Light Switch". When people want to turn the lights on, they usually know the approximate location of the switch and usually find the exact position with their fingers, even without looking at it using proprioceptive feedback. Then, people decide on which part of the switch to press by actually touching the physical switch. Hence, the feedback provided by the physicality of the light switch becomes more important than the visual feedback provided by the switch. Thanks to its similar size and touch enabled interaction, we implemented our prototype on a Pocket PC. Because standard Pocket PCs do not provide tactile feedback, we had to compensate by reinforcing the visual feedback. In our prototype, lighting is switched (on or off) by pressing with a finger on any part of the touch screen of the Pocket PC. This change is accompanied by providing visual feedback through the Pocket PC's high resolution bright screen on whether the lights are on or off (Fig. 1). This on-screen feedback combined with the corresponding change in lighting in the bathroom provide users with immediate visual feedback. This can be compared to the current situation in our homes where visual feedback is mainly provided by the changes in lighting and not so much by the status of the switch itself.

"Natural Light"

Second, due to conceptual difficulties users had encountered on previous lamps when referring to the change between cold and warm colour temperature of white light (when white light changes from a bluish white light to a more yellowish white light), in our design we aimed at referring to light in a way that would make sense to users. We addressed this issue by proposing a "Natural Light" metaphor, trying to appeal to the emotional skills of our users. Most people are unfamiliar with the concept of colour temperature in the context of artificial lighting and do not know what

cold and warm means before they see it. A very simple phenomenon in nature gave us an idea on how colour temperature could be represented with the help of a metaphor that builds upon common knowledge of nature. The transition between cold and warm colour temperature of white light occurs in nature when, on a sunny day, white fluffy clouds cover the sun, making the light colder. As the cloud goes away, the light becomes warmer. In our interface, variations in colour temperature of white light are represented by a "sunny sky" or a "cloudy sky". A sunny sky corresponds to maximum warm white light, while clouds covering the sky correspond to maximum cold white light (Fig. 2). The user can control the ratio between warm and cold by dragging clouds onto the sunny sky using press-and-drag (up or down) with a finger. Similarly, variations in intensity of light represent "day" and "night". A clear blue sky provides a natural source of light and represents day. As our light source starts fading away, it eventually becomes total darkness which represents night. The intensity of light can be increased or decreased using the same interaction style (press-and-drag up or down) depending on the direction of the movement.

Building upon the "Natural Light" metaphor, we explored possibilities to represent different colours provided by the system. We looked into natural phenomena that influence our perception of light. As we were aware of the differences in colour perception across different people and cultures, we concentrated on finding phenomena that people would almost universally agree upon as for which colour it represents. During a sunset, for example, a warm orange light influences what we see. We decided to explore to what extent these associations made sense to users and ask them what they meant to them. The associations made were, Sunset – Orange, Forest – Green, Water – Blue, Desert – Yellow, Snow – White, Eclipse – Red and Lavender – Purple. In our interface, colours are represented as marbles containing abstract information about a given colour. The marbles contain the name of the natural phenomenon associated, an icon to help illustrate the concept behind the marble, and the colour itself.

"Fish-eye View"
Third, we needed to first simplify the representation of groups of lights in the bathroom and second to allow selecting, positioning and changing the intensity of light, hopefully, in one action. We addressed these issues by proposing a "Fish-eye View" metaphor to represent a generic bathroom. Due to the variety of bathrooms, namely differences in sizes, shapes, furniture, elements, etc., we decided to aim for a generic way of representing any bathroom. With a physical fish-eye optical lens, any rectangular or square bathroom is seen as a circle. In our interface, the bathroom is represented by a circle with a fixed reference point (a door) to help users find their way around the bathroom. Lighting areas that a given bathroom has to offer are represented by smaller black circles and are located inside the bigger circle representing the bathroom (Fig. 3). These lighting areas could match activity-related places (i.e. bathtub, mirror, etc.), but in other bathrooms these areas could be different. Another problem we addressed here was that creating presets from scratch can be quite frustrating because users are not yet aware of the possibilities the system has to offer. Beusmans (Beusmans 2004) reported a similar experience where two groups were controlling atmospheres created with coloured lighting. One could use presets and the other had to create atmospheres from scratch. In the second condition, users were unable to see all the options they had, so they lost interest. The only way to really get them going with designing atmospheres was to show them first what the possibilities were. Therefore, in our interface, presets serve as guidance for users. In the initial state of the system when one of the presets is activated coloured Marbles in use are already located in the bathroom, while unused ones remain in the top part of the interface. By pressing and dragging a given marble into the different circles that represent areas within the bathroom, three things occur. Firstly, by pressing, a given colour is selected. Secondly, by dragging the marble across the bathroom, a physical location is selected. Thirdly, dragging the marble inside one of the black circles and moving it towards the centre of the black circle can increase intensity of that light. Therefore, three

different functions can now be combined in one seamless action.

4. Evaluation

We evaluated our design by means of qualitative tests with 10 participants who had already seen the bathroom lighting demo either because they collaborated in the user study or because they had visited the demo at another occasion. In this way, participants were able to evaluate the new controller without being positively biased by the initial impressiveness of the lighting demonstrator.

4.1 Goal and Method
The goal of the evaluation was to investigate how people would perceive and interact with our system. To achieve this goal, the evaluation was focused on three main aspects, namely, "task completion", analysis of the TAM (technology acceptance model) "questionnaire" (Davis 1989) and "understanding of the metaphors". First, in task completion we were looking for difficulties participants may encounter while performing a given set of tasks. Second, with the analysis of the TAM questionnaire, we wanted to use a validated measurement scale for predicting user acceptance of our system. The questionnaire consists of 10 questions (Table 1), with the first 6 questions addressing the perceived ease-of-use dimension and the rest of the questions the perceived usefulness. Furthermore, by observing specific items of the questionnaire we could address and evaluate some of our usability goals we had previously set in the conceptual design phase. These items were Q6 and Q9 for "ease of use", Q1 and Q5 for "ease of learning", Q2 and Q7 for "feeling of being in control" and Q8 for "joy of use". Third, we let our subjects explain how they have understood different elements of the user interface in order to see whether their interpretation would correspond to the meaning intended by us.

4.2 Procedure
The evaluation consisted of two experiment sessions. In the first experiment, we evaluated simple functions that users will most likely use on a daily basis, namely switching the lights on and off, and

Table 1: Ten questions (items) of the TAM questionnaire

N	Questions of the TAM questionnaire
	Perceived ease-of-use
Q1	I find learning to use the system easy.
Q2	I find it easy to get the system to do what I want it to do.
Q3	My interaction with the system is clear and understandable.
Q4	This system is flexible to interact with.
Q5	I find it easy to become skilful at using the system.
Q6	I find it easy to use.
	Perceived usefulness
Q7	I find that by using the system I am able to control lighting rapidly.
Q8	I find that by using the system I can enjoy controlling the lights.
Q9	I find that by using the system it is easy to control the lights.
Q10	I find this system useful at home.

changing both the intensity of light and colour temperature of white light. In the second experiment, we evaluated a more complex task, namely creating atmospheres by means of modifying a given preset. In the beginning of both experiments, an interactive explanation was given by the facilitator as a way of introducing the interface to the participants. Participants then had 5 minutes to play around with the functions relevant to the tasks that were being evaluated. Finally, participants individually performed the tasks for 10 minutes and filled out a questionnaire. At the end of the two experiments, participants were asked to verbally describe their understanding of the system.

4.3 Results

Task Completion

All participants but one were able to complete all tasks in experiment 1 during the first try. The remaining participant was able to complete the task that was causing problems on the second try. For the tasks in experiment 2, all participants were able to complete them in the first try with only minor difficulties.

Analysis of the TAM Questionnaire

Based on our usability goals, we set success criteria for each of the TAM questions. A usability goal was reached and accepted when the mean rating of participants was ≤ 2.5, with a standard deviation < 1.4, on a 7-point Likert scale where 1 is strongly agree, 7 is strongly disagree, and 4 is neutral. A maximum standard deviation of 1.39 was defined to prevent the ratings from reaching the neutral point (4.0) in case of a mean equal to 2.5. In this way, we had a rough estimate to reject items that would comply with a mean ≤ 2.5 but that had been perceived as negative by some participants (rating 5, 6 or 7 on the 7-point Likert scale).

For the first set of tasks, we reached our success criteria for 8 out of 10 goals. Table 2 shows the mean ratings on the Likert Scale per item on the TAM Questionnaire. The dotted line shows the threshold for the mean ratings (2.5) corresponding to our success criteria. The white bars show the items where the success criteria were met. Dark grey columns show items that did not meet the criteria. Items 4 and 7 were rejected both for high mean ratings (2.8 and 3.2, respectively) and for reaching the neutral point (4.0) due to their high standard deviations (1.32 and 1.48, respectively).

For the second set of tasks, we reached our success criteria for 6 out of 10 goals (Table 3). Item 8 did not meet the usability criteria because one participant rated the interface with a 6 (where 1 is strongly agree, 7 is strongly disagree). As a result, the mean stayed within an acceptable range (2.2) but the standard deviation did not (1.62).

Regarding our usability goals, ease of use (Q6 and Q9) was fully reached for simple functions, and partly reached for creating atmospheres. Ease of learning (Q1 and Q5) was fully reached both for simple functions, and creating atmospheres. The "feeling of being in control" (Q2 and Q7) was only partly reached for simple functions and not reached for creating atmospheres. Finally, "joy of use" (Q8) was fully reached for simple functions and not reached for creating atmospheres.
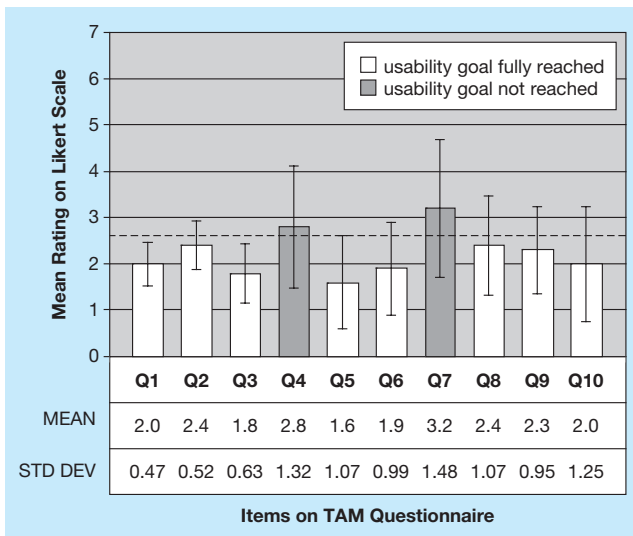
Understanding of Metaphors

For most functions, participants agreed the interface provides good feedback on the state of the system as well as on what the user can do at every stage.
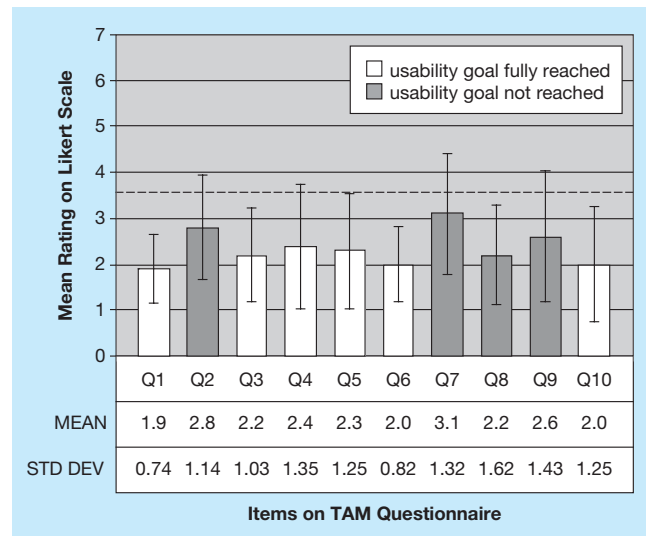
- Most participants said it was clear to them that they needed to move the clouds away from the sun to have a warmer colour temperature of white light. The link between yellowish light and the sun was clear to them.
- Two participants misinterpreted the clouds as ice and snow. However, this difference in interpretation did not prevent them from understanding the core of the metaphor and how it was supposed to be used.
- All participants could map the marbles to the colours the system had to offer in terms of lighting. However, some colour associations made more sense

Figure 4: Evaluation – Interaction (left) and location of the interface (right)

Table 2. Mean ratings ≤ 2.5 with a standard deviation < 1.4 on 7-point Likert scale for the first set of tasks

Table 3: Mean ratings ≤ 2.5 with a standard deviation < 1.4 on 7-point Likert scale for the second set of tasks

than others. Red connected to an Eclipse seemed rather arbitrary.

- All participants could map the abstract representation of the bathroom to areas within the bathroom.
- All participants were able to modify presets with the controller and said it was easy to understand and to use. One participant said only initially he had to remember the centre corresponded to full intensity.

5. Discussion

Overall, the user interface was rated highly with regard to its perceived usefulness and ease of use. While in experiment 1, the success criteria was reached for 8 out of the 10 TAM questions, in experiment 2, 6 out of the 10 goals were reached.

Regarding our usability goals, in experiment 1 "ease of use" and "ease of learning" were both fully reached. Providing a familiar interaction style (press, plus the extension of press-and-drag) that would consider the perceptual-motor skills of users proved to be the right choice for the interaction style. The "feeling of being in control" was only partially achieved because participants did not think the system allowed them to control lighting rapidly. There were four main reasons for this low "feeling of being in control". First, users had to change their habits since they could no longer switch lights on or off by proprio-

ceptive feedback due to the touch screen interface. Second, although in our rationale we decided to compensate for the lack of haptic feedback with extra visual feedback on the screen of the Pocket PC, users did not have audio feedback when the switch had changed its state. Therefore, users had to rely only on visual feedback both from the screen and from the lights in the bathroom. Third, the relatively slow response rate of the system to process users' requests was a critical issue, especially for tasks that control several lamps at a time. And fourth, the prototype on the Pocket PC demanded a high level of precision to press the touch screen either really hard or with their nails, otherwise, the system would not respond according to their actions, making it unreliable. Finally, "joy of use" was fully reached by including metaphors in the user interface control that made sense to users and that were aesthetically pleasing, thus appealing to their emotional skills.

In experiment 2, "ease of use" was only partially reached while "ease of learning" was fully reached. Again, our usability goal for the "feeling of being in control" was not reached since participants did not think it was easy to get the system to do what they wanted it to do due to the latency problem and thus participants could not control lighting rapidly. "Ease of learning" was only partially reached since participants did not think that by using the system it was easy enough to control the lights. Apparently,

it was not clear to them which colours could be dragged to which areas. Therefore, some of the proposed simplifications representing groups of lights were not easy to interpret. Finally, "joy of use" was again fully reached by providing the metaphor of "natural coloured light" adding fun to the interaction.

6. Conclusions

An interaction concept has been created for controlling an advanced multi source lighting system in the bathroom based on the results of extensive user research. The new design reduces the complexity of interaction by providing an interface involving small touch screens which employ the metaphor of a "Light Switch" for controlling basic functions for groups of lights such as switching on and off and changing the intensity of light. The small touch screens are located in strategically chosen activity-related areas in the bathroom. The "Light Switch" provides a familiar interaction style (press plus the extension of press-and-drag) by taking into account the perceptual-motor skills of users. Changing the colour temperature of white light, which had been found conceptually difficult with other lamps providing this function can now be achieved through a "Natural Light" metaphor. Variations between warm and cold colour temperature are represented by a "sunny sky" or a "cloudy sky". The "Natural Light" metaphor has shown to

be appealing to the emotional skills of users by creating an aesthetically pleasing interaction. The concept has been expanded through a "Fish-eye View" metaphor to allow more advanced functions such as creating atmospheres for relaxation by means of coloured lighting. The new interaction concept allows selecting a colour, positioning the colour on an abstract map of the bathroom, and changing the intensity of light of that given colour in one seamless action instead of three separate actions. In the final evaluation, the interaction concept was highly rated by participants on its perceived usefulness and "ease of use". The metaphors used to represent the complex lighting system and its functionality, as well as for presenting the spatial configuration, were successfully interpreted. New designs for advanced lighting systems should aim at user-friendly interfaces that make the transition from ordinary light switches to these new interfaces as simple and natural as possible. Future work includes integrating such a control for other areas in the house and expanding the idea of creating atmospheres for relaxation. Atmospheres could be created not only through lighting, but also by including music, odours, or projecting images.

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