EI-RO; A tangible user interface to prevent food waste

FBP; Adventures in food

By: Olivier Blom

Coach: Joep Frens

Date: 16/06/2022

Squad: New Futures CHESS

[42]

EXECUTIVE SUMMARY

This report shows the final result and process of the design of EI-RO as result of a final bachelor project. EI-RO is an innovative food waste prevention system targeting the average consumer household. By using theory on tangible, rich and multi-modal interaction this food waste prevention dashboard grabs the attention of the user and encourages to explore and participate. Consumers are aware of food waste and want to take action, however they do not know how. EI-RO provides tips, tricks and overview to the household by using food purchase data and projecting that onto the dashboard. Tangible notifications will represent an often wasted product and slowly move towards the center of the dashoard, metaphorically the waste-bin.

This project resulted from an initial brief to create an innovative rich interactive device situated in the household of the future connected (smart) home. Through double loop learning and iterative concepting and designing phases, EI-RO was created. By investigating trends of the future and applying interaction theory low-fidelity prototypes were created to evaluate the designs useability and projected perception by participants of a series of usertests.

It should be mentioned however, that the trends investigated are subject to change. The trends could not evolve at all or come to life earlier, which would change the outcome of this project. Additionally, the result of this project is a concept based on the iterations during this project. With post-hoc knowledge it could be argued that there are more options towards the manifestation of the end-product.

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PROLOGUE

In the future connected digital products will increasingly soak up our focus. Increased connectivity between product and user and product to product will result in increasingly complex systems. From my vision to help people by creating thought-through, comprehensive designs, and my interest in interactive interface design I saw the opportunity to increase my experience in this area. Creating a connected product meant playing into the future trend of complex connectivity and building on knowledge of distributed systems and technical interconnectivity I gained during my internship. Although creating connected products for the future smart home sounds like adding a lot of pressure on the environment it poses a fine challenge of improving quality of life as well as exploring the idea of creating something that is used differently than ordinary household products. And as the squad focuses on designing for the year 2035 I felt driven to create an innovative concept. With these things in mind I was excited to start my final bachelor project at New Futures CHESS (Connectivity in the Home with Energy, Systems and Sound).

0.INTRODUCTION

0.1.Trends around life and food in 2035
Humanity will need to limit its carbon footprint as the earth will otherwise become uninhabitable. There are numerous points of improvement and a lot of them are just one step away. Personal carbon emissions can be decreased by terminating plane travel, taking a bike to work instead of a car, buying second hand and eating less meat are all actions that will aid the environment. The government also acknowledges this as they are pushing drastic improvement of public transport [23].
Artificial intelligence will also find more ways into our everyday lives. Most relevantly in the areas of recommendations, suggestions and predictions [11]. Together with increased connectedness and technological advancements the smartphone could become an extension of people's lives. Humans will become more connected and technology more embedded in everyday life [14]. Computer systems and humans should complement their respective strengths to create a symbiotic relation to create efficient systems [3].
Technological advancements will also mean that we will buy, package and prepare our food differently. Plastic packaging could be ruled out and products could be provided with a tracker that functions as a barcode, enabling a wide range of automated systems to use and add data to a product. Instant delivery and automated orders could be the norm. This makes insight into your food use possible. Just as you currently have insight into your bank accounts history, future and spending categories. There is also the possibility that we will be charged for eating unhealthy, environmentally unfriendly produce as well as for other taxes. Institute for the Future mentions the example of additional health insurance costs paid to farmers [30].

We might eat differently in the future. Predominantly plant based food will become the norm and having meat for dinner could be a thing of the past [21]. Because of climate change some products could become unproducable or its production is moved to other locations. Sustainable food innovations will therefore become more and more apparent as investment, research and adaptation will keep growing [26]. This reduction in meat consumption will aid our carbon foodprint (Appendix, Word list) already. Still, humanity needs to stay at work to battle climate change and reduce CO2 and other greenhouse gas (GHG) emissions. Carbon capture is a phenomenon that could become a reality if GHG reductions are not high enough [28]. Another opportunity to reduce our carbon foodprint is to prevent food waste. This would lead to a reduction in the necessary production of food along the supply chain.

0.2.Food waste
Food waste is still a big problem. Despite the EU mandate [6] to reduce food waste by 50% by 2030 there is still a large problem with loss of edible resources in the whole supply chain. Food adds up to about 30% of our personal carbon footprint, which makes it an enormously important category to improve on [32].

0.INTRODUCTION

In light of the theme of the New Futures squad it is an easy choice to target food waste. Consumer food waste still accounts to a minimum of 920 Ktons CO2 eq. per year in the Netherlands alone in 2019 [38]. A total reduction of food waste could feed almost five million people for a year as the Netherlands is one of the most wasting countries in the EU [10]. And even though food waste was reduced by 17% in 2019, compared to 2016, [37] food waste is still 34 kg per person [37]. Even though most people are aware of food waste, it is not enough. People indicate that they do not have the knowledge to battle food waste in the first place [7].

This shows that food waste is a serious problem and will stay relevant in the future as well as that there is a need for providing knowledge to consumers to prevent food waste.

With regard to the New Futures squad and its setting in the future household three sets of scaling were identified to battle food waste. Use data to strengthen food waste prevention efforts, targeting food waste to reduce greenhouse gas emissions by providing the means for people to adapt, and change their behavior and norms to reduce food waste [27]. If food waste would be eradicated, the supply chain would also have to change to adapt to the reduced need for food. By totally preventing food waste an enormous amount of resources, energy and emissions can be saved. The most preferable course of action is prevention [9].

Project goal

This Final Bachelor Project focuses on the world of food and everything it entails and is themed ‘Adventures in food’. The product of this project should be a design ‘featuring a rich experience around food production, consumption, and management’. After initial desktop research into the matter discussed above, the design brief was formulated as follows.

‘As it turns out, food waste is an enormous problem that needs to be tackled in an effort to limit climate change to an increase of 1.5°C. It proves difficult for consumers to eat everything they buy before it expires. Therefore an innovation, fitting in the context of 2035, is needed to assist the average consumer to entirely prevent food waste in the household through a rich interaction experience.’

1.RELATED WORK

1.1.Tangible interactive systems

Interactive systems are all around us. However, very little of these interactions are designed efficiently, with all human capabilities in mind or with intuitive interaction possibilities. At the Industrial Design faculty well-designed interactive systems are appreciated and a lot of knowledge is created in the domain of tangible interactions. An increasing range of interactive products with IoT capabilities reach the market. Examples are automated lighting, speech enabled assistants and connected household appliances. These types of products often receive the term 'smart', but these devices predominantly only use a touchscreen or speech interaction.

It is argued that tangible and embodied interaction can enrich the experience in multiple ways. Familiarities within the physical world can be used when designing tangible interfaces. Interaction styles and habits are adopted by users which find their way back into new interactive products [12]. This familiarity could reduce the mental effort needed of the user, as well as playing into the desire to use one's hands during interaction [40]. Additionally by making an interaction tangible, multi-modal or rich, all cognitive abilities of the user are respected and could provide for multiple ways of interaction. This could lead to a wider adoption of use through resonant interaction, as described by Hummels and van der Helm [19].
Van Campenhout, et al. (2013). advocate thoughtful design to prevent unnecessary dematerialization. Physical shapes guide our interactions and provide more and richer feedback [25]. Frens (2006). proposes a rich interaction framework that opts to design for interactions by incorporating all human skills and connecting form, interaction and function [12, 13]. This framework proposes areas of exploration to take into account when designing interactive products. Depending on the scenario or problem at hand, explorations through this framework result in concepts that provide feedforward.
Another framework is the interaction frogger framework [39]. It is a tool that helps coupling action and function of an interactive system through feedback and feedforward. The framework provides a practical viewpoint to enrich action possibilities in a product. To reveal the full potential of feedforward, Vermeulen et al. (2013). [34] introduced a practical framework using Hartson's affordances [17] and created four new classes of feedforward, differentiating feedforward from similar principles like feedback and signifiers as introduced by Norman [24]. This set of frameworks helps designers know when and how to use feedforward.

An example of feedforward is product semantics. Product semantics entail how users project meanings onto products and interact with these products accordingly. Van der Vlist (2014). explains that users will often attribute a different meaning to products than the designer intended [35]. It is explained that in a well-designed interface users follow three stages. Recognition, where function is identified, exploration, when the user explores the functionalities and reliance, when the user handles the interaction naturally. This is then coupled to the theory of the benefits of tangible interaction and it is stressed that affordances are important to provide the user with the knowledge of how to interact with a product and what will happen when interacting [35]. It is important to manage the perceptions of users. Symbols, icons, colour, form and the laws of grouping [15] can all be used to guide users' perceptions.

It is believed that future products in a technosymboiant relationship with the user will prove to be successful. By not only taking into account the task at hand, but also the way an interactive system relates and relies on the user, a human-computer relation is created. Brangier & Adelé, [3] argue for the use of technology to create a techno-symbiosis by creating efficiency in people's daily lives based on behavioral patterns that show the user masters the technology. This provides a mutual benefit and creates a system that aids the user.

Tangible user interfaces (TUI's) can take different forms (e.g. multi-user, modular) and are inherently changeable. Take IoT systems as tangible user interfaces. Software can be updated to display different things and products can be added to a system. Frens (2017). presents four approaches for designing embodied and rich interfaces that are able to grow. The hybrid approach, 'combining screen-based interaction with rich action possibilities.' The modular approach where the system can grow by adding or removing interactive parts. The shape changing approach, which resulted in a disputable ability for growth. And lastly, the service approach, providing interchangeable parts as updates [12].

1.2.Battling food waste in the household

As mentioned before, food waste is a massive challenge for which direct action will immediately improve the situation. Consumers often are aware of food waste, but do not know how to take action. With organizations like Voedingscentrum [36] and EU-Fusions [8] providing vast amounts of useful information and regulations the general public is, sadly, not often reminded of the problem and its solutions. 'Verspillingsvrije week' (waste-free-week) is a lonely example of a dutch campaign to battle food waste each year. SIRE made a rather clear statement with their digital campaign in 2015 [29]. However, food waste doesn't happen in one week, it happens every day in sometimes almost invisible ways. The body of knowledge on food waste and what actions can prevent it will be of great use for this project.

A study on food waste in the household provides interesting insights into the target group as well as on what can be done to prevent food waste in the household effectively. It turns out that people are very involved in the topic, but appraise their concerns with too little factual knowledge on how to prevent food waste [7, 20]. This study also states that 40% of respondents do not understand the environmental impact of food waste. This is important to note as reducing climate impact of food waste is part of the goal of this design project. It is argued that

primarily factual knowledge should be promoted. Advice and feedback based on facts could help to improve individual situations. Concrete examples are knowing what ‘use by’ and ‘best before’ mean, what to store in the fridge, freezer and elsewhere.
Voedingscentrum provides a factsheet to battle food waste in the household [5] . Again, it is clear that people are prepared to reduce their food waste. Food waste is accounted for by purchasing too much, storing products incorrectly and having prepared too much food. All in all food waste increases our carbon footprint by 154 kg CO2 eq. yearly [5].
As explained before, the actions to battle food waste are often very simple, and people have the confidence that they can perform these tasks. However, the same people also explain that they lack the time or argue that it is not possible to pay attention to food waste, when they have guests for example. All solutions to prevent food waste seem barely adopted in people’s routines.

Examples of concrete solutions proposed by Voedingscentrum to food waste are:
‘Checking pantry and fridge before going shopping, Preparing a meal with products that are close to their use-by or best-before date, Preparing the right amounts with a scale for example, Freezing bread, Buying smaller packages, Making a shopping list and sticking to it, Know how to store products, Creative cooking with leftovers, Setting the refrigerator to the right temperature.’ [5] EU Fusions research acknowledges these solutions [7].

By preventing all food waste, households could save up to €120 a year per person, as well as reduce their total carbon footprint by 154 kg CO2 eq. [7] A review on 10 interventions [27] tackling food waste explains that integrated solutions to prevent food waste at the household level are needed. Tips, communications and resources are mentioned as solutions to promote food waste preventing behavior.

2.DESIGN

Figure 1, EI-RO, a food prevention dashboard, in context. [41]

2.DESIGN

2.1.EI-RO

With the apparent need to assist people with preventing food waste it is important to consider the design space. The kitchen is a lively environment in the house. It provides a hub for social activities and manifests numerous devices and systems for humans to accommodate the storage and preparation of food. Whether you like to eat, cook or chat, the kitchen is often a central place in the household. However positive the kitchen is perceived, this is also the place where food waste occurs. Humans waste a lot of food, which probably nobody is happy about. What if food waste could be prevented altogether?

EI-RO is a tangible user interface that provides the means for people to fully prevent food waste in the household. By providing reminders, knowledge and assistance EI-RO acts as an innovative food management dashboard for perishables.
Placed in the kitchen users will be reminded of the products they have stored in their fridge and might have forgotten about, need suggestions for its use or improve habits with regard to certain products.

Figure 2, Close-up of EI-RO

2.DESIGN

The system is built on several pillars consisting of tangible notifications (TN's) representing perishing products. The dashboard with built-in screen and navigator and sensing units, being a scanner on the dashboard and the waste sensor placed in a households waste bin. Additionally a back-end that manages the dashboard is present behind the line of visibility. Figure 4 describes the different pillars of the dashboard.

The user provides the dashboard with purchase data by scanning (digital) receipts. The system categorizes the purchased products in one of six categories.
Bread & potatoes, dairy, fruit, vegetables, leftovers and non-perishables. The mentioned perishables are categorized on the dashboard. If one of the categorized products nears its shelf life it appears on the dashboard as a tangible notification. EI-RO encourages the user to explore their own food by presenting the tangible notifications to the user. The TN's are shaped to provide a recognizable icon that can be easily identified from a couple of meters away. Once a TN in a certain category is active it will light up in the color of the product it represents. This is the moment that the user can start interacting with the TN. Its recognizable shape and its simple but intricate texture invites the user to touch and thus, explore the item.
The user will learn that by touching the TN's additional information will be displayed in the central screen. On this screen the user will find the exact product and an approximated shelf life along with additional information. This information consists of suggestions on how to use the product in a dish for example, but could also be a tip on how to store the product to improve its shelf life. The user can easily access this data by using the navigator under the screen. The navigator is used to access additional information as well as confirm actions, for example sending a recipe to the users phone.

Through symbiosis the connection between the interface and the user is stronger. The product focuses on mapping the food the user brings into the house and builds upon a co-action symbiosis. By continuous cycles of information exchange the user and system rely on each other. The system aims to provide a joyful experience of saving food from being wasted.

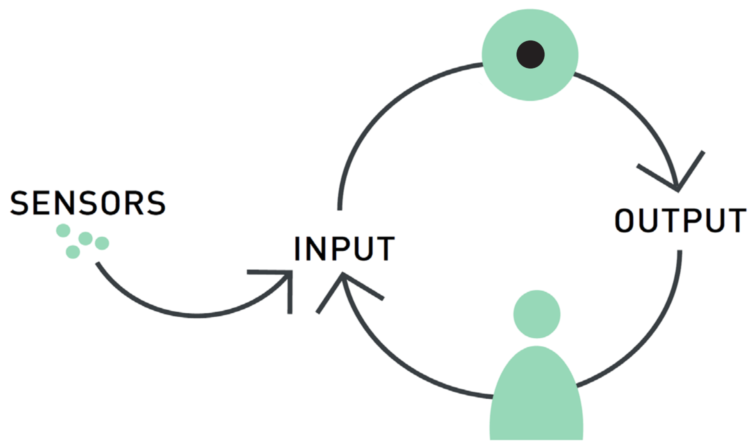


Figure 3, Visual of the human-computer symbiosis

2.DESIGN

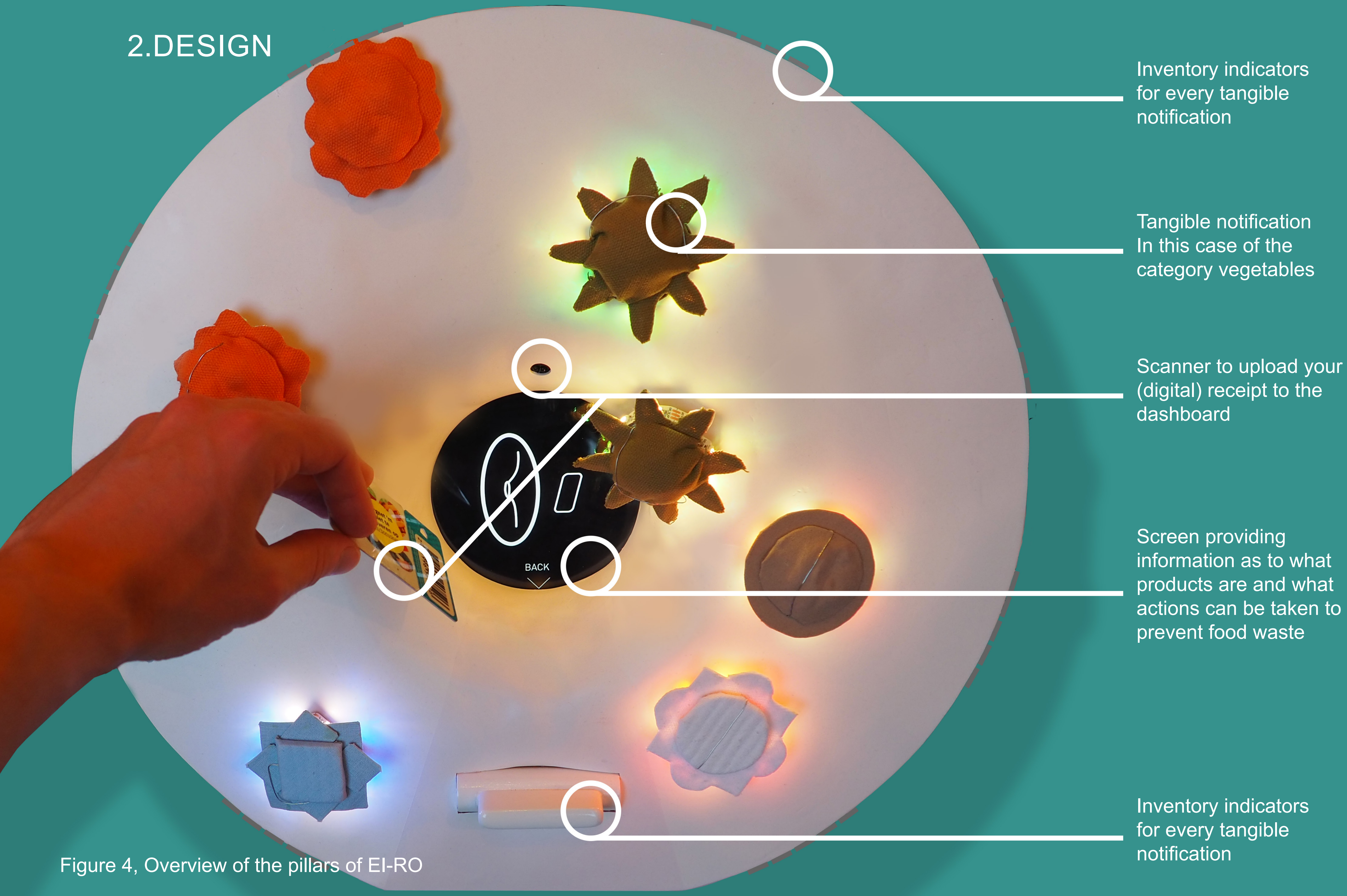


Figure 4, Overview of the pillars of EI-RO

2.DESIGN

The TN's will each slowly move towards the center of the dashboard to communicate the product is nearing the end of its shelf life. The task of the user is to prevent the TN's from falling into the center. The circles at the resting state of the TN's represent the desired state of the system. (Figure 5) When the TN is nearing the center it starts asking more attention from the user. The lights will start fading and flickering occasionally and the pattern of the light will change to having sharper edges by turning different LED's on.
Additionally upon interaction with the dashboard the user will automatically be shown a suggestion on how to use the product that is nearing its shelf life. If the user consumes a product without wasting anything the TN will turn off and return to its original position at the edge of the dashboard. The TN's represent a different product everytime a product represented by a TN is consumed or wasted. The TN's are physical as this promotes discovery and participation by the user [2].
On the occasion that the user wastes a product and thus throws it away, albeit partially, the dashboard will receive this information from the waste-bin sensor and the TN will fade on and off at the edge of the dashboard to inform the user of an action. Upon interaction the dashboard will provide the user with a tip to prevent the wastage next time. This tip could be to buy less of that product, or how it could have been used to extend the shelf life.

Figure 5, The desired state of the dashboard. No food is being wasted.

Figure 6, A semi-chaotic state where the user has several products nearing the center.

Sensing units

The system has two sensing units, the scanner incorporated in the dashboard and the waste sensor placed in the waste bin. The waste sensor has the important task of marking the successful or unsuccessful consumption of products automatically. It will turn on when the waste bin is opened and it will take a picture before and after rubbish is thrown in. The images are compared to create an outline of what parts were just thrown in which can then be masked and identified as stemming from one or more objects and classified as a product from the inventory. Additionally sound will be recorded very shortly to identify the weight of the waste to identify how much was thrown away as the sound of the impact in the trash bag will differ between products and amounts.

The scanner on the dashboard is used to activate the data transfer between the users' (digital) receipt and EI-RO. The reason this process is not automated is to put the user in control of the data transfer as well as letting the user consciously partake in their own journey of preventing food waste. The dashboard will then relay feedback on what was scanned and what was added to the dashboard. This feedback will provide the user with a recap of what they bought as well as show the relation between the products that were added to the inventory and their relative place on the dashboard.

Data processes

EI-RO makes extensive use of data, databases, data aggregation, image recognition and prediction models. All this is necessary to provide a fluent user experience that creates a direct impact. The use of databases of the products supermarkets offer is important. Luckily they already exist as Voedingscentrum uses them in their app [36]. The breadth of this system is large and would need a database of products, including their shelf-life, name, picture and relevant suggestions. Important for the sensing units is data safety. The waste pictures will not pose a large thread, but possible texts on paper waste like postal packages should not be identifiable if intercepted. The scanner on the dashboard also should not unintentionally function as an IoT security camera that can be intercepted by hackers. Therefore the placement is important but the moments this camera turns on as well as its placement and point of view. The proposed manner of handling this is to assess the content of the pictures taken directly and relay the information flow securely to be handled by the system.

Sustainability
The goal of the system is to prevent food waste with the end-goal of reducing the environmental impact people have by their lifestyle. A concept with such a goal should in itself also limit its environmental impact. EI-RO does that in two ways. Firstly through its use. By providing users with knowledge their environmental impact because of food waste will ultimately halt. This creates a sustainable impact through saving the user money, GHG emissions and energy. Ultimately the whole supply chain will adapt because of the more efficient use of food, reducing emissions even more. Secondly the production of EI-RO should be as little polluting as possible.

In a hypothetical scenario based on the prototype EI-RO would consist of the following parts and materials.

If you argue that the electrical content of the dashboard is comparable to a smart-phone or part of a laptop then the total carbon footprint of EI-RO with the components described above would emit a rough estimate of around 60 kg of CO_2 per unit [16, 18, 22, 31, 32, 37].
All parts however would be designed to be able to be taken apart and reused or recycled, reducing impact after the product life-cycle. This approximation is also solely based on the prototype. In the future the driving technologies can differ, as well as the development of more sustainable materials.
The most important technologies used in EI-RO are the screen and the TN movement system. In the future this movement would not be achieved by moving a magnet with a motor. It is envisioned that rather low energy movement is possible by creating liquid magnetic fields. Studies suggest the possibility of manipulating fluids and electromagnets to power devices [43], and create movement [44].

100% recycled polypropyleen, 1 kg. for the dish and frame
2 stepper motors
A 4.1 inch screen
2 microcontrollers, 1 for EI-RO and 1 for the waste sensor
80 LED’s
Sensors, small detection camera’s
Miscellaneous metals 100 gr. , screws, springs, magnets & coils
1 power adapter

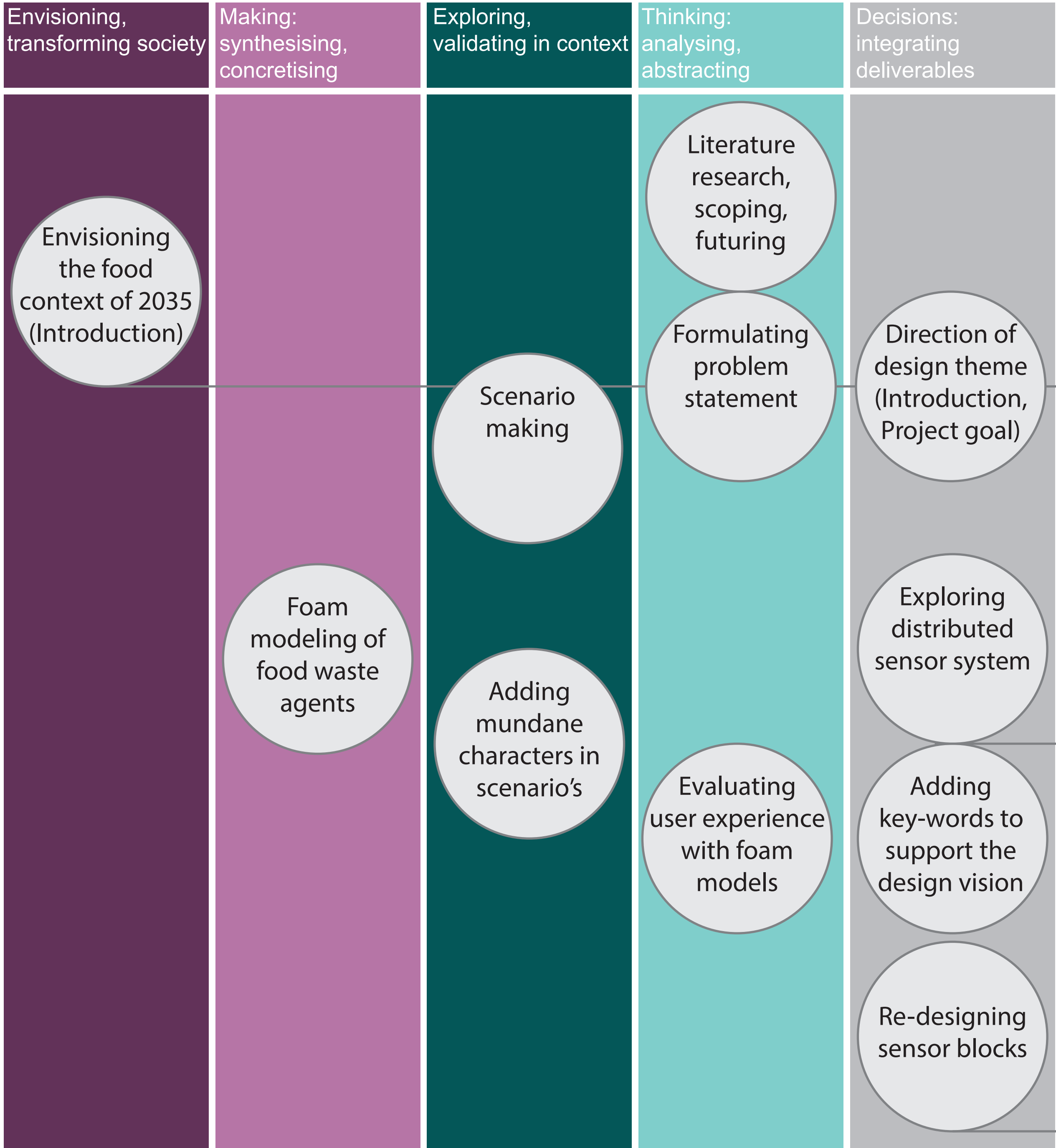
3.DESIGN PROCESS

After having confirmed the theme, adventures in food, I started doing desktop research on trends that could develop in 2035. These trends were used to create a vision of the context of food in the household in 2035. This is important as I needed to find an area of interest that fit my professional identity and vision. My designs are meant to fill a need, which I had to find first. This trend-research led to the discovery of a gap in design output with regard to preventing food waste. As mentioned in the introduction, the problem statement and project goal was formulated as ‘Design a product that assists the average consumer in fully preventing food waste in the household of 2035’.

As a designer I often take on the role of researcher and prototyper. Within these roles I find that I can provide value to a project. Ofcourse for this final bachelor project I had to take on the role of planner, Ideator and project leader as well. It proved challenging to fulfill every role successfully. I took elaborate action to plan this project well, but would sometimes still lose grip by taking too much time making decisions or taking too little consideration resulting in fast and slow paced developments along this project.
Additionally a question driven design process was provided to lead the project phases. The design phases are formulated as ‘Defining the design space’, ‘towards concept freeze’, ‘Towards evaluating your design’ & ‘Final iteration and documentation’. I would describe the phases of this project as having an exploration phase towards formulating a concrete concept. And a concept development phase towards developing a final prototype.

The following figures and details show the process and thoughts behind the design explorations done during this project.

3.1.CONCEPTING PHASE



To ground the concept as a futuristic vision it was important to get clear what that future looks like and what would be possible to achieve in that future.

Looking for a way to incorporate the possibility for a growing system a system of multiple interactive sensor blocks monitoring food and food waste was explored.

The exploration of a system of multiple sensor blocks 'agents' showed too little opportunity for feedback and reflection, thus needing a central interface.

3.1.CONCEPTING PHASE

Figure 7, First range of iterations.

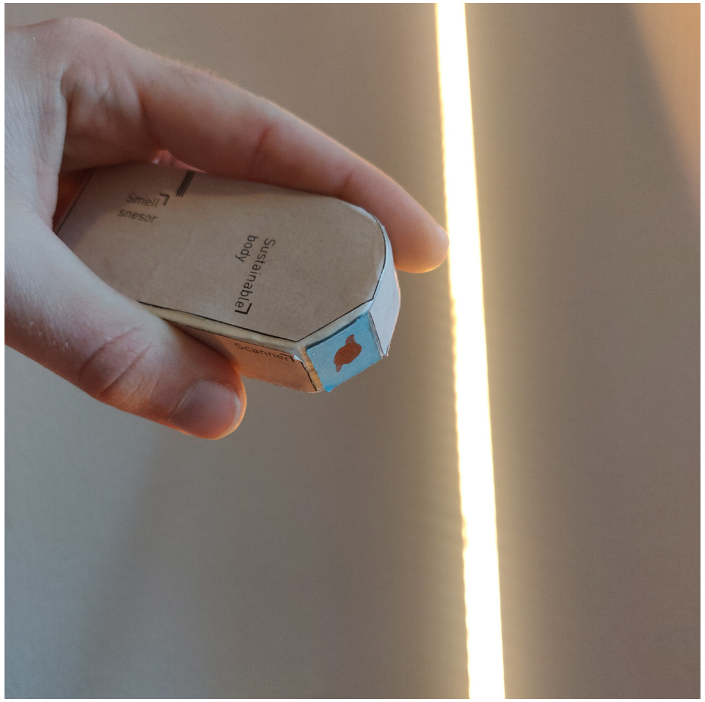
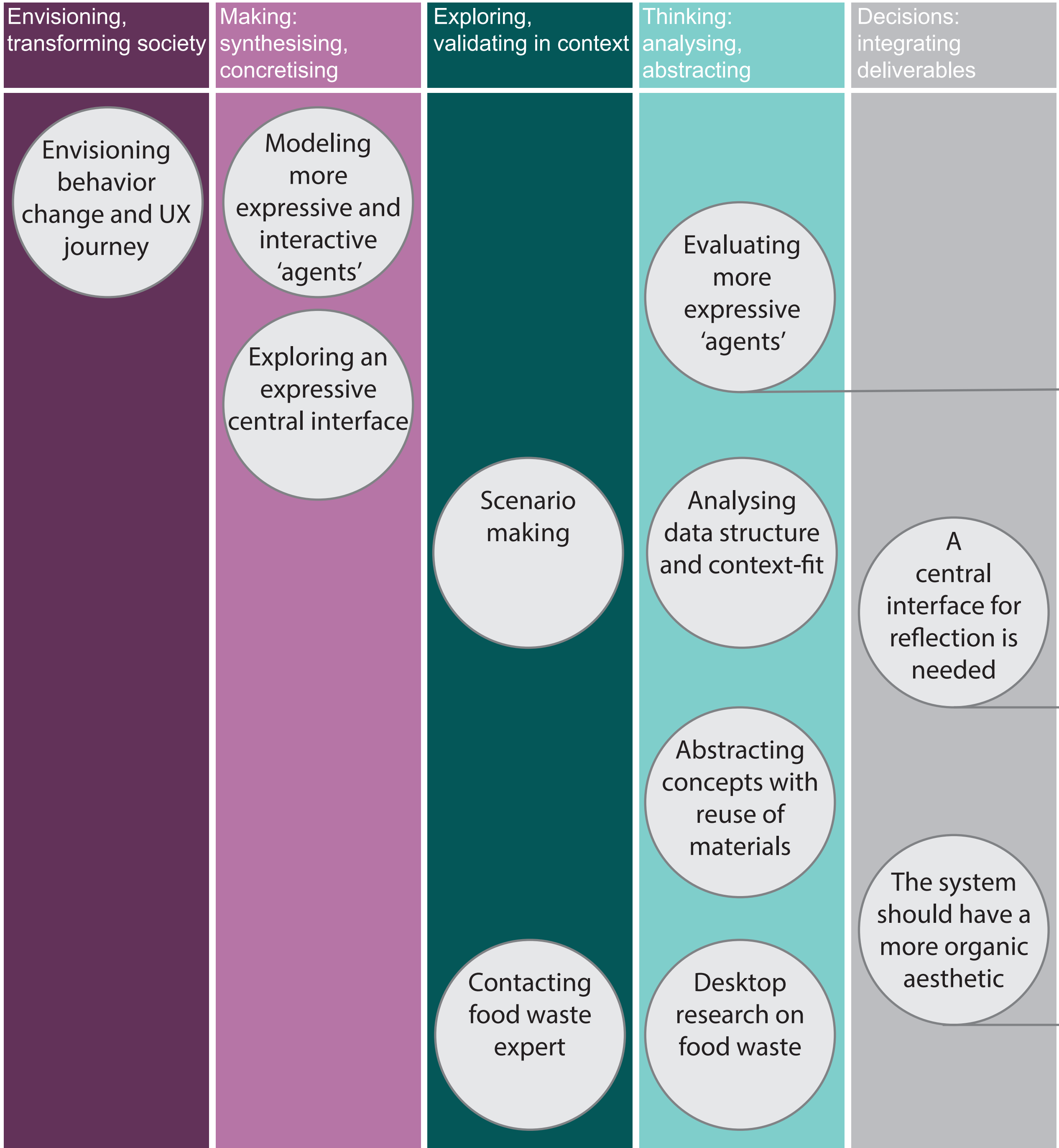


Figure 8, Feedforward implied by the way of holding the product and position of the scanner.

The first range of explorations consisted of these agents that had a range of sensor in it to determine what food was in the household, what the environment of the food was and thus when the food would perish. These ‘agents‘ would be placed around the house in the fridge, fruit bowl and pantry. This first iteration already incorporated a scanner.

3.1.CONCEPTING PHASE



Although the sensors blocks could now grab attention from the user to make clear interaction was possible, it was not clear what that interaction was.

It seemed illogical to have multiple sensor blocks when not that much external data was need. What was lacking was feedback and reflection to help the user prevent food waste.

The possible metaphors with a plant inspired interface offered more connection to the dashboard then technology focussed manifestations.

3.1.CONCEPTING PHASE

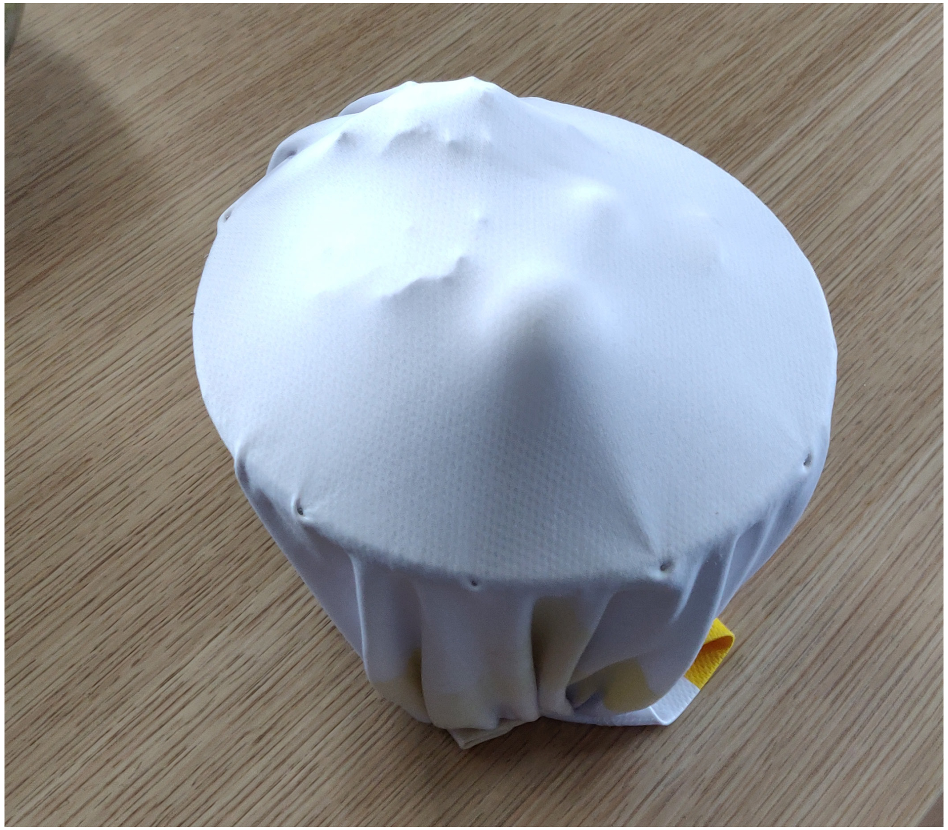


Figure 9, Exploring a central interface with expressive feedback. Spikey areas would represent food waste and rounded areas show food that was saved.

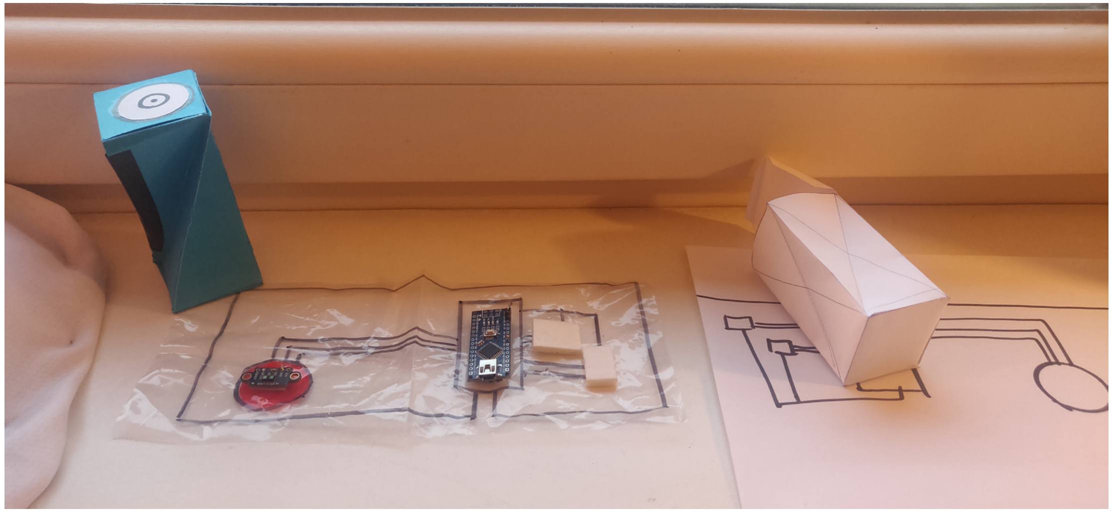
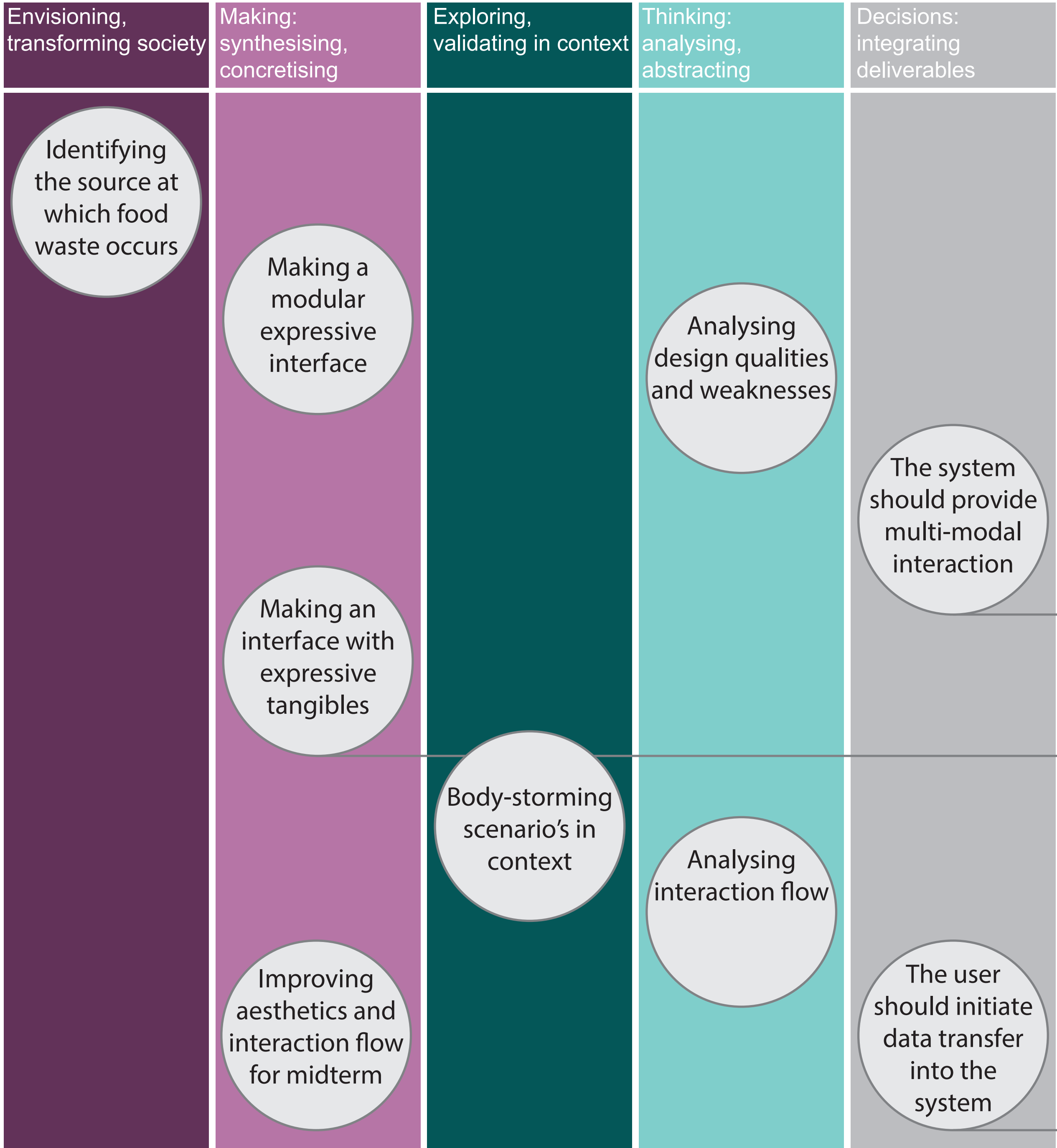


Figure 10, Explorations of sensor agents that provided a rich interaction. The blue sensor block uses shape change to indicate a product needs to be eaten and the foil prototype is folded around a product and monitors it that way.

Scenario’s proved to be important in creating rich interaction devices. By enacting what the user would see, feel, hear or smell you get a better idea of the interaction flow of your designs. This iteration opened doors towards further explorations of shape change, as the richness of a changing surface was appealing to me.

3.1.CONCEPTING PHASE



When assessing previous iterations it became clear that expressivity and communication were important.By allowing bi-directional communication the narrative will become more clear. Feedforward should play a role to provide an intuitive interaction and experience.

Physical elements provide a multi-sensory experience and encourage discovery and participation.

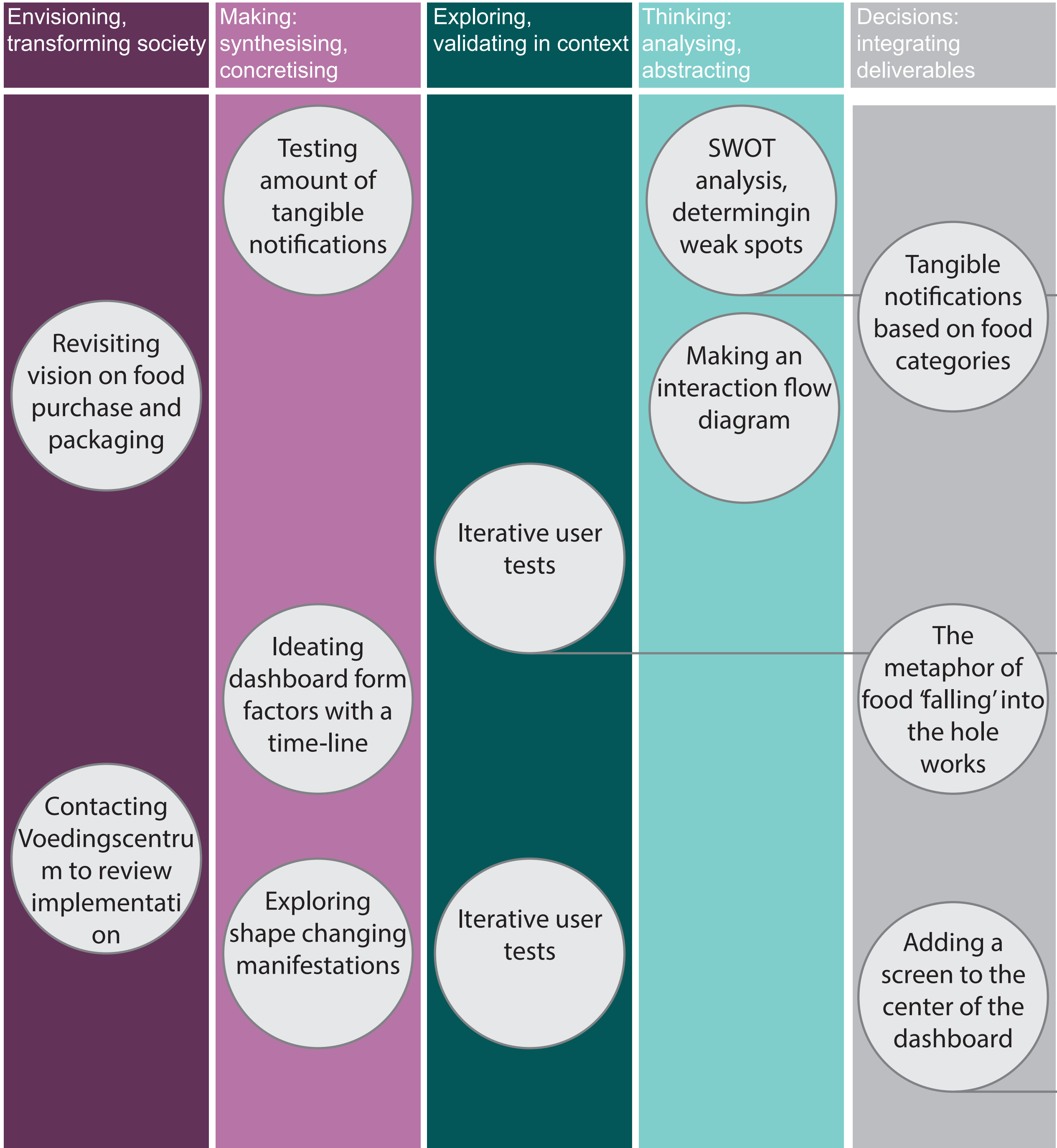
To prevent a black box-effect and increase data transparency the user should initiate a data transfer between the physical world and the digital world within the system.

3.1.CONCEPTING PHASE

Figure11, A modular cactus of scanners and sensor with a morphing flower as interface. This flower would bloom if the user needed to take action to prevent

Figure 12, Reiterating on an organic looking interface with expressive elements resulted in this prototype. A handheld scanner provided both the user and the system with information on the available food. Tags would be placed on the items in the fridge to monitor them and the flowers on the dashboard would bloom and move to the black hole if the items were nearing their shelf life. This was an important iteration as visions and concepts of previous iterations came together.

3.2.CONCEPT DEVELOPMENT PHASE



By analysing feedback from the midterm demoday and evaluating design decisions threats and opportunities were identified. (Appendix A.3)

A series of usertests was conducted with a development stage between each test. This allowed for rapid evaluation of design implementations.

In the end it turned out that a screen could offer an improved interaction flow. Because of its versatility it fit naturally as a bridge between interaction and feedback and feedforward

Figure13, A series of user tests was done to gain insight into the useability, understandeability and perception of the participants. Here I tested the useability of shape changing buttons as well as develop an understanding of what the TN's needed to become in terms of tangible artefacts providing rich interaction possibilities.

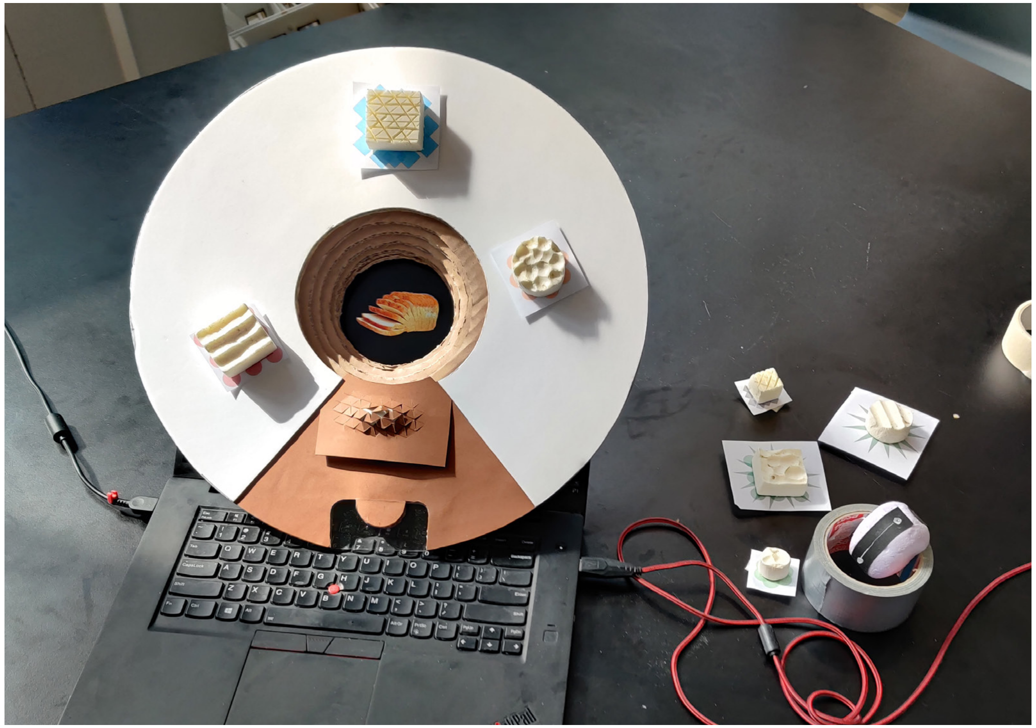


Figure14, By quickly scaling up the fidelity of the prototype I could very easily gain insights on added features. By keeping the elements simple however I could increase the rate at which I was developing all pillars of the dashboard.

3.2.CONCEPT DEVELOPMENT PHASE

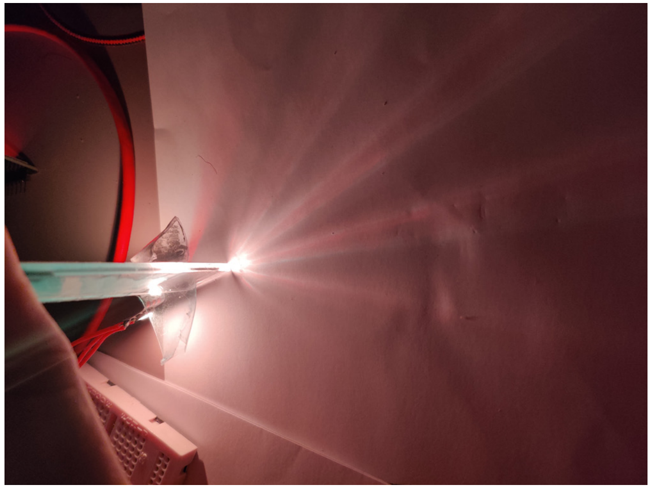


Figure 15, While user testing I also developed the individual elements further. The refractions of light for the TN's for example.

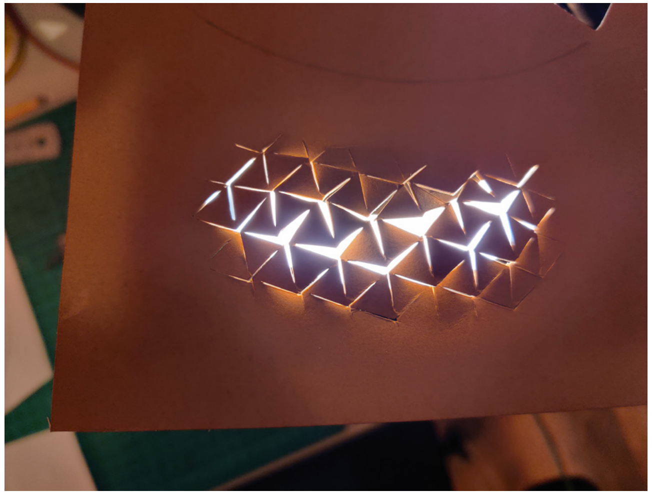


Figure 16, Exploration of a shape changin button.

Figure 17, Exploration of Making shapes out of cardboard pulp. This was not viable in the end.

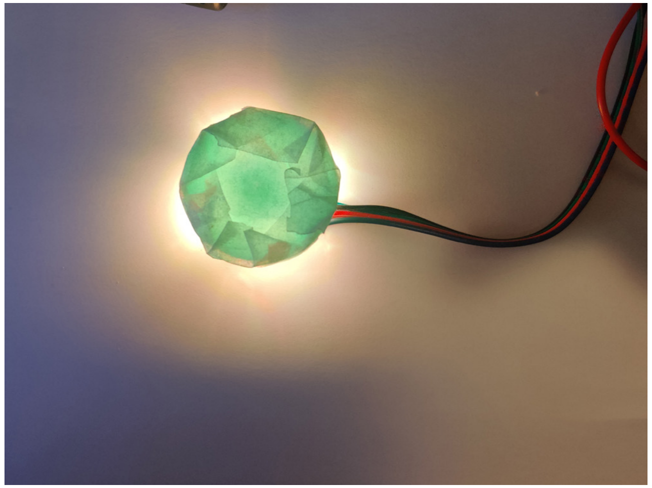


Figure 18, More explorations of light reflections for the tangible notifications.

3.2.CONCEPT DEVELOPMENT PHASE

To realize the concept I had in mind I had to prioritize the elements that were central to the experience. These elements include interaction with the TN's and the provision of knowledge to the user.

It proved hard to nail the tangible notifications. The abstractness allowed for own interpretations, but that should not interfere with encouraging exploration and participation.

As a final evaluation of the design I went to the studio were I did my internship. Three participants active in the design industry provided their insights on the user experience resulting in some final reiterations.

3.2.CONCEPT DEVELOPMENT PHASE

Figure 19, To create the shape of the dashboard I needed to hand form polyester sheets as a vacuum former was too small. This cost 4 iterations.

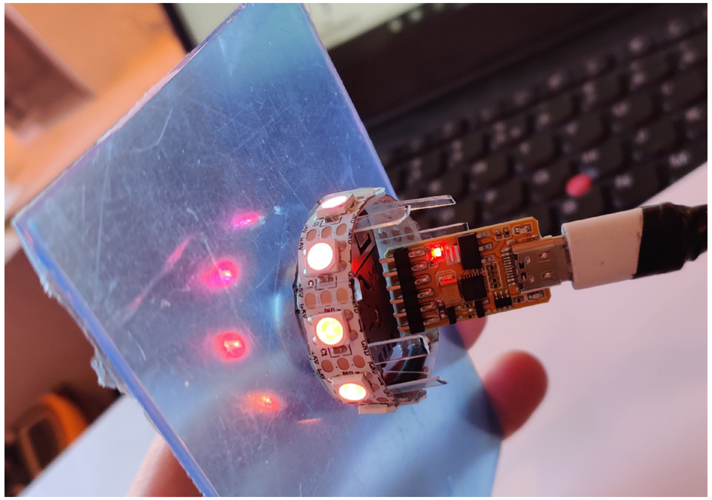


Figure 20, One of the TN's should move over the dashboard as to show how its motion would look and function. This required some advanced DIY techniques.

Figure 21, Final tests with reflective materials for TN's.

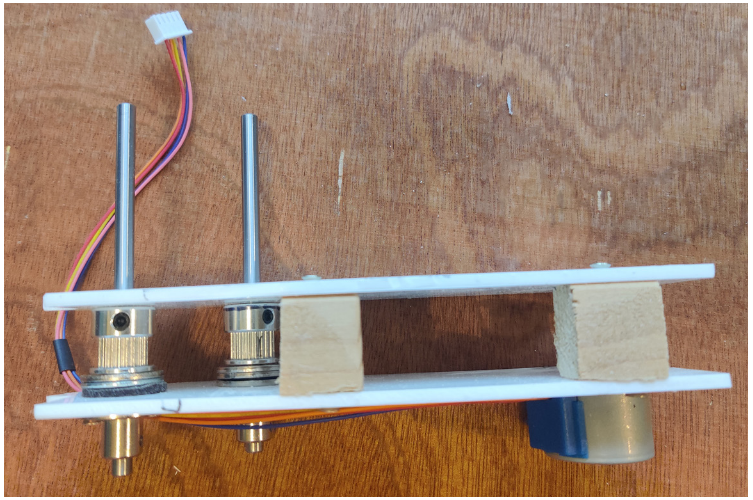


Figure 22, To move the tangible notification an belt driven magnet system was built to allow for programmable movement.

3.2.CONCEPT DEVELOPMENT PHASE

Figure 23, Making the final iteration of the tangible notifications, considering materials, shapes and feel deeply. By learning the strong points of the older iterations from the user tests the final designs were made.

Figure 24, The TN's, upholstered and being soldered.

3.2.CONCEPT DEVELOPMENT PHASE

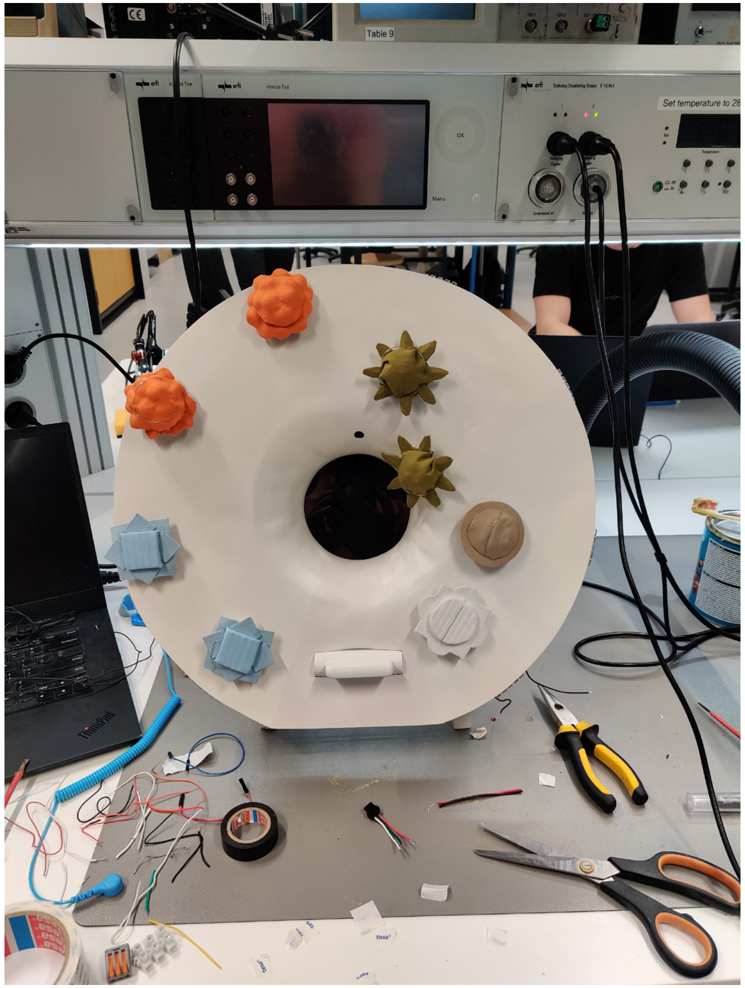


Figure 25, Lastly soldering and programming. All separate elements were tested, made and programmed beforehand to ensure an experiencable prototype.

Figure 26, Time for the final demoday. I learnt again that you should always be prepared for unforeseen circumstances as a combination of wifi and Ipad problems made it difficult to experience the prototype fully.

Figure 27, EI-RO

4.DISCUSSION

The product of this project is a concept to prevent food waste in the household. It has been made clear that knowledge should be provided to consumers to be able to battle food waste. EI-RO does precisely that, assisting the user by creating an overview of the users’ food situation and providing knowledge to the user. There are however quite some unused elements that make the situation of preventing food waste complicated. For instance advising users to buy or prepare smaller portions. This would be an impactful way of reducing leftovers, however the current situation in supermarkets will not always allow that. For this concept it is assumed that users and suppliers collectively change their habits to make this work. Another example would be food waste in the supply chain. Although food waste in the household accounts for he largest share of food waste in the supply chain [5] it is clear that holding consumers responsible is not the whole picture. This concept proposes a solution in a household setting, but an overhaul of the whole supply chain is necessary in the future.

In this report I explain the concept of tangible notifications. This manifestation of tangible representation of food, provides the user with a physical element that offers easily recognizable features. The success of the shapes and implementation however is debatable. By categorizing the types of perishables an overview is created, but it can be argued that the TN’s could stand alone as well. Currently represented as small flower like elements the TN’s offer individuality as they represent one product at a time. The way they move along the interface creates an intended messiness that creates a dilemma. If understood correctly the mixed metaphors of falling into the hole in the center, representing food waste, and organic products, represented by technology, provide the user with information. In the instance where a user misinterprets the system they might not know which notification to target first. This is an argument in favor of one scaled up tangible notification that would have a clear resting state. In this example the interface would be made up of several leafs, representing food categories, that would fall (perish) when the corresponding food is nearing its use-by date. In this example the user would know to try and take action to ‘resuscitate’ the fallen leaf.

The last version of EI-RO uses a simple switch to accept suggestions and control semi-automated processes. It could be argued that a well-designed futuristic system would not need this ‘old-school’ controlling element. I explained that the scanner is available to the user at all times, and will provide feedback when turned on. The same could be thought out for accepting recipes or data transfer. It is arguably a better user experience if the system automates as much as possible, for instance providing suggestions and tips should always be present to the user without extra steps. And sending a recipe to the users’ phone could also be accepted more naturally by moving the phone towards the interface, instead of rocking a switch, which does not provide more feedback than just a ‘click’.

4.DISCUSSION

Lastly, it is important to note that the environmental impact of EI-RO is uncertain. In theory this concept should result in a net decrease of a person's carbon footprint. This is assuming that food waste is not reduced substantially already before 2035. In that case it would be illogical to use a system that currently has an estimated carbon footprint of 60 kg of CO_2 (Design) to reduce a substantially lower impact of food waste. EI-RO's impact can be increased by having multiple owners use the system after having been provided with the knowledge and experience of the system. If food waste is reduced fast then an earlier adoption should be considered.

5.FUTURE WORK

The concept described in this report is not a finished product, as is common with such prototypes. If this concept would be developed further I would propose additional development in several areas. Earlier adoption and implementation of a system such as EI-RO, increased sustainability, both in materials as well as implementation in the market, and certain aesthetics (of interaction).

As mentioned in (4.Discussion), current trends of food waste decrease are rather positive. This would argue for an earlier adoption of food waste prevention systems, pushing knowledge towards consumers in an accessible and planned manner.

As a result of my discussion with Simone de Waart on sustainability and materials I would propose to look into designing EI-RO with as little materials as possible. This would ensure the recyclability as well as the increase in carbon equivalent reduction through the use of EI-RO. Sustainably sourced materials, recyclability and added value are elements of a sustainable design that should be on-point.

Finally I want to argue that the interaction flow with the dashboard can be optimized. The visuals visible on the screen should be developed further and tested more thoroughly than a panel of three participants. For this the user experience questionnaire could be used [33]. This test would uncover problems related to efficiency, transparency and overall user experience.

ACKNOWLEDGMENTS

I want to thank Joep Frens for being my coach during this project. I could always rely on your insightful and honest feedback, if I asked the right questions anyway. I thank Joep Elderman for challenging me to dig deeper, overcoming my indecisiveness. Lastly, I appreciate the participants and experts that spent their valuable time helping me with my project.

REFERENCES

[1] AgriFood Capital. (2019). agrifoodcapital. https://www.agrifoodcapital.nl/nl/actualiteiten-verhalen/nederland-verspilt-minder-voedsel/

[2] Bakker, S., Antle, A. N., & Van den Hoven, E. (2011). Embodied metaphors in tangible interaction design. Personal and Ubiquitous Computing, 16(4), 433–449. https://doi.org/10.1007/s00779-011-0410-4

[3] Brangier, R., & Hammes-Adelé, S. (2011). Beyond the Technology Acceptance Model: Elements to Validate the Human-Technology Symbiosis Model. Ergonomics and Health Aspects of Work with Computers, 13–21. https://doi.org/10.1007/978-3-642-21716-6_2

[4] Campenhout Van, L. (2016). Experimental payment terminal [Video]. https://www.youtube.com/watch?v=enpEUMXMyN8

[5] Consumer food waste fact sheet. (2017). Voedingscentrum. https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Service/English/Factsheet%20Food%20waste.pdf

[6] directive on waste. (2018). europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0098-20180705&from=EN

[7] drivers of current food waste. (2014). eu-fusions. https://www.eu-fusions.org/index.php/download?download=111:drivers-of-current-food-waste-generation-threats-of-future-increase-and-opportunities-for-reduction

[8] EU FUSIONS. (2022). Eu-Fusions. https://www.eu-fusions.org/

[9] Food waste measurement. (2020). Food Safety. https://ec.europa.eu/food/safety/food-waste/eu-actions-against-food-waste/food-waste-measurement_en

[10] Food waste: the problem in the EU in numbers [infographic] | News | European Parliament. (2017, 15 mei). Europa.Eu. https://www.europarl.europa.eu/news/en/headlines/society/20170505STO73528/food-waste-the-problem-in-the-eu-in-numbers-infographic

[11] Freeman, R., PhD. (2021, 15 december). When to NOT use AI or use it based on my experience. Medium. https://towardsdatascience.com/when-to-not-use-ai-or-use-it-based-on-my-experience-abb58c063aba

[12] Frens, J. (2017a). Designing for Embodied and Rich Interaction in Home IoT. Proceedings of the Conference on Design and Semantics of Form and Movement - Sense and Sensitivity, DeSForM 2017. https://doi.org/10.5772/intechopen.71130

REFERENCES

[13] Frens, J. W. (2006). designing for rich interaction: integrating form, interaction, and function. Technische universiteit eindhoven. https://doi.org/10.6100/IR608730

[14] fy2020 future of living. (2019, augustus). iftf. https://www.iftf.org/fileadmin/user_upload/downloads/ourwork/FY20_FutureofLiving_082019__1_.pdf

[15] Gestalt Laws of Perceptual Organization and Our Perception of the World. (2021, 25 april). Verywell Mind. https://www.verywellmind.com/gestalt-laws-of-perceptual-organization-2795835

[16] Graham, E. (2021, 26 augustus). What is the Carbon Footprint of a Smartphone? Secure IT Asset Management and Data Solutions for Business. https://s2s.uk.com/news/general/what-is-the-carbon-footprint-of-a-smartphone/

[17] Hartson, R. (2003). Cognitive, physical, sensory, and functional affordances in interaction design. Behaviour & Information Technology, 22(5), 315–338. https://doi.org/10.1080/01449290310001592587

[18] Haughton, N. (2021, 1 oktober). What Is The Carbon Footprint Of A Laptop? Circular ComputingTM. https://circularcomputing.com/news/carbon-footprint-laptop/

[19] Hummels, C., & Van der Helm, A. (2004). ISH and the search for resonant tangible interaction. Personal and Ubiquitous Computing, 8(5), 385–388. https://doi.org/10.1007/s00779-004-0303-x

[20] Janssen, E. (2010). voedselverspilling in huishoudens; determinantenonderzoek. afvalcirculair.nl. https://www.afvalcirculair.nl/publish/pages/92585/eindrapport_determinantenonderzoek_voedselverspilling__rescon_sept_2010_.pdf

[21] Kloosterman, R. M. A. (2021, 4 juni). 6. Vleesconsumptie. Centraal Bureau voor de Statistiek. https://www.cbs.nl/nl-nl/longread/rapportages/2021/klimaatverandering-en-energietransitie-opvattingen-en-gedrag-van-nederlanders-in-2020/6-vleesconsumptie

[22] Life-Cycle Assessment of Polypropylene Production in the Gulf Cooperation Council (GCC) Region. (2021). mdpi-res.com. https://mdpi-res.com/d_attachment/polymers/polymers-13-03793/article_deploy/polymers-13-03793-v2.pdf?version=1635932888

[23] Ministerie van Infrastructuur en Waterstaat. (2019, 13 juni). The future of public transport. Mobility, Public Transport and Road Safety | Government.Nl. https://www.government.nl/topics/mobility-public-transport-and-road-safety/public-transport/the-future-of-public-transport

REFERENCES

[24] Norman, D. A. (2008). THE WAY I SEE ITSignifiers, not affordances. Interactions, 15(6), 18–19. https://doi.org/10.1145/1409040.1409044

[25] Physical Interaction in a Dematerialized World. (2013). International Journal of Dsign. http://www.ijdesign.org/index.php/IJDesign/article/view/1124/554

[26] Pyett, S. (2020). the future of proteins. WUR.nl. https://www.wur.nl/en/newsarticle/The-future-of-proteins-according-to-Stacy-Pyett.htm

[27] reducing fod loss and waste ten interventions scale impact. (2019). world resources institute. https://files.wri.org/s3fs-public/reducing-food-loss-and-waste-ten-interventions-scale-impact_1.pdf#page=62

[28] Roberts, D. (2019, 22 november). Climate change: pulling CO2 out of the air could be a trillion-dollar business. Vox. https://www.vox.com/energy-and-environment/2019/9/4/20829431/climate-change-carbon-capture-utilization-sequestration-ccu-ccs

[29] Sire. (2015). 2015 - Voedselverspilling Kliekipedia. https://sire.nl/campagnes/voedselverspilling-kliekipedia/

[30] Smith, S. (2018, 3 januari). artifacts fromthe future incentivized receipt. iftf. https://www.iftf.org/future-now/article-detail/artifacts-from-the-future-incentivized-receipt/

[31] Staff, P. (2017, 9 augustus). Use of rPET drastically cuts carbon footprint. Plasticstoday.Com. https://www.plasticstoday.com/packaging/use-rpet-drastically-cuts-carbon-footprint

[32] Uncovering the Carbon Footprint of Everything - Our World. (2019). Ourworld.unu.edu. van https://ourworld.unu.edu/en/uncovering-the-carbon-footprint-of-everything

[33] User Experience Questionnaire (UEQ). (2022). Ueq-Online. https://www.ueq-online.org/

[34] Vermeulen, J., Luyten, K., Van den Hoven, E., & Coninx, K. (2013). Crossing the bridge over Norman’s Gulf of Execution. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. https://doi.org/10.1145/2470654.2466255

[35] Vlist, Van Der, B. J. J. (2014). Semantic connections : explorations, theory and a framework for design. Technische universiteit eindhoven. https://doi.org/10.6100/IR762658

[36] Voedingscentrum. (2022). Homepage. https://www.voedingscentrum.nl/nl.aspx

REFERENCES

[37] Voedselverspilling feiten en cijfers | Samen tegen voedselverspilling. (2022, 21 april). Samen Tegen Voedselverspilling. https://samentegenvoedselverspilling.nl/voedselverspilling-feiten-en-cijfers/

[38] Voedselverspilling in Nederland - monitor voedselverspilling update 2019. (2019). Ministerie van landbouw. https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2022/03/08/voedselverspilling-in-nederland-monitor-voedselverspilling-update-2019/voedselverspilling-in-nederland-monitor-voedselverspilling-update-2019.pdf

[39] Wensveen, S. A. G., Djajadiningrat, J. P., & Overbeeke, C. J. (2004). Interaction frogger. Proceedings of the 2004 conference on Designing interactive systems processes, practices, methods, and techniques - DIS '04. https://doi.org/10.1145/1013115.1013140

[40] Dourish, P. (2004). Where the action is: the foundations of embodied interaction. MIT press. Shaer, O., & Hornecker, E. (2010). Tangible user interfaces: past, present, and future directions. Now Publishers Inc.

[41] CDN. (2022). White and wood one wall kitchen [picture]. http://cdn.home-designing.com/wp-content/uploads/2018/06/White-and-wood-one-wall-kitchen.jpg

[42] Idesign. (2022). Foto kuhni studii [picture]. https://idesign.cosmetius.com/wp-content/uploads/2018/07/foto-kuhni-studii_04.jpg

[43] Rubin, A. (2017). Magnetic pixels: a world beyond touchscreens. https://www.nature.com/articles/srep21068

[44] Wang, K. (2016). Magnetic field induced motion behavior of gas bubbles in liquid. https://www.nature.com/articles/srep21068

APPENDIX

A.1.Wordlist

Carbon equivalent footprint (CO_2 eq.):
By living our everyday lives greenhouse gasses get emitted into the atmosphere. The composition of these gasses (e.g. NO_2, CO_2, CH_4) are more insightful if we bundle them as carbon equivalent footprint.
Foodprint:
Foodprint means the part of our carbon equivalent footprint of all our food consumption and use.
Human computer symbiosis (human technology symbiosis):
With this phrase we mean the interconnected symbiosis between a (physically manifested) computer program and a human who work together in their best capability to reach certain higher or personal goals. Four types of techno symbiosis are mentioned: co-extension, co-evolution, co-action, co-dependence.
Interface:
the place at which independent and often unrelated systems meet and act on or communicate with each other, the man-machine interface.
EI-RO:
EI-RO, food waste prevention system, which' shape is inspired by the Einstein-Rosen bridge, and provides the user with the tools to prevent food waste ('faster-than-light') effectively through an innovative tangible user interface (TUI).
Life cycle assessment:
A life cycle assessment (LCA) study involves a thorough inventory of the energy and materials that are required across the industry value chain of a product, process or service, and calculates the corresponding emissions to the environment.The LCA assesses cumulative potential environmental impacts.
Perishables:
Often wasted categories of food, being bread, potatoes, fruit, vegetables, dairy and leftovers.

A.2.PDP

PDP: https://docs.google.com/document/d/1cdf_31rJB3gNNpD-scaiF3niFQARvZgIpasrxWolL20w/edit?usp=sharing

A.3.Additoinal imagery:

MIRO: https://miro.com/app/board/uXjVOE3Dmqc=/?share_link_id=239780632617