SMILA: Design and Evaluation of a Smart Mirror for Monitoring Health

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***Abstract*— Chronic diseases among elderly people have an increasing impact on healthcare systems. Telehealth interventions using smart phones and low-cost sensors have been shown to potentially increase quality of life and reduce re-hospitalization rates. While usage of Internet and smart phones is generally increasing in elderly people, there is still a digital divide between younger and older users making usability a key aspect of telehealth intervention design. In this work, we introduce SMILA, an interactive, voice-controlled smart mirror supporting elderly people in self-monitoring of parameters relevant to chronic heart failure. We present the design, construction, user identification using wrist-bands and linkage of the mirror to a telehealth service based on the Internet of Things mediation framework *symbIoTe*. Finally, we present initial results from a pilot study evaluating user acceptance and usability.**

Keywords- smart mirror; telehealth; human-computer interaction; smart home; Internet of Things.

I. INTRODUCTION

The economic policy committee estimated that in 2050, one in three Europeans will be older than 65 years [1], with the process of aging being influenced by various factors, such as employment, education lifestyle and presence or absence of chronic diseases. Especially cardiovascular diseases have a huge impact on quality of life and hospitalization rates. The rise of smartphones and low-cost sensors has led to new health interventions referred to as telehealth, allowing patients to track health parameters at home using a smartphone, feeding this data into health data centers for inspection by health professionals. Telehealth interventions have shown to reduce hospitalization rates [2] and - by promoting self-management knowledge and skills - support preventative approaches that are key to managing chronic disease [3].

While the use of Information and Communication Technologies (ICT) is generally increasing in elderly people, it has been shown that there is a digital divide between young and elderly people when it comes to ICT usage, especially in elderly people with low education and income, as well as physical frailty status being directly related to ICT usage [4].

Aside from smartphones, the last decade saw a rise of smart objects commonly referred to as Internet of Things (IoT) especially in the area of health. Examples include fitness wristbands measuring heart rate, sleep duration and quality and daily activity. From a technical perspective, these devices are usually tied to vendor-specific IoT platforms leading to a large fragmentation of the IT landscape. The EU-funded project symbIoTe (symbiosis of smart objects) [5] seeks to implement a mediation

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framework between these platforms providing application developers with unified interfaces across different IoT platforms on various levels, such as hardware and software and the network layer.

Against the backlight of these developments, the objective of our work is to investigate how an unobtrusive telehealth intervention in the area of cardiovascular disease can be designed and built on top of the symbIoTe mediation framework.

We introduce Smart Mirror Integrated Living Assistant (SMILA), an interactive smart mirror for assisting elderly people with daily measurements of physiological parameters relevant for the treatment of cardiovascular diseases.

“Smart mirrors” are devices mounted to the background of a semi-transparent mirror in order to augment the reflective surface of the mirror with digital information.

The use of smart mirrors in a health context is interesting as people use a mirror on a daily basis. The use of smart mirrors in the context of health has been investigated in a number of scenarios: “Fit Mirror” [6], a smart mirror using gesture control to provide physical exercises to elderly people, “Wize Mirror” [7] using 3D optical sensors, multispectral cameras and gas detection sensors to derive a wellbeing Index and a non-contact health monitoring system [8] analyses facial expressions, posture and voice changes.

The contribution of our work to this field is two-fold: (1) we merge the concepts of telehealth interventions in the area of cardiovascular disease with the smart mirror concept and (2) we aim to investigate end-user acceptance with two stakeholder groups (a) eldery people and (b) young people in order to explore differences in user interaction between these two groups.

The rest of this paper is organized as follows: First, we describe the design of the interactive mirror. Second, we describe how the end-user evaluation design has been setup. Third, we describe the overall interaction workflow and discuss results from an initial user evaluation.

II. METHODS

A. Smart mirror

SMILA was constructed of a wooden frame (40x30x4 cm, gross weight 2,5kg) housing the semi-transparent mirror hiding a Samsung Galaxy Tab A 10.1 Android tablet. The idea for constructing the smart mirror from scratch and not taking a commercially available product was primarily economically driven. By using off the shelf materials and simple constructions, the total costs for one smart mirror could be held below 300€.

In idle mode, the mirror displays the current time and the weather situation at its current location. We decided against showing more information for several reasons: (1) to prevent information overload and to only provide context-relevant information and (2) to keep battery and bandwidth usage low.

B. Sensors and user-recognition

As we chose the area of cardiovascular diseases, a number of vital parameters are interesting facing the telehealth perspective: regular measurements of heart rate, blood pressure, body weight and daily activity are relevant to the therapy in order to assess effectiveness, as well as to detect any deterioration in a person’s health status. For initial evaluation, we chose connecting the smart mirror to a Bluetooth-enabled scale for two reasons. (1) a scale is most likely to be found in bathrooms and (2) a sudden increase in weight is an indicator for hospitalization [9]. Moreover, SMILA uses voice input to collect information on personal well-being using Google’s Cloud Speech Application Programming Interface (API).

Another important aspect is user identification, as most likely many people are living in a two-person household. We considered several options for user identification: (1) identification and authorization by a separate device using PIN codes once the device is close to the mirror (2) facial recognition and (3) wearable Bluetooth low energy beacons for identification.

Bluetooth Low Energy (BLE) beacons are devices transmitting signals containing their ID along with other technical information on a regular interval. Devices such as smartphones or tablets can identify these radio signals within a limited range and apps can react to the presence of such beacons. We favored this approach especially to biometric identification as it is (1) more privacy-preserving and (2) BLE beacons can be exchanged by fitness wristbands, thus combining identification with reading further health measurements. BLE beacons have been used in various scenarios, most prominently in eCommerce settings offering consumers guide within shops. For our initial evaluation, we decided to use wristband type beacons or devices that can be attached to a keychain (D15 UFO Bluetooth). The latter can be incorporated in a necklace as well.

SMILA is connected to the KIOLA telehealth platform, a data collection framework and therapy management system for various chronic diseases [10]. Weight measurements and personal well-being are collected through SMILA and then transmitted to KIOLA. To provide interoperability to other platforms (e.g., consumer health platforms), data transmission and retrieval is handled through the symbIoTe mediation framework using standardized RESTful interfaces.

C. End-user evaluation design

End-user evaluation of SMILA was conducted at the COSY Living Lab at the University of Vienna, a multi-purpose user study laboratory equipped with furnishing and technical set-up to support a home-like test-setting that is observable through semi-transparent windows and audio-visual equipment. We designed a lab-evaluation concept that aims at collecting overall usability feedback to the SMILA prototype as well as inquiring the participant’s own experience with health monitoring tasks and relating the SMILA concept to it. We conducted semi-structured interviews [11] that establish such personal experience regarding medical monitoring and self-management with chronic disease as well as regarding technology usage in this context and generally, in order to answer the research question: *Can SMILA support the way the participants manage self-monitoring tasks with chronic conditions?* This was followed by observation of participants using SMILA in the Living Lab while they complete a pre-defined task of monitoring their weight and overall well-being as well as a concluding survey on experience and usability of the smart mirror's audio-visual interface and interaction, utilizing the System Usability Scale (SUS) [12].

The evaluation was carried out in two phases: first, the prototype was tested with university students to gain initial feedback and test feasibility of the system. Second, the prototype was tested following the same schema with elderly people.

III. RESULTS

A. Overall workflow

The end-user wears a BLE-enabled wristband and enters the bathroom. In idle mode, SMILA constantly scans for BLE signals and reads the ID of recognized beacons. Using this ID it queries the symbIoTe mediation framework, receives an access URL for the KIOLA tele-health platform and receives personal information on the user resulting in an acoustic personal greeting. It then asks the end-user to step on the scale performing the measurement (see Figure 1). While standing on the scale, SMILA displays the current weight (as seen in Figure 2) on the display. Once the measurement is taken, SMILA finishes asking for the personal wellbeing with the-end-user answering using voice-input. Finally, using the ID of the scale, SMILA queries the symbIoTe mediation platform for an end-point and transmits the data to the KIOLA telehealth platform. The whole process is guided through voice output.

Figure 1. From left to right: (1) Living lab evaluation scenario; (2) SMILA and (3) user interacting with the device

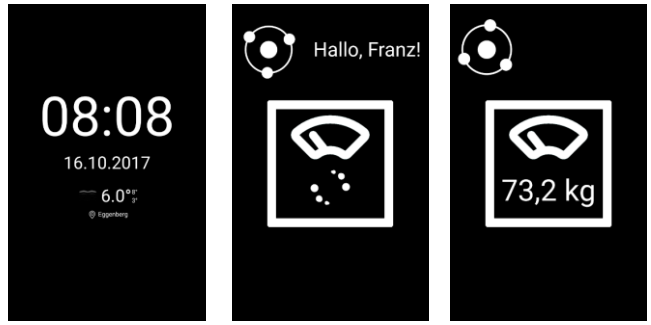

Figure 2**.** From left to right: (1) mirror idle – showing time and temperature; (2) greeting specific user and guiding through the workflow; (3) SMILA showing the result of a weight measurement

B. Evaluation results

The user evaluation was conducted in two phases with 18 participants providing initial insights on the technical feasibility and basic usability of the SMILA prototype. Evaluation was conducted in two groups with group A consisting of 11 participants (4 female / 7 male; 18-35), all students of computer science. Group B consisted of 7 participants (6 male / 1 female; 60-69 years old). During the test, the participants had to follow SMILA's vocal instructions of stepping on the scale and getting their weight, as well as entering their current state of being via voice input. 16 out of 18 tests were completed successfully. Personal well-being has been correctly translated into text in 9 out of 10 cases with the speech recognition API providing a confidence score (a score between 0 and 1) of 0.83 (±0.13) on average. Average length of inputs was 3.81 (±2.72) words.

When asked if users could picture themselves using the device at home, 10 answered with yes, 4 with maybe and 4 could not think of using the device at home.

IV. DISCUSSION

Interviews revealed potential usability improvements, such as a perceived lag between stepping in front of the mirror and being identified, as well as uncertainty when voice input was possible. Moreover, participants complained about the "robotic voice" as provided by voice output. Feedback on design included the incorporation of the bracelet into jewelry (e.g. a brooch) and both groups suggested face recognition or voice recognition as alternative form of user recognition though both groups raised privacy issues. When asked for additional usage scenarios for the mirror, elderly people named (a) support in management tasks (blood pressure measurements), assistance with medication intake and medication reminders, as well as support of scheduling appointments with physicians. In terms of the overall interactional quality, elderly participants consistently voiced their preference for such technology to have a "companion-like" quality they can have a trusted relationship with, rather than a tool for easy communication with medical and care professionals.

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University students named benefits in supporting adherence to fitness goals.

V. Conclusion and Future Work

We presented a smart mirror for self-monitoring of health parameters relevant to cardiovascular therapy. User identification using BLE-wristbands is feasible and initial evaluations showed that the method is reliable, though a higher responsiveness of the system is required. Moreover, using BLE wristbands has security implications that need to be addressed in further research. Using voice recognition for recording personal well-being proved to be sufficiently accurate in a controlled environment.

Next steps include the extension of workflow to include smart watches as mode of user recognition and the inclusion of fitness data for display on the mirror. This setting will be tested in another trial, where users can test the device over the period of one week.

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