FLOT

Tracking fluid intake with ease

M2.1 Design Project

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CONTENTS

SUMMARY

The following report describes the process of the development of the proof-of-concept system FLOT: a tool that allows for tracking liquid-intake easily.

In this report, I briefly discuss the literature and research which came before this design project. Next, I show the iterations and creation of the sleeve prototype, later to be called Puck.

After evaluating this prototype with medical professionals, the project went from designing a single tracking device to a system. A display part called Hub was added to give data insight. The design choices and creation of this part are described.

Finally, I will briefly touch upon the behavioural and business aspects of this system and give considerations for future steps.

INTRODUCTION

After studying the usability of MyBeaker last semester, I decided to create a new tool, using the knowledge I had gained. As it had become clear through research and talks with medical professionals, how much a tool like this could help. That alone was motivating.

Next to this, this challenge provided me with a set of learning aspects that interest me. multi-user design, behaviour change strategies, technical development are the main three.

In all these areas, I want to grow and develop. For example, I always find framing a challenge quite hard. And this one, with multiple users and a range of scenarios that the item could be applied in, would challenge me in this aspect.

Next to this, this project had behavioural aspects that interested me and allowed me to apply earlier learned knowledge.

By aiming to create the prototype, I expected this project would challenge me to improve my technical skills and develop new ones such as CAD modelling and PCB design. This combination of behavioural, usability and technical aspects felt like a fitting challenge for me as a designer to develop my abilities.

In my previous semester, my development was heavily focused on the honing of skills connected to the Design Research Processes and User & Society competencies, with Technology and Realisation having more of a background role. To balance, I wanted this project to have more focus on the development of technical skills.

RELATED WORKS

In this chapter, I will recap the most important information from my research paper, then discuss more practical related work concerning the design process described in this report. I refer to my research paper for more background information.

TRACKING INTAKE

In the hospital, several types of patients have their fluid intake tracked. Older adults are generally more at risk of dehydration due to factors such as reduced thirst signal and forgetfulness (Hart et al., 2020; Rolls & Phillips, 2009; Hamilton, 2001; Yamamoto & Mori, 2018; Plecher et al., 2019; Thomas, 2020). Heart and (hemo)dialysis patients also benefit from limiting their intake to reduce blood pressure, no matter their age (de Vecchis et al, 2015; Welch & Davis, 2000).

The current method is nurses keeping lists (Dutch: vochtlijsten). These are, however, labour-intensive to fill in and sensitive to errors (Kreutzer et al., 2013; Kreutzer et al., 2015). To combat the issue, specialized cups (e.g. MyBeaker have been created to track the fluid intake of patients automatically (Janssen, n.d.). However, these are not very reliable, nor user-friendly (van Iterson, 2021).

SELF-CARE STRATEGIES

Next to smart devices, there are self-care strategies for patients who need to track to increase or reduce their fluid intake (Welch & Davis, 2000; Hodgkinson et al., 2003). These often require the patient to self-track on paper or via an app (Burke et al., 2005; Dowell & Welch, 2006; Welch et al., 2007). On the Google Appstore, one can find a multitude of examples of self-tracking apps for increasing or regulating fluid intake (Jewell, 2020). Most of these apps, and those used in scientific papers, build on prompts and notifications throughout the day, reminding them to drink (Hackett et al., 2020; Lehman et al., 2018). This doing this effectively is hard, as people respond very differently to push notifications (Bidargaddi et al., 2018).

BEHAVIOUR CHANGE METHODS

There are different ways to motivate a person to change their behaviour. The Trans Theoretical Model (TTM) (Prochaska et al., 2008) explains the different stages of change, ranging from pre-contemplation to maintenance. This model can be used to determine what type of support someone might need based on the stage they are in. From a different perspective, Self-determination theory (SDT) (Gagné & Deci, 2005) provides a set of needs for one to feel fulfilled and have the motivation to change.

TECHNOLOGY

The technology I aim to use in this design uses weight tracking and movement determination using an accelerometer and gyroscope, which have also been used in recent research. Micromovements like sipping and drinking can, by using just a smartwatch, be determined with an estimation error limited to 15%, thus 85% accuracy (Hamatani et al., 2018). A similar study proved a 90-91% accuracy in determining drinking movements (Chun et al., 2019). Research in which an accelerometer was placed in a 3D printed cup also tested the accuracy of tracking drinking movements and showed an 89.92 - 85.88% accuracy using a k-nearest neighbours model (Liu et al., 2020).
Additionally, weight tracking has also been done before using loadcells (Chan & Scaer, 2018). Using load cells, the tracking of a cup can be done within a three-gram error range.

HEALTHCARE DEVICE

Technical innovation in hospitals always seems to catch up slower than in other fields, even though healthcare professionals are often enthusiastic (Safi et al., 2018; Ravitz, 2020). Thimbely (2013) states: the product or tool needs to solve the right problem, there is always a cost for integration, and the question of security and monitoring

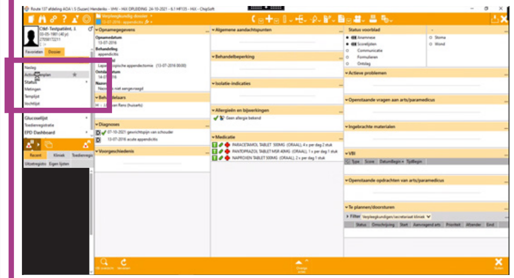
To ease integration for the end-users, I will design the prototype with the suggestions of the paper of Thimbleby in mind. Aiming to create an item easy to use, accurate and considering ethical and monitoring concerns.

CURRENT SITUATION

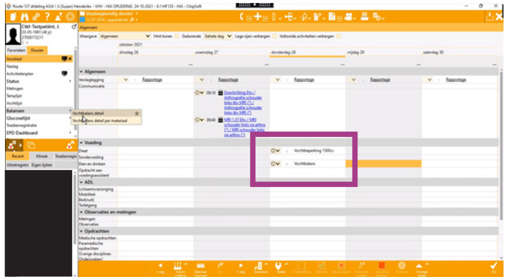
To get a more detailed understanding of the current system, I spoke with Suzan Hendrikx, a nurse from the IC department at the MMC. She is familiar with tracking fluid intake using the Hix system, a widely used patient dossier program, and showed me the entire process (Figure 1).

As can be seen, automating the tracking can remove seven steps for every drink, and another three when a drink was not finished. With only the verification step at the end of the day (+-00:00), the nurse's interaction with the screen with the system is dramatically reduced, and no longer breaks their workflow.

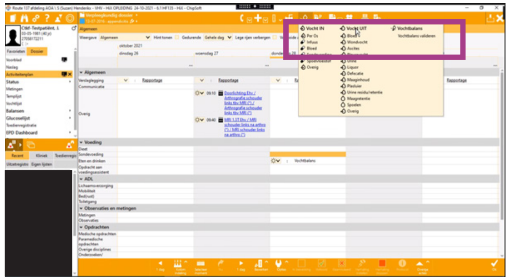
PROCESS 1: FILLING IN LIQUID INTAKE



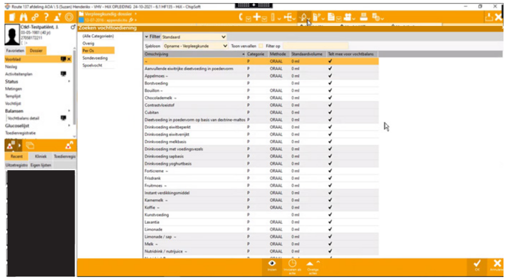
1. On the home screen, go to 'activiteitenplan'



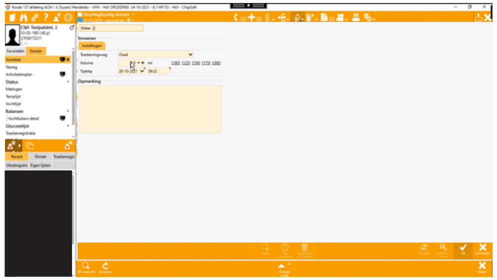
2. Find signalling for fluid tracking



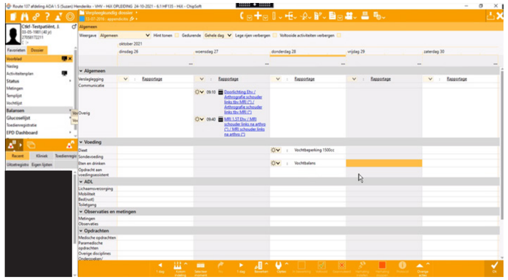
3. Click to fill in fluid in/out



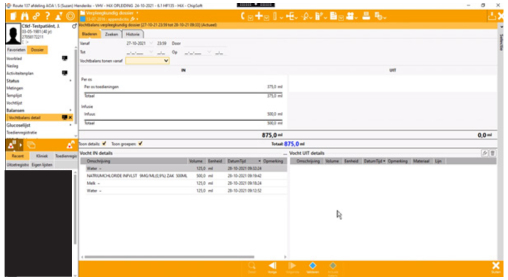
4. Find fluid type



5. Fill in amount drunk (4 fields)

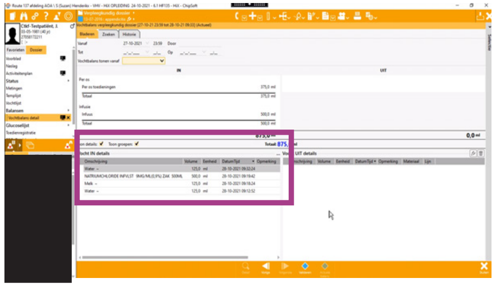


6. Back at activiteitenplan

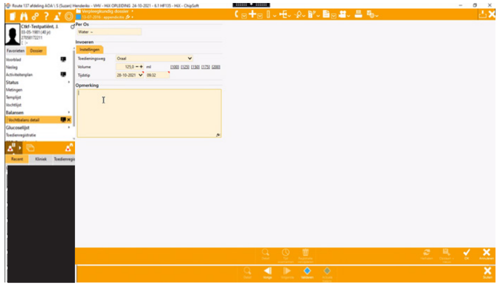


7. Checking total in/out

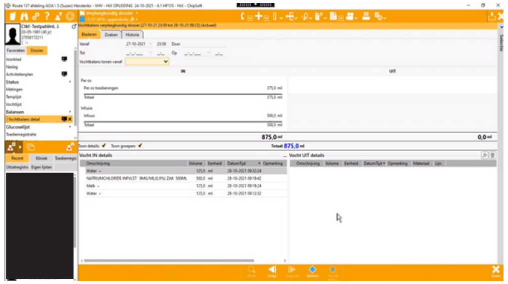
PROCESS 2: CORRECTING LIQUID INTAKE



1-2. Go back to the total in/out screen, find registration that needs correction

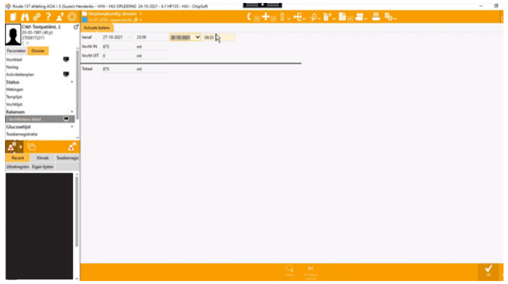


3. Edit the fluid in



4. Checking total in/out

PROCESS 3: VERIFICATION



1-2-3. Go to the verification screen via total in/out and verify the amount drunk this day.

Figure 1. Hix processes.

Figure 2. Mybeaker Sleeve iteration as presented in research.

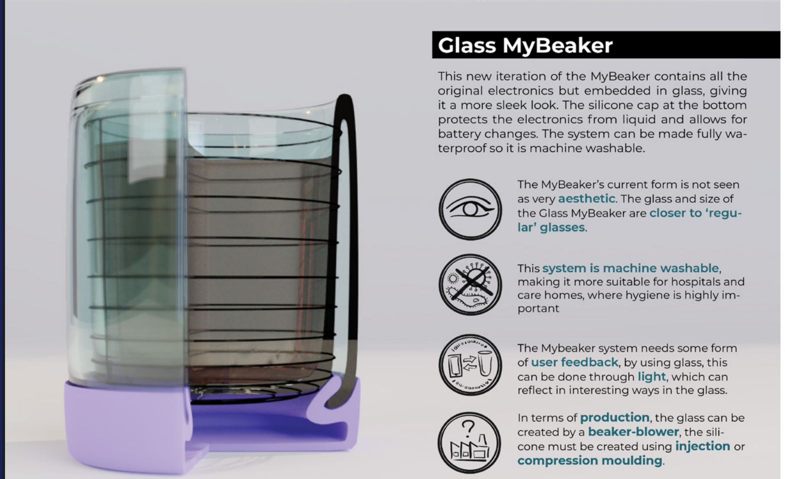


Figure 3. Glass Mybeaker iteration as presented in research.

Figure 4. Tiny Mybeaker iteration as presented in research.

IDEATION & INITIAL REQUIREMENTS

I see most purpose in the sleeve-attachment (for the 3 options see Figures 2,3,4) form for the following reasons:

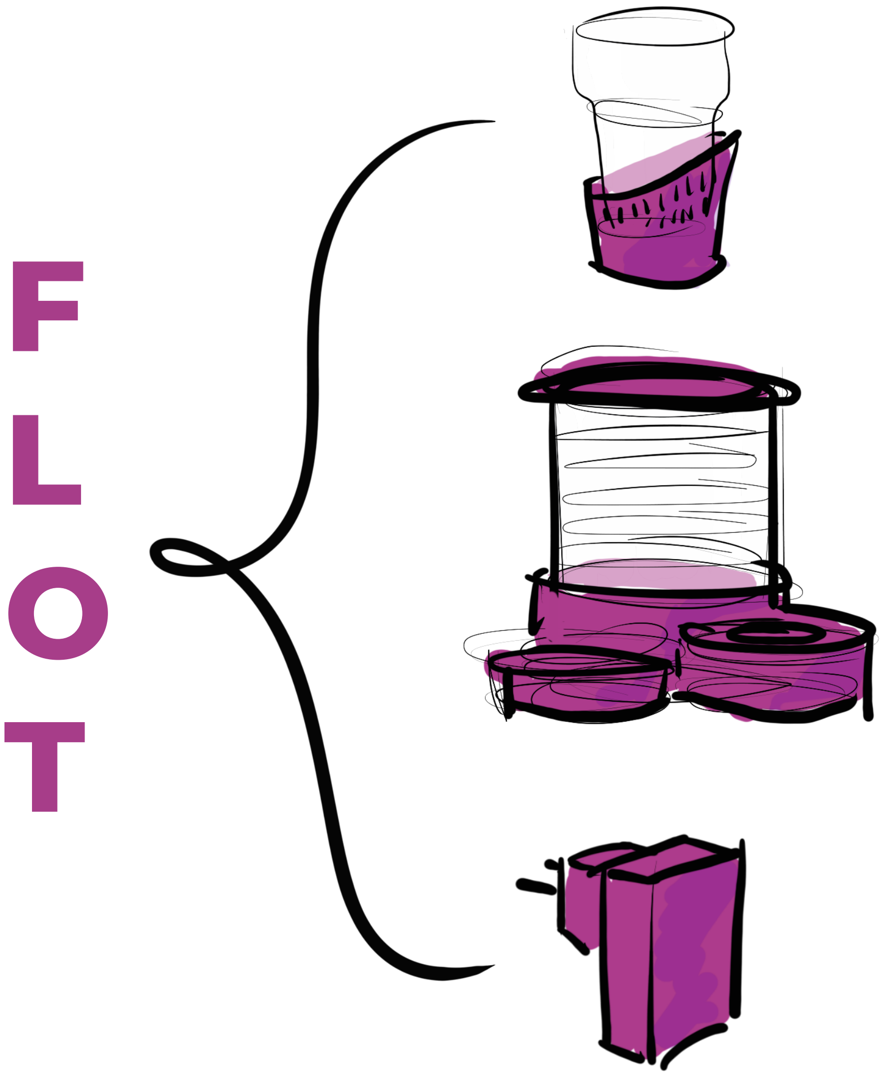
1) Versatility, as it can be attached to several types of cups.
2) Hygiene: the sleeve must be removable so the cups can be cleaned without exposing the electronics to heat and water.
3) Investment for the hospital: Being able to remove the tool means that each patient only needs one.
4) Robustness: should the mug break, the attachment can still be intact, whereas, for the glass or plastic cups, the entire system would have to be replaced.

Because of this, I decided to present this idea to Suzan. She was enthusiastic about this idea and gave some insights into user requirements she would want to see in this system. Using her insights and those from research, I set up the first set of broad requirements.

REQUIREMENTS

SYSTEM		**USER**	**BUSINESS**
HARDWARE	SOFTWARE		
Detect liquid content	Determine the amount drunk / thrown out	Easy to remove & place	Able to produce in mass
Detect motion	Secure data sending	Robust	
Water-resistant		Withstand disinfecting	
Able to send data		Information display	
Rechargeable battery		Lightweight. Cup + content <=600gr	
		Less work than the current system	
		Easy to hold - not to wide	
		If a cup- no thick rims	

FLOT - SYSTEM



FLOT Puck

> Attachable to cup or mug
> Weighs the fluid
> Detect drink/throw away motion
> Sends estimation data to FLOT Hub

FLOT Hub

> Receives data from FLOT Puck
> Charging station for FLOT Puck
> Displays amount drunk using Light
> Can be connected to FLOT Net

FLOT Net

> Connects to local network

> Connects with multiple FLOT systems for data sharing with caretaker/hospital

Figure 5. FLOT System overview.

FLOT - PUCK

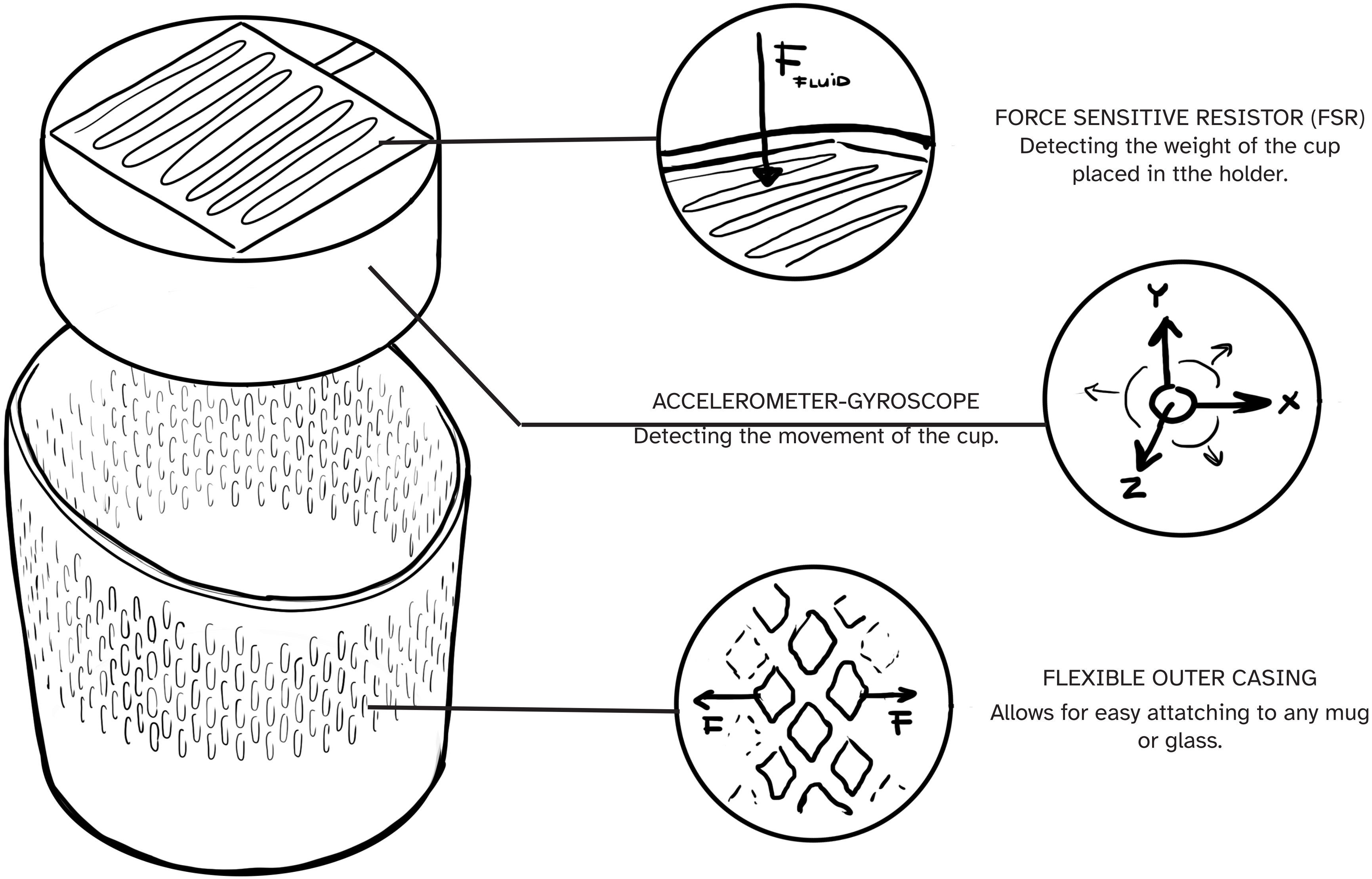


Figure 6. FLOT Puck overview.

FLOT PUCK DESIGN

Puck is based on the sleeve attachment as shown in Figure 2. In the following chapter, I will show the process of how Puck came to be the sensor of the system, sensing, tracking and estimating the amount of liquid drunk, using embedded sensors, and why it is the shape it is.

HOW IT WORKS

The Puck can be attached to the bottom of a cup (Figure 9). While attached, the sensors in the puck detect the movements. When the glass is standing stationary, it measures the weight of the cup using an FSR. Using this information, it makes an estimation of the amount drunk or discarded.

Figure 7. Render of the STL file.

Figure 8. Thanks to the wave-inspired slope, FLOT can also be placed under cups with ears.

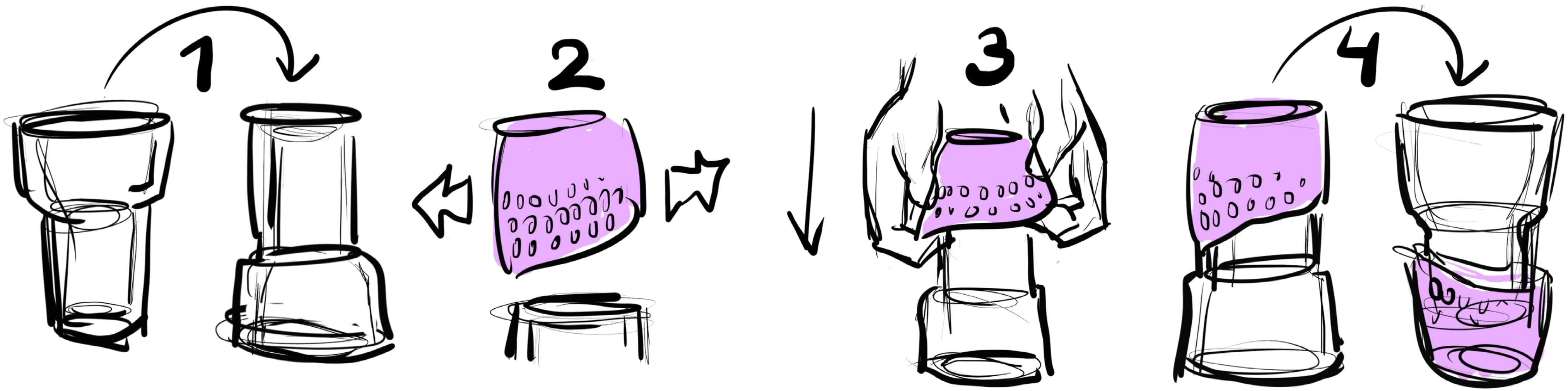


Figure 9. The easiest way to place the Puck on a cup.

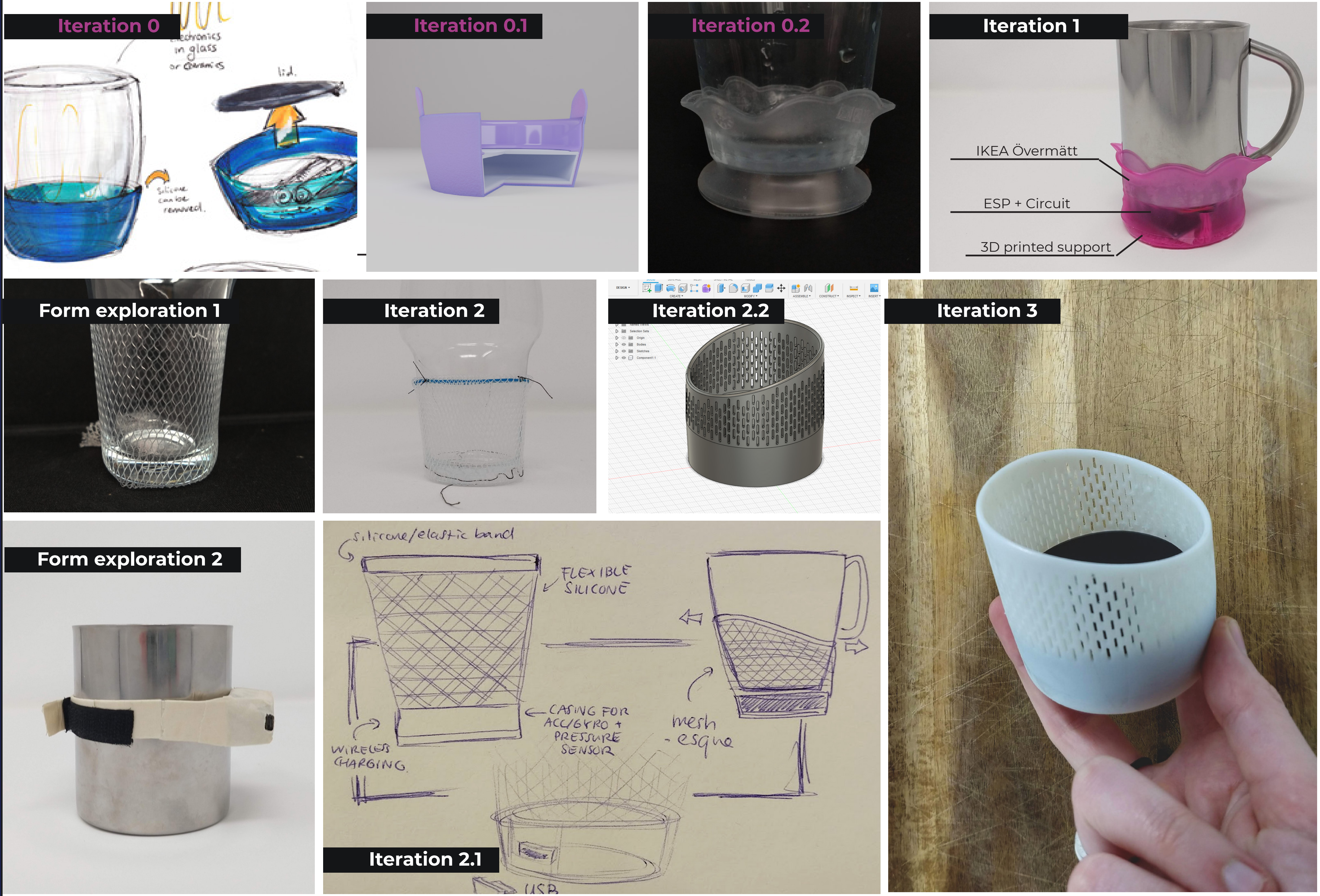


Figure 10. Iteration and exploration process for the form of Puck.

HARDWARE - CASE

In Figure 10, iterations for Puck's shape can be seen. The first three steps, coloured purple, are from my research report.

EVALUATION

Iteration 1, and the exploration forms were presented to two nurses working at the cardiology department of the MMC. They interacted with the prototypes, gave their opinions and told me about their tracking method and helping patients track their fluid intake. The latter will be discussed later in this paper.

During the interaction, they gave comments (Figure 11). In essence, Iteration 1 was thought to be too tough for some older adults to place, and a more flexible material would be prefered. Exploration 1 provided this flexibility. Exploration 2 was quickly disqualified for reasons ranging from the number of steps it takes to put on, to its ability to move around.

Using these insights the following choices were made:
- Placed at the bottom: this is the easiest location for tracking the content and for a secure attachment.
- The outside needs to be cleaned. So either i) the whole puck either needs to be a fully waterproof system or ii) the electronics must be removable so the outside can be washed.

For these reasons, the latest version of Puck consists of two parts: the internal 'electronics puck' and a silicone sleeve around this puck to attach it.

FUTURE STEPS

The next step is having the form poured in silicone and then evaluating the user experience and the robustness of the current model. There currently are moulds being made (Figure 12 & Figure 13).

Figure 11. Medical professionals comments on low-fi prototypes (Dutch).

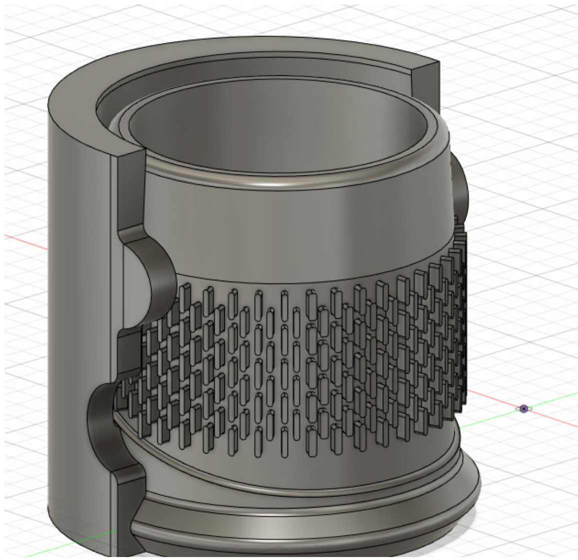


Figure 12. Three-part open-pour mould of which the inner part and one outer part are showing.

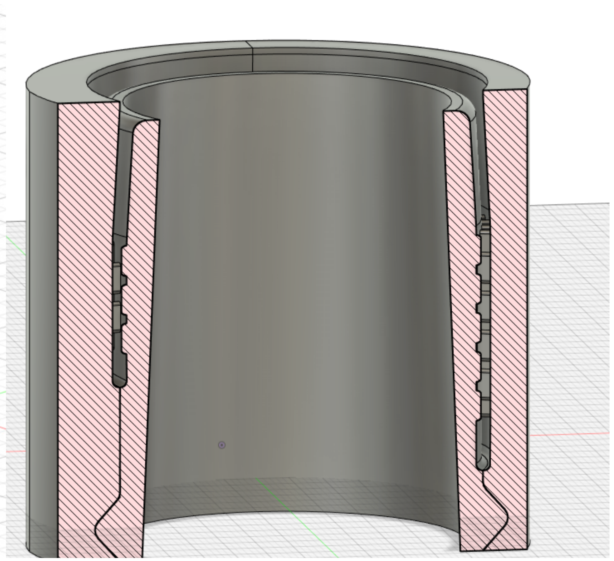


Figure 13. Section analysis showing how the moulds fit together.

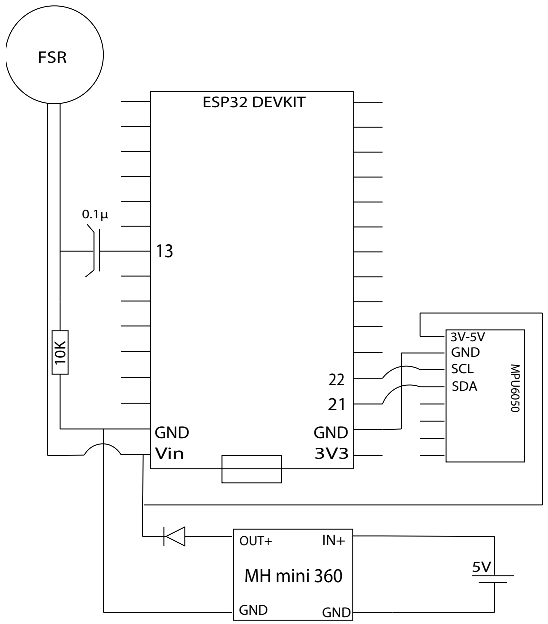


Figure 14. Circuit version 1 (v1).

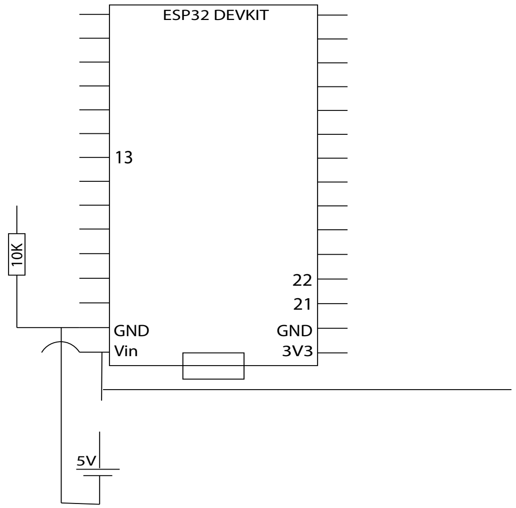


Figure 15. Circuit version 2 (v2).

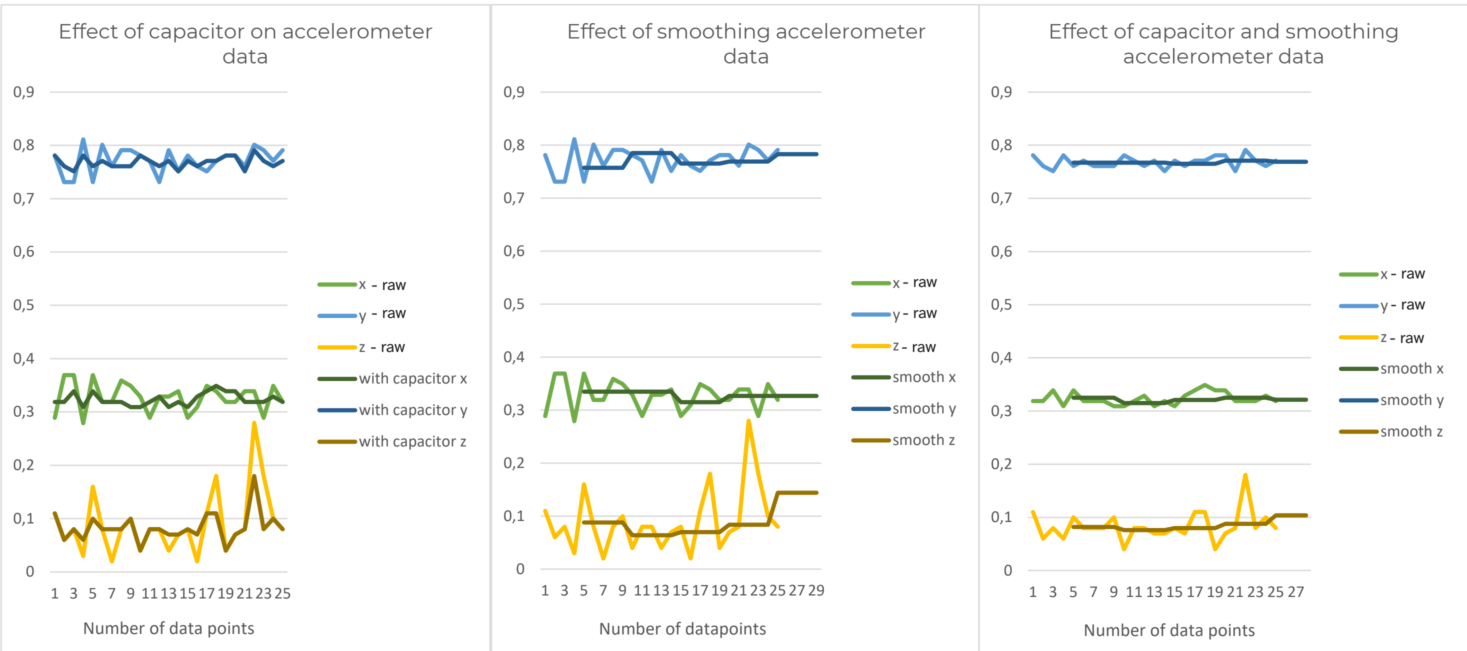


Figure 16. Analysis of the effect on the raw data of the cup standing still, using a capacitor and/or using softwaremetic smoothening.

HARDWARE - ELECTRONICS

The hardware of Puck is embedded in the internal box as shown in Figure 18.

FORCE-SENSITIVE SENSOR - FSR

The FSR is placed in a voltage divider circuit, allowing one to control the sensitivity of the FSR. This integration is described in the Electrical Integration guide from the manufacturers of the FSR (Appendix III).

In v1, a 0.1 uF was placed before Pin13, to lessen any peaks that the ADC pins readings, as described by the Espressif programming guide (espressif, 2021). However, the capacitor drew too much power from the board, causing the MPU to faint thus it was removed. This caused a slight increase in noise in the data, but this can be reduced through smoothening the data before analysis (Figure 16).

BUG IN THE BOARD

When connecting the FSR to the board, an internal bug in any ESP32devboard must be taken into account if one wishes to replicate this system. There are two power rails on the board. The FSR pin must be on an ADC pin which is on a different power rail than the wifi chip, to prevent power lapses when the ESP32 is in transmission mode ((espressif, n.d.)). Try attaching the FSR to an ADC1 pin if ADC2 does not work and vice versa.

ACCELERO-GYROSCOPE - MPU5060
The MPU5060 is a gyroscope, accelerometer & temperature sensor.

MICROCONTROLLER - ESP32 DevBoard
An ESP32DevBoard is relatively small (3x6cm) and has built-in wifi and BlueTooth making it a good candidate. In later iterations, using just the ESP32chip allows for a smaller PCB (Figure 19 & Figure 20). Currently, the size was reduced by designing the circuit in such a way that the ESP32 is placed 'over' the other components (Figure 17).

POWER SUPPLY
Iteration 1: CR2032. After using the USB port as power source, the next step was using two CR2030 batteries in series, adding up to approximately 6V. This was then scaled back to 3.5-3.3V using a Buck converter to the Vin of the ESP board, as the ESP runs on 3.3V. Unbeknownst to me, the power through the Vin goes through the built-in scale-down circuit of the ESP. This double scale-down, caused the ESP to 'faint' through lack of power. Powering it via the 3v3 instead of the Vin port works, but the MPU6050 quickly drains the batteries.

Iteration 2: Li-ion. To power the circuit and the ESP, I tried using a small Li-ion. The Li-ion (2500mAh) can power the circuit without the ESP or MPU showing any signs of fainting. I did have to add a charging circuit and a surge protection circuit, but these are both relatively small (Figure 22).

FUTURE STEPS
There is still a lot to be done. Most importantly, the system needs to be tested, to understand what needs improvement. Technical aspects, such as the duration of the battery life using different rates of data collection and data sending, and the overall accuracy of the system should be tested.

In terms of usability, the Puck will need a way to display what its current status is (charging, on, nearly empty etc). Most likely a light will suffice, but this too should be explored. A similar setup to the usage of LEDs like in headphones is a route I would want to explore.

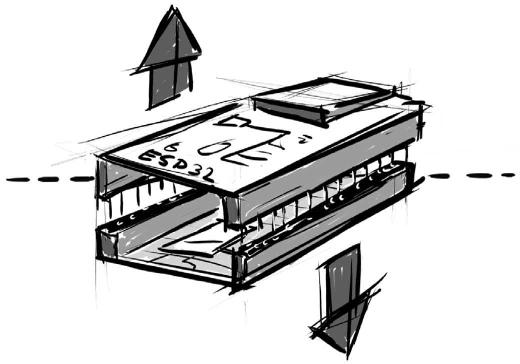


Figure 17. How the pcb and the esp connect.

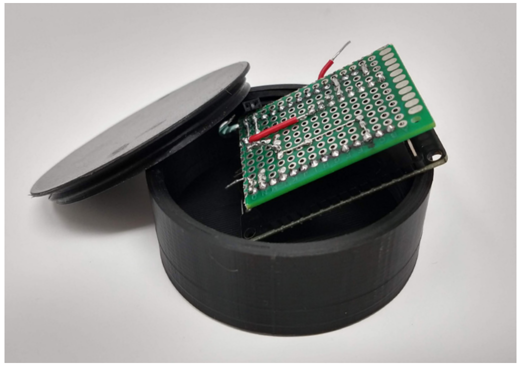


Figure 18. Circuit in embedded box.

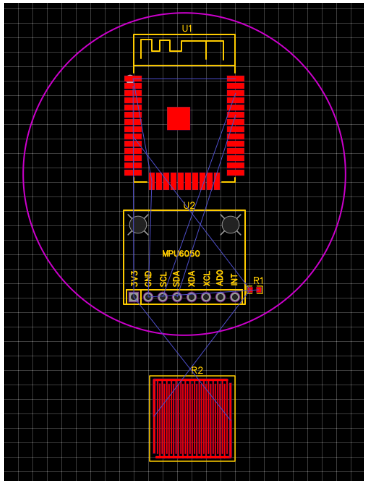


Figure 19. PCB components on 3cm radius circle.

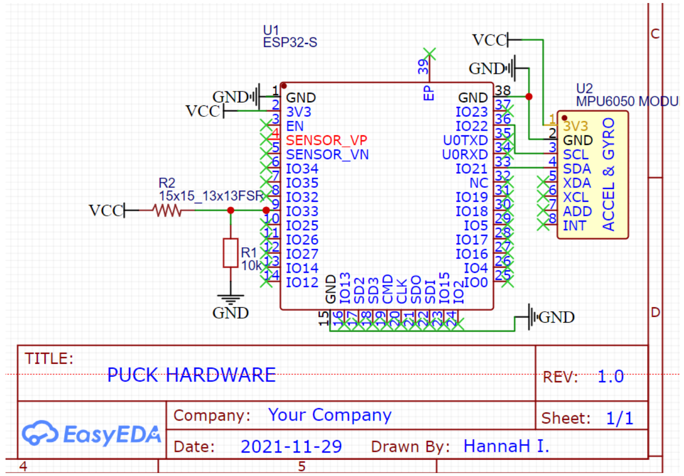


Figure 20.Example of PCB design using only the ESP32 chip, reducing the size to +-2x3 cm.

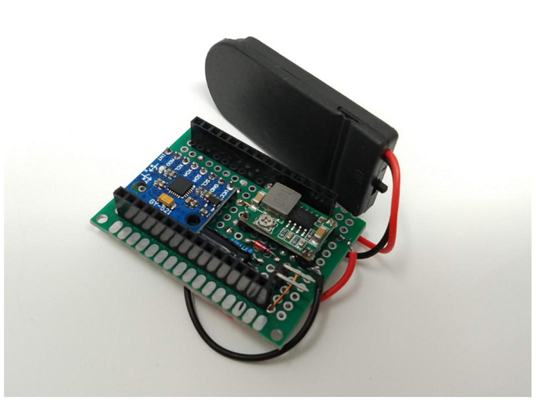


Figure 21. v1 circuit, ESP32 removed, charged with 2x CR2032 batteries.

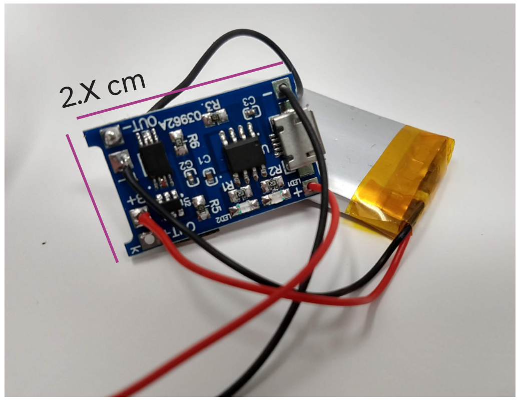


Figure 22. Li-ion batttery connected to the charging circuit.

SOFTWARE

Full annotated code can be found on GITHUB (van Iterson, 2022)

RECEIVING & MAPPING DATA

The raw data from the FSR needs to be mapped before use. Generally, one can follow the graph as provided on the datasheet (Figure 23).

ANALYSING DATA

Identifying whether the content of the cup was drunk or discarded can be identified using the accelerometer and gyroscope data, as they 'look' quite different as shown in Figure 25.

I have tried and failed in creating a better model than the one presented in my research project, which was 66-75.3% accurate (van Iterson, 2021). Using Tensorflow and Tensorflow light I got to about 55-64% accuracy with the data I had collected. This is barely better than a cointoss, thus not really exciting. I have had accuracies shown using KNN models that showed a 90% accuracy, however, using a small data set, the model likely became overfited, and thus only accurate on my specific movements.

Luckily, my envisioned method has been shown by several papers to be functional. Chun et al. (2019) showed a smart-wristband and can determine drinking the movements with 85-91% accuracy. Even more similar is the paper by Liu et al (2020), in which a cup with an embedded accelerometer can estimate the drinking movements with similar accuracy.

ACCURACY

As stated in the datasheet, the FSR is accurate in the range between 30 gr and 1000g. Glasses and cups rarely exceed the range between 50g and 500g, with an additional weight of 250-300g of fluid, this is well within the range of the sensor.

The accuracy of the force sensor differs from +-5 to +-25% depending on the sensor. Initial tests of this sensor showed a +-6%-8% error range. This is below the current 20-30 % off when done by nurses ((Kreutzer et al., 2013)). However, this is given the case the sensor is pressed evenly and placed correctly.

FUTURE STEPS

Based on the reseach, it is quite certain that a KNN movement estimation model will work.

Else, a convolutional neural network (CNN) could be promising. CNNs are used often for visual imagery. Visual image detection algorithms are very abudant, and are one of the most developed types of classification models (Dang, 2021). Therefore, attempting to make a visual detection model based on the smoothed data from the accelerometer could give interesting results.

Next to this, as with the hardware, tests will need to be done to determine the overall accuracy of the weight detection system is throughout the day.

Finally, a mitigation plan will have to be designed to catch any errors made through mistakes in the classification model. False negatives and False positives have different implications and will need strategies to prevent and solve the problems they might create.

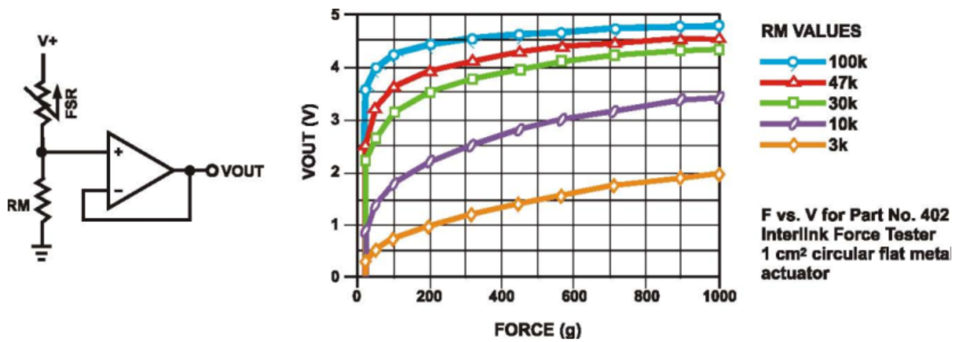
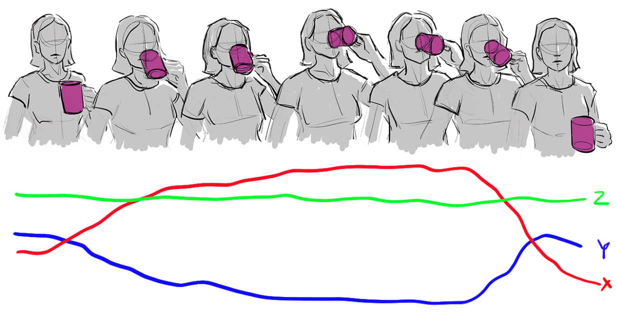


Figure 23.Force vs Vout curves in a voltage divider configuration. Vin =5V (Interlink Electronics, n.d.)



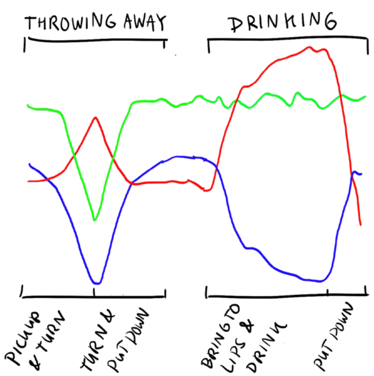
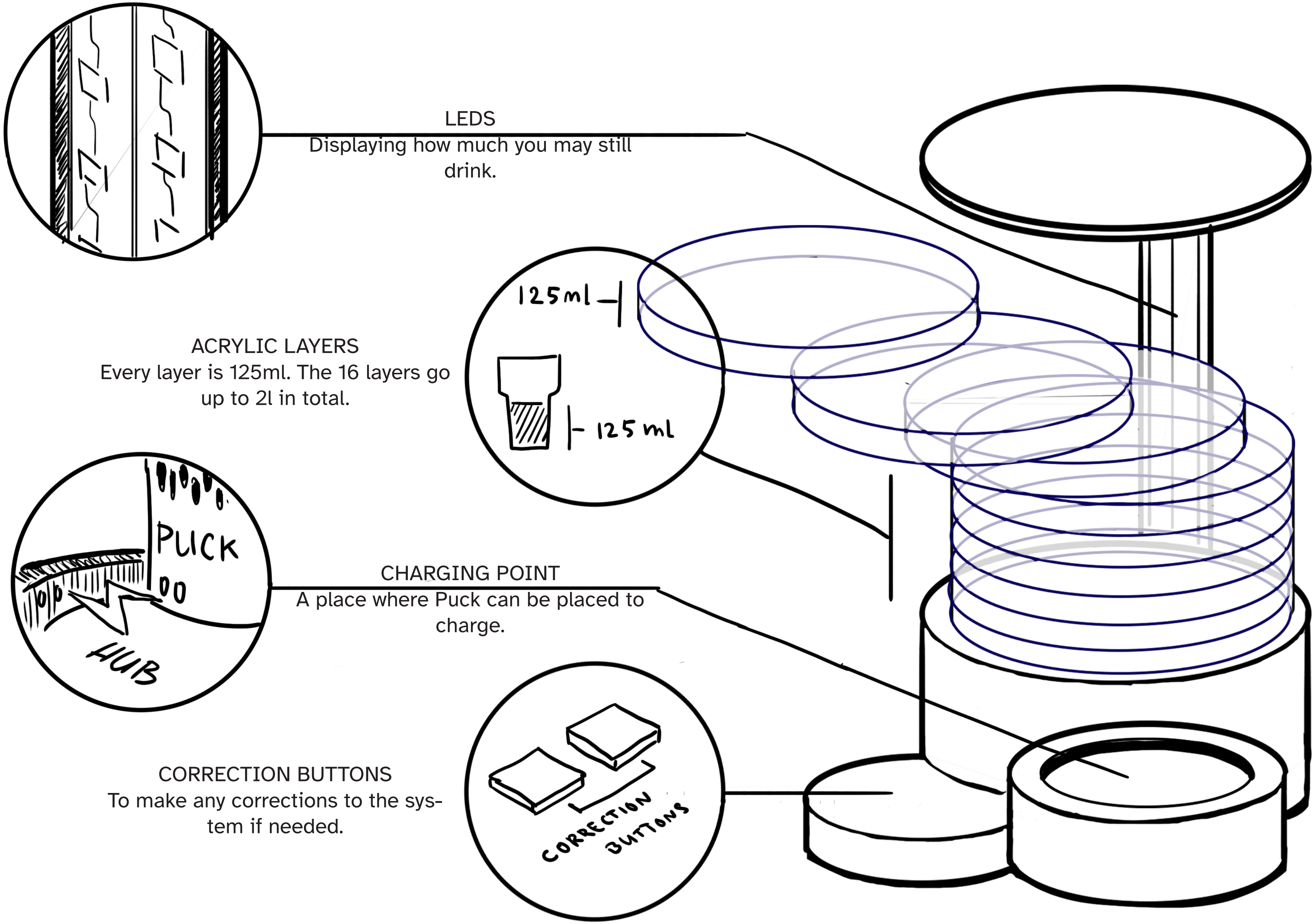
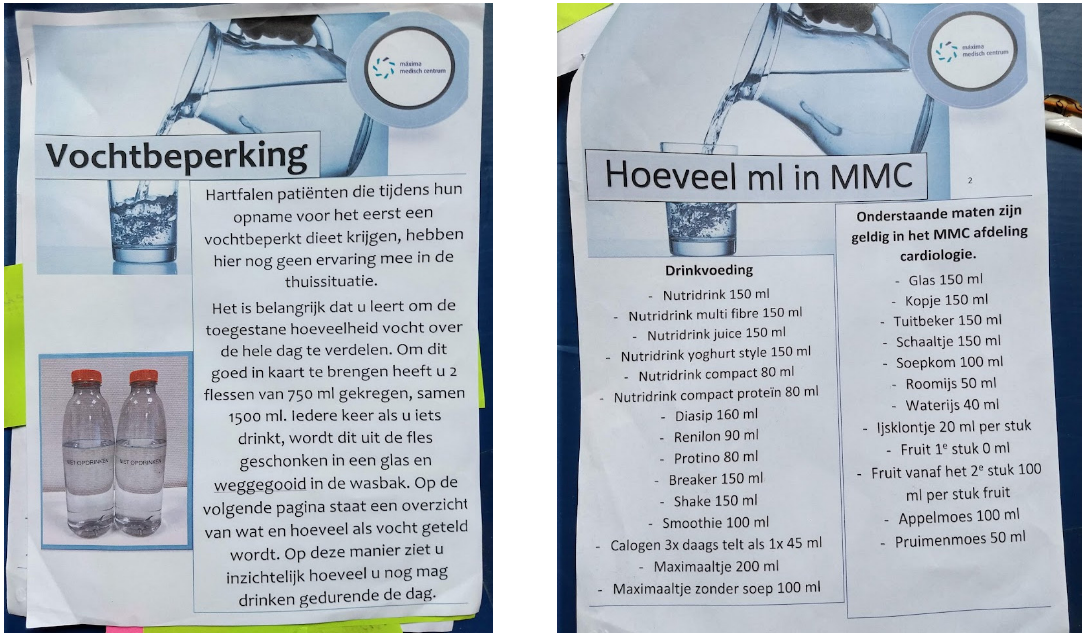


Figure 24. (Left) Detailed image of the drinking movement and the different accelerometer graphs.
Figure 25. (Right) The difference in the x,y and z-axis graphs from the accelerometer for the drinking, and throwing away movements.

FLOT - HUB



LEDS
Displaying how much you may still drink.
125ml
125 ml
ACRYLIC LAYERS
Every layer is 125ml. The 16 layers go up to 2l in total.
PUCK
HUB
CHARGING POINT
A place where Puck can be placed to charge.
CORRECTION BUTTONS
To make any corrections to the system if needed.
CORRECTION BUTTONS



Vochtbeperking

Hartfalen patiënten die tijdens hun opname voor het eerst een vochtbeperkt dieet krijgen, hebben hier nog geen ervaring mee in de thuissituatie.

Het is belangrijk dat u leert om de toegestane hoeveelheid vocht over de hele dag te verdelen. Om dit goed in kaart te brengen heeft u 2 flessen van 750 ml gekregen, samen 1500 ml. Iedere keer als u iets drinkt, wordt dit uit de fles geschonken in een glas en weggegooid in de wasbak. Op de volgende pagina staat een overzicht van wat en hoeveel als vocht geteld wordt. Op deze manier ziet u inzichtelijk hoeveel u nog mag drinken gedurende de dag.

Hoeveel ml in MMC

2

Drinkvoeding

- Nutridrink 150 ml
- Nutridrink multi fibre 150 ml
- Nutridrink juice 150 ml
- Nutridrink yoghurt style 150 ml
- Nutridrink compact 80 ml
- Nutridrink compact protein 80 ml
- Diasip 160 ml
- Renilon 90 ml
- Protino 80 ml
- Breaker 150 ml
- Shake 150 ml
- Smoothie 100 ml
- Calogen 3x daags telt als 1x 45 ml
- Maximaaltje 200 ml
- Maximaaltje zonder soep 100 ml

Onderstaande maten zijn geldig in het MMC afdeling cardiologie.

- Glas 150 ml
- Kopje 150 ml
- Tuitbeker 150 ml
- Schaaltje 150 ml
- Soepkom 100 ml
- Roomijs 50 ml
- Waterijs 40 ml
- Ijsklontje 20 ml per stuk
- Fruit 1e stuk 0 ml
- Fruit vanaf het 2e stuk 100 ml per stuk fruit
- Appelmoes 100 ml
- Pruimenmoes 50 ml

Figure 26.Folder given to fluid-restricted patients who need to track their intake.

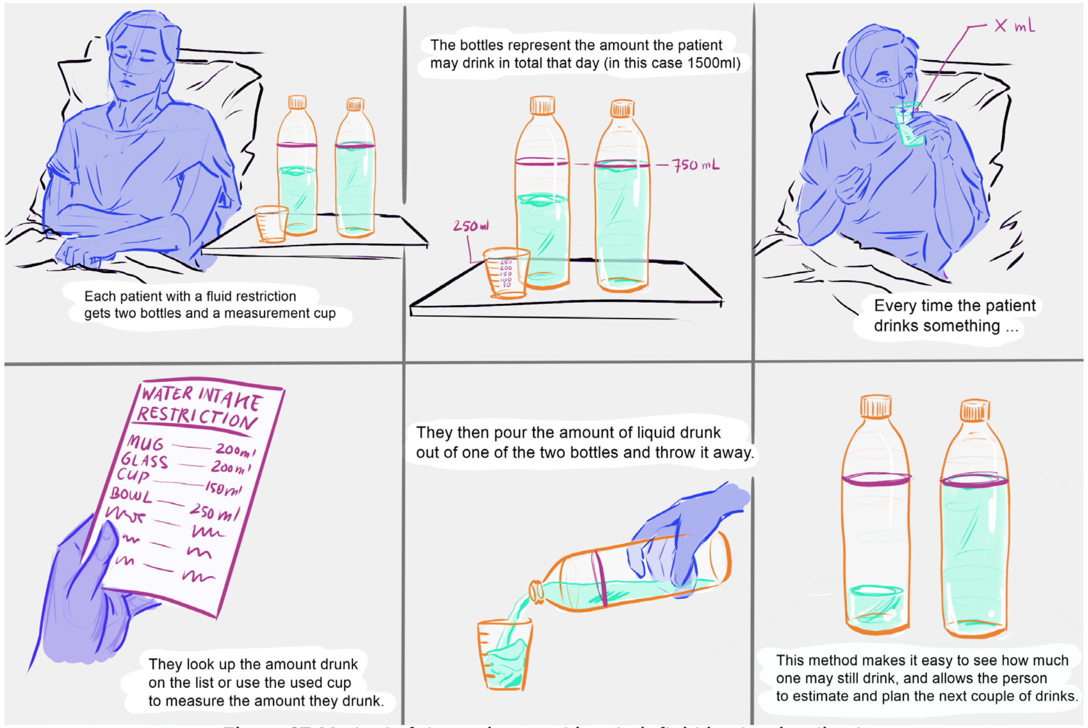


Figure 27. Method of the patient tracking their fluid intake visualised.

FLOT HUB DESIGN

HUB, the charging home and the ambient display of FLOT.

HOW IT WORKS

The Hub receives the data from the Puck and visualises this using LEDs behind acrylic circles. Each layer represents half a cup drunk. Through the scattering of the light, the user can, from every angle, see the amount they have left to drink during the day.

WHY AN ADDITIONAL ITEM AS A DISPLAY?

The reasoning behind the display is based on the feedback I got during my conversation with the cariology nurses. They explained that they aim to teach their patients to keep track of their fluid intake themselves. They tell them why it is important, give them simple tools to do it, and help them with it during their time in the hospital.

This method provides both the nurse and patient with immediate insight into the amount they may still drink that day, allowing them to plan their behaviour. More on this in the chapter “design for behavioural change”.

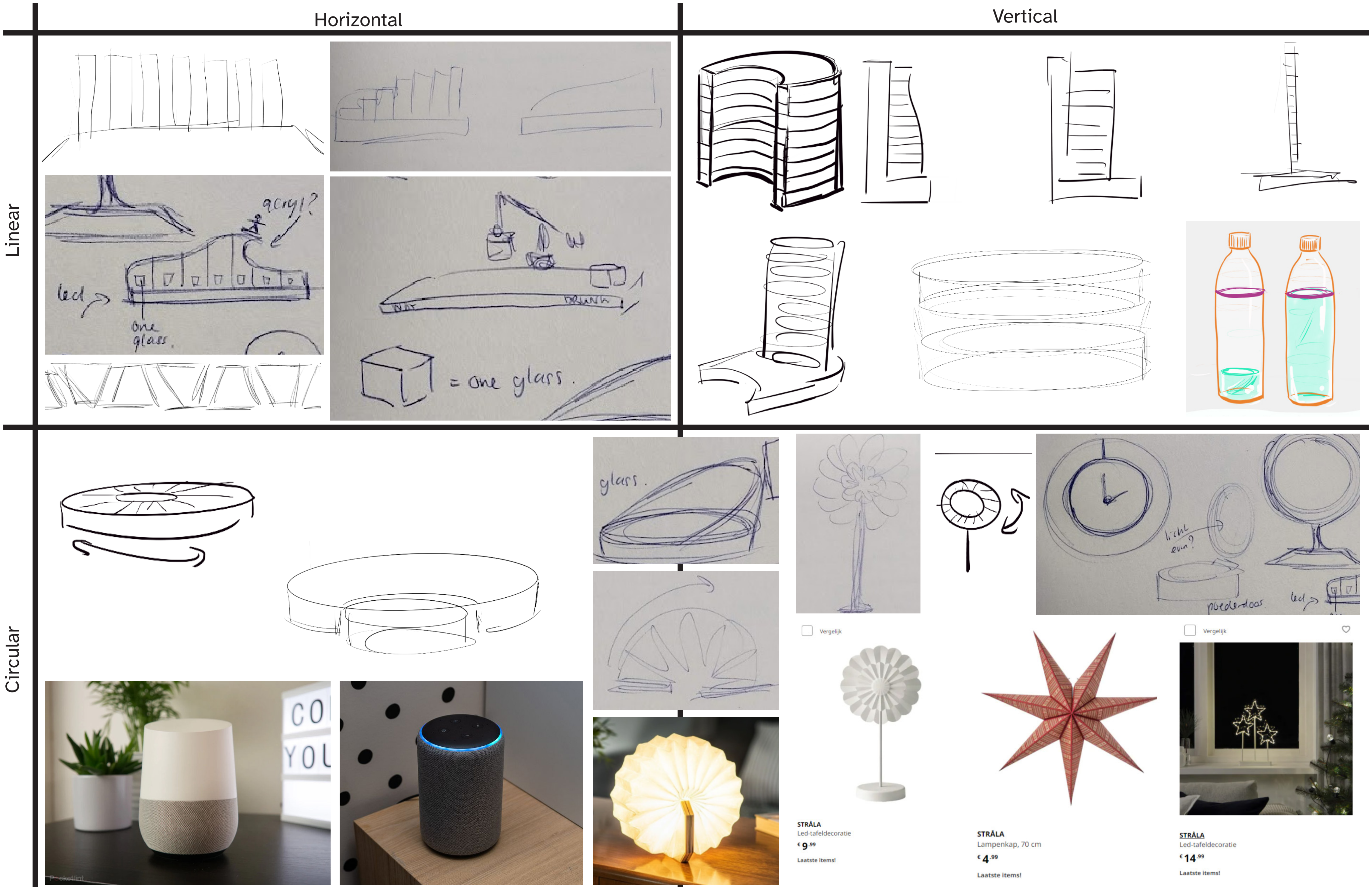
REQUIREMENTS

The main function of this prototype is to display data. This data must be displayed in an ambient way to optimise the visibility of the system and help people stay aware of their intake limit.

An important aspect of the data visualisation is the fact that the system should allow for the user to go over their set limit. If they drink too much, this must be shown. In essence, this means the system should be able to go over 100%.

Finally, users must be able to correct the system if any mistakes are made. The display is the best place to do this as they can immediately see the effect of their changes.

VISUALISATION ITERATIONS FOR HUB



Google home (Pocketlint, 2019)

Alexa (C. Welch, 2019)

Ginko accordion lamp (Gingko Design Store, n.d.)

Lamps from the IKEA catalogue (IKEA, n.d.)

Figure 28.Visualisation of the different iterations for the design of Hub.

HARDWARE - CASING

Figure 28, shows the form ideation for Hub, which is based on its primary function: displaying info. I determined that presenting it in similar to the bottle system used in the hospital (vertical linear display) will be most intuitive.

CURRENT FORM

The size is currently determined by the electronics that need to fit in the case. The height of the tower was a consideration between readability from across the room (hight of the tower) and logic in terms of liquid amount per cup. Considering between the 20-8 layers, I chose to go for 16. As 2L/16 = 125ml per layer = +-half a glass. While 8 layers (250ml each) might have been more intuitive, the height of the tower made it hard to make an estimation from afar.

ADDING UP OR COUNTING DOWN

Almost all forms of Hub allow for ‘adding up’ how much liquid you drunk, and ‘counting down’ seeing how much you still may drink. To check which is preferred, I conducted a small questionnaire under people who track their intake. out of the 7 people I asked, 6 preferred to see the amount they have left (Figure 30).

GOING OVER THE LIMIT

When patients drink too much, the system must be able to display this. How Hub tackles this is shown in Figure 31. The colour change makes the change between the two states clear and also starkly changes the environment around the Hub.

For manual corrections of the system, colour is used to show the user what the effect is of their correction (Figure 32). Using contrasting colours makes the change easier to see.

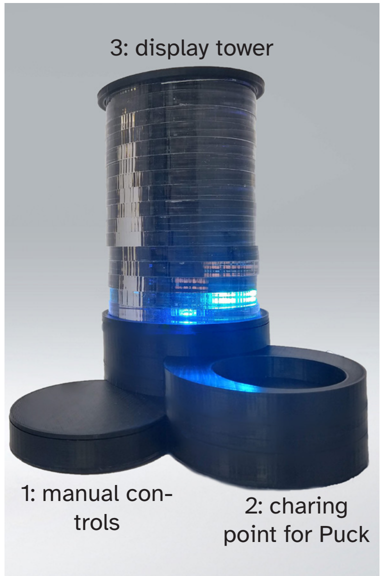


Figure 29.Current form of Hub.

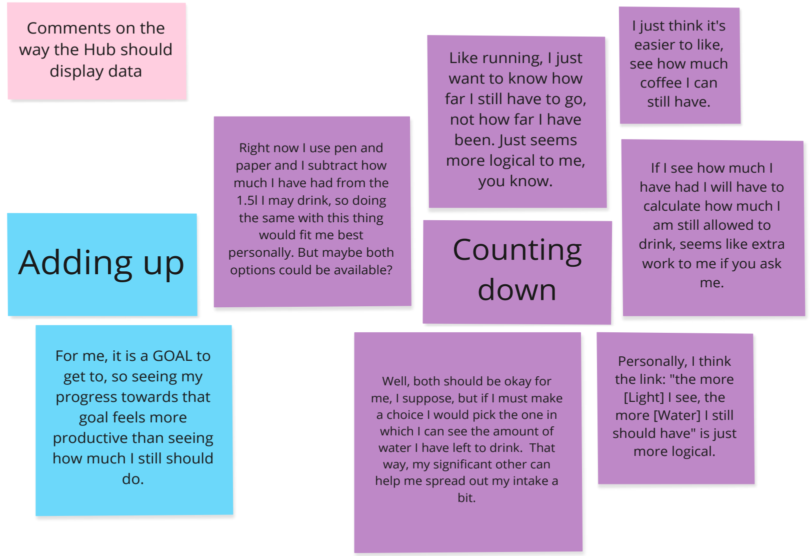


Figure 30. Comments on the display style of Hub by potential users.

Figure 31. How Hub displays going over the limit set for that day.

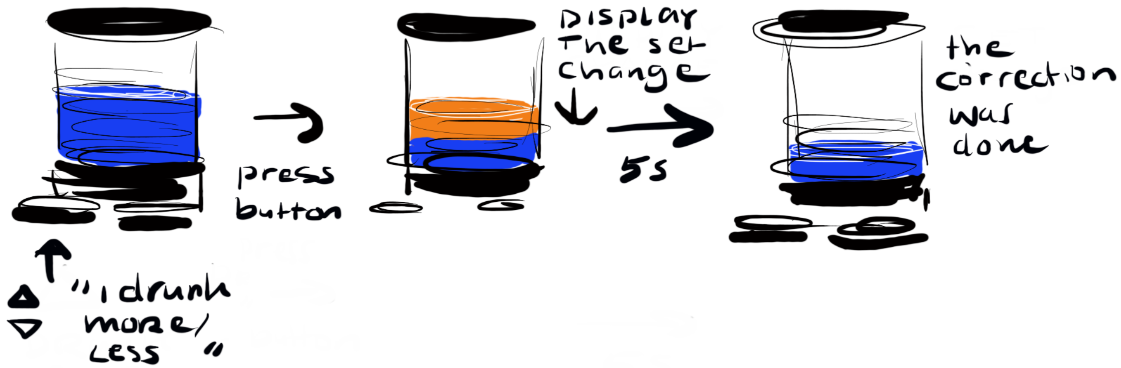


Figure 32.How Hub displays a manual correction of the system.

HARDWARE - CIRCUIT

It is an ESP32 DevBoard connected to an addressable LED strip of 16 LEDs long and is powered via a 5V charger (Figure 33).

The light of the LEDs shines through the acrylic layers or segments of the tower, causing scattering of light (Figure 35).

SOFTWARE

Currently, the software for the Hub simply receives the data and visualises this via the LED lights. For each 125ml drunk, one light will go out (Figure 34).

FUTURE STEPS

CURRENT FORM

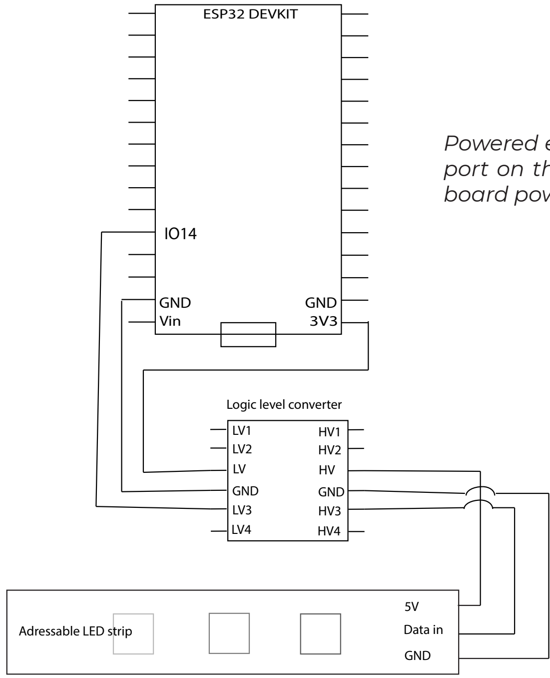
The most important future step is validating the current system and the current form. First impressions by healthcare professionals were mostly positive, but questions were asked about the ease of cleaning, the overall robustness of the item and the size. Personally, I wonder if the 'resolution' of the current tower is high enough to be accurate.

INTERACTION WITH THE SYSTEM

A first iteration must be made of the interaction of correcting the system in case of an error in the data from Puck.

ENERGY SAVING

In the current setup Puck does all the calculations and sends its results to Hub. As Puck runs on batteries, while Hub is plugged in, it might be better for the battery life of Puck that Hub does the calculations on the data send by Puck. However, all the data then needs to be sent to Hub, whereas it currently is a single string with 'X amount drunk'. This increase in the usage of wifi might end up costing more power. No tests have been done on the current energy usage. This should be tested, so a well-informed decision can be made.



Powered either by 5V using the USB port on the ESP or via a 12V breadboard powering circuit.

Figure 33.Circuit of the Hub.

Figure 34.LEDs in the tower.

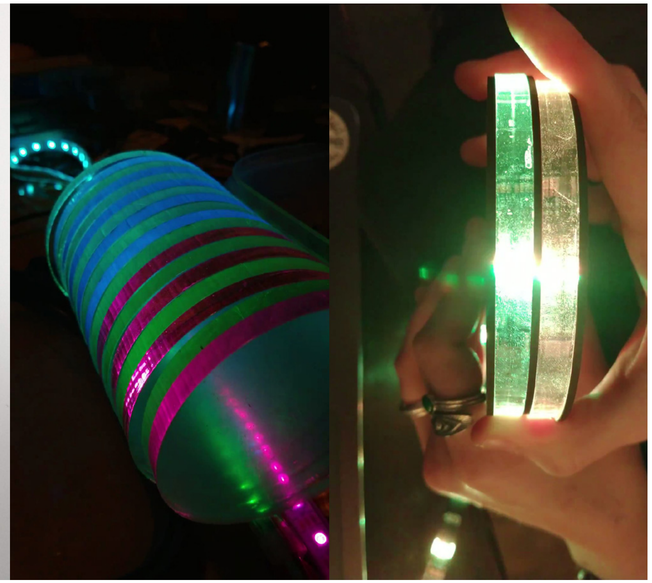


Figure 35.Light scattering through acrylic.

DESIGNING FOR BEHAVIOURAL CHANGE

Throughout the process of creating this device, the goal for the nurse was to reduce the workload of tracking fluid intake. For both them and the patient, I aimed to be aware of the aspects that help a person change their behaviour.

THE NURSE AS USER

SWITCHING COSTS

For the nurse, learning a new way of tracking will be time-consuming at first. This cost of switching must be low enough to make the switch attractive and the final product must -in the end- lower the workload. I aimed to do this by significantly reducing the number of steps, and by making the task of helping people stick to their goal easier through the peripheral display.
Whether this is enough is to be tested.

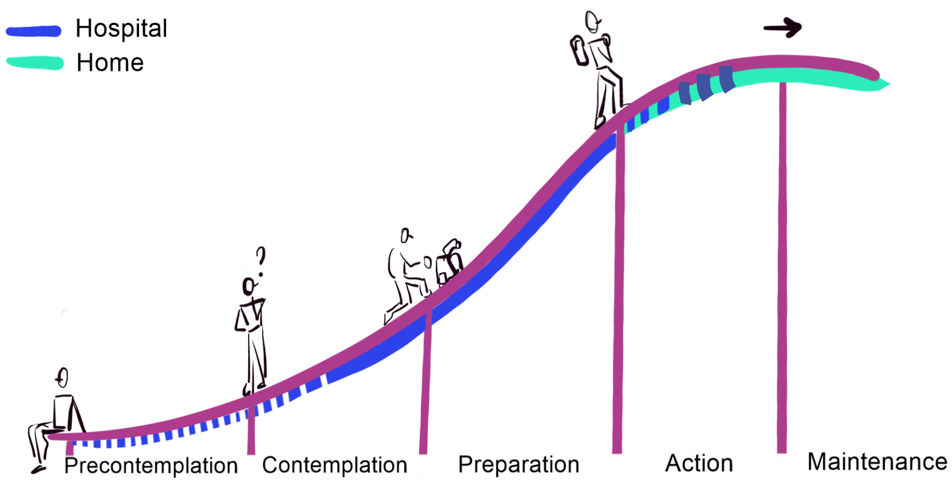


Figure 36.Transtheoretical model visualised.

THE PATIENT AS USER

TRANS THEORETICAL MODEL

Using the TTM (Prochaska et al., 2008), it can be determined in which part of the behavioural change the patient might be when in the hospital. Ideally, the patient-user is (made) aware that changing their habits is helpful for them in the long run, and they are preparing for action. The system can make the step to start tracking their fluid intake easier, as the 'cost' of starting and maintaining is made low. But it does not help them in the process before taking action (Figure 36).

SELF-DETERMINATION THEORY (GAGNÉ & DECI, 2005)

Starting and keeping up a habit requires motivation. To be motivated intrinsically, one needs relatedness, competence and autonomy. FLOT mostly plays into the aspect of competence: it makes the task simpler, giving people the tools to do the task effectively and accurately.

To do this effectively, the system must be simple to use and be very clear in its feedback. The latter is done very nicely with the bottles (Figure 27) but rather crudely, and later in Hub as well.

SOCIAL TRANSLUCENCE (ERICKSON & KELLOGG, 2000)

This form of display is intuitive and provides a peripheral awareness of the amount of liquid drunk. This peripheral awareness creates social translucence. The choices of the user are visible, the display creates awareness, in them and those around them. This can help them in aiding and understanding the user better, and it allows the user themselves to have insight into their behaviour, helping them plan ahead. However, while visibility and awareness are helpful, accountability might not be the best motivator. People should not feel judged if they make a mistake if it is there for all to see.

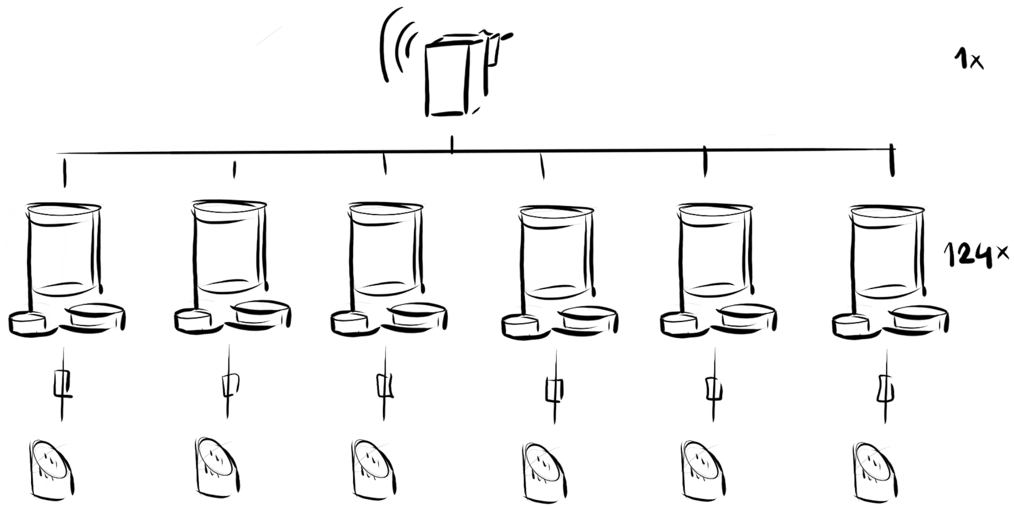


Figure 37. Many-to-one link between Hubs and Net and one-one link between Hub and Puck.

Bill Of Materials (Hub)		
ESP32 DevBoard	1x	€10,60
logic level shifter	1x	€1,50
Addressable LED-strip	16 x LEDs	€13,20 /m +- €1,50 /16LEDs
Single-core wires	+-10cm	€1,- /m +- €0,10 /10cm
MircoUSB charger	1x	€1,50
Total		€16,10

Table 1. Bill of materials for Hub

Bill Of Materials (Puck)		
ESP32 DevBoard	1x	€10,60
MPU6050	1x	€4,-
Resistor	1x	+-€0,05
Single-core wires	+-5cm	€1,- /m +- €0,05 /5cm
FSR	1x	€5,49
Charging circuit	1x	€3,-
Li-ion 2500mAh + protection circuit	1x	€10,-
Total		€33,19

Table 2. Bill of materials for Puck

SYSTEM DESIGN

WHY SYSTEM DESIGN?

The moment Hub was added to FLOT, a clear system and data flow had to be established. To do this properly, I spoke with a software and an electrical engineer. They helped me understand what is possible using this hardware, and what is handy in terms of software. Their insights are shown in Appendix II.

The main tip they gave for this stage of the project, was to add Net. Mainly for ease of use in a hospital setting where multiple FLOTs will be present, Net is connects to the router and sets up a network specifically for Hub. Multiple Hubs can connect to this network and securely send data to the hospitals dossier (Figure 37).

BUSINESS ASPECTS

After discussing the current system with Erik Janssen -the creator of MyBeaker- shared with me his insights as a business owner. He gave me quite the wake up call when discussing possible pricing.

I had aimed to make the Puck as cheap as possible, but the costs of just the electronics were already higher than I had expected (Table 1 & 2).

With an automated production line, I expected it to sell for no more than €10-15,- above that. However, as Erik explained, I 1) underestimate production cost, and 2) there are investment costs (think of moulds, setting up that production line). A price around €70-80 is probably still low, as currently the price of the casings and the cost of maintaining and making software are not included.

Additionally, the product would need to be tested if it fits medical standards of hygiene and security. Which will also be rather expensive, as it will most likely take several iterations.

PRIVACY CONSIDERATIONS

With any device that tracks and saves data, the ethics need to be considered.

DATA SECURITY

Privacy and security are in the digital age, very important. The AVG law in the Netherlands is one of the security measures taken that already changed a lot in terms of consent for cookies and your right to have your data deleted from certain companies. However, for medical devices, the rules are stricter. Examples of this are the GDPR (General Data Protection Regulation (GDPR) – Official Legal Text, 2019) and the NEN7510 (ISO/IEC 27001 — Information Security Management, 2021).

METADATA

However, these laws do not take into account the risk of home usage of any data, nor any meta-data that might be collected when collecting patient data. In the case of the FLOT system, the latter needs to be taken into account.

Every time a nurse interacts with the system in the hospital, either via moving the Puck to a new glass, or by correcting a mistake that was made, this data is saved. Using this data, one can determine how regularly a patient is visted by staff, or how often corrections are made. While this data may sound harmless, it could be used to check the work of nurses in great detail. This again can be used for good, or be used against them. E.g. blame them for playing favourites with one patient, or get checked on how fast they respond to a call or question.

This risk needs to be minimised. To do this, a plan must be made to identify what data is necessary to save and for how long. Both to ensure revision can be done, but without endangering the privacy of both the patient and the nurse.

CONCLUSION

Past semester, I aimed to create a proof of concept system to track liquid intake of patients in the hospital, with the intention to lower the nurses workload. Throughout the project via conversations with medical professionals, a second goal, was adopted: to aid nurses in teaching their patients the habit of tracking their fluid intake.

This resulted in FLOT, a two-part system consisting of Puck and Hub. Puck, the sensor which is placed under a cup and senses the weight changes of the contents of the cup and uses motion tracking to estimate how much was discarded or drunk. Hub, which displays the data and gives nurses and patients insight in tothe drinking behaviour of the user.

While there is still a lot to be done before the prototype can be called a fully-fledged product, the first building blocks are there to further develop FLOT.

Future steps include validation of the form, interaction and the tracking system. Next to this, there are business and ethical considerations that need to be done.

ACKNOWLEDGEMENTS

I want to thank all the healthcare professionals that helped me by sharing their ideas, opinion and insights.

The engineers who took a look at this project and were willing to help me realise it.

The people at d.search who always wanted to help me out with moulds or STL.

All my peers for either giving feedback, testing something small or helping me out by proofreading my paper.

The PCB creation companies, the FSR manufacturers and the other contacts that shared their knowledge with me.

Finally, I want to thank Panos for once again coaching me through a project.

REFERENCES

Bidargaddi, N., Pituch, T., Maaieh, H., Short, C., & Strecher, V. (2018). Predicting which type of push notification content motivates users to engage in a self-monitoring app. Preventive Medicine Reports, 11, 267–273. https://doi.org/10.1016/j.pmedr.2018.07.004

Burke, L. E., Warziski, M., Starrett, T., Choo, J., Music, E., Sereika, S., Stark, S., & Sevick, M. A. (2005). Self-Monitoring Dietary Intake: Current and Future Practices. Journal of Renal Nutrition, 15(3), 281–290. https://doi.org/10.1016/j.jrn.2005.04.002

Chan, A. B., & Scaer, R. (2018). Hydration Tracking Coaster with BLE Android App Public. Worcester Polytechnic Institute.

Chun, K. S., Sanders, A. B., Adaimi, R., Streeper, N., Conroy, D. E., & Thomaz, E. (2019). Towards a generalizable method for detecting fluid intake with wrist-mounted sensors and adaptive segmentation. Proceedings of the 24th International Conference on Intelligent User Interfaces. https://doi.org/10.1145/3301275.3302315

Dang, A. T. (2021, December 26). Top 10 CNN Architectures Every Machine Learning Engineer Should Know. Medium. Retrieved January 1, 2022, from https://towardsdatascience.com/top-10-cnn-architectures-every-machine-learning-engineer-should-know-68e2b0e07201

de Vecchis, R., Baldi, C., Cioppa, C., Giasi, A., & Fusco, A. (2015). Effects of limiting fluid intake on clinical and laboratory outcomes in patients with heart failure. Herz, 41(1), 63–75. https://doi.org/10.1007/s00059-015-4345-9

Dowell, S. A., & Welch, J. L. (2006). Use of electronic self-monitoring for food and fluid intake: A pilot study. Nephrology Nursing, 3(3).

Erickson, T., & Kellogg, W. A. (2000). Social translucence. ACM Transactions on Computer-Human Interaction, 7(1), 59–83. https://doi.org/10.1145/344949.345004

espressif. (n.d.). Conflict Between Wifi & analogRead()? · Issue #102 · espressif/arduino-esp32. GitHub. Retrieved December 4, 2021, from https://github.com/espressif/arduino-esp32/issues/102

espressif. (2021). Analog to Digital Converter - ESP32 - — ESP-IDF Programming Guide v4.3.2 documentation. Analog to Digital Converter. Retrieved December 4, 2021, from https://docs.espressif.com/projects/esp-idf/en/stable/esp32/api-reference/peripherals/adc.html

Gagné, M., & Deci, E. L. (2005). Self-determination theory and work motivation. Journal of Organizational Behavior, 26(4), 331–362. https://doi.org/10.1002/job.322

General Data Protection Regulation (GDPR) – Official Legal Text. (2019, September 2). General Data Protection Regulation (GDPR). https://gdpr-info.eu/

Gingko Design Store. (n.d.). SMART ACCORDION LAMP [Photograph]. SMART ACCORDION LAMP. https://www.gingkodesignstore.com/collections/new-products/products/smart-accordion-lamp

Hackett, K., Lehman, S., Divers, R., Ambrogi, M., Gomes, L., Tan, C. C., & Giovannetti, T. (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, 32(1), 22–50. https://doi.org/10.1080/09602011.2020.1794909

Hamatani, T., Elhamshary, M., Uchiyama, A., & Higashino, T. (2018). FluidMeter. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 2(3), 1–25. https://doi.org/10.1145/3264923

Hamilton, S. (2001). Detecting dehydration and malnutrition in the elderly. Nursing, 31(12), 56–57. https://doi.org/10.1097/00152193-200131120-00027

Hart, K., Marsden, R., & Paxman, J. (2020). Generation of thirst: a critical review of dehydration among older adults living in residential care. Nursing and Residential Care, 22(12), 1–12. https://doi.org/10.12968/nrec.2020.22.12.6

Hodgkinson, B., Evans, D., & Wood, J. (2003). Maintaining oral hydration in older adults: A systematic review. International Journal of Nursing Practice, 9(3), S19–S28. https://doi.org/10.1046/j.1440-172x.2003.00425.x

IKEA. (n.d.). IKEA Sfeerverlichting [Screenshot from website]. Sfeerverlichting. https://www.ikea.com/nl/nl/cat/sierverlichting-14971/

Interlink Electronics. (n.d.). Application Information FSR 402 [Graph]. https://www.trossenrobotics.com/productdocs/2010-10-26-DataSheet-FSR402-Layout2.pdf

ISO/IEC 27001 — Information security management. (2021, February 16). ISO. Retrieved January 12, 2022, from https://www.iso.org/isoiec-27001-information-security.html

Janssen, E. (n.d.). My Beaker. De website van erikjanssenconsultancy! Retrieved January 12, 2022, from https://www.mybeaker.nl/

Jewell, T. (2020, August 25). The Best Hydration Apps of 2020. Healthline. Retrieved October 11, 2021, from https://www.healthline.com/health/hydration-top-iphone-android-apps-drinking-water?c=836843835291

Kreutzer, J. F., Pfitzer, M., & D'Angelo, L. T. (2013). Accuracy of caring personnel in estimating water intake based on missing liquid in drinking vessels. 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). https://doi.org/10.1109/embc.2013.6610592

Kreutzer, J. F., Ramesberger, S., Reimer, S. M., Entsfellner, K., & Lueth, T. C. (2015). Automatically detecting fluid intake using conductivity measurements of beverages in a cup. 2015 IEEE International Conference on Automation Science and Engineering (CASE). https://doi.org/10.1109/coase.2015.7294319

Lehman, S., Graves, J., Mcaleer, C., Giovannetti, T., & Tan, C. C. (2018). A Mobile Augmented Reality Game to Encourage Hydration in the Elderly. Human Interface and the Management of Information. Information in Applications and Services, 98–107. https://doi.org/10.1007/978-3-319-92046-7_9

Liu, K. C., Hsieh, C. Y., Huang, H. Y., Chiu, L. T., Hsu, S. J. P., & Chan, C. T. (2020). Drinking Event Detection and Episode Identification Using 3D-Printed Smart Cup. IEEE Sensors Journal, 20(22), 13743–13751. https://doi.org/10.1109/jsen.2020.3004051

Plecher, D. A., Eichhorn, C., Lurz, M., Leipold, N., Böhm, M., Krcmar, H., Ott, A., Volkert, D., & Klinker, G. (2019). Interactive Drinking Gadget for the Elderly and Alzheimer Patients. Lecture Notes in Computer Science, 444–463. https://doi.org/10.1007/978-3-030-22015-0_35

Pocketlint. (2019, September 13). Google home [Photograph]. Google Home-Recensie: Een Betere Stemassistent Dan Amazon Echo? https://www.pocket-lint.com/nl-nl/smart-home/reviews/google/139617-google-home-review-speaker-slimme-assistent

Prochaska, J. O., Redding, C. A., & Evers, K. E. (2008). Chapter 5 The transtheoretical model and stages of change. In Health Behavior and Health Education: Theory, Research, and Practice, 4th Edition. https://iums.ac.ir/files/hshe-soh/files/beeduhe_0787996149(1).pdf

Ravitz, R. (2020, March 31). Why healthcare can be slow to adopt technological innovations. Med-Tech Innovation. Retrieved December 3, 2021, from https://www.med-technews.com/medtech-insights/why-healthcare-is-slow-to-adopt-technological-innovations/

Rolls, B. J., & Phillips, P. A. (2009). Aging and Disturbances of Thirst and Fluid Balance. Nutrition Reviews, 48(3), 137–144. https://doi.org/10.1111/j.1753-4887.1990.tb02915.x

Safi, S., Thiessen, T., & Schmailzl, K. J. (2018). Acceptance and Resistance of New Digital Technologies in Medicine: Qualitative Study. JMIR Research Protocols, 7(12), e11072. https://doi.org/10.2196/11072

Thimbleby, H. (2013). Technology and the future of healthcare. Journal of Public Health Research, 2(3), 28. https://doi.org/10.4081/jphr.2013.e28

Thomas, M. (2020). Why is dehydration a problem in older patients and care home residents? Nursing Times, 116(8), 45–48. https://www.nursingtimes.net/clinical-archive/nutrition-and-hydration/why-is-dehydration-a-problem-in-older-patients-and-care-home-residents-06-07-2020/

van Iterson, H. C. (2021, June). How do older adults living at home experience using MyBeaker and its mobile application?

van Iterson, H. C. (2022). GitHub - Hannahathome/FLOT: Annotated Code. GitHub. Retrieved January 12, 2022, from https://github.com/Hannahathome/FLOT

Welch, C. (2019, October 29). Amazon Echo [Photograph]. Amazon Echo (2019) Review: Middle Child Syndrome. https://www.theverge.com/2019/10/29/20934980/amazon-echo-2019-3rd-gen-smart-speaker-alexa-review-price-specs-features

Welch, J. L., & Davis, J. (2000). Self-care strategies to reduce fluid intake and control thirst in hemodialysis patients. Nephrology Nursing Journal, 27(4), 393. https://www.proquest.com/openview/d8da79bffe98f60c8136bf92047edf91/1?pq-origsite=gscholar&cbl=45638

Welch, J. L., Dowell, S., & Johnson, C. S. (2007). Feasibility of using a personal digital assistant to self-monitor diet and fluid intake: a pilot study. Nephrology Nursing Journal, 34(1).

Yamamoto, S., & Mori, H. (Eds.). (2018). Human Interface and the Management of Information. Information in Applications and Services. Lecture Notes in Computer Science. https://doi.org/10.1007/978-3-319-92046-7

REFLECTION - 938w

For my M2.1, I continued with my research project by developing a new solution for the studied problem. I chose this as I felt it would help me develop in the field of Technology and Realisation and help me develop new hard-skills. Next to this, I aimed to design aware of user behaviour.

PROFESSIONAL SKILLS

GOALSETTING

The, hardest thing this project was to keep the problem simple. I wanted too much in one project, and creating a clear report of what I did exactly was very hard to do. For next semester, next to ensuring my PDP goals are SMART, I must make sure my overall project goals are also SMART. Thus, clear indicators of success and quantifiable.

ADJUSTMENT OF GOALS

Where I started this project, keen on creating a fully functional full version of the new MyBeaker, about halfway through I came to the point at which I had to choose whether to fully engineer this prototype or to design the setup and the foundations of the full system I had thought up, which can then be made by professionals in their respective fields. I chose the latter. I aimed to still make prototypes to help me explain my ideas and plans to stakeholders, but would not spend more time on creating learning models and nice-looking optimised software.

MATH, DATA AND COMPUTING

Even though I chose not to make the model fully functional, and while I could not get it working better, investigating machine learning and the different models was very insightful. I have tried to make a model using a variety of programs, such as Weka, Tensorflow, Tensorflow light and Python. Through trial and error, I now have some idea of how to work with these programs and will be more confident in future projects with trying different types of software.

TECHNOLOGY & REALISATION

I was able to do most things I set out to do for this competenciy: the revision of older skills such as soldering and pcb design, and some new ones.

LEARNING CAD MODELLING

Learning 3d modelling is something I have wanted to do, but it have put off. However, this semester I finally started by attempting to create a 3d model of a mould for the outside of the Puck and Hub. It challenged me to think differently. But though loads of YouTube tutorials, and even more trial and error and feedback from the lovely people at d.search, I eventually made two different moulds for different production processes and the 3d-print files for the first iteration of the HUB. Which feel like a good indicator that I learned.

PRODUCTION PROCESSES

Through the creation of this mould, and the 3d print. I have also picked up knowledge of this production method of silicone/plastic pouring and 3d printing. While it is only the basis, I now feel more confident in determining whether it is possible to make a mould of a certain item or whether it would be easier to 3d print. Knowing the possibilities and limitations of these systems can help me better determine the right creation or prototype method in future projects.

USER AND SOCIETY

USER INTERACTION

I feel like I could have done much more in terms of usability and user interaction. The moment the system was functional, many things popped up next to the correction buttons. This shows me just how much difference additional iterations can make and how much of a tunnel vision one can land in.

Next to this, while I took behavioural aspects into account, I should have elaborated and experimented with them a bit more I feel. However, I also think that is easier in a longer-term user test, as habits take quite a while to form. Still, I would like to dive further into the application of behaviour change techniques, as I feel like I missed out on that a bit with this projects' focus on technology.

I am however happy with the contact I had with potential users throughout this project, in spite of the restrictions due to the pandemic. Working with the multitude of stakeholders in this project was also a good challenge.

CREATIVITY AND AESTHETICS

While I feel the Puck has quite a nice design, the Hub still needs a lot of work in terms of aesthetics, both in looks and interaction design. However, having a prototype will make testing in the next stage easier, therefore I feel the current form is justified to speed up further development. Still, I aim to be more aware of the look and feel of my final prototype in my FMP.

For Puck, I have dealt with the different constraints set in my previous project in terms of form. Weight, size, content and width of the cup were all part of this.

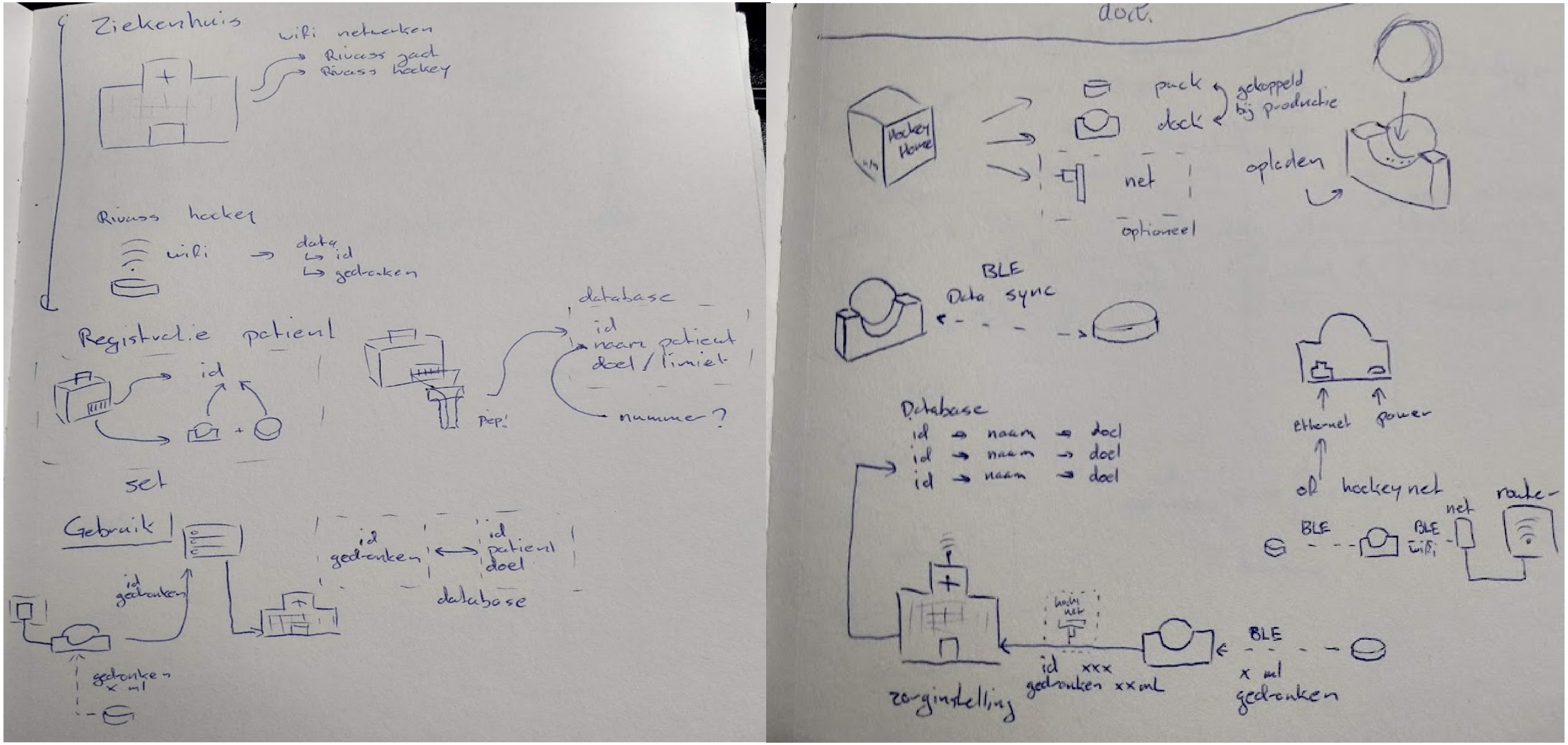
BUSINESS AND ENTREPRENEURSHIP

Thanks to my contact with Erik, I got a lot of business insights. He helped me get a more realistic view of the market and what this means for any financial model I make for a prototype or product. I was also woken up in terms of handling risks in a project. Moulds can fail and will need reiteration, software can hit critical errors. Calculating risks in your planning is simply becoming more important the more complex a project becomes.

FINAL MASTER PROJECT

Next semester, I will continue with another project. While working further on the MyBeaker could be interesting, I am up for a new challenge. There are other fields I am interested in and I want to fully take the chance to take new learning opportunities with another usergroup, new tech and a new challenge in my final semester.

APPENDIX I: ENGINEERS INSIGHTS

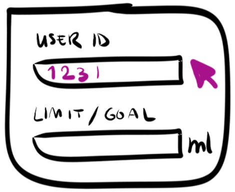


In these images, one can see the ideation process of a software and and electrical engineer thinking about a possible system for the full FLOT system. In these images, the items are called the Puck and Dock, which later are Puck and Hub. While most of their ideas were not within the scope of this project to realise, their insights and ideas might be useful for further ideation.

APPENDIX II - USER MANUAL

SETTING UP THE SYTEM

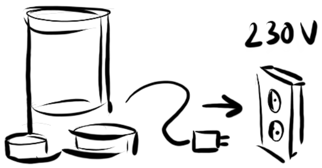
Before use, the system must be set to a specific user and their limit/goal should be filled in. This is done by connecting the Hub to the computer using a micro-usb cable.



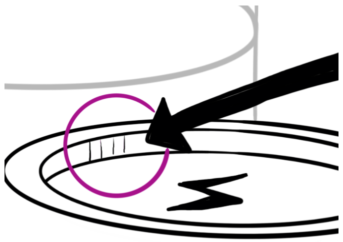
CHARGING

Using FLOT starts by pluggin in the FLOT Hub to an outlet.

Charge Puck by placing it in the charging circle in the middle of the three circles of Hub.



Puck displays a red LED while charging. When fully charged, it will turn green. The two devices are linked at production and will, once they have power, automatically start exchanging data. No linking required.



Puck light meaning		
Colour light		
Red	Constant	Charging
Green	Constant	Fully charged
Blue	Constant	Puck is on and sending data
Blue-red	Alternating	Puck cannot find Hub --> check power Hub

STARTING USAGE

Check if Puck is charged. If Puck is on, it displays a blue light. A flashing light indicates a nearly empty battery.

Using the system starts by attaching Puck to the cup or glass you wish to use. Make sure Puck is always placed on the cup you are using. Puck will automatically track the amount you drink. Changes in the amount you have left will be displayed on Hub.

READING INFORMATION HUB

Using blue light, Hub shows the amount of liquid you have left to drink for this day. Each band on Hub stands for 125ml.

Should you go over your limit set for the day, Hub will start filling up from the bottom using red lights.

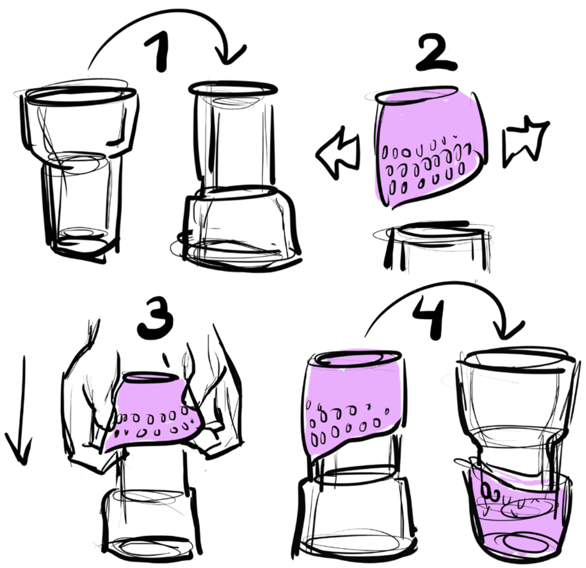
CORRECTING WEIGHT

- Too *little* was tracked

Adding any addtional drinks you have had can be done via the buttons on the lowest circle of Hub

- Too *much* tracked

Subtrackting any drinks which were tracked which you did not (fully) drink, can be done via the buttons on the lowest circle of Hub

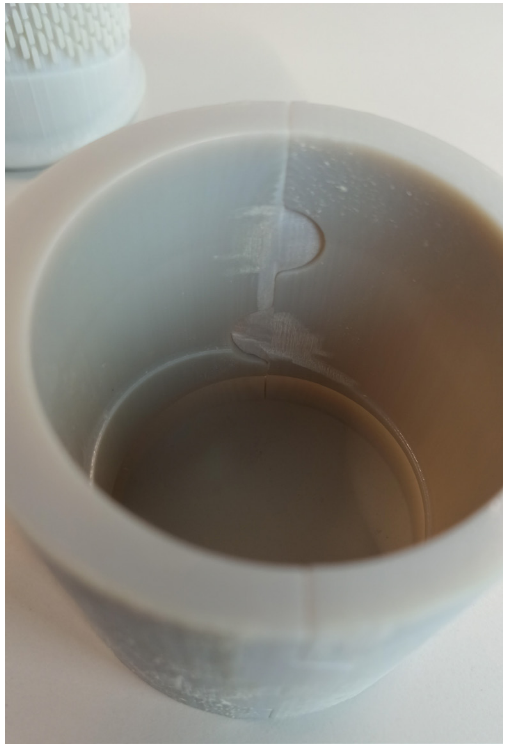


?

While I was making this manual, I realised that there was a need for a way to make corrections on the system if any tracking was not done properly. The exact buttons where not yet thought of, and are thus something that must be thought about in future iterations. However, the way it could be displayed is as written in the report.

APPENDIX III: MOULD UPDATE

Just before the deadline the moulds were created. For completeness I add them here.



APPENDIX IV: INTEGRATION MANUALS FSR

Following the links below, you will be able to read the integration manuals which were shared with me by the manufacturing company of the FSRs. These gave me insight in how to use them during the project.

Mechanical Integration

Electrical Integration

Thank you for your interest in our FlexiForce® products.
Tekscan sensors are water resistant, but not water proof -- water will eventually seep in if left submersed. Please recall that Tekscan sensors are fabricated from two thin sheets of polyester sheet, joined by an adhesive. For production reasons, the adhesive must be screen printable. The production adhesive is reported to result in an open cell foam that provides an adequate barrier to water for an hour or two, but eventually water will wick or penetrate through it.

Attached please find our Integration Guides on how to use our sensors.

Best Regards,

Mark Ma
Inside Sales & Technical Support