An Interactive Curtain for Media Usage in the Shower

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ABSTRACT

Access to digital information became almost ubiquitous. There are only few situations left where digital media cannot be accessed. Showering is probably the only regular and common activity that does not allow to access and interact with digital media. Based on a large-scale survey, we identified potential applications that users want to use in the shower and designed a system that augments the user's showering experience to provide pervasive media access. We developed a projection-based system that augments shower curtains from the back side and recognizes user input using a thermal camera. Through a user study in a running shower, we collected feedback from potential users and evaluated different algorithms to recognize touch input on a shower curtain. Our results show that participants are enthusiastic about accessing and controlling media using an interactive shower curtain. Furthermore, we identified two algorithms that are robust enough to be used in challenging environments such as a shower.

Author Keywords

Interactive Shower; Intelligent Bathroom; Projected UI; Thermal Camera; Camera-Projector Systems

ACM Classification Keywords

H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

INTRODUCTION

Vast amounts of information and digital media became ubiquitously available in recent years. Users literally have information, media, and services at their fingertips in almost all situations. Dey et al. found in 2011 that participants' phone was within the same room 88% of the time [4] and market research[1] found in 2012 that 91% of smartphone users are always or most of the time within arm‘s reach of their smartphone. Smart watches and smart glasses are representatives for the ongoing trend to further reduce the time it takes to access digital media [18]. Today, only few situations are left where digital media cannot be accessed instantly.

Figure 1. A user is interacting with projected content on an interactive shower curtain.

One of the few situations that does not allow interacting with digital media is showering. While it can be argued that humans need phases of reflection and disconnectedness, this should be the user‘s choice and not restricted by technical limitations. A few analogue devices, such as AquaNotes [2] a water-proof notepad that enables writing down notes while showering, are available to augment the showering experience. Furthermore, waterproof mobile devices are available but typically not usable with wet hands. Current devices either do not provide access to digital media or are not usable in the shower.

In this paper, we present a system for accessing digital services, which is specifically designed for the shower. Informed by previous work and a large-scale survey, we develop an interactive shower curtain. The system‘s UI is projected from the back of the shower curtain (see Figure 1). To make the curtain touch sensitive and retaining the users' perceived privacy a thermal camera senses when the user touches the curtain. The system enables the user to control different media, sing karaoke, or simply read news. Also it displays the showering duration to the user. Through an evaluation of the system in a real shower, we provide insights about algorithms for detecting users' input. Furthermore, we found that participants are enthusiastic about the system and the gained opportunities.

[1] Edison Research - The Smartphone Consumer - **http://www.edisonresearch.com/wp-content/uploads/2012/06/The_Smartphone_Consumer_2012_by_Edison_Research.pdf** (last access Feb 2015)

[2] AquaNotes - waterproof notepad **http://www.myaquanotes.com** (last accessed Feb 2015)

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RELATED WORK

In the following we provide an overview of relevant research areas for interactive showers, namely, interaction in the bathroom and interactive surfaces.

Bathroom Interaction

Previous research already started exploring media usage in the bathroom. Lashina [14] outlined three basic requirements for an interactive and intelligent bathroom. Firstly, bathroom media usage prototypes should be capable of dealing with wet hands. Secondly, acoustic control of media should be avoided because of the noise level in the bathroom. Thirdly, controls should be integrated directly into the furniture or walls of the bathroom. Following these requirements, systems for interactive media usage have been proposed.

Takahashi et al. proposed a system that uses a projector and a depth camera to enable displaying interactive projected content on top of the water in a bathtub and recognizing interaction from under the water surface [11]. They are using bath salts to whiten the water in the bath and making it more suitable for projection and IR depth sensing. The Spalogue [8] system is capable of entering text using the bathtub. Another bathing-based system is Bathcratch [7], a DJ-controller for scratching music in the bathtub using a microphone. Furthermore, the bathtub is augmented with touch sensors for track selection.

The second major concept for multimedia systems in the bathroom is the usage of interactive mirrors [14]. The persuasive mirror [3] helps the user to overcome unhealthy habits by displaying quantified self data in a mirror. The AwareMirror [5] system recognizes the presence of a user through a proximity sensor and identifies the user by reading an RFID-tag of the used toothbrush. The system then displays context-aware and user-specific content such as weather information, public transportation information, or the user's calendar.

All introduced projects show the potential of multimedia systems in the bathroom. A patent application [2] suggests viewing content while showering by mounting a flat screen into the shower cabin. Also design concepts for interacting with touch-sensitive displays in the shower for controlling temperature have been proposed (e.g., the Piezo shower[3]). Other concepts, such as Le terme shower[4], suggest interacting with digital content as well.

Interactive Surfaces

Multiple techniques for making surfaces interactive have been proposed. On the one hand, hardware capable of sensing the user input is integrated into the surface. For example, Zhou et al. use pressure sensors to create smart table cloth [21]. However, embedding sensing directly into a curtain is cumbersome. Thus, cameras can be used to detect the user's input. The Touchlight [19] project uses the merged input of two video cameras to recognize interaction with a semi-transparent surface. Multi-touch displays can be created on arbitrary projected surfaces using a depth camera [6, 20]. In addition to detecting touch input using a depth camera, the dSensingNI [10] framework is also capable of detecting gestures in front of a projected display. However, all of these techniques would require having a camera inside the user's shower.

Another way to interact with projected user interfaces is using a thermal camera. ThermoTablet [9] uses this technique to draw images based on heat-traces which are detected from behind a thin surface. Their main use case is a painting application that draws on a projected canvas at the position where the user is touching the surface. Larson et al. [13] explore interaction that can be sensed using a thermal camera in combination with classical computer vision. They are able to distinguish between hovering over a surface and performing low and high pressure touch gestures. Their setup uses a thermal camera that is positioned in front of a surface. The Dante [15] system is a top-mounted system combining a Kinect depth camera and a thermal camera for detecting multiple touch points from multiple users. It is even capable of recognizing in-air gestures and identifying users based on a combination of depth and a user's thermal footprint. Kurz [12] created a mobile system using a thermal camera for detecting touch on planar surfaces and objects in for using them as an input in augmented reality applications. Recently, it has been proposed to use thermal reflections for detecting gestures in front of reflective surfaces [16]. Unfortunately, in the shower this would infringe the user's privacy as the whole body is reflected.

EXPLORING USER'S REQUIREMENTS

Interacting with content in the shower has been suggested in research and has also triggered commercial interest. However, the popularity of applications used in the shower might differ from regular smartphone applications. Therefore, we conducted an online survey to get an overview about different types of showers, desired use cases, and requirements. At first, we investigated the showering behavior and the type of shower, participants are commonly using. Then, we present ten activities that are most frequently performed with smartphones [17]. Participants rated how likely they would perform these activities in the shower on a five-point Likert scale. Furthermore, we provided a form where users could enter activities they could imagine to perform in the shower in addition to the proposed ones.

We distributed the survey using university mailing lists, social networks, and company mailing lists. As a compensation for the participants, we raffled four 25€Amazon vouchers. A total of 381 participants (97 female, 284 male) took part in our online survey. The participants were aged from 17 to 65 ($M = 27.96$, $SD = 8.19$). We had a wide cultural background with participants from various countries in Europe, Northern America, and Asia. The participants' backgrounds comprise students of various majors, nurses, software engineers, product managers and many more.

Quantitative Results

Regarding the user's showering behavior, we found that participants are taking a shower on average 6.19 times ($SD = 2.31$)

[3]Piezo shower - **http://piezo-shower.blogspot.de/2010/04/control-panel.html** (last access Feb 2015)

[4]Le terme shower cabin with built-in touch-interactive OLED display **http://www.homecrux.com/2012/08/25/615/le-terme-shower-cabin-with-built-in-touch-interactive-oled-display.html** (last access Feb 2015)

per week. The mean time of all participants for taking a shower is 12.88 ($SD = 8.66$) minutes. Most participants are showering in the morning (70.34%), 3.93% are showering at noon, and 58.79% of the participants are taking a shower in the evening. As some participants are taking a shower multiple times per day, the percentages add up to over 100%. With a total of 51.57%, most of the participants are using a shower with a shower curtain. Another 24.47% of our participants have access to a shower with plastic walls and 25.26% are using a shower with see through glass walls. A small number of 2.89% of the participants have milk glass walls in their shower. Furthermore, 0.52% of the participants have a shower made of brick-built walls and 0.78% are taking a shower in a public group shower (e.g., at a gym).

In the main part of the survey, we explore which types of applications the participants would like to use in the shower. The results reveal that the top three types of applications participants would like to use in the shower are: listening to music ($Med = 5$), watching videos ($Med = 2$), and reading news ($Med = 2$).

Qualitative Feedback

The participants also provided qualitative feedback. In addition to the ten proposed activities, participants would like to receive quantified self information (e.g., showering time), water consumption, and water temperature. Furthermore, participants suggested applications for controlling smart home applications, for example changing the lighting conditions or a projected scenery or playing interactive games under the shower.

Discussion and Design Principles

Most participants have a shower with a shower curtain. Therefore, we decided to focus on a shower curtain scenario for our prototype. Regarding the shower duration, with 12.88 minutes the results of the survey is comparable to other surveys. A survey by Echo[5] from 2010 in the UK found that the average showering time is 13 minutes. However, a sensor-based study by Unilever[6] found that an average shower takes about 8 minutes.

Further, we derived four design principles for an interactive shower experience that are based on the insights we gathered from our online survey and from previous work:

Deploy visual sensors outside the shower cabin: Our respondents were concerned about their privacy when having a camera to enable gesture input directly in the shower. Therefore, visual sensors (e.g., RGB-cameras, depth cameras, or thermal cameras) should not be deployed inside the shower cabin. They should only be deployed outside the shower and be active when the user is inside the shower for sensing input.

Integrate controls into the environment: The respondents stated that the interaction with the system should not interfere with showering. Therefore, an interactive shower should not require the user to hold a device for interacting with the system while showering. The control should rather be integrated directly into the environment (cf., [14]).

Provide alternative input opportunities: The user might hold the shower head while taking a shower and therefore, cannot use the hands directly to interact with the system. To enable an interaction at all times, the system should also be able to detect input from the shower head.

System should be capable of getting wet: As the control for an interactive shower should be inside the shower cabin, the system has to be capable of getting wet (cf., [14]).

INTERACTIVE SHOWER CURTAIN

To fulfill our previously discovered design principles, we project onto a white shower curtain for displaying controls from outside the shower cabin. Thereby, the system is not affected by the wet environment. As for interacting with content, we experimented with different prototypical setups, which preserve the users' privacy. A speech control is not feasible due to the noise level in the shower. We also tried to detect touch with the curtain using a Microsoft Kinect depth camera mounted outside the shower cabin. However, this setup was inaccurate as it only detects touches which result in a movement of the curtain. Slight touches with the curtain could not be detected at all.

Based on this knowledge, we chose to use a thermal camera for detecting user input. Both thermal camera and projector are placed outside the shower (see Figure 3). The thermal camera is positioned in a way that the camera's area covers the projection area which makes the content touch sensitive. In our setup the projected image has to be mirrored horizontally to be viewed correctly inside the shower. Our prototype uses the Optris PI160 thermal camera, which has an optical resolution of 160×120 pixels and a frame rate of 120 Hz. For projection we use an Acer K335 projector having a resolution of 1200×800 pixels and 1000 ANSI Lumen.

Using a thermal camera for detecting touch with a shower curtain enables multiple ways of interacting. During our tests we identified three ways of interacting with the curtain: finger touch, full-hand touch, and detecting water coming from the shower head (see Figure 2). Our system can automatically distinguish the three interaction techniques as they result in a different thermal image. All interaction techniques can be used to trigger touch events on the curtain. Also, these interaction techniques preserve the user's full privacy as only touch points with the curtain are captured by the camera.

In our online survey, we identified applications that users want to run while showering. We built several shower applications, which comprise a music player, a video player, a karaoke application for singing under the shower, and a Whack-a-Mole game. Furthermore, our application is capable of displaying the weather, the latest news, the current water temperature, water consumption, and the showering duration.

[5]Echo shower survey - `http://ech2o.co.uk/downloads/Is%20the%205%20minute%20shower%20an%20urban%20myth%20report.pdf` (last access Feb 2015)

[6]Unilever shower study - `http://www.greenwisebusiness.co.uk/news/brits-using-nearly-as-much-water-showering-as-bathing-unilever-study-finds-2816.aspx` (last access Feb 2015)

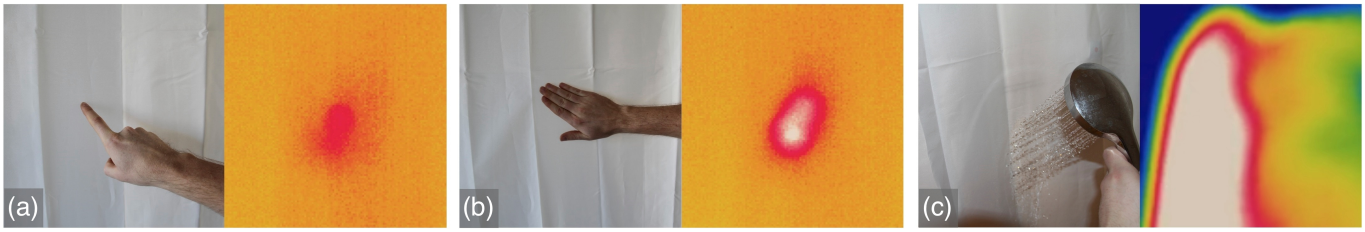

Figure 2. Overview about the interaction techniques that are supported by our system. The right image shows the thermal camera's image that is taken from the back side of the curtain: (a) touch using one finger, (b) touch using a full hand, (c) interaction using the shower head.

Algorithms for Detecting Touch with the Curtain

We developed three different algorithms for detecting touch with the shower curtain using a thermal camera. Each of the algorithms is able to detect each of the three previously introduced interaction techniques. As the touch area needs to cool down to the average curtain temperature after a touch event occurred, all algorithms implement a timeout mechanism. During the timeout new touch events are blocked at the position where the previous touch event occurred. In a preliminary test, we empirically determined appropriate threshold parameters through iteratively testing the system in the shower. The main challenge for designing an algorithm for touch interaction in a running shower, is that the algorithm needs to be robust to droplets coming from the shower while perceiving the user's privacy.

Hottest Point

The *Hottest Point* algorithm runs through all pixels of the thermal image. If there are pixels that are warmer than a threshold of $2.5\,°C$ compared to the average temperature on the curtain, a touch event is fired at the position of the hottest pixel. The *Hottest Point* algorithm requires a timeout of 5 seconds to prevent false touch events on areas that were warmed by previous touches. The advantage of this algorithm is that it is easy to implement. However, this algorithm could be prone to errors caused by a warm spot, for example, a hot pipe on the wall.

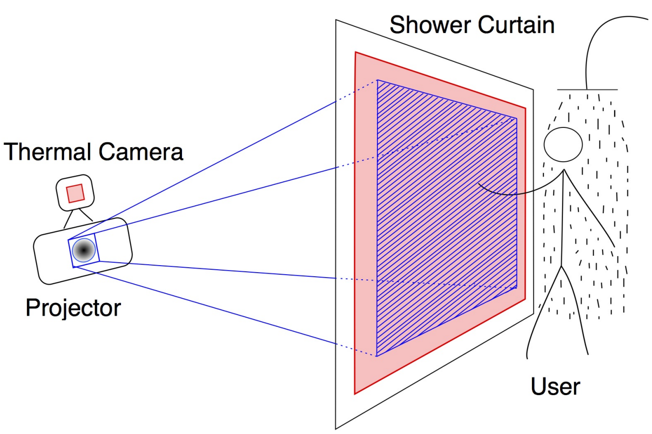

Figure 3. Overview about our system's setup. Red area is covered by the thermal camera, blue area is covered by the projector. The user can interact with the shower curtain while taking a shower.

Background Subtraction

Our second algorithm is a *Background Subtraction* algorithm, which takes a 500 ms old frame and compares it to the current frame. The algorithm calculates an alteration rate for each pixel. If one or more pixels have an alteration rate that is higher than a threshold of $2.5\,°C$, a touch event is fired at the pixel with the highest alteration rate. This algorithm is highly responsive and can compensate for permanently warm spots. Therefore, this algorithm's timeout only needs to be 0.5 seconds. However, this algorithm might also be triggered by warm droplets coming from the shower.

Area-based

As a third algorithm we introduce an *Area-based* algorithm which operates on the thermal camera's 160×120 RGB-image. Using OpenCV background-subtraction, the algorithm divides the background from the foreground. We used the Canny edge detection algorithm [1] to determine areas in the foreground. The areas are then sorted by the acreage in a descending order. If the area with the highest acreage is larger than 200 square pixels, a touch event is triggered in the middle of this area. This algorithm disables falsely detected touches caused by small droplets and can compensate for permanently warm spots. However, it is not as responsive as it needs a longer amount of time to warm up a sufficiently large area which triggers a touch event. As the touch area needs to cool down again, this algorithm implements a timeout of 5 seconds.

EVALUATION

We conducted a user study in our shower lab (i.e., a shower room in the university's gym that was used for the experiment) to explore how potential users interact with the shower curtain. Thereby, we compared the three previously introduced algorithms.

Method

We conducted the experiment using a repeated measures design with the algorithm as the only independent variable. Each participant used each of the three algorithms in a counterbalanced order according to the Latin Square to reduce learning effects between the conditions. We used objective and subjective measures as dependent variables. As objective measures we used the number of correctly hit targets per minute (points). Additionally, we collected quantitative subjective feedback through 5-point Likert scales about the algorithms' responsiveness. Additional qualitative feedback has been collected through a semi-structured interview after all conditions.

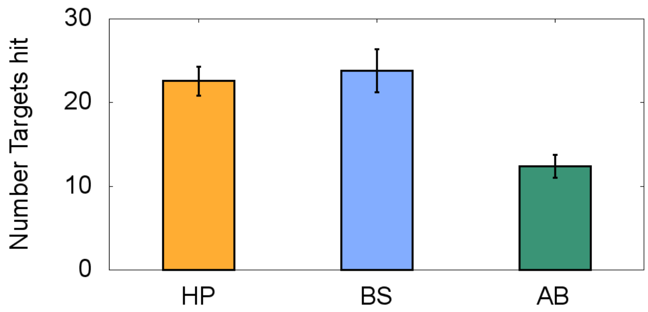

Figure 4. The number of hit targets according to the used algorithm (HP = Hottest point, BS = Background Subtraction, AB = Area-based). Error bars depict the standard error.

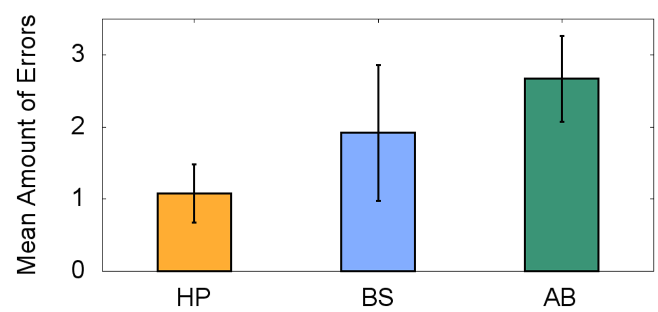

Figure 5. The mean number of errors made during the study. An error was counted as recognized input in a tile without a mole being shown. Error bars depict the standard error.

Apparatus

We deployed the previously described prototype in our shower lab. Prior to the study, we performed a 4-point calibration on the shower curtain to arrange camera and projector. During the calibration the four corners of the projection are aligned with the camera image. This calibrated apparatus was used for all participants. To ensure the same conditions for each participant, the room temperature in the shower room was set to 25 °C during the whole experiment. However, the used algorithm was not calibrated to work with a defined water temperature as the participants were able to adjust the water temperature freely.

Procedure

After explaining the purpose of the study and the procedure, we asked the participants to switch to their bathing suits. Next, the participants stepped behind the shower curtain, turned on the shower, and set the water to a pleasantly warm temperature they would take a shower with. At the beginning, the participants explored the interactive curtain. Thereby, the participants controlled the video and music player and tried the karaoke application. The content was projected at a height from 1.20m to 1.80m and had a width of 80cm. To get familiar with the system, we asked the participants to perform 24 exemplary tasks that guided them through the menu of our shower curtain. Comparing the algorithms, the participants played a Whack-a-Mole game with each algorithm once in a counterbalanced order using the full hand interaction method. In the game, the participants had to hit a mole that appeared at a random position on a 3x3 grid. The participants had one minute to hit as many targets as possible. We used the number of moles hit as a performance measure. Further, we measured the number of interactions that were triggered in areas, where no mole appeared and counted them as errors. After each condition, we asked each participant to rate the used algorithm on a five-point Likert scale. We repeated the procedure for the other algorithms. After dressing again, we conducted a semi-structured interview.

Participants

We recruited 12 participants (1 female, 11 male) aged between 19 and 28 years ($M = 23.5$, $SD = 2.72$). The participants were computer science students recruited via mailing lists.

Results

Comparing the detection algorithms, the *Background Subtraction* algorithm works best ($M_{BS} = 23.8$, $SD_{BS} = 8.9$), followed by the *Hottest Point* ($M_{HP} = 22.6$, $SD_{HP} = 5.9$) and the *Area-based* ($M_{AB} = 12.4$, $SD_{AB} = 4.7$) algorithm (see Figure 4). A repeated measures analysis of variance (ANOVA) shows statistically significant differences between the algorithms, $F(2, 22) = 10.397$, $p = .001$. A follow-up Bonferroni-corrected post-hoc test shows that the *Area-based* algorithm is statistically significantly worse compared to the other two.

We further analyzed the number of errors that were made using the different algorithms (see Figure 5).. The *Hottest Point* algorithm introduced the lowest error rate ($M_{HP} = 1.08$, $SD_{HP} = 1.4$), followed by the *Background Subtraction* algorithm ($M_{BS} = 1.92$, $SD_{BS} = 3.26$). The algorithm that introduced the most erroneous inputs was the *Area-based* algorithm ($M_{AB} = 2.67$, $SD_{AB} = 2.06$). However, a repeated measures ANOVA did not show a significant difference, $F(2, 22) = 1.674$, $p = .211$.

Looking at the subjective ratings, the participants liked the interaction with the first two algorithms ($Med_{BS} = 4$, $SD_{BS} = 0.5$, $Med_{HP} = 4$, $SD_{HP} = 0.9$) more compared to the third ($Med_{AB} = 3$, $SD_{AB} = 1.3$) (see Figure 6). A Friedman ANOVA shows that these differences

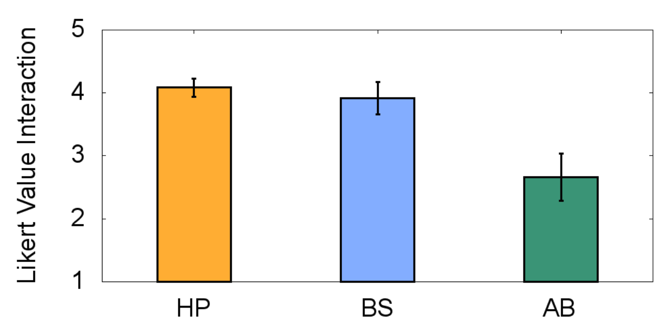

Figure 6. The mean Likert scale values indicating how the participants liked the interaction with the different algorithms. Error bars depict the standard error.

are statistically significant, $\chi^2(2) = 11.200$, $p = .04$. Using Wilcoxon tests for pairwise comparisons, the differences between the *Background Subtraction* and the *Area-based* algorithm, $Z = -2.642$, $p = .024$, as well as the *Hottest Point* and the *Area-based* algorithm, $Z = -2.599$, $p = .027$, are statistically significant.

In the interviews, most participants stated that the curtain is fun to use, innovative, and an interesting concept to enrich showering. One participant stated that *it increases the efficiency because you can finish tasks you started at your mobile on the curtain* (P3). Several participants came up with application ideas such as browsing email (P10), social media (P11), or the current traffic situation (P1). However, two participants are concerned that the curtain will increase showering time (P5, P9). Nevertheless, they would like to view some ambient information such as *a live view at the ocean* (P5).

LIMITATIONS

The parameters used for the detection algorithms rely on the user's showering preferences (i.e., water-temperature). They could be further optimized by adapting them to the user. However, the chosen parameters used in the evaluation are sufficient to reliably detect user interaction. Further, we chose a lab study to increase internal validity since we believe that for a first assessment a controlled setting is beneficial. While we tried to make the experience as realistic as possible (i.e., participants took a shower) the external validity is reduced as showering in the presence of the experimenters is still artificial.

CONCLUSION

In this paper we presented the design, implementation, and evaluation of an interactive curtain for media usage in the shower. We derived requirements and potential applications for an interactive shower curtain from a large-scale survey. A projection-based system that augments shower curtains from the back side has been developed. We implemented a set of applications and potential algorithms to detect users' input using a thermal camera. The evaluation shows that the *Background Subtraction* algorithm and the *Hottest Point* algorithm are robust enough to reliably detect users' input and that potential users are enthusiastic about the system's potential.

Based on the experience from the conducted study we assume that enabling access to media and information might extend the time users shower. While water consumption is not a concern in a number of countries including most parts of northern Europe, using our system might also increase energy consumption. The system could, however, also inform about the showering duration. In future work we will investigate the effect of an interactive shower on the time users shower and build immersive applications that are tailored to showers.

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