Interactive Drinking Gadget for the Elderly and Alzheimer Patients

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Abstract. With this contribution we want to give insights into the development of a drinking gadget which is useable by the elderly and dementia patients with the goal to create an automated drinking protocol. Through the literature and available smart cups, we deduced important strategies for the design of a drinking aid. Our natural solution is integrated into the daily workflow, hence enables the caregivers to react to the needs of the elderly without additional burden. Therefore, we identified some key requirements for both user groups. Furthermore, we integrated aspects of expandability with software, a vision of rich interaction between user/gadget and focused on the convenience during the daily usage to reach the elderly and caregivers alike.

Keywords: Dementia · Alzheimer patients · Games for elderly · Gadgets for elderly · Drinking detection · Dehydration · Caregivers · Retirement home

1 Introduction

Reduced fluid intake is an often occurring side effect of aging [1], partly because older persons tend to forget their daily drink. This increases with diseases such as Alzheimer. The result is a threatening and often overlooked risk of dehydration, leading to a higher demand for nursing care. In combination with the shortage of care personnel, missing innovation in the field of elderly care and the demographic change it contributes to the much discussed care crisis [2].

This paper presents various gadgets to motivate and remind the elderly to drink, thereby decreasing the workload of the nursing staff (see Fig. 1).

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Fig. 1. Gadgets for supporting the elderly and the caregivers

The drinking behaviour is improved by the integrated use of these smart gadgets with games designed especially for elderly people. We developed a combination of smart sensors and feedback mechanisms to build up a detailed protocol of the patients' fluid intake. Our method detects and internally counts the amount of liquid consumed by patients, thereby providing an overview of the hydration state for the nursing staff. Several gadgets for elderly people have been developed at chairs from the Technical University of Munich (TUM), supported by chairs from the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) as part of the project *enable* [3].

2 Reasons for Dehydration of Elderly People

In 2016, 120.107 people in Germany (all age groups) had to be treated in hospital because of dehydration and 5.217 died during their stay [4]. The number of cases increased drastically since the year 2000 and a high percentage of those people are older adults [5]. There are many known reasons for this situation. Table 1 lists such reasons, classified into *Psychological factors*, the *Aging process* and *Situational factors*. Since this can be a cause of death, generating a better understanding is important [6,7].

Impaired vision [8], functional impairment [9] and cognitive impairment [9] through typical, age-related diseases like Alzheimer's are influencing the drinking behavior noticeably [5,10]. Crawley and Hocking [11] wrote a guide for elderly care listing influencing factors due to which dementia patients can be malnourished. Sufficient liquid is needed to have a balanced blood flow such that it can carry away waste and transport nutrition. Furthermore, there are cancer types (e.g. bladder cancer) which occur more frequently when people do not drink enough [12,13]. To support the liquid intake, fluid rich nutrition sources such as yoghurts, soups, vegetables and fruits should be incorporated in the daily meal menu [11].

For elderly people, two main reasons exist for insufficient water intake [5]:

Table 1. Reasons for dehydration, white background for elderly in general and blue background especially for Alzheimer patients

Psychological factors	Aging process	Situational factors
Depression	Diminishing thirst sensation due to decrease in taste and smell [5]	Wounds (e.g. after an operation)
Forgetting the task: *Doorway effect/location updating effect,* entering a new room/performing another task and forgetting the first one [5]	Chronic disease	Medication: Excreting additional water [6]
Anxiety/Confusion: E.g. Worrying about money, fear of incontinence [7]	Functional impairment: Chewing and swallowing	Communication to caregivers
Changing mood: Skipping multiple meals	Limited mobility	Climate change: Heat waves [7]
Distraction, then leaving the table without reason	Decrease in kidney function	Diabetes mellitus
Appetite changes rapidly and changes aren't communicated to the caregivers	Natural decline in memory capabilities	

1. They forget the intention to drink because their prospective memory is unable to connect properly with other necessary brain areas to remember the action.
2. The sensation of thirst may be altered, as during the aging process or disease development, the responsible area in the brain may not function the same way as before.

In summary, dehydration is a cause of morbidity, resulting in increased mortality rates [5,6]. In consequence, drinking protocols were introduced in nursing homes.

3 Drinking Protocols in Nursing Homes and the Requirements for Change

To ensure a healthy daily drinking volume, the German law demands for the documentation of the liquid intake in the form of a drinking protocol in nursing homes. Yet, thus far, there are no regulations on how to measure the liquid intake [6]. The drinking protocols are still handwritten in most cases and the liquid intake is just estimated. This leads to multiple issues. Kreutzer et al. [6] have researched the accuracy of estimating the water intake by the care personnel in a nursing home environment. Even when focusing only on care personnel with experience in measuring liquid levels on a daily basis, the measured volume was by 10% off on average. Taking a sequence of unfavourable estimations into consideration, improvement is urgently necessary. As the number of patients per caregiver in nursing homes is growing and people start to be aware of the disadvantages of handwritten, estimation-based drinking protocols, the need for higher efficiency and automated documentation to maintain the necessary healthcare [14] is growing. Automating the drinking protocols opens new opportunities, such as more time available for interacting with the elderly or instant feedback, e.g. when there is a critical shortage in fluid intake.

A number of basic requirements exist. Studies show a deficit of assistive technology, suited to the daily life of those being assisted. Automation requires gadgets capable of measuring the fluid intake. Many disabled people don't own the necessary equipment for their personal needs [15]. Appropriate infrastructure needs to be ubiquitously available, integrated into the daily routine. It must be distributable and affordable. Furthermore, it must be understandable and acceptable. New technology allows to solve challenges, but constantly adapting to this ever occurring change is hard for some groups of society like the elderly [16]. There must be motivating incentives for the elderly wanting to use the technology.

4 Assistive Technology for Activities of Daily Living

Personal assistance via caregivers and technological assistance through equipment are the two options to counter age-related decline symptoms, which hinder continuing the Activities of Daily Living (ADLs). Assistive Technology (AT) is used to maintain or improve capabilities of cognitive, physical or communication for disabled people [17,18]. In the form of smart devices and *Environmental Interventions (EIs)* such as modifications of objects in the home environment, AT can reduce the burden on caregivers, lower care costs and most importantly improve the independence of the elderly [15,19]. Over time various concepts and devices have been developed, but only a small number of them focuses on drinking and eating habits [19]. Furthermore, many AT devices deal with ADLs, but leave out modern technology based solutions or focus just on monitoring movement [2]. Many forms of AT exist.

Assistive Technology for Information and Communication Technologies (AT ICT) is defined as devices that help a person with disability to process information in various forms. These can be devices to overcome perceptual decline like seeing aids or to support ADLs such as calling a person for support with the overall focus on using some sort of information and communication processing unit [20].

Intelligent Assistive Technology (IAT) extends AT with an integrated computing capability and the option to transmit information in a network (similar to AT ICT). An IAT device is most often used to sense the environment, process the data and inform the user, if there is a benefit (*intelligent decision making*). To maximize the adoption of IAT, a user-centered design approach is beneficial. Through this approach, the needs, preferences and limitations of patients are the foundation of design decisions and extensive testing is performed over the entire development process. Ienca et al. [17] categorized existing IAT with respect to six points of interest: *Technology type, application, function assisted,* *user-centered design, primary target-user population* and *evidence of clinical validation*. The most common form of IAT with 148 findings in their study, was technology designed to support dementia patients with ADLs. They identified, that only around 40% of the identified IAT is based on user-centered concepts. Missing user focus, high observed drop-out rates and small sample-sizes, which lead to a slow translation of IAT into the actual usage. Another common area of IAT development found by Ienca et al. [17] were robots. Besides daily support with household activities, social and emotional support in the form of assistive companions could be identified as a trend in future IAT development. Because of various, changing needs, "a holistic and multi-level support" [17, p. 1336] for the users is beneficial. IAT can become an ubiquitous trend in dementia care. There is an urgent need to translate innovative technology to *care-oriented IAT* to benefit the elderly and their caregivers alike.

Brain-Computer-Interaction (BCI) can be categorized into three application types: *Communication, functional control* and *entertainment*. Since disabled people and the elderly cannot fully benefit from traditional AT due to motor disabilities, BCI can be extended to generate hybrid systems by combining it with traditional AT, thereby creating hBCI systems. Those intelligent, interactive concepts should be based on helping people to interact with the system, motivating them to use the system by integrating enjoyable experiences. Through *self-adaption* the user can choose when to interact with the system and what kinds of interactions are necessary. Millán et al. [20] experimented with BCI to support disabled people with new interaction possibilities by incorporating the outside world.

Wearables are technology directly worn by users (not just carried), possibly integrated into their clothes. They hence represent the most closed-up form of non-invasive human-computer interaction [17]. A recent example is the use smartwatches to monitor users' health parameters and behavior at home [21]. This concept is quite frequently used to support dementia patients by combining multiple devices and an intelligent computing unit (IAT) to a wireless sensor network (smart home applications). This allows to give feedback for actions and improves the orientation and safety of the person [21]. Other concepts focus mainly on measuring health parameters or detecting tumbles by the elderly [2]. Lutze et al. [22] detected various parameters with a smartwatch to categorize ADLs and react with feedback if necessary. A similar concept was used by Zimmermann et al. [10] who used Internal Measurement Units (IMUs) with acceleration and gyroscope data to classify the movement. Their goal was to detect the drinking activity and the amount which has been drunk with the help of a smart cup. Vidya et al. [23] even suggest a cup which can compensate for the handshaking of Parkinson patients.

Biomedical and Health Informatics (BMHI): The goal is to optimally use the available medical information acquired directly from the patient (biomedical signals), often in combination with a ubiquitous solution (e.g. wearables such as smartwatches). Providing this kind of assistance at home is still a challenge due to the limited availability of devices with interfaces usable for the elderly or disabled. For that reason, during the development of so called *Digital City Frameworks* the target is to create technologically-supported environments for assistance of the elderly [24].

Serious Games are games that convey more than only entertainment content. They are complemented by concepts of Gamification which add gaming elements to non-game applications [26]. For the elderly, recent concepts focus on teaching the elderly to use mobile devices and apps. Therefore, various *Serious Games* were developed with custom interfaces, personalized concepts and additional motivating elements [27]. The concept of providing "fun" through a game (including challenge, curiosity and fantasy), pertains to the goal of immersing the elderly in the *game flow*. The theory of *flow* by Csikszentmihalyi [28] focuses on the level of engagement, hence the absorption in the current activity, which results in enjoyment without the need of future benefit [20]. With the objective to benefit the elderly in health related challenges or ADLs such as liquid intake, *Serious Games* can become a form of AT, especially, as the mobile devices on which they are running, can be easily extended with additional sensors or wearables.

Prototyping and Do-It-Yourself 3D Printing: With the availability of 3D printers for home usage, the *Prototyping* section for AT purposes increased noticeably [18]. With the advance of 3D printing technology, patient-specific medical aids can be developed [29]. Expensive technologies such as artificial hands can be accessible through 3D printers for more users worldwide. However, in terms of assistive devices for ADLs, drinking gadgets are rarely found. There is only a noticeable interest on printable everyday items, such as pill boxes [18].

The field of AT is diverse. But getting an understanding of the input of calories and amount of liquid intake is up until today a challenge. Obstructive approaches, such as using electrodes in the food or beverage, or the need to constantly wear hardware on the body like cameras, limits the possibilities for a target group like the elderly [31]. A new view on drinking aids seems to be necessary, hence the question for a useful sensor strategy must be researched.

5 Approaches to Liquid Level Sensing

Liquid level sensing is an important challenge with varying requirements in multiple industrial areas. For example, a car fuel tank has strict security regulations and needs to be precise in every situation. On the other hand, a water tank will need an approach which doesn't involve endangering hygiene when having contact with the water. Multiple solutions have been developed and researchers such as Kreutzer et al. [14], Hambrice and Hopper [32] and Lanka and Hanumanthaiah [33] documented their usage. We have structured the most relevant ones into four identifiable strategies:

1. **Movable objects:** A common example would be a floating swimmer. The floating object is attached to a string and swims on top of the liquid. The approach is quite simple with high repeatability, but unreliability and the risk of

a short lifetime because of moving parts. These approaches rely on an object directly moving in the liquid to calculate the liquid level, hence are quite troublesome for the usage in a drinking cup scenario because of hygiene concerns or the danger of swallowing the swimming object.

2. **Distance measurement:** More precisely described, it is the measurement of the delay of the Round-Trip Time for the used waves to travel to the surface and back. A typical example would be an ultrasound sensor. A pulse is sent which hits the surface, bounces back to the emitter as echo and the time needed is measured. A potential challenge is the tilting of the cup which needs to be detected to avoid measuring false values. On top of that, the min/max distance to the surface of the specific module to work correctly needs to be taken into consideration. In terms of usage in a drinking cup, a solution would be to mount it in an extension of the handle cup. But the sensor can come in the way when drinking because of its placement.
3. **Liquid feature:** Liquids have various specific features, which can be utilized or manipulated to measure the liquid level. For example, because liquids are typically conductive, two electrodes inside of the container can measure the conductivity, which increases with a higher liquid volume. This approach usually has a high level of precision [34]. One downside would be the potential issue of varying behavior of the sensor readings with different liquids. These approaches aren't based on moving parts in the liquid, but can be influenced by the liquid in the human body when touching the cup. Liquid flow measurement can be a solution too, as shown by Kreutzer et al. [30].
4. **Weight measurement:** A strategy with various types of sensors which all utilize the weight of the liquid, e.g. load cell, where the deformation of the strain gauge can be measured. This category has an advantage because of the fact that there is in general no contact with the liquid itself and any type of cup can be placed on the sensor.

After structuring the found approaches, we further want to compare the various concepts with a focus on using them in a drinking cup scenario. We have chosen *Contact with liquid* as important point because of the hygiene requirement. *Usage of own cup* is based on our experiences in the retirement home, where the elderly people often want to use their own cups or different varieties over the whole day. Another issue is stigmatization, a *Visible modification of the cup* can lead to rejection as the elderly people who still can use common cups, don't want to be seen as requiring help. For that reason, we have created an overview table (see Table 2):

When looking at the various concepts, a "winning strategy" should have no contact with the liquid, the usage of an own cup is recommendable and the modification for the measurement should be as small and inconspicuous as possible. The weight strategy section offers some promising concepts.

Table 2. Liquid level sensing methods

	Measurand	Contact with liquid	Usage of own cup	Visible modification of the cup
Movable objects				
Floating swimmer	Height	X	-	X
Magnetic float gauge	Height	X	-	X
Distance measurement				
Ultrasonic sensing	Delay	X	X	?
Magnetostrictive level transmitter	Delay	X	-	X
Laser	Delay	-	X	?
Radar	Delay	-	-	?
Optical sensor	Current	X	-	X/?
Guided microwave	Delay	X	-	X
Liquid feature				
Conductivity	Voltage	X	-	-
Capacity	Capacity	X/-	X/-	-
Hydrostatic devices	Water pressure	X	-	X
Flow meter	Volume	X	X	X
Vibration	Frequency	X	-	X
Radioactive radiation, obviously not usable	Current	X	-	X
Weight measurement				
Hydrostatic pressure	Pressure	-	X	-
Load cell	Mass	-	X	-
Force Sensing Resistor	**Force**	**-**	**X**	**-**

6 Smart Cups on the Market

Already existing smart cups on the market (see Table 3) are not designed for the elderly or the care environment. They are not easy to use for the elderly, the displays are often too small, and they are not expandable (closed systems). Additionally, most cups are focused on benefitting the user as individual products. They do not provide remote data access and thus cannot be integrated into a nursing infrastructure.

In consequence, we designed our own gadget that is usable by the elderly and can be integrated into our games and apps for motivation purposes. It is open for integration into a diverse ecosystem of gadgets, developed not only by us, but also by external developers.

Table 3. Smart cups on the market

Name/Manufacturer	Selling point	Liquid leveling	Interactive/ Motivating	Suitable for Elderly
Smart Water Cup (VSON)	Reminder, Display, LED	Load cell, Accelerator sensor	Display, App	Display too small
HeyDo (ILOOF)	Reminder, water analyzer, thermometer	Weight	Display	Too big, complicated, hygiene
SPE Hydrogen Generator (AlkaVoda)	Water ionizing	-	Display, App	Too small display for interaction
Ceramic mug (ember)	Heating drinks	-	LED, App	√
Cup (GYENNO)	Reminder	Yes?	Display, App	√ Big screen
Java+ (Ozmo)	Reminder, coffee heater	Yes, Weight	LEDs, gamified app	Too complicated, too big
Smart CUP	Measuring liquid intake	Load cell	Own cup, sound, LED, App	√ made for the elderly
Tumbler (Droplet)	Reminder, measuring drinking frequency	-	Changeable cup, LEDs, sound messages	√ made for the elderly
OBLI	Reminder with app and colorful LEDs	Weight	LEDs, sound, App	√

7 Prototypes

Prototype 1: Cup with an Accelerometer. We used the Development Platform *MetaWear* CPRO by MBientLabs in combination with a 3-axis accelerometer to detect only the drinking gesture. The sensor data was sent to an Android app to compute the tilting angle. Based on threshold of tiltedness we assumed a drinking event. The technical equipment was stored in a double-layered base and had no contact with the liquid (see Fig. 2).

Prototype 2: Cup with an Ultrasound Sensor. We used the ultrasound HC-SR04 module to measure the distance to a surface. The minimum measuring distance for useful values is 2 cm and the maximum distance is up to 4 m with an overall good precision. The sensor was placed at the top of the cup. Furthermore, to

Fig. 2. Prototype 1: Cup with Development Platform *MetaWear* CPRO [25] and an accelerometer

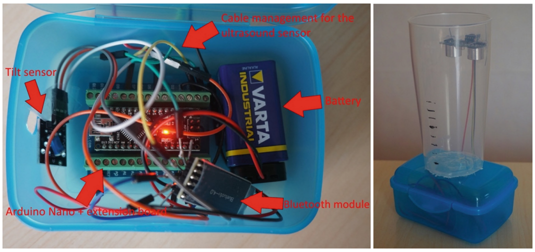

Fig. 3. Prototype 2: Arduino Nano, extension board, Bluetooth module, battery and cable management for the ultrasound sensor and tilt sensor

reliably detect the drinking behavior in contrast to the standing cup situation, a tilt sensor has been integrated (see Fig. 3).

8 The Smart and Interactive Drinking Platform for the Elderly

Based on experiences made with prototypes 1 and 2 during real-world testing in retirement home environments, we derived a set of requirements (see Fig. 4),

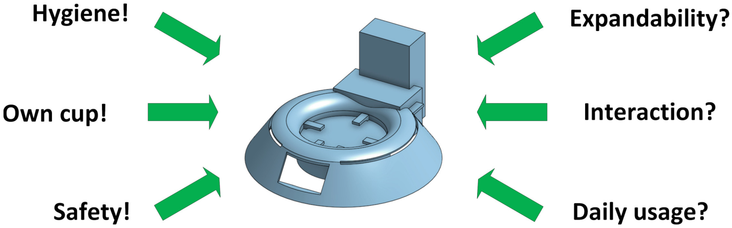

Fig. 4. Requirements for the drinking platform and the challenges which needed to be addressed

resulting in a further prototype. It should have a high level of *Expandability* for the hardware (common microcontroller) and also an open system approach (Bluetooth) for future usage in various applications. We chose a user-centered design approach with the goal of developing an *IAT* solution. The platform should benefit the elderly and additionally, with intelligent design choices, it should be able to support the caregivers in their *Daily Challenges* [17]. More importantly, as described by Ienca et al. [17], only a small amount of *IAT* projects for dementia patients (a substantial focus group for our evaluation) has targeted the reduction of isolation and offered social *Interaction*. We see a unique opportunity for such a drinking gadget (*Expandability*) by incorporating our developed *Serious Games* to further enhance motivation and life quality [27]. We want to utilize BCI concepts to help the elderly people to interact with the system by creating enjoyable experiences (*entertainment*). Another core concept of *BCI* is connected to *self-adaption (hBCI)*, where the user can choose when and how to interact with the games. We extend this with incentives, such as showing a banner now and then to remind the person to drink [20].

For this concept we tackled three base requirements for the design and sensor approach:

- **Hygiene:** Elderly people are very susceptible to disease and hence there are harsh regulations on products designed for the elderly. A daily used drinking cup needs to fulfill the precondition of begin dishwasher safe. From our previous project results and described experience of researchers like Kreutzer et al. [30], we think no sensor contact with the liquid should be an important point when choosing the sensor approach (exclusion of most *Liquid feature*-based and *Movable objects*-based approaches, see Table 2). Sensors inside the liquid, such as electrodes (e.g. conductivity measurement), will be a risk factor for mold and deposits. And as demonstrated by Kreutzer et al. [14], designing a cup with integrated sensors to be dishwater safe, will always be a challenge.
- **Usage of the own cup:** When experiencing the daily routines in a retirement home, it became soon clear, there is a given, small selection of cups and tumblers in use. Furthermore, elderly people are preferring their own drinking cup over a given one, especially if the given cup is different in shape and look than the others. The most obvious reason for that rejection is the perceived stigmatization by the elderly people, e.g. when using plastic cups over regular ones. In terms of usability, the typical smart travel cup concepts (see Table 3) are too big and bulky to be used anyway for the elderly. On top of that, the elderly people have issues to adapt to new behavior and approaches. For those reasons, we want to aim for an approach which incorporates existing cups/drink glasses for a natural approach (understanding of *EIs*), hence strategies which need a more substantial modification of a cup, such as described in *Distance measurement* strategies (see Table 2), are not suitable.
- **Safety:** Another point to consider would be the overall safety for the elderly. Therefore, strategies such as *Movable-objects* in the liquid are not suitable as parts could accidentally be swallowed. Because elderly people often suffer from

motor decline like shaking, they are not able to pick up/put down the cup on a too high platform. Furthermore, the solution should add no additional risk of dropping the glass, e.g. by encouraging a slippery grip around the glass.

With these main requirements in mind, we came to the conclusion to choose an approach with a 3D printed platform (*Prototyping*), where the user will put his glass or cup on top of a sensor stand. This means choosing a *Weight measurement* approach, which would allow us to have no sensor contact with the liquid, people can use their own cups and an inconspicuous design can be created by imitating a traditional beermat. For most elderly people putting the glass on a beermat is a natural way of positioning it on the table, hence we are just extending an existing, socially accepted solution with additional functionality (*EIs*).

Besides these core design choices, the following non-functional requirements exist for the platform:

- **Size of the sensor and components:** A typical glass with a volume of 0.2l has a very limited surrounding for fitting sensors and other parts. Therefore, the resulting solution must be as compact as possible and easy to handle even when the elderly person has to reposition the platform.
- **Appearance of the platform:** To build up some confidence and not to disturb the elderly in their daily life, the platform should be inconspicuous (beermat) and more importantly, only actively interacting when needed.
- **Multiple platforms, one mobile device:** In the retirement home scenario many people are sitting around the table. Therefore, the software part of the platform should support such a situation. To achieve this, we want to have a strategy with a mobile device being responsible to collect the data from multiple stations at once.

When looking at the different sensor choices for our smart beermat, the following approach stands out.

9 A Force Sensing Resistor to Measure Liquid Intake

Inspired by Zhou et al. [31], we chose a Force Sensing Resistor (FSR) to measure the weight changes of a drinking glass. They implemented a dining monitoring system with the goal to pervasively measure parameters like calorie intake. Their approach is based on monitoring the dinning activities through pressure changes on a fabric-based pressure matrix in combination with FSR sensors. Thereby the FSR sensors deliver information about the weight changes. This allowed a detailed composition of the eating activity in comparison to other food measuring techniques, e.g. image-based approach. Overall in their study the pressure measuring concept showed high reliability and usability. For us this approach (see Fig. 5) allows a combination of stability and thinness (with the help of a 3D printed stand and a cardboard beermat on top of it). The sensor's height is only 2 mm and if correctly calibrated, the results can be quite accurate. For that reason, we looked at the sensor data under pressure and when no object is being placed on top of it and plotted one function for each case.

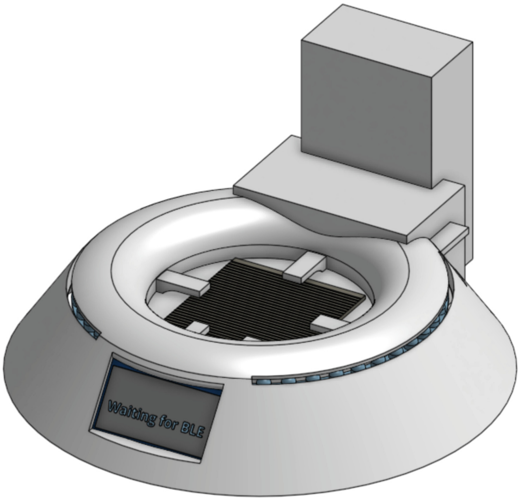

Fig. 5. CAD model with components

10 Situation in the Retirement Home and Platform Integration in the Workflow

To prevent dehydration, a common reason for hospitalization of the elderly [12], a drinking gadget should incorporate typical daily situations in a retirement home.

Day-to-day, elderly people will meet in a living area for eating, entertainment or having a talk with each other (see Fig. 6). There is no room for items which can be damaged through spilled water or accidental force as such incidents will happen frequently. Furthermore, a drinking gadget should be integrated into the environment *(EIs)* in a natural way to enhance the acceptance of the elderly target group. On the other hand, the device should be able to inform the elderly person and/or the caregiver if there is an issue. We thus want to utilize information and communication technology for assisting purposes (*AT ICT*). Another requirement would be to support the caregivers in their workflow, instead of adding additional workload.

For that reason, we will assign one platform to one elderly person for the whole day to collect information about the liquid intake. Thus, as long as the drinking cup or glass stays the same, the weight loss or gain will always resemble the drunken volume by the person. No pre-calibration is necessary. One mobile device (e.g. tablet) is needed as control unit, to which all the individual gadgets connect and send their data. The caregiver can surveillance the drinking volume per station and act if necessary. To incorporate the *hBCI* ideas [20], additional mobile devices can be situationally integrated to increase the mood of a person or sharpen his/her sense for drinking enough liquid with the help of entertaining

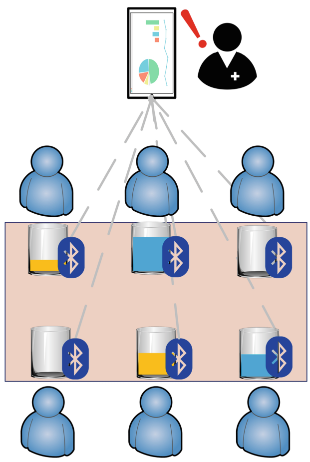

Fig. 6. Multiple cups connected to one device, transmitting data in the background

Serious Games. A trigger for that could be a notification for the caregivers when a person is behind with the liquid intake.

11 Features of the Platform

As described above with this platform approach we want to tackle some challenges found in previous attempts. The result should be an on daily usage focused, interactive gadget which can be integrated in various projects, e.g. *Serious Games*.

11.1 Expandability

We wanted to use a standardized microcontroller and have chosen the Arduino Nano platform. This allows us to extend the gadget with the necessary components and by using the Adafruit Feather nRF52832, there is already a Bluetooth module integrated in combination with a dedicated port for power delivery. With the open nature of the Bluetooth implementation, it is possible to integrate the gadget into various app projects. This often overlooked aspect in commercially available smart cups, can be used to expand the functionality above the predefined one with the help of software developed for mobile devices.

11.2 Interaction

One core aspect, which we wanted to address with this concept, is to create a vision for interaction in two directions. First, by informing the user about an important issue (device $\Rightarrow$ human) and secondly by providing interaction opportunities (human $\Rightarrow$ device):

Fig. 7. Interaction methods in the form of LED stripes and a display

- **LED stripes:** On each side one stripe has been integrated (see Fig. 7), with the specific purpose of displaying information to the elderly with simplistic light patterns. For example, a rainbow pattern is displayed when the glass is taken off the station. The idea behind this is to remind the person of putting the glass back on its place when the drinking process is finished. During the entire process, the pattern will be constantly visible to the person.
- **Display:** The display is a further communication facility of the device (see Fig. 7). It can show information about the status of the gadget. Because of the small screen size, it is suitable rather to the care givers than to the elderly.
- **Serious Games:** The second type of interaction (initiated by the elderly person) occurs through our *Serious Games*. In such games, we pop up a banner which reminds the elderly person of drinking. The gadget then acts as control element and the banner on the screen will only disappear when the weight of the glass decreases, hence the person has drunk. This combination of *game flow* [28] and drink reminder proved to be an interesting incentive for most elderly people in our first study [35].

Conforming to our demand for *Expandability*, the display and LED stripes can be separately accessed via Bluetooth and offer developers the opportunity to send individual commands to the platform.

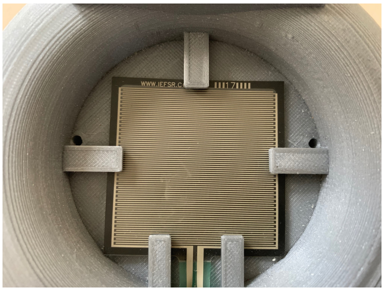

Fig. 8. FSR sensor with mounting solution for the beermat and holes to remove spilled water

11.3 Daily Usage

Besides our focus on the usage of the gadget by the elderly people, we are aware of the routines of the caregivers in a retirement home. Through our experiences, we identified an issue where the elderly people are sitting around the table (see Sect. 10) and over time are changing places. New drinking cups are handed out frequently. In that situation it is difficult to identify the exact drunken volume for each person. We want to solve this issue by not only creating an automated, digital documentation in the background, but also actively assigning one gadget to one elderly person and showing his or her name on the display. This information is more useful for the caregivers, who are normally repositioning the cups and stations for the elderly.

Another concept is to incorporate aspects of security by e.g. having holes at the top of the drinking platform which avoid a flooding of the internal space (see Fig. 8). The loading process of the battery is focused on ease of use with standardized parts to minimize downtime. Three AAA sized, rechargeable batteries are providing all the energy for at least one whole day of continuous usage. The whole gadget has only one physical switch which turns it on and off. When turned on and the mobile device app is open, the connection will be automatically established without the need of doing anything else.

12 Future Work

For the future we want to focus on various aspects to expand our vision of an interactable, smart drinking gadget:

- **Intelligent decision making:** When looking at the understanding of an *IAT* device, the platform already allows us to sense the environment (liquid intake) and to some extend to process the data (safe the data in a structured table). We want to extend this capability with a smart app, which can visualize the information (e.g. graphs), makes decisions and then informs the user, if there is a *care-oriented* benefit [17].
- **Hardware optimization:** Currently the FSR outputs realistic measurements, but it does take 10 s to do so and because of the nature of this sensor, environmental factors can influence the results, e.g. temperature. With the help of a mathematical model behind the sensor readings, more reliability in terms of outliers can be achieved. One particular possibility would be the Kalman-Filter, which can reduce some of uncertainty in the values.
- **Wide-range evaluation:** We already conducted a first study in a retirement home with dementia patients with interesting and promising results [35]. In this scenario we visited the elderly people for some hours per day and played a selection of *Serious Games* while monitoring their liquid intake. We want to conduct a wide-range evaluation with the help of our project *enable* partners from FAU. An important goal would be to satisfy the need of "a holistic and multi-level support" [17, p. 1336] for our device, which should be beneficial for the majority of elderly people.

- **Framework for developers:** For the integration in the developed *Serious Games*, we already created basic functionality to connect to the platform in Unity and access the LED stripes and the display. As we see the importance behind the vision of an expandable gadget, we want to extend the possibility to integrate the gadget in more applications. For that reason, we will develop additional support for more platforms and expand the functionality of the gadget in future iterations.
- **Combining the platform with further AT:** In another line of research of project *enable*, we investigate aspects of the life of elderly people to develop technologically-supported environments [24]. We want to utilize AT, such as wearables, AR and smart home concepts to achieve this. Wearables can collect health parameters (e.g. heart rate) and those can be combined with lifestyle information (e.g. drinking volume) to achieve a better understanding when health issues occur (*BMHI*). Thereby a useful combination of gadgets and software solutions, which combine all the data, can result in a powerful platform. This has the potential to improve the life quality of the elderly and their caregivers alike, the understanding of *care-oriented IAT* [17].

13 Conclusion

Existing smart drinking cups are not suitable for the elderly and on top of that, waste potential by only providing a closed-up system with no option to access the data outside the delivered app. With the help of AT projects in the literature, we identified interesting focus points for the development of such a gadget. We then experimented with various prototypes to gain our first experiences with a new view on drinking aids. The result was a clear vision of daily requirements (*hygiene, usage of the own cup, safety*) and the perceived need of interaction and expandability. We chose a weight measurement approach with an FSR to automatically document the liquid intake of the elderly person. For the design we created a 3D printed platform which mimics a beermat as natural way of placing the glass on the table. In the gadget design we incorporated two LED stripes to signal an elderly person to put the glass/cup back after drinking. A display provides the caregivers with the name of the current elderly person assigned to the cup, hence reducing the work of distributing new ones. We provide Bluetooth access for further interaction possibilities and benefit with motivation concepts in the form of *Serious Games*, which have been overseen in most other drinking gadget projects. When looking at our user study in a retirement home, we can identify the potential of hardware and software being combined to a powerful platform, which is integrated in the surrounding to support elderly and caregivers alike [35].

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The 3D shape has been designed in Onshape (https://www.onshape.com) with an Education license. Thank you to the support team for the permission to publish it. Thank you to the developer team of PDF3D (https://www.pdf3d.com) who made the interactive experience with the 3D model possible.

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