Development of an Intelligent Drinking System for the Prevention of Dehydration in Old Age

Elisabeth Haslinger-Baumann, Anneliese Lilgenau, Katharina Gugenberger
Department Nursing Science, FH Campus Wien
Vienna, Austria
e-mail: elisabeth.haslinger-baumann@fh-campuswien.ac.at, anneliese.lilgenau@fh-campuswien.ac.at, katharina.gugenberger@fh-campuswien.ac.at

Gernot Korak, Sebastian Geyer, Udo Unterweger, Stefan Tiefenbacher
Department Engineering, FH Campus Wien
Vienna, Austria
e-mail: gernot.korak@fh-campuswien.ac.at, udo.unterweger@fh-campuswien.ac.at, sebastian.geyer@fh-campuswien.ac.at, stefan.tiefenbacher@fh-campuswien.ac.at

Franz Werner
Department Health Sciences, FH Campus Wien
Vienna, Austria
e-mail: franz.werner@fh-campuswien.ac.at

Abstract— **This paper describes the user needs analysis for a system that supports the professional management of fluid balance in older people to prevent dehydration. Dehydration is a frequent age related issue that typically leads to a steep decrease in physical and / or mental performance. Severe cases are life threatening due to risks of circulatory collapse or loss of consciousness. Hence, the prevention of dehydration is of particular importance. For data gathering, social-scientific methods (individual interview, focus group interview, cultural probes and documentary research) were implemented. The survey involved primary end users (elderly, dependent people), secondary end users (informal and formal caregivers), experts from ethics and the analysis of care documentation from older users. The main results were derived from the data by using a thematic analysis and subsequent data fusion as well as consolidation concepts on result level. As a conclusion, aside of valuable system-specific recommendations, a concept for reminding and motivating could be designed and will be implemented.**

Keywords: Active and Assisting Living; health care and nursing; dehydration prevention; interdisciplinary research

I. INTRODUCTION

Ensuring a sufficient supply of fluids to the body is a major challenge for the elderly, or the caregiving family members or nursing staff in a mobile care setting. With increasing age, the water content of the body, as well as the feeling of thirst decreases significantly [1-3]. This makes elderly people particularly vulnerable to dehydration. The effects of dehydration are extremely serious. Impairment of consciousness, fatigue and weakness, dizziness, muscle cramps and headaches are possible symptoms. With old people even a minor water deficiency leads not only to a drop in salvia production with mouth dryness, but also to reduced urine production and dry skin, which, in turn, can easily break up or develop pressure sores. In case of an even greater water deficiency, an accelerated pulse, an increase in body temperature, dizziness, weakness, impairment of consciousness and a decrease in physical and mental performance occurs. The onset of disorientation, states of confusion, apathy and a life-threatening circulatory collapse with loss of consciousness are possible consequences [1]. In elderly people, other causes such as heart disease or dementia are erroneously suspected without considering an insufficient supply of fluid as a possible cause. The consequences can also be life-threatening in the case of unconsciousness, circulatory or renal failure. Frequently, hospital admission is required. According to a study conducted in two English hospitals, 6.5 and 22.5 of 1,000 hospitalizations are based on dehydration. The mortality rate of hospitalized elderly people with dehydration symptoms is 45-46% [2].

The prevention of dehydration is therefore particularly important in mobile as well as in stationary care. Particularly in mobile care, the estimation of the quantity of liquid intake can only be carried out inaccurately, as the often very dependent clients live alone at home and are not supervised continuously. This means that elderly people cannot be cared for adequately in mobile care.

The presented research was conducted within the experimental research project "DrinkSmart" (2016-2018), which has the main aim to support the autonomy of elderly people with and without chronic diseases in order to facilitate their living in their own environment. The project led by the University of Applied Sciences "FH Campus

 ISBN: 978-1-61208-565-4

Wien" was funded by the Austrian research promotion agency (FFG) and carried out in interdisciplinary cooperation with the software company "akquinet ristec", the plastic mug manufacturer "Schorm" and the home care provider "MIK-OG".

II. STATE OF THE ART

Technical solutions for adequate hydration are already being developed in this field. They are mainly advertised as lifestyle products and are aimed at a young IT-savvy user group. These include the "Pryme Vessyl [1] " and "hidratespark[2]" systems. Apart from the pure analysis of the drinking quantity, these systems also offer the analysis of the liquid inside the drinking cup. Further they provide an optical warning function when too little liquid was drunk. In addition, a connection with a smartphone app for iOS or Android is to be made via "Bluetooth low energy", which should enable the future entry of individual data of consumed fluid quantities and body data like weight and size combined with GPS function. Alternatively, a lid cap has been designed for a cup, which measures the amount of fluid drunk with different sensors. This information should be transferred to a PC.

All described products focus on the needs of a young target group, not on older, dependent people and care contexts. Specifically those systems were not designed to transfer data to an electronic care documentation system. Such systems are important to assure the quality of care and are typically used to document the health status of the patient and the activity of nurses. Both aspects are core concepts of the here presented approach.

III. METHOD

For the survey of user needs and the development of the intelligent drinking system with appropriate sensors in the drinking vessel, which is used to measure the daily liquid consumption, qualitative scientific methods were used. The needs assessment in the primary and secondary target group was conducted using different socio-scientific survey and evaluation methods: guideline-specific individual [4] and focus group interviews [4][5]. For all interviews and focus group interviews guides including the structure, timing and detailed open and closed questions were developed. The data was analysed according to Mayring [5]. Furthermore, the ethnographic method of "Cultural Probes" [6] was used to obtain detailed insight into the existing drinking habits of the target group. A documentation analysis [7] of the existing care documentation completed the survey. The methods were chosen based on the individual research questions. Focus groups and individual interviews were chosen based on the individual timing possibilities of the recruited participants. A wide mix of methods was chosen to become able to conduct cross-method triangulation [12] of results. Researcher triangulation was undertaken for further quality assurance. The data gathered showed clear signs of saturation, which was to be expected considering the large user base.

TABLE I. OVERVIEW ON DATA COLLECTION METHODS

Data collection methods implemented		
Data collection method	***User group***	***Number of users involved***
Literature research	-	-
Discussion and interviews with experts from ethics [4]	Ethics experts	2
Cultural probe studies [6]	Primary users	6
Single-user, semi-structured interviews [4]	All user groups	40
Focus-group interviews [4][5]	Secondary users	22 (in 4 groups)
Analysis of care documentation [7]	Older dependent users and formal caregivers	5 documentations

The development of the intelligent drinking system, which is based on the summarized user requirements and follows the product specifications, adheres to the user-centered design approach [8] combined with the phase model on product development according to Glende [9]. The implementation of the user studies with selected participants was accompanied by a process- and result-oriented evaluation approach [10][11] with regard to the technical and social-scientific aspect.

IV. RESULTS

The summary from interviews and cultural probes shows the following common aspects despite the heterogeneous user groups involved.

The material should be comfortable to touch and not breakable. A modular design is desirable, that is, the drinking cup should be adaptable to different end user requirements. Care dependency may be a fluctuating phenomenon, which means that in the case of an acute disease, independent drinking might only be ensured with devices on the cup itself, such as the handle, or the spout, which might not be necessary in the further course of the disease.

An important additional component is the design of reporting functions. With the help of acoustic and optical signals, reminder functions should be realized, which remind the user of drinking. At the same time, the cups should facilitate a motivating design or component for motivation as users often knowingly object drinking.

The system should provide an overview of the quantity of liquid that has been drunk. It is important that the signals issued by the system (e.g. to remind or motivate drinking) should not be irritating and the optical and functional design of the system should appeal to different senses. This was considered in particular regarding used colours, materials and the design of the user-system interaction.

The results of the cultural probes studies with a duration of one week each and involving a subset of the primary user group (n = 6), underline the complexity of existing drinking

[1] https://myvessyl.com/prymevessyl, last checked on 2017.5.10
[2] https://hidratespark.com, last checked on 2017.5.10

habits. For example, drinks were consumed in parallel from several vessels; several differently shaped vessels were preferred in the course of the day or "favourite cups" were used which cannot easily be replaced by a single new system. As a consequence, the planned drinking system is limited in practice regarding the accuracy of the measurement of the total amount of liquid intake during a day, due to the users' habits. Further due to ethical concerns we found a need for a system that does not force users to change previous habits through alarms.

The analysis of nursing documentation shows that with many clients the focus is on the description of the risk of dehydration in terms of symptoms and causes. On this basis nursing measures and resources are formulated for the nurses to carry out. The objective of this standardized approach is to mitigate the symptoms of dehydration, to eliminate the causes, if possible, and to strengthen the resources of the clients by direct and indirect measures.

Based on the results of the conducted user need analysis a non-functional mock-up was created within a rapid prototyping process using the generative production method of Selective Laser Sintering (SLS). Due to the consistent consideration of the user needs, a simple and handy mug with clearly visible and intuitive visual and acoustic signals could be developed and is depicted in figure 1.

Figure 1. Mock-up of the modular system based on the user needs analysis. Comprised of a cup (inside), a plastic cup holder with electronics compartment and a grip. Acoustic and optical motivational and reminder functions are not yet visible. (left design-study showing the motivational component, right 3D printed system).

The optical components were realized as a dynamically growing seedling with seven leaves. Depending on the daily volume drunk, the leafs light up simulating a growing plant. This gives users a definitive feedback on the drinking volume reached up to the time X. By holding the system, the current drinking quantity status is displayed; otherwise the cup does not produce any acoustic or optical output to minimize potential irritations during night-time. The liquid within the cup forms a second optical component. It can be illuminated with an LED and in this way acts as a reminder for the users. This visual reminder is displayed when, within a predetermined interval, no liquids have been consumed.

At the end of the research project in 2018, the crucial result will be a market-oriented prototype (hardware and server / application software) for a smart drinking system. For the design of the corresponding sensors in the drinking cup, the liquid intake is measured via the Drink Smart Mug and controlled by means of reminder signals (visual and acoustic) and notification functions (e.g. SMS / E-mail). By connecting to a computer-aided care documentation already used in nursing care companies, the collected data can be recorded and documented. The caregivers are thus informed promptly and can react accordingly in acute cases.

The system is going to be evaluated within a home care setting including around 20 users for the duration of 4 weeks. Data gathering will be undertaken by implementing questionnaires, diaries, individual interviews and participatory observation. This qualitative research approach is important taking the complexity of the system and early prototype phase into account. The used social-scientific methods focus on the users' perspective and the nursing result quality, including also a risk-assessment for technology aversion. Technical evaluation methods test the efficiency, ease of use and technical practicability.

V. CONCLUSION

The consistent user-oriented approach ensures that the needs of the users and their relatives, as well as their caregivers, are largely covered in the development of the intelligent drinking system. The use of the documentation analysis method, as well as several different survey methods for the primary and secondary target groups, and the Cultural Probes method form a comprehensive data material, which clearly identifies the needs of the user groups by data fusion and structuring and greatly facilitated the design of the drinking system.

In the current technical implementation phase, the requirements generated from the results have been implemented as far as technically possible, and the resulting first prototypes (mock ups) have been subjected to further testing by the clients.

Thus the drinking system can be used as a supplementary aid in the future to prevent dehydration in old age and thereby it can be used in a low-threshold manner as a contribution to the management of chronic diseases. Consequently, elderly people are supported to live autonomously in their own homes, and help by caregivers can be targeted.

ACKNOWLEDGMENT

This research is sponsored by the Austrian research promotion agency (FFG) under grant number 856166. Projectpartners are: MIK-OG (Austria), Schorm (Austria) and acquinet ristec (Germany).

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 ISBN: 978-1-61208-565-4