How do older adults living at home experience using MyBeaker and its mobile application?

Hannah van Iterson
Department of Industrial Design, Eindhoven University of Technology
Eindhoven, The Netherlands
h.c.v.iterson@student.tue.nl

ABSTRACT
Older adults are at risk of dehydration, to combat the issue, fluid lists are manually kept by nurses but this process is labour intensive and sensitive to errors. Current technologies that automate this tracking have not been evaluated in terms of user experience. In collaboration with the Maxima Medical Centre and MyBeaker, a user-experience trial was done to investigate the usability and identify design opportunities for the MyBeaker and similar assistive technologies.

This resulted in a set of four themes indicating different field in which MyBeaker must improve. These themes and their respective subthemes are discussed, after which a set of new conceptual iterations for the MyBeaker are presented.

With these new iterations, further research can be done to continue the development of this specific technology, which will lower the workload on nurses and hospital staff and help older adults stay healthy and live independently for longer.

Author Keywords
Assistive Technology; Fluid Intake; Tracking; Design;

CCS Concepts
• Human-centered computing →Human-computer interaction (HCI) → HCI design and evaluation methods → User studies

INTRODUCTION
Between 1980 and 2017 the number of people above the age of 60 has more than doubled [42]. That number is expected to double again between 2017 and 2050, while the number of those over 80 is projected to triple. While a longer lifespan is favourable for many, an ageing population does bring challenges [43]. Specifically in the field of healthcare, as it is expected that a significant part of the older population will need some form of care [16].

A serious issue that is often encountered with those that are already in need of care, is dehydration [15, 39]. It is hard to spot the first symptoms and can have deathly consequences [14], especially for those who already have another condition, e.g. heart issues, impaired vision, functional or any form of cognitive impairment [30, 38, 40, 46]. Older adults have, even without any of the conditions mentioned above, other factors that put them at risk for dehydration [14, 38]. For example, increased forgetfulness combined with a reduced thirst signal can create a negative feedback loop [24, 28, 34]. Once dehydration occurs, there is no strong reactive response of the body urging the person to drink more [37, 39], thus they keep drinking too little. Finally, next to physiological and psychological factors, situational factors might be at play. Medication, climate and the general environment are examples of this [14].

Several methods to provide fluid to patients have been created. However, reviews have shown that there is yet to be found an optimal method of maintaining adequate hydration in older adults [17]. Currently, the best option is a fluid-rich diet, with soup, vegetables and fruits. In combination with this, hospital staff or caretakers keep a ’fluid intake list’ of the patients at risk for dehydration. Doing this is labour-intensive and studies have shown it to be a rather inaccurate way of tracking fluid intake [25, 26].

The Maxima Medical Center (MMC) in Eindhoven wants to look into options in the current food and liquid tracking devices, and invest in future ones. In collaboration with them, this paper will investigate the current user experience and usability of an Assistive Technology (AT) in this field, the MyBeaker [23].

The MyBeaker is a cup that is designed to be used by older adults. It can detect whether a liquid was drunk through capacitive lip detection, and measures the amount of liquid drunk [1, 23]. This information is relayed to an application. The current iteration of MyBeaker is tested on usability and ease of use, as these insights are needed to determine avenues for improvement.

The specific objective of this study was to understand the current experience of the MyBeaker by its expected users. Data for this study was collected using a mostly qualitative approach, combining a field study in which the primary users use the MyBeaker, after which in an in-depth interview with them and their supporting caretaker. Additionally, quantitative data was gathered through the usage of the User Experience Questionnaire (UEQ) [2, 27] for references in future studies.

This resulted in four themes: Reliability & Robustness, Comprehensibility, Look & Feel and Practicality. These themes contain subthemes and important aspects on which the MyBeaker must improve to improve the user experience.

RELATED WORK

Assistive Technologies

The usage of Assistive Technologies (ATs) in the field of healthcare has been proven effective and useful in many fields: ATs can help in communication as well as in cognitive or physical tasks [4, 19]. Through these technologies, older adults can live independently for longer, and the strain on their caretakers is lowered [18, 32]. However, even though caretakers are often positive about ATs, few have been adopted by their intended user group [33], the main reason for this is the lack of insight into the usage in the real-life context.

Cups and beakers

For the challenge of tracking or aiding in fluid intake, many cups, beakers and attachable devices have been brought to the market. Examples of these include the Ozmo [36], Droplet [8], Hidrate spark [21], CupTime [22] and the MyBeaker [23]. There have been early initiatives such as the one by Vessyl [35], which started out promising but failed due to bad investments. Pletcher et al. [38] created a vast overview of products that are or were on the market and their specific features and affordances.

Alternatively, several smart cups have been discussed in academic papers. Liu et al. [31] describe a cup that relies solely on an accelerometer and an algorithm that determines moments at which the user has drunk something. Zimmermann et al. [46] designed a smart cup that can also detect the consumed amount using a force sensor, and an accelerometer and a gyroscope to measure the movement. Similarly, Griffith et al. [10] used a bottle with an attached triaxial accelerometer and a gyroscope to calculate the drinking volume. Bobin et al. [3] present the SyMPATHy specifically for stroke patients that collects information about its orientation, the liquid level and its position compared to a reference target and tremors to aid the patient in rehabilitation. Slightly different in design, but closer to our challenge is the FLUiT design by Habibovic et al. [12]. The FLUit is a 'smart sleeve' that is wrapped around a cup or bottle, and it will use an accelerometer and a touch sensor to detect drinking moments and in combination with gauging the amount of liquid in the container log, the estimated quantity drank.

Applications

Next to beakers and cups, applications are offered as options to combat the issue. Most related work presents mobile applications. Such as 'Remind Me ToRemember' [13], and the Augmented Reality application by Lehman et al. [30]. The former is a novel application of which a pilot study showed promising results in helping older adults to drink more using. Through prompting the users regularly, they were reminded to drink. A simple interface, and a clear task -making a photo of your beverage- helped people stay on task and get a good result. The app by Lehman et al. [30] presents an Augmented Reality (AR) game, which can be played on a mobile phone. It actively engages the user in a game that gives them real-life tasks to do, such as drinking water or taking their medication.

Figure 1. MyBeaker held in hand

While all these technologies look and sound promising, very few are adopted. Some are simply developed as a research tool rather than a product, in others technology is too hard to use for a broad audience, and some do disregard a set of requirements for ATs for older adults [7]. Because of this, it is important to continue research in this field and find what aspects in terms of ease of use, ease of data collection and privacy ATs need to have to increase the rate of adoption amongst the intended user group.

MATERIALS

In this chapter, the specific supplies which were used during the field study and the reasons for using them are described. The materials used for this study are as follows:

1. MyBeaker, with CR2032 battery included
2. Phone with an Android Operating System (OS) 5 or above with the MyBeaker app installed.
3. Charger for the phone.
4. Printed version User Experience Questionnaire.

MyBeaker

The design used in this research is the MyBeaker [1, 23] as seen in Figure 1. It is one of many cups that has been designed to track fluid intake. This cup uses capacitive sensors, in combination with an accelerometer. Using this information, the app can detect whether the liquid was drunk or thrown away and how much it was. The product has the CE marking and is patented, and a small batch of this iteration was produced, which are used for this study.

Phone and the MyBeaker application

Providing the participants with a phone and charger with the MyBeaker during the field study was chosen to ensure ease of use, ease of data collection, and privacy.

Ease of use. By providing the participants with a phone with the application already installed, the participants do not need to spend time or be instructed to install the app.

Ease of data collection. Additionally, the extraction of the data after the study becomes easier, as the researcher can simply pick up the phone and extract the data at home.

Privacy. Thirdly, the personal phone of the participant is not used in the study at all. This separation of phones ensures that no personal data from the participant's accounts are saved during the data collection.

Phone settings and MyBeaker

The MyBeaker and its application communicate via Bluetooth to transfer data from the beaker to the phone where it is saved locally. The app works on Android 4.3 or above because the phones require the ability to connect to the MyBeaker using BlueTooth Low Energy (BLE) which was implemented in that version of the OS [6]. Using phones with Android 5 ensures that the phone has the soft- and hardware needed to connect. iOS, the OS created by Apple, is not an option because the application can only be downloaded as a .exe, which cannot be installed on iOS. The phones were prepared with a clean installation of the latest Android OS available for the given device.

UEQ

The UEQ [2] is provided to the participants on paper. The paper version is always added to the set of materials the participants get, to ensure they have the paper, and to serve as a reminder to fill it in at the end of the study.

METHOD

Participants

Criteria for selecting the subjects were as follows: The participant is 75+ years old, has no cognitive impairments (dementia, Altzheimers etc.), and has no severe physiological disabilities. The participant either lives at home, or in a care facility. No other excluding factors were applied.

The study was done with a total of eight participants, including one pilot study. All participants live independently. These participants are labelled A-G and P for the pilot participant.

Caretaker A, the local nurse helping participants A, C, E and G also agreed to share her insights on the MyBeaker.

Field study

Ethics & Privacy. Commencing the study, ethical clearance was sought from the university for which I conduct this research. Once agreed, each participant gained a code in the form of a letter to ensure their anonymity. The small scale of the study allowed for a simple coding system.

Setup. Participants were provided with the set of items as described in Materials. They were then requested to use the MyBeaker in their daily lives for the following three to five (3-5) days, using the cup as if it was the only cup they had, drinking everything from it.

After the usage, an interview about their experience with the cup was done. The interview was semi-structured and asked about the participant' best and worst experiences with the MyBeaker, and how they had felt during the usage.

Analysis. The qualitative data from the interviews was analysed using thematic analysis methods following the example by Guest, MacQueen and Namey [11] as well as Braun [5]. The UEQ will be used as a reference when doing further research on the user experience of new iterations of this or similar technologies.

Experts

Finally, the resulting conceptual iterations of the MyBeaker were presented to and discussed with experts from the fields of healthcare, such as nurses, dieticians, ergo therapists etc. in an open-ended interview in which they could share their insights.

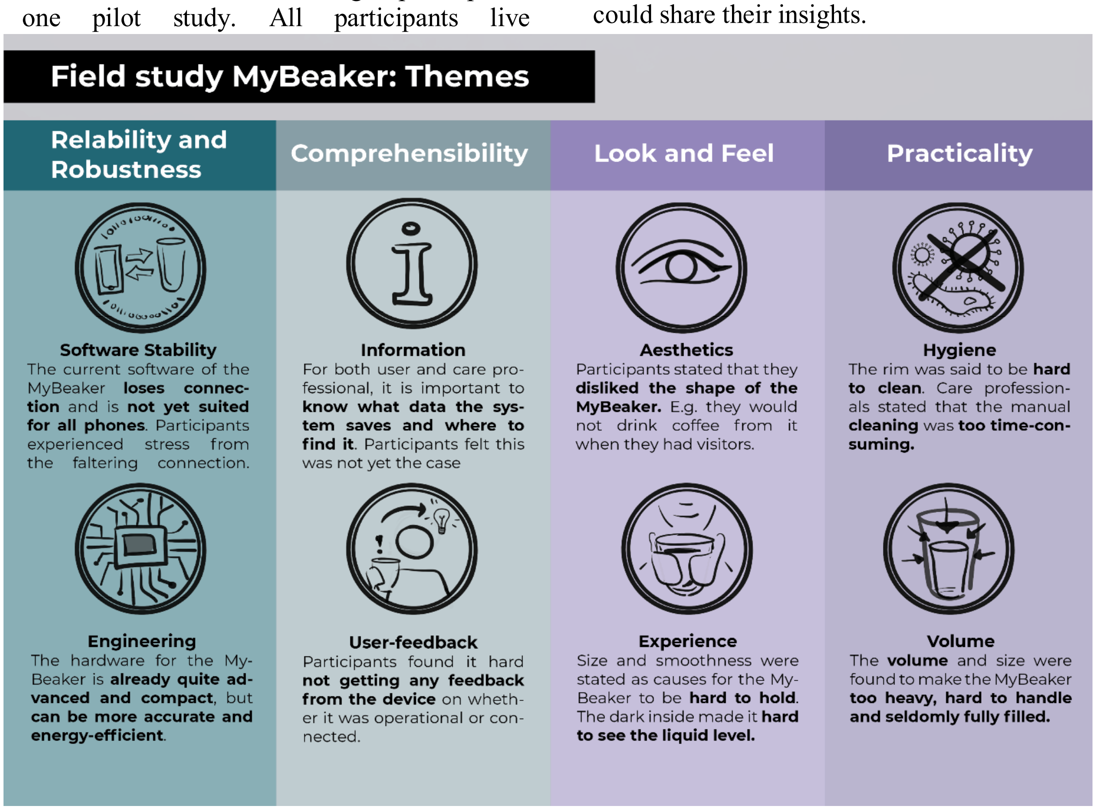

Figure 2. Identified Themes

RESULTS

Using a thematic analysis, the comments of the eight participants were analysed and coded and placed into a set of themes. Using transcription and observational notes from the interviews, four themes were identified.

In the following chapter, these resulting themes, as summarized in Figure 2, are discussed and supported. The results from the UEQ are briefly discussed.

Reliability & Robustness

The theme of reliability and robustness of the system is mostly about engineering issues. The soft- and hardware performance and overall reliability.

Application The MyBeaker app is not yet available in the Appstore. This means that a .exe file must be downloaded from the MyBeaker site, and manually installed. This process caused parsing errors on older devices. Additionally, once installed, the application was hard to navigate due to overlaying, or unresponsive touch boxes. In figure 3, a MyBeaker is connected to a phone (Motorola g6 plus), if one wants to go to settings, the button to access the settings is below an overlay of the upper bar, making the button (nearly) impossible to press.

Connection The connection between the MyBeaker and the application had problems that were noted both by the researcher and the initial pilot tester.

Once the MyBeaker connected, and one navigated to the "Statistieken" (statistics) and after that returned to "Home" the beaker would have been disconnected.

When not interacting with the device, nearly all phones lost connection after approximately 20 minutes. Due to this unreliable connection, it was impossible to gather (reliable) data, an absolute must as a medical device.

The application was tested on the Samsung Galaxy S III Mini, Samsung Galaxy S IV Mini Samsung Galaxy core2, HTC 10, Motorola g6 plus, Samsung Galaxy J5, LG G4. The application installed successfully on Samsung Galaxy core2, HTC 10, Motorola g6 plus, Samsung Galaxy J5, LG G4. Yet only the LG and Motorola proofed to be relatively reliable in terms of the number of app crashes and the connection with the MyBeaker.

Conclusion. The overall reliability of the connection between devices is unstable and needs improvement. The system needs to be able to work on more devices.

Comprehensibility

The theme of comprehensibility is about the understanding of the system. How well could people without training use and control the MyBeaker and app?

Application. The application was shown to all participants. All stated they understood the different screens, but only half of the participants felt comfortable using the app themselves. The study showed however that the app was not easy to use, mostly due to the issues described in

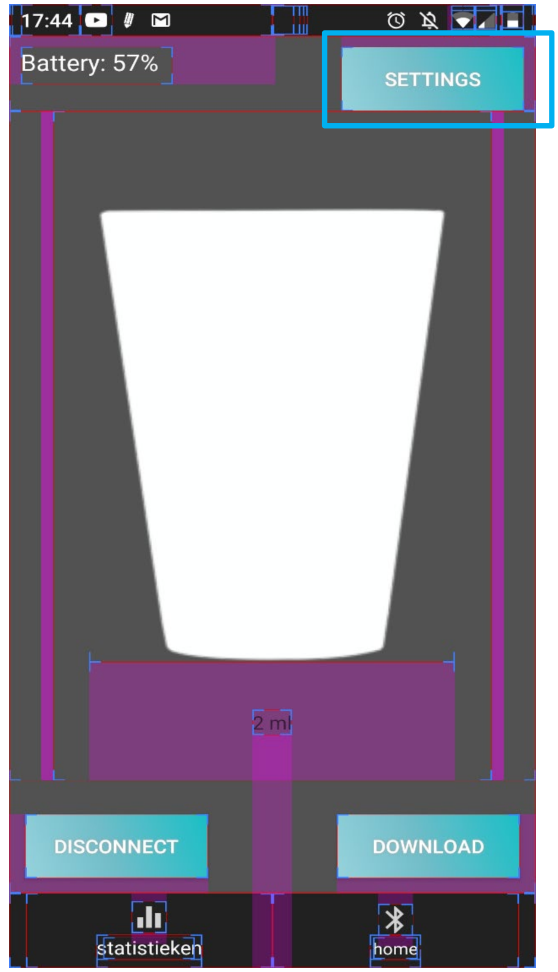

Figure 3. Application

In the statements by Participant A and P, confusion and the disconnect between their mental model and the reality of the system become apparent.

"I found it a bit uncomfortable, I thought I understood the app quite well. The setup [of the app] is in itself rather clear, but somehow I just could not quite use it properly." (Participant P)

"I expected the button to be clickable, but it did not seem to work" (Participant A)

Beaker-app connection. There is an overall lack of feedback from the system to the user. In the moments the connection was functional, there was no indication of successful pairing between the application and the MyBeaker on the physical MyBeaker. Participants B & D stated that they expected such a notification. They even asked if they had missed the signal. This lack of feedback leaves the user confused or annoyed, as it is not clear whether the system is operational.

Conclusion. The lack of feedback from the system, and the software issues in the app, make the system is hard to operate

Look and feel

This theme is about how the MyBeaker feels in the hands of the participants and how they perceive it.

Conformity. The aesthetics of the cup should not result in the feeling of social exclusion. Participants P & E said they could imagine this cup being used in a hospital, but for those living at home, the aesthetic of the cup is not very inviting to use when visitors are over, and often was not used. Participant P explained:

"I just drink coffee during a social gathering, to be 'gezellig' and you just don't quickly get the beaker if everyone is using coffee cups."

If the cup leads to people feeling the cup is too 'different' or stands out too much when with others, the likelihood of them using the cup decreases.

Aesthetics. The aesthetics of the cup does not fit with all drinks. Participant E's quote on the 'ambience' of using MyBeaker:

"I drank some wine from it, and it just does not give off quite the same feeling, say, the ambience is different, it feels less luxurious, even though the wine was good." (Participant E)

Dark inside. The cup must not have a dark inside. There are two reasons for this. Firstly, the dark colour camouflages dirt. As can be read in Figure 5, participant B found the ridges on the inside hard to clean and knew that would get dirty. Secondly, the colour makes it hard to estimate what level the liquid is at. Which is particularly dangerous with hot drinks like coffee or tea.

"I was drinking coffee, and because the coffee is black, and the inside is black could not see where it was, ... so I was constantly thinking, when will it touch my lips, you see?" (Participant A)

When asked about what they would want to see changed, the participants were unanimous in preferring the cup to be see-through.

Rim. The rim of the MyBeaker is uncomfortably thick. All but two participants noted this, the most common reason was the 'feel' of this thick rim. Participant B wrote this down as *"unpleasant that thick rim to drink from, (maybe it is something to get used to)"* (Figure 4)

Lid. The lid is not needed in a home setting, for it was seldomly used by the participants. Participants got annoyed by the lid, as twisting it off often caused the inner cup to also release.

"When I twist off the lid, I often have the in and outside loose in my hands and the lid is still on the inside part of the cup." (Participant G)

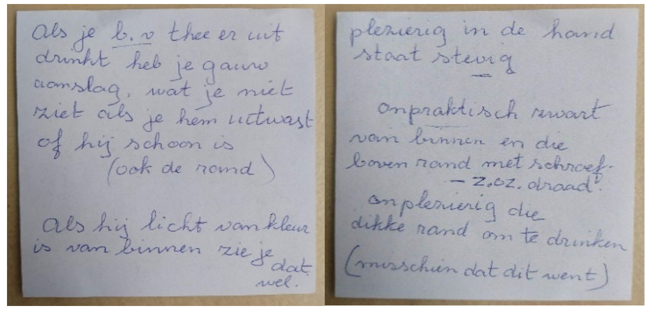

Figure 4. Notes by participant B

Figure 5. Inside view of the MyBeaker

Grip. The MyBeaker in its current form is too smooth and too large to be comfortably held.

Only participants B and P found the cup to be nice to hold. Worth mentioning are the different ideas other participants had to tackle the grip problem they experienced. Participant E wanted the MyBeaker to have the shape of a beer glass, they even provided me with their favourite one to take measurements from. Participant D thought that a relief -in de sculpting sense- of the logo could help give grip. Participant G, who had wrapped a postal elastic around the beaker to increase their grip, suggested creating an elastic sleeve for the cup or attachable handles.

Their wide range of ideas suggests that the lack of grip is an issue to be tackled in future iterations.

Conclusion The look and feel of the cup are too different from the current tableware. The dark inside makes it hard to gauge the liquid level. The lack of grip makes the MyBeaker hard to hold and the rim is unpleasant to drink from.

Practicality
This theme is about the ease of use in daily life and how this product gets integrated into the social practices.

Size / Volume. Closely connected to grip is the volume, a large volume makes the cup heavier and thus harder to hold with insufficient grip.

The current version of the MyBeaker is too large. All participants disliked the volume. This could be deduced from the comments on decreasing the size. The majority of the participants (6/8) mentioned either cut the volume by half (from 500 to 250 ml) which is closer to regular glass (200-250ml) or make the cup the size of that of a soda can (330 ml). Reasons given for this ranged from the grip and grip strength to reducing weight and waste of drinks not being finished. From the interviews, it also became clear that some people seldomly filled the cup.

"*I cannot remember if I ever filled the cup full to the rim. I often just poured a cup of coffee and then transferred it to your beaker (MyBeaker)*" (Participant C, A agreed)

Battery change. The task of changing the small CR2032 battery is too difficult for the intended user group and too time-consuming for their caretakers. Participants noted that with their lessened fine motor skills and sometimes deformed fingers it was nearly impossible to change the battery. Additionally, many feared breaking the electronics in the process. Caretaker A, the local nurse helping participants A, C, E and G stated:

"I was curious to see what this device did, and -Participant C- asked me to take a look because the cup was not working, but I had to shake the battery out"

Dishwasher safety. The MyBeaker cannot be washed in a dishwasher. None of the participants found this a particular issue. It should be noted that six of the eight participants did not own a dishwasher. However, for use in a hospital or care home, the system must be able to withstand machine washing.

Additionally, the current MyBeaker contains a lot of ridges on the inner part of the rim. This is a place that is hard to clean, especially when the dirt is hard to see on the black inside.

Caretaker A stated that if they would have to add this task to their already tight schedule, machine washability, or some kind of interchangeable item would be preferable to ensure that the tracking system can be used all day round.

Personalising. In the households where two participants used the MyBeaker, or in hospitals where there are multiple, a form of personalization is needed to keep track of everyone's cup.

While the option of personalization was not mentioned as a key feature, one of the dieticians from Pleyade I spoke with about the new versions of the MyBeaker specifically inquired about the personalising options of the cup. During this, she referred to the paper by Dunne et al [9], in which evidence is shown that by using cups and plates in colours that create strong visual contrasts, patients who do have cognitive disabilities generally drink and eat more. She noted that, if the cup can be changed in colour, techniques from Dunnes paper could be included in the design.

Conclusion. The current volume is excessive. Next to this, maintenance tasks such as cleaning and changing the battery are either time-consuming or hard to do properly. The option of personalization is preferable.

UEQ
The results from the User Experience Questionnaire, can, due to the small number of participants, not lead to statistically significant results. However, in combination with the qualitative results, they can be used to draw a general picture of the User Experience.

Average Score	Seen as more:
-0.375	Annoying
+0.75	Understandable
-0.375	Creative
-0.75	Easy to learn
-0.5	Valuable
-0.5	Boring
+0.125	Interesting
+0.571	Predictable
-0.125	Fast
+0.125	Conventional
-1	Obstructive
+0.125	Bad
+0.5	Easy

Average Score	Seen as more:
-0.25	Unlikable
+0.625	Leading edge
-1.125	Unpleasant
+1	Not secure
0	Motivation/Demotivating
+0.375	Does not meet expectations
-0.286	Inefficient
-0.286	Clear
-0.625	Impractical
-1.25	Organized
+1	Unattractive
0	Friendly/Unfriendly
+0.625	Innovative

Table 1: UEQ results

As can be viewed in Table 1, many of the averages are between +1 and -1. Only when the response is +1 can it be counted as a positive impression, -1 for a negative impression [2,27]. Thus, from this questionnaire, we can cautiously conclude that the current MyBeaker is seen as more obstructive than supportive, more unpleasant than pleasant and more unattractive than attractive.

Combining these results with the qualitative results discussed earlier, the obstructive and the unattractiveness are both most likely directly related to the

difficulty of using the system. As discussed in the themes Look & Feel and Practicality, the cup was seen as hard and unpleasant to drink from, hard to clean, and for some hard to hold and handle. This all most likely contributed to the unpleasant score. Consequently, when a product is hard to integrate into daily life, the system becomes unattractive for the potential users.

The negative score in the segment of “security” or “familiarity” also implies that people feel uneasy using the system, which will most likely also play a part in the feeling of unpleasantness using the system.

Interestingly, the system is seen as organized. A possible reason for this could be the clarity that participants stated the application gave when not taking into account the current software limitations. Yet this is unclear.

Finally, When looking ahead for further development, the neutral score in (de)motivating is interesting. Development of this Assistive Technology might want to venture into possibilities of having the system motivate the user to drink. However, this is only possible once the more practical design developments have been completed.

Conclusion. The results from the UEQ are in line with the findings through the thematic analysis of the interviews. The scores themselves cannot be statistically analysed to create a definitive answer, but do suggest an overall negative impression of the current version of the MyBeaker.

PROPOSED REDESIGNS

Based on the results, I propose three possible other shapes of this fluid-intake technology.

MyBeaker 2.0

This design (Figure 6) is most closely related to the current version. The most profound changes are as follows.

Practicality: Volume. The volume is changed to 250 ml. Made of plastic, the cup is very light and is not easily broken (packaging).

Practicality: Hygiene The connection between the inner and outer parts of the cup must be strengthened by creating a different screw-on connection, preferably at the top of the beaker. This can be made be tight enough to also aid in making the cup waterproof.

Aesthetics: Lid. The lid of the cup is removed, removing the ridges on the inside of the cup to ease cleaning.

Aesthetics: Experience. The inside of the cup is light.

Comprehensibility: User feedback The system must indicate that the cup is connected. The simplest way to do this is to utilize LED lights in different colours to signal the Beaker being on, off and connected. Preferably more research is done on this specific topic.

Figure 6. Small MyBeaker

Figure 7. Technology Sleeve on a glass

Figure 8. Glass MyBeaker

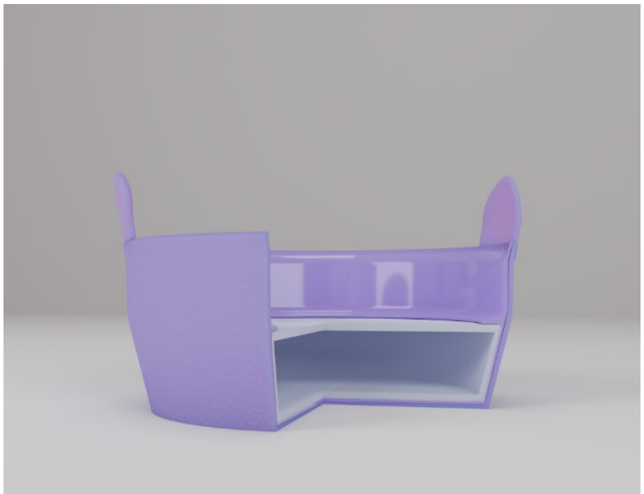

Figure 9. Technology Sleeve cut-trough

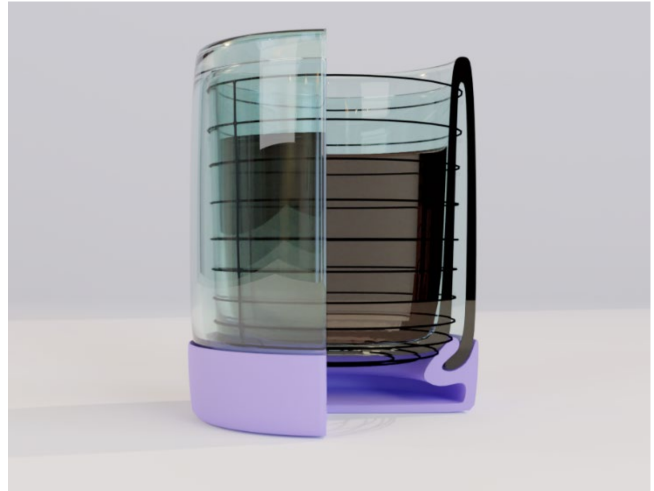

Figure 10. Glass MyBeaker cut-trough

Technology sleeve

This design is a sleeve that contains the technology which can be placed at the bottom of any glass (Figures 7 and 9).

Aesthetics: Experience. A range of cups and glasses can be used in combination with this iteration.

Practicality: Hygiene. The sleeve can be removed from the glass or cup when it needs to be washed. Still, the seal using a simple food wrap [20] is right around the bottom of most glasses with a diameter of 4.5-5cm. Tight enough for the seal to be waterproof. Research should be done to test if this can be recreated with technology inside. Because of the adaptability of this type, it was preferred by both the ergo therapist and dietician I spoke with. They both work with patients who aim to go back home or are still very much aware of their environment. Being able to use this technology with their own tableware would lower the threshold to keep using it. Additionally, when a glass breaks, the MyBeaker sleeve can simply be placed on a new one.

Comprehensibility: User feedback. Depending on the glass, the system could show light through the bottom of the glass, or use a sound or small outside light to indicate being off, on or on and connected. Preferably more research is done on this specific topic.

Reliability & Robustness: Engineering. Because there is no simple option to use capacitive touch, this system could measure the weight of the cup instead, and estimate the amount of liquid.

While this option is easier to implement and still allows the sleeve to be used on any cup, it brings the issue of needing a base measurement of the weight to which the sleeve is connected. It should be done quick and implicitly, otherwise, it would require additional action, which is not preferred. Research should be done to investigate whether this is handy and wanted in a routine.

Without capacitive touch, the drink-detection also becomes more difficult. To tackle this issue, a simple classification model can be trained to identify whether a liquid has been consumed or not. Initial tests of creating such a model are promising, but creating a full working model falls out of the scope of this study.

Glass MyBeaker

This glass version of the MyBeaker (Figures 8 and 10) is a more complex version of the Technology sleeve. The glass is double-walled and capacitive touch wires are embedded in the glass, and make contact with the electronics situated in the bottom of the glass.

Reliability & Robustness: Engineering. Expert Gert Bullée at the Glasmuseum Leerdam states copper embedded or encased in glass is possible. According to him, most metals bring tension in the glass, but with copper this is minimal. He redirected me to an expert who creates scientific glassware, who will be able to share further insights.

Practicality: Hygiene. The silicone seal should be made tight enough for the seal to be waterproof. Research should be done to test if this can be recreated with technology inside, and what form of silicone would be suited for this. Glass is easy to clean

Comprehensibility: User feedback. The system can show light through the bottom of the glass. Preferably more research is done on this specific topic.

General requirements

Handles. A dietician and aphasia therapist noted that for future designs, the possibility of adding handles to the cup would allow for the cup to be used by more people in the user group of those who do have some form of cognitive disability.

Lids. Additionally, the aphasia therapist from Pleyade advised against lids that ask for the user to drink from one specific side of the cup. In her experience, these are seldom used, as most intended users are unable, or find it difficult, to do this.

Still, the option to add a lid is beneficial for patients who are bedbound, as they have to drink laying down, and this is most easily done using a straw that is secure in a lid.

Intake-detection. Whereas lip detection seems to be an innovative way of tracking fluid intake, it is hard to make it work in many types of cups. Additionally, it limits the design of this device to a beaker. Other avenues of detecting whether the user has or has not drunk the liquid in the cup can be explored. One of these that I took the liberty to explore is through a simple machine learning model.

Using classification and a small dataset, I was able to distinguish a drinking motion, from the motion of emptying the cup.

DISCUSSION

The findings of this study are in line with other studies discussing requirements for creating Assistive Technology for older adults [7]. The results from this study are rather specific for the MyBeaker, thus it is yet to be determined if the found requirements are useful in other settings.

While this study has provided some valuable information that can be gained to further the development of the MyBeaker, it was limited by time and with the number of participants. A longitudinal study, with more users, could result in more insights into the integration of the MyBeaker over time. This will also give more insight into any social influences the system might have for people living at home applicable for using this technology.

While all participants for this study were all in the intended age group of 75+ and fitted all the exclusion criteria, they are different from patients in a hospital or care home. The aesthetics of the MyBeaker may be less important for people who are actively trying to recover from an illness or who have some form of cognitive disability. Their goals are immensely different. Therefore, the next iterations of the system should be tested in more care intensive settings such as care homes and hospitals.

This study mostly relied on the insights of the older adults drinking from the cup. However, if the MyBeaker is to be used in more intensive care settings such as hospitals, the nurses and other healthcare professionals must also be able to easily interact and extract the information they need from the system. In further research, their needs and goals will need to be investigated, as the ease of use for the nurses and other caretakers may weigh heavier than the views of the patient e.g. in intensive care.

Furthermore, this research focussed on the physical part of the MyBeaker, the design and the ease of use. The application, hardware inside the cup and the software running on the microcontroller in this hardware should also be addressed when further developing the MyBeaker.

CONCLUSION

This study set out to understand the user experience of the MyBeaker by its intended user group and identify design opportunities for the next iteration of this assistive technology.

From the findings, a set of four themes were identified: Reliability and Robustness, Comprehensibility, Look & Feel and Practicality. These themes each suggest a set of aspects that need to be changed to improve the usability and overall user experience of the MyBeaker. These include but were not limited to: a change in size and colour, a need for user feedback and clarity in communication and finally practical needs such as ease of cleaning and maintenance.

Using the findings, three conceptual iterations for further development of the MyBeaker were presented. These concepts were further iterated upon after comments from experts in the fields of healthcare and manufacturing. Lastly, the iterations and the highlighted needs for change were provided to the MyBeaker company, which they can use in the continuation of their design process.

The scope of this study was limited to the use of the physical MyBeaker, further work for this AT would have to be about specific parts of the system, e.g. the application or the user feedback the system provides. Another limitation of this study was that the MyBeaker was only used by healthy older adults living independently. Because the MyBeaker is intended to also be used for those who are in hospital care, future work should be conducted to validate if these findings are generalizable to this user group.

ACKNOWLEDGMENTS

I want to thank the experts from Pleyade who were involved in this project who did not wish to explicitly be named but did want to share their professional insights.

I want to thank Gert Bullée from the Glasmuseum in Leerdam for his full tour of their workplace and the insights he shared on the glass-blowing process.

I want to thank Erik Jansen from the MyBeaker company for providing the MyBeakers to work with and for allowing me to help him further the development of this interesting assistive technology.

I want to thank Anja Mantelers and Tijmen Stroeken for their enthusiasm in this projects and their aid in the search for participants to participate in this study.

I want to thank Panos for his knowledge and his guidance through this project.

Finally, I want to thank all the participants who helped me conduct this research.

REFERENCES

[1] 2020. INTELLIGENT DRINKING CUP. https://nl.espacenet.com/publicationDetails/biblio?FT=D&date=20200909&DB=&locale=nl_NL&CC=EP&NR=3704998A1&KC=A1&ND=4

[2] Jörg Thomaschewski Andreas Hinderks, Martin Schrepp. 2018. User Experience Questionnaire. https://www.ueq-online.org/

[3] Maxence Bobin, Margarita Anastassova, Mehdi Boukallel, and Mehdi Ammi. 2018. Design and study of a smart cup for monitoring the arm and hand activity of stroke patients. IEEE journal of translational engineering in health and medicine6(2018), 1–12.

[4] Erin Buehler, Stacy Branham, Abdullah Ali, Jeremy J. Chang, Megan Kelly Hofmann, Amy Hurst, and Shaun K. Kane.2015. Sharing is Caring: Assistive Technology Designs on Thingiverse. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems(Seoul, Republic of Korea)(CHI '15). Association for Computing Machinery, NewYork, NY, USA, 525–534. https://doi.org/10.1145/2702123.2702525

[5] Victoria Clarke and Virginia Braun. 2014. Thematic analysis. In Encyclopedia of critical psychology. Springer, 1947–1952.

[6] Android Developers. 2020. Bluetooth low energy Android Developers.https://developer.android.com/guide/topics/connectivity/bluetooth-le.html

[7] Guy Dewsbury. 2001. The social and psychological aspects of smart home technology within the care sector. New Technology In The Human Services14, 1/2 (2001), 9–17.

[8] Droplet. 2019. Dementia Aids and Alzheimer's Products for Improving Health: Droplet. https://www.droplet-hydration.com/hydration-aids/dementia/

[9] Tracy E Dunne, Sandy A Neargarder, PB Cipolloni, and Alice Cronin-Golomb. 2004. Visual contrast enhances food and liquid intake in advanced Alzheimer's disease. Clinical Nutrition23, 4 (2004), 533–538.

[10] Henry Griffith, Yan Shi, and Subir Biswas. 2019. A Container-Attachable Inertial Sensor for Real-Time Hydration Tracking.Sensors19, 18 (2019), 4008.

[11] Greg Guest, Kathleen M MacQueen, and Emily E Namey. 2011.Applied thematic analysis. sage publications.

[12] Mirela Habibović, Eva Broers, Jordi Piera-Jimenez, Mart Wetzels, Idowu Ayoola, Johan Denollet, and Jos Widdershoven.2018. Enhancing lifestyle change in cardiac patients through the Do CHANGE System ("Do Cardiac Health: Advanced New Generation Ecosystem"): randomized controlled trial protocol. JMIR research protocols7, 2 (2018), e40.

[13] Katherine Hackett, Sarah Lehman, Ross Divers, Matthew Ambrogi, Likhon Gomes, Chiu C Tan, and Tania Giovannetti.2020. Remind Me To Remember: A pilot study of a novel smartphone reminder application for older adults with dementia and mild cognitive impairment. Neuropsychological Rehabilitation(2020), 1–29.

[14] Sandy Hamilton. 2001. Detecting dehydration & malnutrition in the elderly.Nursing31, 12 (2001), 56.

[15] Kirsty Hart, Rachel Marsden, and Jenny Paxman. 2020. Generation of thirst: a critical review of dehydration among older adults living in residential care. Nursing And Residential Care22, 12 (2020), 1–12.

[16] Thomas Haustein and Johanna Mischke. 2016. https://www.statistischebibliothek.de/mir/receive/DEMonografie_mods_00003349

[17] Brent Hodgkinson, David Evans, and Jacky Wood. 2003. Maintaining oral hydration in older adults: a systematic review. International journal of nursing practice9, 3 (2003), S19–S28.

[18] Helen Hoenig, Donald H Taylor Jr, and Frank A Sloan. 2003. Does assistive technology substitute for personal assistance among the disabled elderly? American journal of public health93, 2 (2003), 330–337.

[19] Marcello Ienca, Jotterand Fabrice, Bernice Elger, Maurizio Caon, Alessandro Scoccia Pappagallo, Reto W Kressig, and Tenzin Wangmo. 2017. Intelligent assistive technology for Alzheimer's disease and other dementias: a systematic review. Journal of Alzheimer's Disease56, 4 (2017), 1301–1340.

[20] IKEA. 2021. ÖVERMÄTT Voedseldeksel, set van 3, silicone veelkleurig. https://www.ikea.com/nl/nl/p/overmatt-voedseldeksel-set-van-3-silicone-veelkleurig-80417311/[21] Hid

[21] Hidrate Inc. 2020. Smart Water Bottle - HidrateSpark Bluetooth Water Bottle + Tracker App. https://hidratespark.com/

[22] IngDan. [n.d.]. Cuptime. https://en.ingdan.com/projects/cuptime/

[23] Erik Janssen. [n.d.]. My Beaker. https://www.mybeaker.nl/

[24] Eleni Kanasi, Srinivas Ayilavarapu, and Judith Jones. 2016. The aging population: demographics and the biology of aging. Periodontology 200072, 1 (2016), 13–18.

[25] Joachim F Kreutzer, M Pfitzer, and Lorenzo T D'Angelo. 2013. Accuracy of caring personnel in estimating water intake based on missing liquid in drinking vessels. In2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). IEEE, 4682–4685.

[26] Joachim F Kreutzer, Stefan Ramesberger, Samuel MF Reimer, Konrad Entsfellner, and Tim C Lueth. 2015. Automatically detecting fluid intake using conductivity measurements of beverages in a cup. In2015 IEEE International Conference on Automation Science and Engineering (CASE). IEEE, 1546–1551.

[27] Bettina Laugwitz, Theo Held, and Martin Schrepp. 2008. Construction and evaluation of a user experience questionnaire.In Symposium of the Austrian HCI and usability engineering group. Springer, 63–76.

[28] Risa J Lavizzo-Mourey. 1987. Dehydration in the elderly: a short review.Journal of the National Medical Association79, 10(1987), 1033.

[29] Chris Lefteri. 2016.Making it: manufacturing techniques for product design. Laurence King Publishing.

[30] Sarah Lehman, Jenna Graves, Carlene Mcaleer, Tania Giovannetti, and Chiu C Tan. 2018. A mobile augmented reality game to encourage hydration in the elderly. In International Conference on Human Interface and the Management of Information.Springer, 98–107.

[31] Kai-Chun Liu, Chia-Yeh Hsieh, Hsiang-Yun Huang, Li-Tzu Chiu, Steen Jun-Ping Hsu, and Chia-Tai Chan. 2020. DrinkingEvent Detection and Episode Identification Using 3D-Printed Smart Cup.IEEE Sensors Journal20, 22 (2020), 13743–13751.

[32] William C Mann, Kenneth J Ottenbacher, Linda Fraas, Machiko Tomita, and Carl V Granger. 1999. Effectiveness of assistive technology and environmental interventions in maintaining independence and reducing home care costs for the frail elderly: A randomized controlled trial. Archives of family Medicine8, 3 (1999), 210.

[33] Hui-Fen Mao, Ling-Hui Chang, Grace Yao, Wan-Yin Chen, and Wen-Ni Wennie Huang. 2015. Indicators of perceived useful dementia care assistive technology: caregivers' perspectives.Geriatrics & gerontology international15, 8 (2015),1049–1057.

[34] M. Naitoh and LM Burrell. 1998. Thirst in elderly subjects. The journal of nutrition, health & amp; aging2, 3 (1998), 172- 177. http://europepmc.org/abstract/MED/10995062

[35] Mark One. 2014. https://web.archive.org/web/20140613032828/myvessyl.com/

[36] Ozmo. 2020. Smart Water Bottle That Integrates With Fitbit: Ozmo! https://www.ozmo.io/

[37] Paddy A Phillips, Barbara J Rolls, John GG Ledingham, Mary L Forsling, James J Morton, Morgan J Crowe, and Leopold Wollner. 1984. Reduced thirst after water deprivation in healthy elderly men. New England Journal of Medicine311, 12(1984), 753–759.

[38] David A Plecher, Christian Eichhorn, Martin Lurz, Nadja Leipold, Markus Böhm, Helmut Krcmar, Angela Ott, DorotheeVolkert, and Gudrun Klinker. 2019. Interactive drinking gadget for the elderly and Alzheimer patients. InInternational Conference on Human-Computer Interaction. Springer, 444–463.

[39] Barbara J. Rolls and Paddy A. Phillips. 1990.Aging and Disturbances of Thirst and Fluid Bal-ance.Nutrition Reviews48, 3 (03 1990), 137–144.https://doi.org/10.1111/j.1753-4887.1990.tb02915.xarXiv:https://academic.oup.com/nutritionreviews/article-pdf/48/3/137/24086145/nutritionreviews48-0137.pdf

[40] Merin Thomas. 2020. Why is dehydration a problem in older patients and care home residents? Nursing Times116, 8(2020), 45–48.

[41] Rob Thompson. 2017.Manufacturing processes for design professionals. Thames & Hudson.

[42] Department of Economic United Nations and Population Division Social Affairs. 2017.World population ageing, 2017highlights. United Nations.

[43] David N Weil. 2006.Population aging. Technical Report. National Bureau of Economic Research.

[44] Xiaomi. [n.d.]. Mi Band. https://www.mi.com/global/miband/

[45] Ahmet Yarış and Aybuke Sezgin. 2017.FOOD PACKAGING: GLASS AND PLASTIC.

[46] C Zimmermann, J Zeilfelder, T Bloecher, M Diehl, S Essig, and Wilhelm Stork. 2017. Evaluation of a smart drink monitoringdevice. In2017 IEEE Sensors Applications Symposium (SAS). IEEE, 1–5

APPENDIX I - REFLECTION

Professional Identity and Vision

During my Bachelor, I have found that as a designer, I want my focus to be on the competencies User & Society and Technology & Realisation in the RDD track.

Mostly because I have an interest in the field Human-Technology Interaction (HTI) with a focus on user experience and behavioural change. I value techniques and theory such as implicit information display and in general think a designer needs to take care of the attention and interactions a design asks of the user, as so many things already ask our attention.

Throughout this year, I have been getting a clearer view of what the "usability" of a product in practice entails. Especially this research project showed me how easy it is to overlook practicality and how the user and their needs can be forgotten. This strengthens my belief that including the intended users in your design process is a key aspect of a successful design, and research-for-design process.

Professional skills

Planning & preparation. This project started a little too slowly to my liking, as I had to wait for the briefing from the MMC. However, the focus on paper research and figuring out what was already on the market in terms of the technology paid off later in the process. After that meeting, the project kicked off and I created a new plan which I was able to follow.

This was until the ERB form did not get accepted in time. I was not in a good place emotionally at that moment due to personal reasons, and that did not help me rationalize and rethink the planning for me. I was really stressed out and felt I would not be able to deliver a project of the needed quality to satisfy the project goals or my personal ones.

However, I have learned to adapt and be more flexible. This was mostly possible because I had everything ready and prepared to start with the study, which made it possible to do a lot in little time.

Design and Research Practices

While doing research is not my forte, and not my specific field of interest, I am eager to learn to use my researching skill to do research for design.

This year I have been doing more research projects and while I am certainly learning, I still feel like I am not structured and organized enough in my methods and setup. Doing a research project alone, therefore, felt daunting I find it difficult to set up a research plan that is specific enough that one can answer a question but broad enough to have -somewhat- generalizable results. This research also has results that are probably not generalizable, and I feel like I should hone my skills doing quantitative research as well. I will do this in the following weeks for Researching the Future Everyday..

The results from this study feel very 'logical' in a sense, but it is important to note that even though I could have guessed some of the outcomes of this research, being able to back them up using explicit and more objective data is powerful.

While I would have liked to have had more time to evaluate the data and findings with experts, I do think that the findings I have presented in this paper are valuable for further research and development of the MyBeaker, a process I am eager to further help them with.

Competencies

User and Society This research was all about usability, user-friendliness and ease of use. It touches on the impact it might and should have on society and social practices. The context of use was the key in this research. I started with research to understand the cognition and the needs, followed by seeing and experiencing the device and finally getting into the emotional and social aspects through interviews was quite enriching in terms of trying to understand user experience.

Creativity and Aesthetics While this competency and US overlap due to the changes needed in the form, interaction and aesthetic of the MyBeaker, the further development of the MyBeaker also has an impact in a larger field. As paper research has shown, this type of product has been long-awaited, as the issue of the inaccuracy and workload of the current methods is well known. A good MyBeaker could change the current daily tasks of care professionals significantly. Because of this, I feel responsible for providing the best options for further development.

Technology and Realisation CA brings us to TR. Because the MyBeaker is not yet implementable, I have -in the course of this research project- had contact with a set of professionals in interesting fields for production. Thanks to them, the presented options for further development presented in the paper are all feasible designs. Additionally, these connections will be valuable in the further development and realization of the next iterations of MyBeakers for the next Design Project.

Business and Entrepreneurship As a part of the related works, current existing technologies were investigated. Additionally, as this research is done in collaboration with the company creating the research artefact, I find it important to have a somewhat feasible plan of production for further steps. While only briefly touched upon in an appendix, I did my best to come up with a small map of the possible routes, it is a rough draft that I can build upon.

Math, Data and Computing I want to learn to work with statistics but was not able to do this because of the small scale of the UEQ. I plan to use it in the next part of this project, as well as in the course Researching the Future Everyday.

While working on the conceptual models and the feasibility of the design, I have created a small machine learning model to check if the classification of a 'drinking movement' and a 'throwing liquid out movement' was possible. Thanks to this I was able to validate that this could be an option in these iterations.

APPENDIX II – RELATED WORK OVERVIEWS

In these tables, a set of the currently (in the Netherlands) available fluid-intake tracking devices are shown.

These overviews were used to identify the current market, but also see what the commonly used sensors were, how the notifications were done and at what moments.

This helped me get an overview of what is possible in the field and get an idea of where MyBeaker sat in the field.

Notification triggers > ***AT***	**Timed interval**	**Pick-up measurement**	**Weight measurement**	**Liquid level detection**	**Personalised via app**
My Beaker					X
Ozmo				x	X
Droplet	X				
Hidrate Spark				X	X
Vochtinname regelaar			X		
HeyDo					X
Joseph Joseph dot water bottle		?			?
ULLA (not a cup)	X				

Table 2. Overview of notification triggers in smart cups

Notification method > ***AT***	**Light**	**Vibration**	**Sound**	**App notification**	**Display change**
My Beaker				?	
Ozmo	X			X	
Droplet	X		X		
Hidrate Spark	X			X	
Vochtinname regelaar	x	x			
HeyDo				X	X
Joseph Joseph dot water bottle					X
ULLA (not a cup)	X				

Table 3. Overview of notification methods in smart cups

Sensors > ***AT***	**Weight measurement**	**Pick-up measurement**	**Lip detection**	**Liquid level**	**Liquid type detection**	**Drink detection**	**Proximity sensor**	**Lid removal**
My Beaker		X	X			X		
Ozmo				X	X			
Droplet								
Hidrate Spark				X				
Vochtinname regelaar	X							
HeyDo				?	X			
Joseph Joseph dot water bottle								X
ULLA (not a cup)							X	

Table 4. Overview of sensors in smart cups

APPENDIX III – THEMATIC ANALYSIS & UEQ

Thematic analysis segment

Robustnes Understanding Aesthetics Practicality

Setting up the device

Participant C: "Dus hij is nu verbonden? Oh oke. Krijg ik daar nog een berichtje van?"

Participant A: "Ik denk dat dat daar moet" "En zit daar dan een lampje onder? Om dan te zeggen dat je wat moet drinken of dat je een bericht hebt (van de MyBeaker app)?"

Participant C: "Wat doet het precies? Waarom zie ik niets? Moet ik ergens op klikken"

Later, after approximately 4h of using the Beaker (a call)

Participant A: "He, ik wilde even vragen of het klopt dat de app meteen weer dichtgaat, doet hij het dan? "

Particpant A: "Ik ben blij dat jij het allemaal al hebt ingelogged op die telefoons enzo"

2 days after the start of the study (a call)

Participant C: He, kun je langskomen om het op te halen, we hebben het wel een beetje gezien. We hebben wat notities, als je langskomt hebben we het erover.

Interview after the study, interesting quotes:

"Ik snap niet wat de app nou moet toevoegen"

"Ik drink meestal koffie voor de gezelligheid, en dan pak je toch niet zo snel zo'n beker als iedereen met kopjes zit.".

"vorm kan beter, kleine handen maken het vasthouden moeilijk.

"het is glad, ribbels zouden debeker makkelijker vast te houden kunnen maken?

"koffie en thee blijven goed warm"

"Ik heb liever een doorzichtige beker, dan kun je beter zien hoeveel erin zit. "

"… kofie is zwart en omdat dat zo is en de binnenkant ook vond ik het lastig om te zien waar de koffie begon en de mok eindigde, de hoogte van het drinken was niet zo makkelijk te zien"

"Ik vond het wel ongemakkelijk, ik dacht de app goed te snappen. De opzet (van de app) is best opzich wel duidelijk, maar op een of andere manier kon ik er niet mee opweg."

"ik had de deksel erop, dacht dat dat moest"

"als de beker omvalt loopt het meteen leeg door dat gaatje in de beker"

Als je de binnenbeker vastdraait en dan de deksel erop doet dan is bij het openen de binnenbeker vaak makkelijker weer los

"als je b.v thee er uit drinkt heb je gauw aanslag, wat je niet ziet als je hem uitwast"

"Als hij licht van kleur is van binnen zie je dat wel"

"plezierig in de hand, staat stevig"

"Onplezierig die dikke rand om te drinken, maar misschien dat dat went"

UEQ results

Average	Average -3 – 3	Seen as more:
3,625	-0.375	Annoying
4,75	+0.75	Understandable
3,625	-0.375	Creative
3,25	-0.75	Easy to learn
3,5	-0.5	Valuable
3,5	-0.5	Boring
4,125	+0.125	Interesting
4,571	+0.571	Predictable
3,875	-0.125	Fast
4,125	+0.125	Conventional
3	-1	Obstructive
4,125	+0.125	Bad
4,5	+0.5	Easy
3,75	-0.25	Unlikable
4,625	+0.625	Leading edge
2,875	-1.125	Unpleasant
5	+1	Not secure
4	0	Demotivating
4,375	+0.375	Does not meet expectations
3,714	-0.286	Inefficient
3,714	-0.286	Clear
3,375	-0.625	Impractical
2,75	-1.25	Organized
5	+1	Unattractive
4	0	Unfriendly
4,625	+0.625	Innovative

Table 5. Results of the UEQ

APPENDIX IV – ITERATION & EXPERTS

Figure 11. Sketches of iteration 1

Iteration 1: Glass with embedded wiring

Shown in Figure 11 are some first sketches of the iteration in which copper would be embedded in the glass to allow liquid level detection, and possibly lip detection technology.

This idea was presented to a glassblower and artisan (Gert Bullé) at the Leerdam Glasmuseum. He was open to showing me around the museum and share his insights on the design and the overall idea. He explained that the the expansion coefficient of copper and the GLASMA type glass they use there is close enough together to embedded copper in the glass without creating too much tension in the glass (what could cause it to break).

Figure 12 shows an example of a glass and copper reaction which is stable. The copper, because of reactions between the metal and the glass gets an interesting reddish colour once the material has cooled.

However, their creation process is mostly artistic, thus every item they create is slightly different and it is not the ideal way to mass-produce items.

He redirected me to a lampworker, who specialised in working with glass tubes to create items. Double-walled teacups are produced by these specialised glass blowers, thus a possibility may lie there. Next to the ability to create larger amounts faster and more precisely, the type of glass used for these items is boron-silicate glass, which is more durable and currently the standard for the average drinking glass.


Figure 12. Photo of the reaction between copper and glass

Iteration 2

The second iteration of iteration 1 adds a sleeve (Figure 13), which is attached at the bottom. The tech inside must have a connection to the wiring inside the glass. According to the glass expert Bullée this is possible if the glass and the copper have relatively the same expansion coefficient, otherwise, some room must be kept to account for this, but he stated that the Lampworker would know more.

In case the embedding of the copper is not possible, this design could still be made feasible with another way of tracking the content of the cup. Along with a way to track if the fluid has been drunk or not.

The detection of the amount of liquid can be done using weight measurement. This has been done by other, similar 'smart cups'.

The drink detection can be done by creating a classifying machine learning model, which can identify between the movement of someone drinking and the movement of someone throwing liquid away. As I have some knowledge-creating these types of models, I created a simple one using example code from the course Interactive Intelligent Products, edited and tested it. Results of this can be seen in Figure 16.

The datasets use a set of recorded movements of drinking (label A), throwing water away (label B) and holding the cup (label C). The data 'recordings' of a movement are explained in figure 14.

The model was tested on an Arduino Nano, and an ESP32. The model is trained using a test and a train set and does not change after it has been uploaded to the device. Naturally, a lot can be improved on this model.

Currently, it used a triaxial accelerometer and only detects the movements correctly when held with the logo facing forward. Therefore, the model is not very reliable, even though it states in Figure 16 that the correctly identified instances are about 80% of the instances.

This problem could be solved by creating a larger, more accurate dataset along with programming the system in such a way it knows how it is held based on its initial position. The latter is currently above my understanding of Machine Learning models, the large dataset is hard to achieve without a lot of people contributing. Further research and testing are needed to see if this is truly a viable option, first tests do look promising.

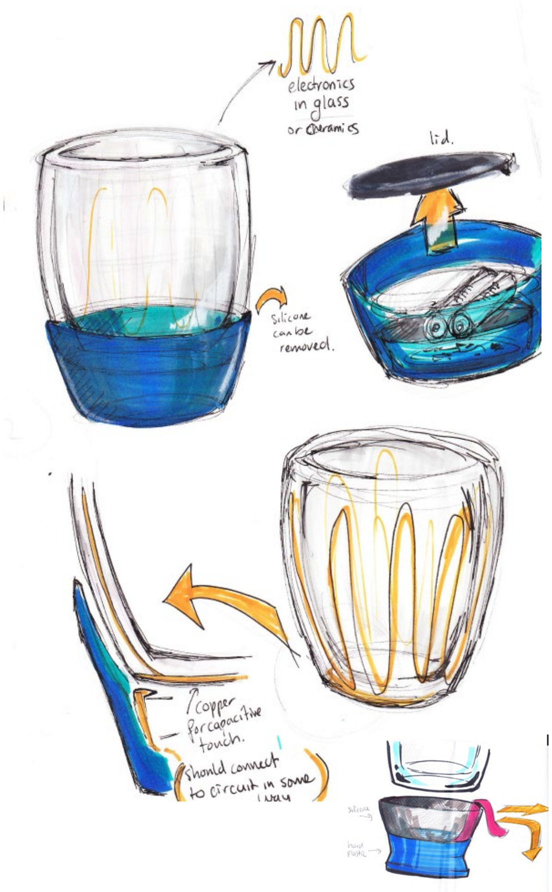

Figure 13. Sketches of iteration 2

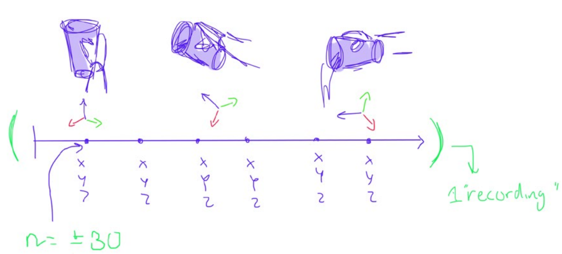

Figure 14. Visual explanation of datacollection

```
Table csvData;
boolean b_saveCSV = false;
String dataSetName = "accDataMyBeaker";
String[] attrNames = new String[]{"x", "y", "z", "label"};
boolean[] attrIsNominal = new boolean[]{false, false, false, true};
int labelIndex = 0;

void setup() {
  size(500, 500);

  //Initialize the serial port
  for (int i = 0; i < Serial.list().length; i++) println("[", i, "]:", Serial.list()
  String portName = Serial.list()[Serial.list().length-1];//MAC: check the printed l
  //String portName = Serial.list()[9];//WINDOWS: check the printed list
  port = new Serial(this, portName, 9600);
  port.bufferUntil('\n'); // arduino ends each data packet with a carriage return
  port.clear();           // flush the Serial buffer

  //Initiate the dataList and set the header of table
  csvData = new Table();
```

Figure 15. Impression of code used

```
Correctly Classified Instances        1883               75.32   %
Incorrectly Classified Instances       617               24.68   %
Kappa statistic                          0.6915
Mean absolute error                      0.2649
Root mean squared error                  0.3533
Relative absolute error                 82.79    %
Root relative squared error             88.3301 %
Total Number of Instances             2500
```

Figure 16. Results of classification model

Iteration 3

Figure 16 shows another iteration, one in which the electronics are embedded in the handle. This handle could then be attached to a cup which would have the copper wiring for the capacitive touch embedded. The connection would be done much like the Xiaomi Mi band charges the device (Figure 17). These forms of connection are waterproof.

As this cup is imagined to be made of stainless-steel as often used for camping cups, the copper can be embedded in the cup, and the issue with the expansion of the metals could be dismissed.

However, as from the study, a strong preference was found for see-through glasses, this idea was abandoned for the time being.

Figure 17: Xiaomi MiBand. [44]

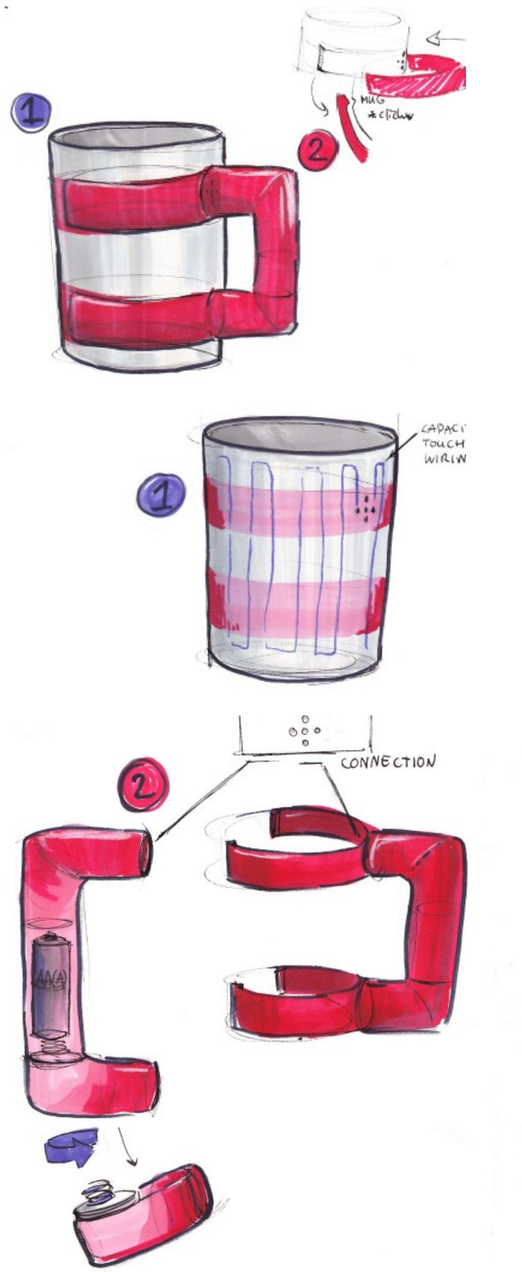

Figure 18. Sketches of iteration 3

Renders of the different iterations

Figure 19. Overview of the Tiny MyBeaker

Figure 20. Overview of the MyBeaker Sleeve

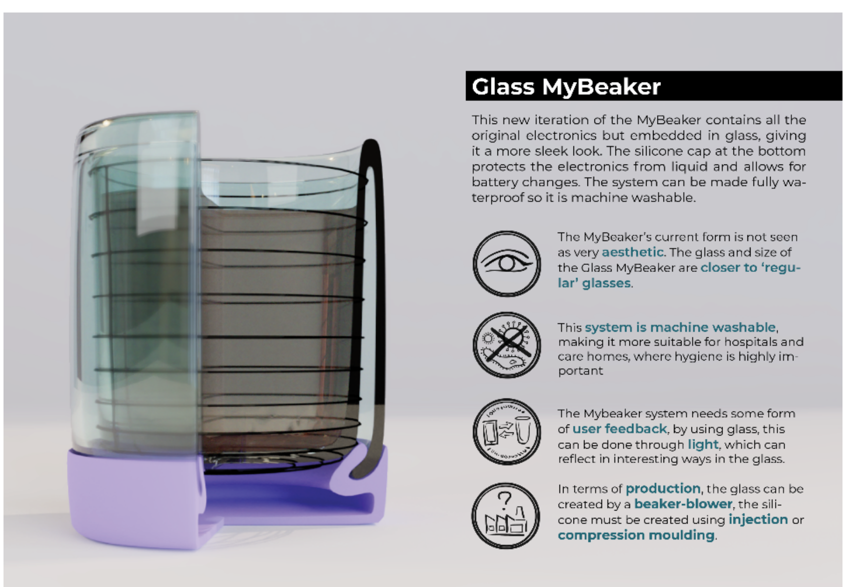

Figure 21. Overview of the Glass MyBeaker

APPENDIX V – PRODUCTION ROADMAP

Information about these techniques is taken from the books Manufacturing Processes for Design Professionals [41] and Making It: Manufacturing Techniques for Product Design [29].

Iteration	Parts	Materials	Production Techniques	Unit price vs capital investment	Overall notes
Small MyBeaker	Inner beaker	ABS/ HDPE/ LDPE	Injection moulding	The unit price for injection moulding is low, but the tools needed often cost somewhere in the 10.000s	As this entire process (apart from the PCB) relies on Injection moulding, the initial investments will be large (10.000-100.000) but after this, many MyBeakers can be created
	Outer beaker	ABS/ HDPE/ LDPE	Injection moulding		
Technology Sleeve	Flexible outer sleeve	Silicone rubber	Dip moulding	Unit price is low and the tools are relatively cheap.	This iteration would also require a large part of the process to be done using injection moulding, which is expensive to start up. However, the silicone outer sleeve which connects to the cup could, if its shape is kept simple enough be drip moulded. This process is cheaper and can be done fast. The electronics box, which should fit in this outer sleeve will have to be injection moulded, and to be able to change the battery, will have different parts, and thus require several moulds. The great advantage of this version is that it can relatively easily be prototyped using existing products.
			Silicone injection moulding	Like injection moulding, the tools needed are expensive	
	Electronics box	Plastic: ABS/PC	Injection moulding	The unit price for injection moulding is low, but the tools needed are expensive.	
Glass MyBeaker	Glass cup	Borosilicate glass	Lampworking	Lampworking has no tooling costs but will have moderate unit costs.	The most complex of the three iterations requiring three different materials for just the casing. Again, the electronics box will need to be injection moulded. The silicone of this iteration is too complex to be drip moulded and thus also requires an injection mould. The glass can be created by a lampworker, but as the copper embedded in this glass is rather experimental, R&D will be needed before any form of production can start.
	Flexible outer sleeve	Silicone rubber	Silicone injection moulding	The unit price for injection moulding is low, but the tools needed are expensive.	
	Electronics box	Plastic: ABS/PC	Injection moulding	The unit price for injection moulding is low, but the tools needed are expensive.	

Table 6. Overview of the production methods for the different MyBeaker iterations