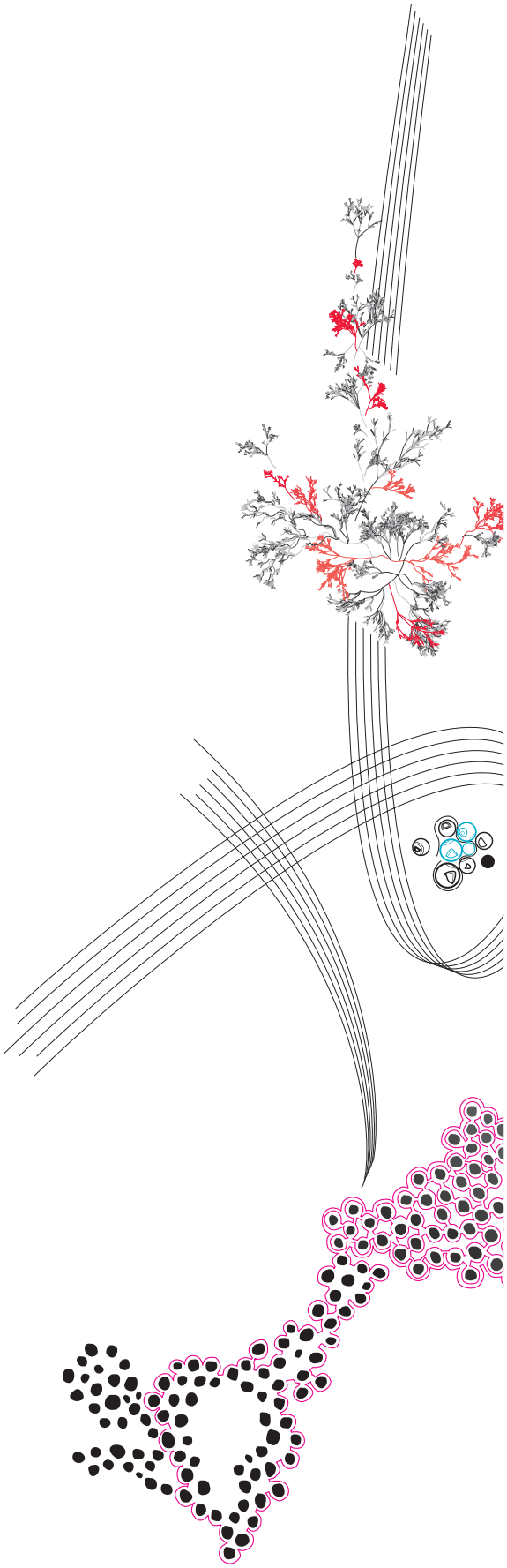

BSc Thesis Creative Technology

Using everyday space as an interface for reducing Late-Night Snacking

Jonathan Jeuring

Supervisor: dr. C.M. Epa Ranasinghe
Critical Observer: dr. M. Gerhold

July, 2024

Creative Technology
Faculty of Electrical Engineering,
Mathematics and Computer Science

Abstract

Non-communicable diseases are the leading cause of death worldwide, with nutrition and sleep being two of the most significant factors contributing to their development. Late-night snacking can negatively impact both factors because snacks are often unhealthy, and eating many calories during the evening may negatively impact sleep quality. This thesis aims to explore the possibility of using an artifact to reduce late-night snacking by making it unobtrusive, tangible, and integrated into the surrounding environment.

This research uses the design thinking process, which emphasizes a user-centered approach to designing. To gain an understanding of the motivations and circumstances behind late-night snacking, interviews were conducted. The conclusions gathered from these interviews were used to design and create a prototype that can reduce late-night snacking, which resulted in a snack dispenser to provide a healthy snack in the evening. This prototype can replace other snacking by creating an easy and satisfying user experience. After the user has finished their snack, the prototype will emit a mint smell to reduce appetite.

Quantitative evaluation of the prototype was performed using AttrakDiff, a detailed user experience questionnaire, while qualitative evaluation was done using a focus group. Both tests resulted in primarily positive feedback from the participants. In addition to contributing a functional prototype, this thesis offers design recommendations based on the results of the focus group. These recommendations provide practical improvements to the design that can be further explored.

Contents

1 Introduction

Non-communicable diseases (NCDs), such as cancer, heart disease, and diabetes are diseases that are not transmitted from person to person but are instead mostly caused by unhealthy behaviors. Currently, they are the leading cause of mortality, contributing to 74% of deaths worldwide and 90% of deaths in the Netherlands [1, 2, 3]. A fundamental determinant influencing the probability of contracting such a disease is one's age. The aging process and the likelihood of developing an NCD can be accelerated by various factors, which may be environmental, metabolic, genetic, or behavioral. An approach to prevent NCDs would be to change people's behavior by improving physical activity, changing unhealthy diets, reducing drug use, and increasing sleep quality [4, 5]. All these problems need separate and unique solutions, because they have different causes.

This thesis focuses on reducing unhealthy eating habits late in the evening or at night. Many people have a habit of eating right before going to bed. According to the 2021 survey by the International Food Information Council [6], about 60% of Americans snack after 20:00, with almost 20% eating a snack after 23:00. Late-night snacking is when an individual eats before going to bed after dinner has been completed. This definition does not include dessert eaten right after dinner or nocturnal eating, where the snacks are consumed after waking up in the middle of the night. While late-night snacking, individuals tend to eat unhealthy foods, which can cause weight gain and other health issues that increase the probability of non-communicable diseases in the long term. Another issue is that eating before going to sleep [7, 8] may reduce sleep quality. These effects are further explored in the background research in Chapter 2.

Kim *et al.* [9] show that 77.1% of college students in the area of Chungnam in South Korea engage in late-night snacking, with more than 60% of those individuals snacking after 23:00. College students often snack more than adults for various reasons, including hunger and social ones, because they care less about their health than working adults. It has been found that some college students experience various health effects that are associated with late-night snacking such as weight gain, psychological issues, headaches, and digestive problems [9, 10, 11]. Because the issue is so prominent amongst college students, this thesis will be focusing on this group.

There are many reasons an individual might eat before going to bed. One of them is an early or small dinner, which can make the person feel hunger later in the evening. Stress, anxiety, or loneliness can cause people to find comfort in food to relieve their emotions. Furthermore, social reasons can result in late-night snacking as people often eat during social gatherings or events. Some individuals experience hunger cravings that are not caused by a lack of food but by a habit of snacking in the evening. These are some example of common reasons for late-night snacking but many motivations exist.

The problem of late-night snacking can be challenging to deal with. Although online advice on how to prevent eating before bed is easy to find, but also easy to ignore, and might not contribute much to behaviour change. Going to a therapist is a big step to take. In the last decade, quite a few apps or devices to support

behaviour change have been developed, for example the calorie tracking app Myfitnesspal which is often used for weight loss [12]. No app or device for supporting reducing late-night snacking was found. This may be because the problem is too specific, or because most people do not care about or are not aware of the impact it has on health.

Another challenge is that there are many different reasons for late-night snacking. These reasons will often require individual solutions, and therefore there exists no solution that will solve the issue for everyone. Late-night snacking might be driven by complex negative emotions, which cause behavior that can be more difficult to change than regular behavior [13]. One of the most common reasons for late-night snacking is because it happens in a social setting, where eating the food is a part of connecting with other people. This can be part of the culture. Social pressure is an important factor in influencing behavior, making it challenging to solve. For all of these reasons, it can be difficult to present a solution that works for all or even most individuals, as it requires a balanced approach. This solution should be general enough so that it can help many people, but it should still be specific to address individual motivations behind late-night snacking.

This thesis aims to explore the possibility of using an interactive tangible artifact that can be integrated into the surrounding environment so that it is unobtrusive. Mobile applications are undesirable for these purposes as those have shown multiple limitations, such as 'display blindness', attention overload, and low recall [14], therefore the goal is to make the device be tangible. The solution should be unobtrusive so that the user is more motivated to adopt it. The research question will thus be: how can a tangible interactive system that integrates into the surrounding environment be used to reduce late-night snacking in university students?

2 Background research

This chapter discusses the background research that has been done for this project to get a better understanding of the problem at hand. First, the health impacts of late-night snacking are clarified, which shows when and how late-night snacking can become a problem. This chapter also introduces habits as a solution for behavior change and describes how they can be implemented. Finally, an overview is presented of the state of the art in the world of technologies that reduce eating in general.

2.1 A definition of late-night snacking

Late-night snacking is when a person has a snack more than an hour after finishing dinner, before sleeping. A desert is not considered to be late-night snacking because it is still a part of dinner. The snack can be any kind of food. The phenomenon of late-night snakcing has been getting more media attention in recent years [15]. Suri and Pradhan [16] state that almost 50% of adolescents snack late at night.

2.2 The health impact of late-night snacking

The research about the health impact of eating before sleeping has produced varying results. When designing an artifact to reduce late-night snacking, it can be important to know what type of snacking has an effect on the body and what those effects are.

2.2.1 Late-night snacking and sleep quality

Research has yielded divided results on the impact on sleep quality from late-night snacking. Sakthivel *et al.* [7] state that the studies on this topic all conclude a worse sleep quality after late-night snacking, except one. This study [17] concluded that there was no significant difference, although it mainly looked specifically at the impact on sleep apnea. Sakthivel *et al.* [7] contributed the deviating results of Geliebter *et al.* [17] to the fact that it used an objective measurement of sleep quality instead of a subjective one like the other studies, which all used surveys to measure sleep quality.

When only looking at studies that use objective measurements of sleep, the results are still divided. Driver *et al.* [18] claim that eating a large meal 2-3 hours before going to bed did not significantly affect sleep, although body temperature did change. The fact that only seven healthy men participated in this study, decreases the statistical power. Another issue is that women might yield different results, which was the case in another study [8]. Here it was found that the intake of high-energy foods correlated with decreased sleep efficiency and increased sleep latency, mostly in women. This correlation was weak in men. The data also suggested that individuals who ate more fat in the evening had decreased REM sleep.

These correlations was not observed by Duan *et al.* [19], which compares the impact on sleep quality and quantity of having a dinner 5 hours before bed, and a dinner 1 hour before bed. It reported no significant differences in any of the sleep measurements. Considering all this, it is difficult to draw a definite conclusion, as the research is in disagreement. More research should be done using objective sleep measurements.

2.2.2 How late-night snacking influences the body

Late-night snacking will decrease fat oxidation in the short term and might cause weight gain. An important consequence of late-night snacking is that lipid oxidation is reduced [20, 21]. This has been found for women in [20], which also shows an increase in LDL cholesterol after late-night snacking. This is supported by the findings of Driver *et al.* [18]. These effects will cause increased body fat, and in the long term, increase obesity chances, which has a significant effect on the probability of contracting non-communicable diseases. Kelly *et al.* [21] agree with the findings about the reduction of lipid oxidation during the night. During sleep, an increase in the respiratory exchange rate (RER) is also observed by Kelly *et al.*; this refers to the volume of CO2 produced per consumed volume of O2, which can be caused by reduced lipid oxidation. The increased risk of obesity from reduced lipid oxidation is supported by McHill *et al.* [22], which found that individuals with high body fat were more likely to eat before going to bed. Even though this is consistent, these results are not found in other studies. An *et al.* [23] find that late-night snacking alone does not affect body weight, and a review [15] reports inconsistent findings regarding this topic. So, although the effects of late-night snacking might be unhealthy and imply an increase in body weight, this result is not always reflected in the science.

Though some effects on the body have been reported, the true impact on the circadian rhythm remains unclear. Where Kelly *et al.* [21] did not find any difference in core body temperature at night after late-night snacking, Driver *et al.* [18] did. This difference can be hard to contribute to one specific factor, but it might be explained by the difference in calories consumed, because the participants in [18] were eating a meal averaging 2846 kcal before 21:00, and the participants in [21] were only eating a 700 kcal late-night snack. A clearer result came from a study on rats [24]. It was found that a low dose of sugar could change the gene expressions of Nampt, Bmal1, Rev- erbα, and Cart, all of which play an important role in the regulation of the circadian clock. The effect late-night snacking has on rats, implies that the effect on humans might be bigger than found thus far.

2.2.3 The impact of different foods on sleep

Only large meals or snacks might have a significant influence on the quality of sleep. A low-energy, nutrient-dense snack (less than 200 kcal) has been found to have no effect on sleep quality [15]. It is common knowledge that mood-altering substances, such as alcohol or caffeine, can worsen sleep quality, but regular nutrients could also have an effect. Alahmary [25] found that consuming added sugars

is related to poor sleep quality in university students. A student with an intake of added sugars throughout the day is 3.5 times more likely to get poor sleep quality as well as a significant chance to get less sleep enjoyment. Alahmary *et al.* [25] did not look at the specific timing of consumption, which makes it less relevant to the research question. Soliz *et al.*[24] shows that rats who got a sweet treat administered right before the sleeping period, had significant negative health effects, indicating a poor sleep quality. More research has to be done into the effects of consuming sugar right before sleeping on humans.

A nutrient that was proven to have benefits when eaten before going to bed is protein [26, 27]. Studies agree that consumption of protein late at night increases muscle protein synthesis and has favorable effects on metabolism, such as an increased resting energy expenditure in the morning.

2.2.4 Conclusions

The goal of this background research was to gain insight into how different factors of late-night snacking impact health, and to answer the research question: to what extent does late-night snacking impact the health of healthy adults? The research relating to this question does not always give clear conclusions and papers often contradict each other, but there are still some insights to be gained. It appears that eating a high-energy meal before bed can impair sleep quality, although not all studies have observed this. It is possible that the effects of eating before bed vary a great deal from person to person, explaining the different results obtained from the studies. Another important consequence of late-night snacking is that fat oxidation will be decreased, which suggests potential weight gain in the long term, but not all science agrees with these results. So, for some people, late-night snacking can have adverse health effects through worsened sleep quality and less fat burning, but this conclusion is not applicable in many situations, including where the snack is small or where the individual is unresponsive to the averse effects of late-night snacking.

For people who are concerned about their health, it is important to know which habits have harmful effects and which habits do not. This is why more research should be done to provide a clearer answer to this research question. The current science is limited because it often does not have many participants, or subjective measurements are used to assess sleep quality. A study on the relationship between the number of calories consumed shortly before sleep and sleep quality is needed, as well as a study that investigates the importance of timing. It should become clear how much time is optimal between the end of the last meal and the start of sleep. Finally, the difference in the impact on sleep from late-night snacking between men and women should be studied, because a difference has been observed, but the science on it is still very limited.

2.3 Habits

Habits play an important part in health-related behavior change. In many cases, health behavior interventions only last for a short time as people quickly go back to their old behaviors, weakening the health effects caused by the healthy behavior

[28]. This is why forming new habits is necessary. Habits will shape a person's identity from a person who does late-night snacking to a person that does not eat much after dinner [29, 30, 31]. These sources also found that identity can shape habits: someone who identifies as a runner, will be more inclined to often go for a run. Creating healthy eating habits will make people healthier and give them an improved self-image.

A method of changing one's behavior is called a Behaviour Change Technique (BCT). To change behavior on the long term, habit formation is required, which is listed as technique 8.3 in the BCT Taxonomy [32]. Listing 93 unique BCTs, this taxonomy presents a clear list of well-defined techniques with consensus. The BCT taxonomy will be used to refer to and define BCTs in this GP.

2.3.1 The difficulty of habit formation

Forming good habits can be difficult, as is eliminating bad habits, but by using the right techniques it becomes easier [29]. People often try to rely on motivation and self-control to change their behavior, but this method is unreliable in the long term. People with problematic habits of overeating with the intention to stop this behavior have been found to fail their goals, because when a cue associated with eating is presented to them their goal-directed behavior transforms into habitual behavior [33]. Reinforced habits that have been repeated many times are immensely difficult to change by relying only on motivation and self control.

2.3.2 How to change habits

The book Atomic Habits by James Clear [29] describes a four-step process of building habits in Chapter 3. A cue associated with the habit is what triggers the habit. This is followed by a craving which is the desire for the result the habit produces. The craving is met with a response, the third step in the process, which is the performance of the action that is involved in the habit. Finally, there is a reward which satisfies the craving. An example would be a person smelling a sweet pastry as they pass by the bakery, which is followed by a craving for that pastry. The person eats a pastry so that the craving is satisfied. This would contribute to a habit of getting a pastry when walking past the bakery.

To change a habit, multiple methods can be used to influence all four of these states. To create a new habit it is important to create an obvious cue that will trigger it. This cue could be a sound or a visual interruption so that it cannot be missed. For a craving, the desired behavior should be made attractive, the desire to do something becomes much stronger when there is an immediate reward for performing that action. By making performing the habit easy, the response will be more likely to happen. The action should not take long and not involve complicated decisions, because a big change in behavior is much more difficult than a small change. At last, the habit should have a satisfying reward in the short-term. By using these four steps, it becomes much easier to continue the habit on the long-term.

FIGURE 1: The Bite Counter

2.4 Existing solutions

A device that specifically aims to reduce late-night snacking has not been created before, but many different devices have been created with the goal of helping individuals lose weight. The problems that come with weight loss are similar to those that occur when trying to reduce late-night snacking, as both goals amount to reducing food intake, only the context and reason behind food intake may be different. For these reasons, mainly general weight loss devices that do not address a specific issue will be looked at.

2.4.1 Tracking devices

The least invasive types of intervention are devices that track how much you eat and tell you when it becomes too much. Such devices often come in the form of a smart kitchen tool or a mobile application, but, as explained in Chapter 1, mobile applications will not be considered because of their limitations. An example of this type of intervention is the Bite Counter [34], as seen in Figure 1. This device can detect wrist motion to identify when someone takes a bite. Normally it displays the time like a regular watch, but when a button is pressed it tracks the number of bites someone takes and displays them. Scisco *et al.* [35] show that this device can be used to achieve a slower rate of eating which can reduce calories consumed for people with a high calorie baseline. Another use would be to provide bite count targets to also reduce calorie intake [36]. An advantage of using a wrist-worn device is that it can be used in any environment to track food, which is not the case when using scales or image processing [34]. The downside is that it cannot measure calories or nutrients on its own.

Another tracking device is the Smart Plate [37], depicted in Figure 2. This plate contains three integrated weight sensors that can measure the food in three different compartments. These sensors share their data with a mobile application that can use the mobile camera to take a picture of the food and can track what food is presented on the plate by using an AI. By combining the data of the weight sensors and the picture the app can analyze the meal, telling us the energy, macro, and micro nutrients the meal contains. This data is then transferred to a virtual coach that

FIGURE 2: A smart plate can track food consumption

helps the user meet their weight loss goals. A limitation of the smart plate is that the user always needs to eat from this plate to consistently track their food intake. The coach needing the data on all food intake could become a problem because food tracking can get cumbersome for users.

Diet tracking with these devices is not a viable long term option for most users, because it requires too much effort and is often inconvenient. It has been observed that when individuals track their diet with the goal of losing weight, the number of logged foods go down after only some a few weeks, implying that individuals become less accurate in their reports [38]. Inconsistent tracking is not effective for weight loss [39]. Because of these reasons, diet tracking is not a permanent solution for most individuals.

2.4.2 Food intake limiting devices

Other solutions for weight loss create a physical barrier when eating food by reducing the available space in the mouth. As described by Ryan *et al.* [40], the SmartByte™ system is a medical device that promotes mindful eating by slowing down the rate of eating by decreasing the volume in the mouth, pictured in 3. It has the end goal of reducing energy intake and accomplish long term weight loss. Every individual needs one that is fitted to their mouth. They only wear it while eating. It was found that eating quickly leads to over-eating and weight gain [40]. Wearing this device resulted in weight loss and improved health.

A similar but more extreme device was reported by Brunton *et al.* [41]. This device was put in the participant's mouth for two weeks without interruption, causing them to not be able to open their mouth more than a few millimeters. This restricts the individual to a diet of only liquids, while the ability to breathe and talk remains. This device is suited for extreme weight loss; the participants in the study had an average BMI of over 40 and lost over 6 kilograms in 2 weeks.

These types of devices have been shown to achieve results in weight loss [40, 41], but are extreme solutions. According to Brunton *et al.* [41], individuals reported to find them occasionally embarrassing and the devices can be uncomfort-

FIGURE 3: The SmartByte™, a device that sits in the mouth while eating

able, making these solutions inappropriate for most of the population. The systems are designed to use temporarily, but a long-term solution is preferred.

2.4.3 Cue removing devices

Finally, there is also a group of devices that focuses on removing the cues that are associated with eating. There are various boxes available that can lock away an addicting things for a set amount of time, including foods [42]. These can work in certain situations, but effective usage can be difficult. Locking away food every evening takes effort and is unrealistic for most people. Another problem is that it is impossible to lock away all foods, thus making these devices only useful when only one certain food is causing the overeating.

FIGURE 4: Someone inserting the NozNoz

Another device that aims to support weight loss through removing cues associated with eating is the NozNoz, a soft wearable nasal insert that reduces the sense of smell by directing airflow away from the olfactory receptors [43]. The smell of food can induce an unconscious cue that can cause a craving for that food. This wearable can reduce cravings for food by influencing the subconscious. It is not as invasive as some of the devices previously mentioned as it does not require effort

to use it and it sits in the nose discretely. NozNoz [43] claims the device is comfortable when the user has adjusted to wearing it, making it a long term option for healthy eating. Someone inserting the NozNoz can be seen in Figure 4.

3 Methods and Techniques

To answer the research question posed in Chapter 1, it is useful to follow a strong methodology that has been proven to solve problems. This chapter discusses how design thinking is used to find a solution to the problem of how to reduce late-night snacking using interactive technology. First, the idea of design thinking and its benefits are explained. This is followed by an overview of the design process and later each step of the process is discussed in more detail and how they are applied in this project. All techniques used to gather or process information will be introduced here.

3.1 Design Thinking

The designing in the project will be done according to the design thinking process as described by the Interaction Design Foundation [44, 45, 46]. It is a process that aims to encourage innovative and creative solutions based on user needs. This is done by creating a deep understanding of the problem and redefining it with a user-centered problem statement to then use that to generate many different ideas for different types of solutions. Fast prototypes are used to evaluate these ideas together with the user. This approach always revolves around the user. For these reasons it is a fitting methodology for this project, because it requires a creative solution with a user-centered approach.

3.1.1 The problem with ill-defined problems

Designers are often faced with ill-defined problems which lack a clear solution and have many uncertain characteristics such as when, why, how, and to whom they occur. Ill-defined problems are always unique and therefore require a unique solution. It is still possible that solutions to other problems can serve as building blocks for this solution, but it can never be copied one to one. Another big challenge when solving ill-defined problems is the fact that the perfect solution does not exist. Often the designer has to estimate what a good solution would be and then commit to it, even though a better solution might reveal itself with hindsight.

3.1.2 The five stages of the design process

There are five stages of design thinking: empathize, define, ideate, prototype, and test as can be seen in Figure 5 [44, 45]. This is the most common order, but these stages are not linear and can done out of order, or at the same time, or they can even be repeated or emitted. The first stage, empathize, is about exploring the problem and getting to know the user; the result should be a a greater insights into the user needs and an understanding of the problems that need to be solved to fulfill those needs. The define stage is about creating a human-centered problem statement based on the information from the previous stage. Designers should not express the statement as a need for themselves, but only for the user. Now the designer can ask themselves how they might fill these user needs and what their

solution would look like. This is the ideate stage. By using various brainstorming techniques the designer strives to find innovative solutions to the problem statement. In the prototype stage, the designer identifies the best solution and creates an inexpensive and fast version of it. These prototypes are used in the test stage to evaluate whether the solution solves the problem well. The results from the evaluation might provide new understanding that lead the designer to return to one of the previous stages.

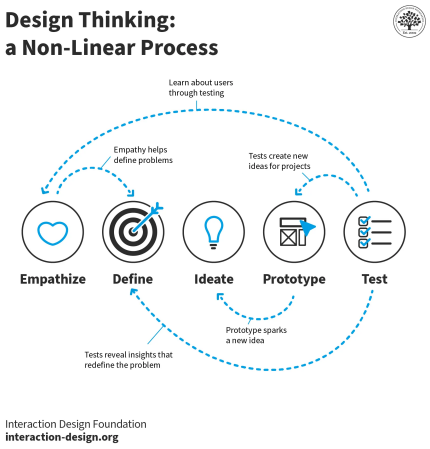

FIGURE 5: Common Elements of design thinking frameworks

3.2 Applying Design Thinking

There exists no single solution that will completely solve late-night snacking because it is an ill-defined problem. Late-night snacking can occur at 04:00 when a party-goer gets hungry and goes to a snack bar, or it can occur when a lonely college student eats before going to bed to cope with their negative emotions. Many variables in late-night snacking differ between individuals, with some examples of the variables being the levels of hunger that the user often experiences during the evening, the type of snacks that are most craved, the environment in which the user commonly exists, and the most common evening routing.

In this graduation project different user research methods were used. All research described here has been approved by the Ethics Committee Computer & Information Science of the University of Twente.

3.2.1 Empathize

To gain a better understanding of the problem at hand, background research was done to discover the scope and impact of late-night snacking, to learn about how behavior is changed, and to look at some existing solutions to related problems,

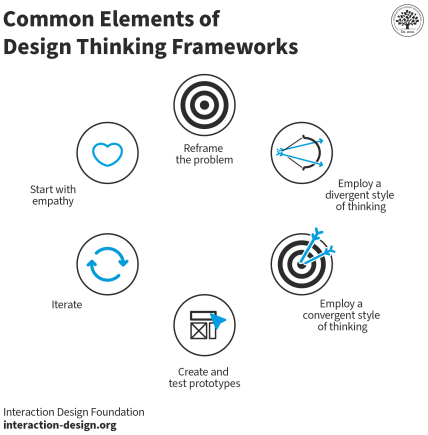

FIGURE 6: Common Elements of design thinking frameworks

this can be found in chapter 2. The research examines studies that have looked at the context and reasons behind late-night snacking, so the situation can be better assessed. The background research was limited by several factors. First of all, many studies were done on other user groups, such as older populations or student in foreign countries. These individuals may have different circumstances during their evenings and different reasons for late-night snacking. Another limitation is that the background research did not report enough detail in the description of exactly why people snack during the evening. Jun *et al.* state possible reasons as, for example, "Hungry" or "Join with people". This information can be useful, but knowing why the user is hungry and who the people are they are joining, would explain more about the motivation of the user for late-night snacking.

Interviews

This is why user interviews are necessary: they provide even further knowledge about the user and clarify the problem. By asking questions that require personal answers, the reasons behind late-night snacking may become more exposed. The advantage of using an interview over a simple survey is that it is possible for the researcher to ask the interviewee to clarify their answers and elaborate on them. This way, a more complete picture of the late-night snacking scenario can be attained, because the participant can walk the interviewer through the events in the evening, explaining all relevant details.

The first step to conduct the interview was to specify the goals of the interview. The format of a semi-structured interview was decided upon, so that follow-up questions could be asked to reach more depth in the interview. The predetermined questions ensure that the interview goals are met while the freedom to adapt remains [47]. This format is often used in qualitative research. The interview questions were constructed so that, after answering some basic questions, the partici-

pants could recall their last experiences of late-night snacking and describe them in detail. There are some optional questions that are only asked if relevant information is missing. The interview participants were found by contacting students on the campus of the University of Twente.

3.2.2 Define

During the define stage, the conclusions that were found in the empathize stage will be analyzed to identify the core problem. This will be expressed as a human-centered problems statement, meaning that it will be of the user needs from the perspective of the designer. It shall look like this: "Users need to ..." This problem statement will give the designer an idea of the functionalities and features the product might need to satisfy the user, ensuring an easy transition to the ideation stage.

The MoSCoW method

A method of defining and prioritizing requirements is the MoSCoW technique [48]. When a project has many requirements, it is often not possible to meet them all due to constraints in time and resources. This is why it is important to prioritize the the essential requirements and ignore those that are insignificant. MoSCoW stands for must, should, could, and won't. These are the four categories that all the requirements will fall into.

- Must: when a requirement is a must, it is essential to the success of the project, and if it cannot be delivered upon the project will be deemed a failure.
- Should: this means that this requirement is highly important and will add much value to the user
- Could: the requirements in this category are desirable, but not strictly necessary, so they can be ignored facing limitations.
- Won't: these can still be desirable requirements, but they will not be implemented in its current stage, because they can be out of the scope of the project. They may be included in the future.

The items in each category have to same priority. An advantage of the MoSCoW technique is that all categories have a clear meaning. This technique will be used during the define stage.

3.2.3 Ideate

After the define stage, the designer aims to generate ideas, based on the conclusions from the empathize stage and the problem statement from the design stage. During ideation brainstorming was used to generate more ideas and think outside the box. The divergence-convergence process was used to quickly generate as many ideas as possible, after a list of ideas has been made, they will be selected

and refined to a set of ideas that are deemed good. Diverging is done by taking inspiration from many different solutions to other problems that share similarities to the one at hand. Here it is important to challenge existing assumptions and improve creativity to find more unique solutions. From the list of ideas, the ones that were the most feasible and impactful were selected and developed further.

3.2.4 Prototype

Due to time constraints, only one prototype was built during this project. This is not ideal, because multiple prototypes allow for comparison when testing to see which solution solves the problem best. With the comparison the designer can get a better insight into what techniques and features work best, thus better design recommendations can be provided. The assignment of this project required a functional prototype and with the available time, it was only possible to make one. This caused a situation where the designer had one guess available as to what solution would be best. This one guess was final as it was not possible to start building a different prototype after the first one was finished. It was made based on the requirements from the define stage. When the estimated best idea had been chosen, the goal was to build a functional prototype made from cheap components that are quick to assemble. The original idea could be changed based on new insight gained during the building process. When prototyping, functionality was constantly tested at every step in the process.

3.2.5 Test

During the test stage, the designer evaluates the product to see if it meets the user requirements and if it helps solve the problem described in the problem statement. Due to time constraints, testing the prototype on a larger scale with a longer time process of multiple weeks is out of the scope of this project. Unfortunately, this means that it can not be tested if this prototype actually works to reduce late-night snacking on the long term.

AttrakDiff

The first method that was used during the evaluations is AttrakDiff [49]. Developed by Hassenzahl, Burmester, and Koller, it is now one of the most popular methods for user experience research [50]. It is a questionnaire containing 28 queries where the participant can choose between two opposing descriptive terms using a seven-point semantic scale. AttrakDiff measures four different categories:

- Pragmatic Quality (PQ): this scale measures the usability, efficiency, and effectiveness of the product or service
- Hedonic Quality-Identity (HQ-I): both hedonic scales measure emotional reactions, this category is about if the product aligns with the users identity
- Hedonic Quality-Stimulation (HQ-S): this measures the stimulation of the user, and if they experience the product or service as new, creative, exciting, or captivating

- Attractiveness (ATT): here the overall value for the user of the product or service is assessed

The AttrakDiff questionnaire should be used for a hi-fi prototype because many of the assessed qualities will only become visible later in development. What makes AttrakDiff better than some other tests is that it gives a more complete overview of the user experience, because it has four different scales that can all stand alone. It will be used to gain insight into the general user perception. The participants that will fill out the survey are first briefed on some of the features of the prototype and they will be able to interact with it.

Focus group

AttrakDiff produces quantitative results for the evaluation, but to be able to improve on specific features it can be important to also get qualitative evaluation results. For this reason, a focus group was used. A focus group allows for direct conversation about the topic, giving the opportunity to investigate deeper into what could be better and the reasons behind that. It also becomes possible to inquire about design recommendations, missing features, and desirable changes. Together in a group, the participants are encouraged to share and discuss their ideas, brainstorming together about further improvements to the design. The opinion of potential users are very important to keep the design user-centered. The focus group was performed with the same participants as the AttrakDiff survey, with the focus group directly following it up. The newly gathered design recommendations can provide some new insights into the user requirements and might bring the project to another ideate stage to further improve it. This is the iterative process.

4 Design

As stated in Chapter 1, the goal of this project is to create a tangible device that integrates into the environment that can be used to reduce late-night snacking in university students; this is still a vague description of a problem, which makes it difficult to see the solution. With this short description many important details remain unknown: what environment is in meant here? What are the most common reasons behind late-night snacking? How can behavior be changed effectively? Before possible solutions can be discussed, an elaborate description of the problem is essential, which will also produce problem requirements.

The whole designing phase will be described in this chapter, from gathering a deeper insight into the problem to finding possible solutions. The chapter starts with the empathize stage that describes the interviews that were held to get a deeper understanding of the user and the problem. This is followed by the define stage which presents the problem statement. During the ideation stage, multiple ideas for the solution are described.

4.1 Empathize

This stage is about understanding both the problem of late-night snacking and the user of the device that will be created. User-centered design requires user-centered research, which is why interviews are conducted, to understand why the problem happens, to find out the details on what the problem looks like, to hear how the potential user feels about the problem, and to understand more about the relation of the potential user to the problem.

4.1.1 Interviews

There was no research found on late-night snacking habits among students in the Netherlands, so small scale interviews can create new information that will be used when creating a solution. Some of this information does exist for Korean students [9]. The study found that 77.3% students do late-night snacking with 47.85% doing it once a week or more. The most common reasons for late-night snacking are hunger with 45.5% and social reasons with 28.5%. Only 2.6% of the students do the late-night snacking alone. The most common time for late-night snacking is between 23:00 and 01:00 with 45.3% of students snacking during this period. Late-night snacking can be heavily influenced by culture, so these values might not be accurate for the Netherlands. This data will be compared to the interview results.

The interviewing process

Before anything else can be decided upon, the goals of the interview need to be identified. These goals are to explore the reasons people have for late-night snacking, to know around what time they snack, to learn at what location people snack, and to discover what tools, such as cutlery or pans, are used the consume the snacks. To reduce late-night snacking, the most important information about the user might be the reason why they do it. This is an essential factor to know

because the solution should be oriented at countering this reason for late-night snacking. Knowing the most common location and timing of late-night snacking can also be useful, because this will help when designing how the device will be used. A smart kitchen tool might look different than a device that sits in the bedroom, which makes knowing the location important. The information about the tools that are used for late-night snacking might shape the device as well when it can be integrated into a specific tool, for example, a smart fork that signals to you to stop eating when late-night snacking. For this example to work, it is important to know that a fork is used for eating.

This interview uses a semi-structured approach, which gives the researcher the freedom to ask in-depth follow-up questions while still keeping consistency within the different interviews so that the results can be easily compared between them. The questions were devised with the goals in mind. After the participant had read the information letter and given informed consent using the consent form found in Appendix D, the interview would start with basic, easy to answer questions so that the interviewee starts to feel more at ease. This beginning part consisted of the following questions:

- What is your age and gender?
- What is your current living situation?
- How important is healthy eating to you?
  - If it is important, What do your struggle the most with when trying to eat healthy?
- At what time do you usually eat dinner?
- At what time do you usually go to bed?
- How often do you eat something between dinner and when you go to bed?

After these questions, the interview comes to its main topic which should reveal how, when, and why late-night snacking happens, what the snack is, and how the participant feels about it afterward. The questions asks the participant to describe a personal late-night snacking occurrence:

- Try to remember the last 2 examples of when this happened. Could you walk me through the process of how that went?

This one question is usually met with long answer and many follow-up questions to try and gather the information that was described in the goal of the interview. Having the interview participant walk through the entire process of a concrete example of late-night snacking may reveal some reasons behind eating that would otherwise be left hidden when just keeping to more regular interview questions because participants are encouraged to describe their process in great detail. After the answer has been deemed sufficient, the final few questions are asked:

- Are these last 2 examples how it usually goes?

  - If not, What was different?

- Do you snack while feeling lonely, sad, anxious, stressed or other negative emotions?

- Have you ever tried to stop?

These final questions are there to ensure that no important information was missed during the previous part. Often, this part follows the previous part smoothly, so that they appear like follow-up questions.

Because the research question is focused on students, the interview participant will have to be students as well. All participants were studying Creative Technology at the University of Twente. This was done for practical reasons because the researcher is in touch with Creative Technology students and therefore they are more willing to help out with research. Six participants were selected and interviewed on the University of Twente campus without interference. The interviews lasted five to seventeen minutes and all of them were recorded. The recording were transcribed using online AI software [51]. Ethical approval was gathered beforehand from the Ethics Committee Computer& Information Science of the University of Twente.

These results were coded using a combination of inductive and deductive coding. Predetermined coding categories are based on the interview goals, but when other relevant information came up in the interview transcripts, this would be made into a new category. The predetermined categories are:

- Living situation
- Dinner time
- Late-night snacking time
- Sleep time
- Common late-night snack
- Common late-night snacking tool use
- Main reason(s) for late-night snacking
- Late-night snacking location

After analyzing the interviews two new categories were added. Interestingly some of the predetermined categories did not yield usable results in the interviews. Participant could not give a single answer to the question or the answers were unclear. This is the case for three categories:

- Common late-night snack
- Common late-night snacking tool use
- Late-night snacking location

Two categories were later added, as relevant information was given about them in most interviews. These are:

- Regret
- view on late-night snacking as a problem

These categories were filled out in a spreadsheet to get an overview of late-night snacking habits in university students.

Interview results

The complete coded results can be found in Appendix A. Now, other findings from the interview will be discussed per coding category.

For the living situation none of the interviewees live alone, one lives with their parents, the rest lives in student housing all having between one and nine housemates. Dinner is eaten together in all 6 households.

The timing of when snacks are eaten is rather consistent. The average participant has their dinner at 18:55, and goes to sleep at 00:20. This leaves 5 hours and 25 minutes between the start of dinner and the end of the day. The average time for late-night snacking is 23:07, meaning that on average there is 1 hour and 13 minutes between snacking and sleeping.

The type of snack and the tool use are heavily related, where the tools completely depend on what snack is selected. There is no common tool that is used far more than other because there is no common snack for any interview participant. The type of snacks that are popular are simple food that do not require much preparation, such as toast, pasta, nuts, sugary snacks, and crisps. These snacks are fast to make and rich in calories.

The most common motive for late-night snacking is social reasons, with four out of six participants stating this as an important reason. Only one participant snacks because of severe hunger cravings during the evening and one other sometimes has mild cravings. A third participant also has hunger cravings but is consistently able to ignore them. Eating to warm up after feeling cold is a reason given by one interviewee and another one mentioned that they eat late-night snacks mostly due to habitual eating and stress eating.

Late-night snacking locations vary a lot amongst all participants, therefore it is hard to conclude anything from it. The bedroom, living room, and kitchen were often mentioned, but no participant expressed that there was a single location that was much more common for late-night snacking.

Two students mentioned that they often regret it when they did some late-night snacking. These same two individuals also said that they find their health important, they emphasized this more than the other interviewees. One of these said that late-night snacking is a problem for them and that they are actively trying to solve it. The other expressed that it is only sometimes a problem. There is one other interview participant who also said that they saw late-night snacking as a problem only sometimes. The other three participants did not.

Discussion of interview results

Here the results gathered from the interview will be interpreted and discussed. A conclusion will be drawn from all coding categories, but some will be more important than others. Some of the limitations of the interviews will be discussed as well.

The living situation of Dutch students are important because the participants said they often eat snacks together with other people in their household, which can have an impact on why the snacks are eaten. With all of the interview participant sharing a household, it is not surprising to see that social reasons are the most common motivation for students to late-night snack, even though it came in as the second most important reason for Korean students [9]. Unfortunately, social reasons are difficult to address with technology because it can often not account for how complex human interaction can be. Social interaction can happen in many different contexts and it is very diverse. A technology that can be applied everywhere would have to be a wearable and would interfere significantly in someone's life which is unwanted in this project. Also, it is unlikely that many students are willing to sacrifice parts of the social life to improve their snacking habits, because a social life is often valued highly. For this reason this project will focus more on solving hunger cravings. This is the second most important factor according to the interviews and it is more solvable with technology.

5 hours and 25 minutes is a long time to fast while awake, so it is normal to crave a snack during this period. For this reason, it is logical to not eliminate late-night snacking but to instead reduce it. According to Sun *et al.* [52], long gaps between food intake can lead to overeating, therefore having a snack after dinner can be beneficial. The average snack, however, is, according to the interview results, taken 1 hour and 13 minutes before bedtime on average, which agrees with the results from students in South Korea [9]. This short time between snacking and bedtime makes it more likely for the snacking to negatively impact sleep quality, increasing the chance of developing NCDs. For this reason, the snack should be had earlier in the evening. A small healthy snack in the evening is a better solution than eating dinner late, because an early dinner is healthier [53]. As mentioned in the background research in Chapter 2, a late dinner might also impact sleep quality, especially for women [18, 8]. A small snack, taken not too late in the evening, will do no harm.

Some factors in the process of late-night snacking vary so much that they are difficult to design for. The location could be one of many different rooms in a house. The type of snack also varies between many easy-to-prepare snacks. It is important for the final design that variance is allowed in where the device is used and what type of snack is consumed using the device so that it is accessible to different users.

From the interview results, it can be concluded that many students do not care much about this problem. For this reason, they will not be willing to put in much effort to solve it. This means that the solution should be so simple to use, that any user can do it without making any sacrifice except for their late-night snacking habits.

There are two notable limitations in this interview. First, all the data gathered

here is self-reported and therefore unreliable. Interview participants may not always recall their eating and sleeping habits accurately, which can cause inaccurate results. Second, the data has a small sample size of only six participants. The results gathered from these six students might not accurately represent all other Dutch students. For these reasons, the results here should be interpreted carefully with awareness of these limitations. Further research with a larger sample size is advised.

4.2 Define

During this stage, the conclusions from the interviews will be combined with conclusions from the background research to create a user-centered problem statement. Because the project is about changing the behavior of the user, the designer can not solve the problem for the user. For this reason the design should be aimed at helping individuals reach their goals.

4.2.1 Problem statement

The main problem behind late-night snacking that will be aimed to solve is that of hunger cravings during the evening, because social reasons are out of the scope of this project and other reasons are rare. To reduce the long time without eating between dinner and bed, and to make the change in behavior much smaller it is important that late-night snacking is reduced or replaced instead of completely stopped. Stopping will be more difficult and it will be much more likely to fail, as discussed in Chapter 2. It is also important that the interaction with the product is easy, fun, and fast so that even students who are less motivated about changing their habits are willing to use it.

When replacing a snack, it should be both healthy and does not impact sleep quality. As shown in the background research in Chapter 2, a snack with 200 calories or less does not impact sleep quality. It might be possible that larger snacks are also safe, but the more calories the larger the risk of impacting sleep quality. Another downside to high-calorie snacks is that they can cause weight gain, as discussed in Chapter 2. For these reasons, the snack should be low in calories for most users.

When taking into account that these changes should be maintained for long term health, it is possible to formulate a problem statement: university students who snack too much during the evening need to reduce or replace their late-night snacking with a controlled low-calorie snack on a long term.

4.2.2 Problem requirements

To prioritize the problem requirements the MoSCoW method is used, as mentioned in Chapter 3. All requirements are based on the conclusions drawn in previous chapters, they can be seen in Table 1.

Category	Requirements
Must	The solution must be tangible The solution must reduce late-night snacking
Should	The solution should be easy to use The solution should integrate into the environment The solution should be fun to use
Could	The solution could be unobtrusive The solution could promote general healthy eating
Won't	The solution won't completely stop late-night snacking The solution won't counter other unhealthy eating habits

TABLE 1: Problem requirements

4.3 Ideate

To generate ideas that may solve this problem it is important to brainstorm thoroughly. By reviewing the problem statement and analyzing the problem requirements beforehand, the direction of the project becomes more clear. To gather more inspiration, the state of the art was also studied further. Here, I will discuss some of the ideas that were explored during this phase. These prototypes were all later evaluated and were then either discarded or improved upon.

4.3.1 Smart kitchen lamp

A smart kitchen lamp replaces the regular lights there. During the evening the lights go out in the kitchen with no way for the user to turn them on, this might be combined with automated curtains for a stronger effect. The user cannot make use of the kitchen during the evening, because it is completely dark. To make the adjustment process easier, the lights can dim slowly in the evening with the kitchen getting darker. This method can still allow for some late-night snacking early on in the evening but late in the evening, the kitchen gets too dark to properly eat. This method reduces snacking but does not replace it. When it is late in the evening, this method can completely stop all snacking as the kitchen becomes inaccessible. Unfortunately, the darkness can be easily bypassed with a torch, weakening this method. There may also be food in other places in a house, which is not accounted for. Another downside is that this method only really controls the timing of snacking and not the amount. A user could still eat too much food early on in the evening instead of reducing their late-night snacking.

4.3.2 Anti-eating smell

During the evening, when snacking should be reduced, a room spray dispenser will emit a mint smell, which will reduce appetite [54]. Another advantage is that this smell can encourage brushing teeth [55, 56]. This dispenser can be placed in any location and can be programmed to activate around a certain time when the user often gets hunger cravings. A downside is that it can be an unpleasant smell

for some individuals. It also does not necessarily reduce or replace snacking, but instead it could stop it in many cases.

4.3.3 Smart snack dispenser

A dispenser that dispenses small snacks during the evening can be used to replace large amounts of snacking. The snack can be made available after dinner when the user can pick it up when they want to. The mint room spray can also be used here after the user has consumed their snack from the dispenser. Other snacks may be restricted by using the smart kitchen lamp or by locking them away. A downside is that this method may encourage late-night snacking because the machine makes it easier to have a snack for the user. This is why the snack should be healthy and low in calories to be of nutritional value and not disrupt sleep.

4.3.4 Anti-eating mouth spray

An anti-eating mouth spray could be carried around during the evening to use when hunger cravings arise. Based on current breath refreshing mouth spray as made by Listerine [57], the product can be sprayed in the users mouth to give a bad taste and reduce appetite. This solution does not only solve late-night snacking, but can also counter general hunger cravings throughout the day. It has similar problems to the smell dispenser, in the sense that it may be uncomfortable for the user and that it does not necessarily reduce or replace snacking. It is also a weak solution, because the user always keeps the option to not use this product when they do not want to.

4.3.5 Smart toothbrush

Brushing your teeth could suppress appetite. To strengthen this effect the smart toothbrush should be able to communicate to the kitchen to restrict access to snacks after the user has brushed their teeth. This can be done by using the smart kitchen lamp or by using locks. This method does stop all late-night snacking instead of reducing it. It does make sure snacks are not eating very late at night and gives the user some control over how late they brush their teeth.

4.3.6 The best solution

There is no single best solution for a complex problem like late-night snacking, but an educated guess can be made on what solution would work well. The snack dispenser shows signs of being a good solution because it meets the problem requirements laid out in the define stage. This solution will be combined with the room spray, because the room spray can be used after the snack from the dispenser has been finished to reduce appetite and thus further snacking. This method uses several behavior change techniques to increase the probability that the desired behavior is adopted and maintained. Two important ones are BCT 8.2 Behavior substitution and 8.3 Habit formation, because this solution replaces a bad habit with a better alternative. The room spray utilizes BCT 12.1 Restructuring the physical

environment, by changing the way the environment smells, snacking becomes less attractive. The next chapter will discuss how this prototype was realized.

5 Realization

During the prototype stage, some of the ideas from the ideate stage are made into prototypes, which are early versions of the product that can be tested for their usability and attractiveness while still being cheap and fast to make. This chapter describes the process of making a prototype of the snack dispenser with room spray because it is the result of the ideate stage. Only one idea was fully prototyped in this project due to limiting time constraints. It is essential that this prototype is functional so that it can be evaluated for usability aspects as well. To ensure this, functional testing was done throughout the entire prototyping stage. Every individual part has been tested on its own and in combination with the other parts.

5.1 Creating a functional device

This section describes what was created for the prototype, what resources were used, and how they were used. Figure 7 shows a functional diagram that shows the interaction between different components.

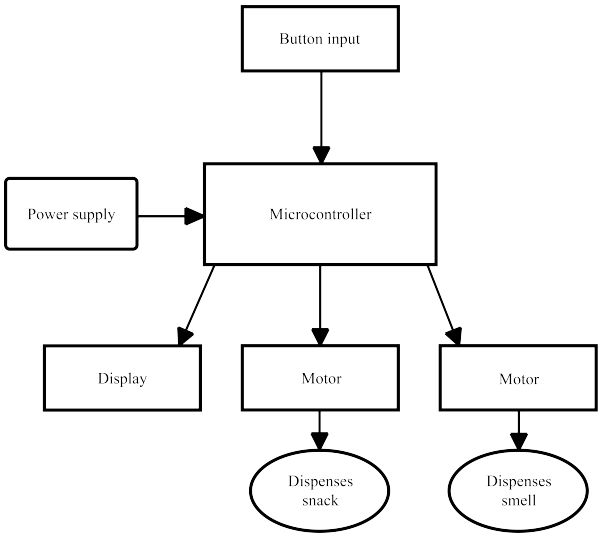

FIGURE 7: A functial architecture diagram of the prototype

5.1.1 Creating a cup dispenser

A snack dispenser can come in many forms. For this scenario it was decided to create a dispenser of already filled cups. This cup can be seen in Figure 8. This format was chosen because it is simpler and more practical. It has the added advantage that portions can be more precisely measured before they are put in the cup. The main downside is that this method takes up more space, because stacking cups would be much more efficient and there are many existing techniques for

FIGURE 8: A cup filled with snacks

disposing cups from an entire stack. This other technique requires the cup to be filled with food by the machine itself, complicating the system and making precise portions much more difficult. Because of this, compactness was sacrificed for a simpler and more precise system.

The cups are standard paper drinking cups. They are held by a 3D printed cup holder, as seen in Figure 9. All parts were modelled using Fusion360. This cup holder went through several iterations to create a tight fit where the cup can still be easily taken in and out. All versions followed a similar design but with different dimensions to test what the best fit would be. The final cup holder was printed six times so that the dispenser would be able to dispense six cups before having to be refilled. The cup holders were placed in a circle formation so that it can turn to bring a new cup to the front. All the holders were put in place in a structure that used press fits to attach them. They can be seen in Figure 10.

An Arduino Uno was used to control the cup dispenser. It takes the place the place of the microcontroller in the functional architecture diagram in Figure 7. The cups were spun by a small stepper motor because it fulfilled the necessary requirements for its task: Precise positioning, repeatability of an action, and the ease of controlling it with Arduino. This motor is connected to a driver that connects to the Arduino with four wires, ground, and 5 Volt. The cup holder structure is connected to the motor using a structure with a loose fit so that it can be easily removed, allowing for modifications to several parts.

FIGURE 9: The holder of a single cup

FIGURE 10: The holder structure with and without cups

FIGURE 11: A bottle of room spray

5.1.2 Adding smell

As seen in Figure 11 an affordable and small room spray was added with mint and eucalyptus smell, comparable to the smell of most toothpastes. It was located under the dispenser with a 32kg servo motor to activate it. This and the stepper motor are the two motors as seen in Figure 7. The smell bottle works by pressing down on the top, requiring a large amount of force to do so. A servo motor was used here because it only takes up one pin and a 32kg would have enough theoretical force to push down on the bottle. There was a structure created for both the bottle and the servo motor so that they were both held into place. Unfortunately, this structure would break during testing, because the PLA used for 3D printing material was not strong enough.

5.1.3 Making the encasing

The user should only be able to access one cup at a time, therefore a cover is required. Only the part with the cups needs to be covered for the prototype, as it is beneficial to keep the part with electronics accessible. To create a simple cover, two circles were lasercut with appropriate holes for the motor to sit in, these would be the top and the bottom of the cup holder structure cover. The side was made from cardboard, attached to the bottom circle using a glue gun. The gap between the ends of the cardboard was made large enough so that large hands could fit it to make the dispenser more accessible, yet the gap was too small to take out another cup than the one intended, this can be seen in Figure 12. A structure for the electronics below the cup holder encasing was made. It turned out weaker than desired so it has been strengthened using a glue gun, as seen in Figure 13. This completed the structure and encasing for this prototype.

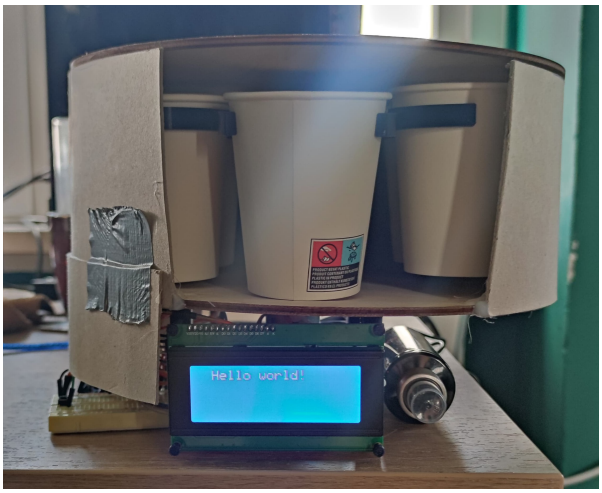

FIGURE 12: A frontal view of the prototype

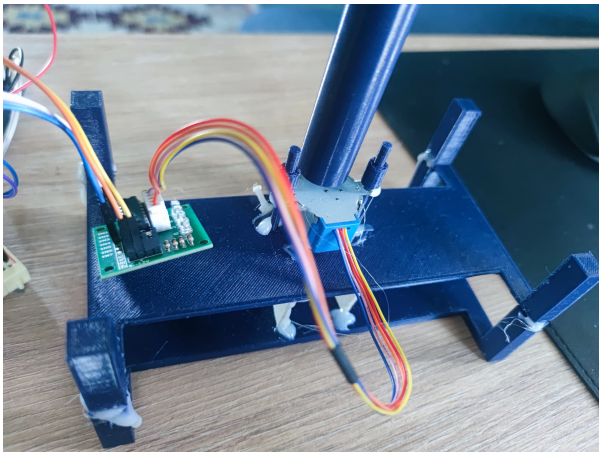

FIGURE 13: The lower structure of the prototype

5.2 Making the device interactive

5.2.1 Input

To give the user the opportunity to deliver input for the device, a small button was added to act for the input button in Figure 7. This button was functional but not satisfying because it was too small to click comfortable, however it suffices for this prototype. Only the simplest of actions can be performed by this button, this action being the offer of a snack to the user. No other actions are needed for the prototype because all that needs to happen is the dispensing of a snack, the release of the smell, and a timer starting until the next day.

5.2.2 Output

It is important to communicate with the user so that the device can give messages to the user about how they can use it, therefore a 20x4 LCD screen was added to the prototype as the display in the functional architecture diagram in Figure 7. This display used I2C to communicate with the Arduino, which saved on Arduino pin usage and made communication very simple. This screen can display 80 characters in total, and can therefore easily show simple messages to the user. There are four different messages that may be shown depending on the situation. When the user may press the button, which is after 09:00 on default, it displays: "Press the button to eat some food". After the button has been pressed this will change into: "Enjoy your food!". Ten minutes later the smell will release and the message becomes: "Now go and brush your teeth!". Ten more minutes later the display turns off until the next day when the dispenser is ready to be used again. With the display, all necessary components have been added. For an overview of the electronics, look at picture 14. This overview does not show all the exact correct components, but it does show how they are interconnected. To give a better overview of how the Arduino pins are used, Table 2 shows the used Arduino pins and how they connect to the components.

Arduino pin	**Connection**
2	button reading
5	servo signal
8	stepper coil 1
9	stepper coil 2
10	stepper coil 3
11	stepper coil 4
SDA	LCD SDA
SCL	LCD SCL
Vin	power supply positive
GND	power supply negative

TABLE 2: An overview of the Arduino pin connections

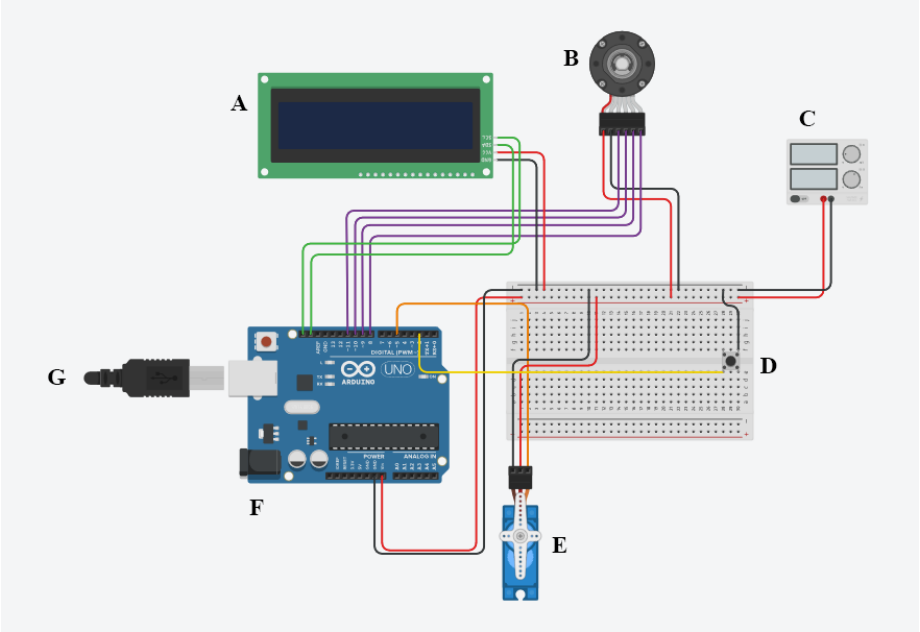

FIGURE 14: A schematic of the electronics in the prototype. A: LCD screen, B: stepper motor, C: power supply, D: button, E: servo motor, F: Arduino Uno, G: a possible laptop connection for programming the Arduino

5.2.3 Programming the dispenser

The dispenser is controlled through the Arduino IDE. The LiquidCrystal_I2C, stepper, and servo libraries are used to control the LCD, stepper motor, and servo motor respectively. The code uses four different states to loop through its daily routine. After the setup of that code has been completed, it enters the first state in which it reads the button input and displays the prompt to eat some food on the LCD screen. When the user presses a button the code enters a second state, which activates the stepper motor to turn 60 degrees and changes the display into: "Enjoy your food!" During the third state the machine waits ten minutes for the user to finish their food. When this state is over the fourth state will spray the smell. In the fifth and final state, the display is turned off and the device waits until the next day. On its default setting it will turn on the provide a snack from 21:00 to 01:00, based on the timings from the interview results. This setting could be easily changed. The code can be inspected in Appendix B.

5.3 The prototype in action

When the prototype is ready to dispense a snack at 21:00, the display will light up and tell the user they may press the button. When the user presses the button the cup holders will turn so that a new cup is presented that is filled with food. They can take out the cup, eat the food and put it back in the machine. Later, the device sprays an eucalyptus mint room spray and encourages the user to go brush their teeth. The screen turns off and the device can be used the day after.

The current method used for refilling is to refill all the cups individually. The prototype knows that it is empty after a number of uses, so it can go into a refill setting. In these circumstances the user can press the button to access a new cup, after which they can refill it. They can press that button again until all cups are filled.

6 Evaluation

This chapter describes the evaluation stage of the design process, where the prototype is evaluated with users. The AttrakDiff questionnaire is used as a form of quantitative evaluation and a focus group for qualitative evaluation. The results from both evaluation methods are presented here.

6.1 Evaluation Goals

During the define phase, the problem statement was defined as: university students who snack too much during the evening need to reduce or replace their late-night snacking with a controlled low-calorie snack on a long term. It is not possible to properly assess if this device helps with solving the problem without a long term study. Because a study where the device is tested over the course of multiple weeks is out of scope of this project, the prototype is evaluated differently, which results in that it is unclear if the problem definition is assessed properly. This evaluation will focus on if people are willing to use the product using a user experience questionnaire, and what they would like to change in the prototype using a focus group. Next to these evaluation methods, the prototype will be assessed with respect to the problem requirements that were described in the define stage.

6.2 AttrakDiff

AttrakDiff is a questionnaire that measures the user experience of a product [49]. It can be used to evaluate user experience of the interaction on a subjective level, measuring both pragmatic and hedonic qualities of a product. In each of the 28 items, the user can choose between two opposite adjectives on a seven-point semantic scale. The questionnaire generates scores on four different scales, as explained in Chapter 3: pragmatic quality (PQ), hedonic quality-identity (HQ-I), hedonic quality-stimulation (HQ-S), and attractiveness (ATT).

6.2.1 AttrakDiff setup

For the evaluation session of the prototype, six participants were selected using convenience sampling, all from the University of Twente, partaking in various bachelor programs. One of these participants was also an interviewee in an earlier stage of the project. One participant canceled at the last moment; the session was continued with five participants. The session was held in a closed meeting room on the campus of the University of Twente, it lasted around 45 minutes.

At the start of the session, the prototype was set up on one side of the room. After a short briefing that introduced to goals of the project, the functionalities of the prototype, and the schedule of this session, the participant would all give informed consent using the consent form that can be found in Appendix E. The participant were seated around the prototype and were shown how it works and could afterwards interact with it themselves. The mint eucalyptus spray was activated using the Wizard of Oz method because the automated system did not work at this time.

The timings of the prototype were different than they would be in regular use, because of time constraints in the session. Instead of having to wait a day to be able to press the button, the participants were now able to press it every 30 seconds. The smell was released twelve seconds after pressing the button instead of the regular ten minutes. This created the opportunity for the participant to interact with the prototype multiple times to be able to better experience the interaction.

After having seen, smelled, and interacted with the prototype, the participants were handed the full AttrakDiff questionnaire. They were instructed to fill it out individually and to not ponder for too long over a single item, but to instead give the response that first comes to mind. They were also reassured that there was no incorrect answer and that they should not be scared to be honest about their feelings and opinions. A snack consisting of nuts, raisins, dark chocolate, and one candy from the dispenser was handed out by the researcher as an expression of appreciation for helping with the research. All participants were finished within five minutes. The results were digitalized and analyzed.

6.2.2 AttrakDiff Results

The scales from the AttrakDiff survey range from -3 to 3, with the higher score signaling a better user experience. The results from each category can be found in Table 3, considering the categories described in Chapter 3. The HQ scale is the average of the HQ-I and the HQ-S scales. All values are rounded to 4 figures.

Scale	Score
PQ	1.086
HQ-I	-0.107
HQ-S	1.171
HQ	0.532
ATT	0.971

TABLE 3: Table of the scores from the AttrakDiff survey

The HQ-I score is more than one whole point lower than the other three AttrakDiff scales, while these other categories all have a similar score. The HQ scale is in between these two values because it is the average of the HQ-I scale and the HQ-S scale. The values in the table are the averages of the responses to the items per category. The individual items can be found in Figure 15, here the average score of each item is shown in a graph. The four different colors represent the different scales, clearly showing the lower scores for the HQ-I scale. The full individual results are available in Appendix C. One response to a single item was missing, this has been ignored when calculating the final scores.

6.3 Focus group

A focus group is a small group of people that can provide feedback and discuss topic about a product or an idea, giving insight into experiences of the potential

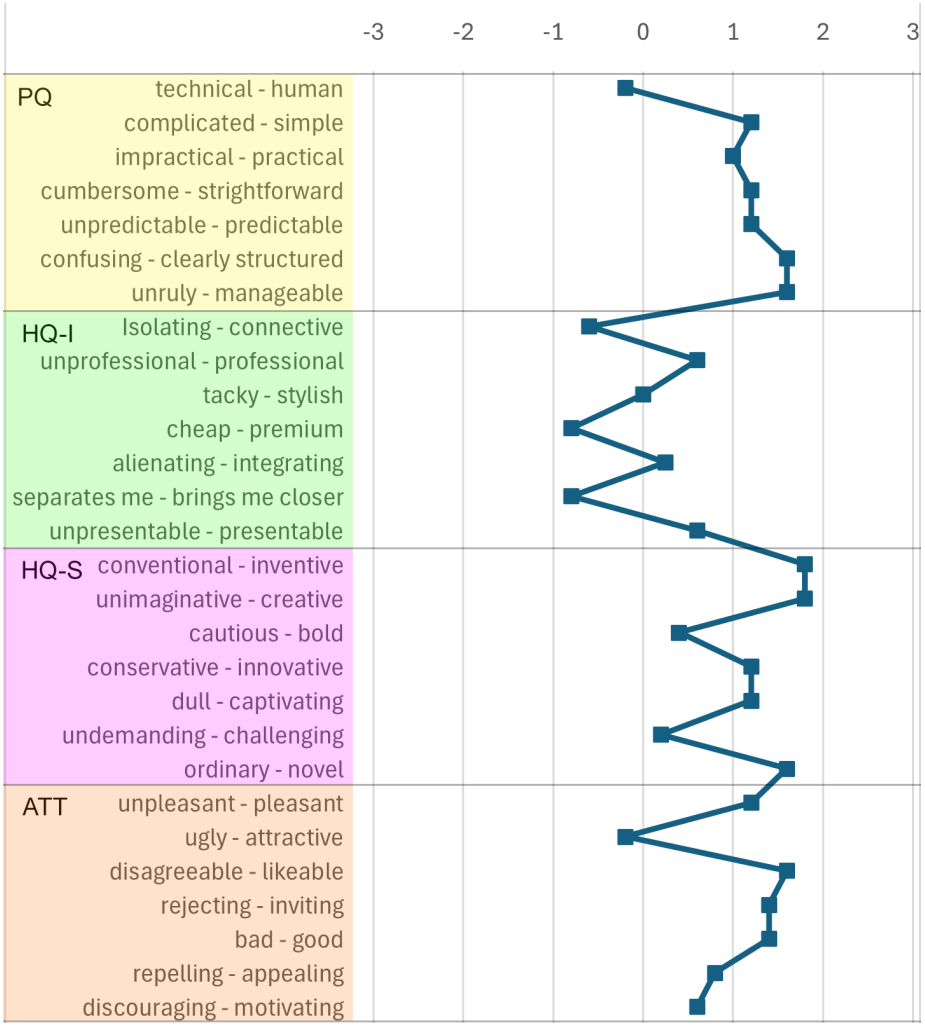

FIGURE 15: AttrakDiff average response per item shown in a chart

user. To evaluate the design results qualitatively, a focus group was used. By using the method, participants can provide more direct feedback, allowing them to explain their thoughts. Reasons behind reactions that cannot be expressed in a qualitative survey can be explored here by asking follow-up questions. With a survey, one can find what the problems are in the product, but because now the origin of the problem is explored, the researcher can try to solve these problem using a more human-centered design.

An even more important benefit is the opportunity to improve future designs. Next to just evaluating the prototype, participants will be encouraged to give design recommendations so that the design of the prototype can be extended by potential users. These future design recommendations can be used to create a better, more effective product in the future.

6.3.1 Focus group setup

The focus group was held in the same session as the AttrakDiff questionnaire. Right after every participant had finished the survey, the focus group started. A variation of the 1-2-4-All method from Liberating structures was used [58, 59]. Liberating structures are approaches that can replace common practices when it comes to brainstorming, meetings, and other such things. They are designed to encourage innovation, trust, and creativity. The 1-2-4-All structure is as follows: first, the participants spend one minute alone pondering on how they can improve features. Then they will spend two minutes in pairs discussing their ideas and further brainstorming on them. This is followed by four minutes in a foursome where the participants go even deeper. Finally, the whole group comes together to talk through their most important ideas. Even in this final stage there might be a spark for new idea generation, which is still encouraged. The cycle may be repeated if needed.

This structure was changed so that it would fit better within the limits of this focus group session. With only five participants, the pairs and foursome phase were fused into one phase that consisted of one pair and one threesome. This phase lasted five minutes because there were multiple topics that had to be discussed as the prototype had various areas that could be changed or improved upon. The final phase where all participants came together lasted as long as necessary to discuss every topic thoroughly. During this phase notes were taken by the researcher to capture the results.

Before the start of the focus group, the participants were encouraged to think about and discuss four different topics: the type of snack, short-term rewards, long-term rewards, and other changes or improvements. It is important to get information about the type of snacks students prefer, to make an informed decision about which snacks the machine can offer. For example, if students would like to eat yogurt, the machine would need to have a built-in refrigerator. The short- and long-term reward are both very important for creating a healthy habit that reduces late-night snacking. To maintain this habit the participant needs to be properly rewarded. For this reason, the machine should have rewarding features. There may be many other options for improvement which is why this should also be discussed by the focus group.

FIGURE 16: An overview of the design recommendations from the focus group

To code the results six categories were created based the topics that were discussed most during the session. These are: type of snack, location, short-term reward, long-term reward, refill option, and user interaction. User interaction was added as a final category to encompass the user interaction recommendations that did not fit in the other categories. All design recommendations were sorted into six categories, with user interaction serving as an overall improvement category for the improvements that do not strictly fit in the other ones.

6.3.2 Focus group results

Because the results of the focus group were coded with six different categories, each category result will be discussed individually. An overview of all the results has been depicted in a mindmap that can be seen in Figure 16. All ideas mentioned here were discussed during the focus group.

Type of snack

First, the type of snack yielded many ideas for potential foods that can be held inside the dispenser. An immediate suggestion was to use nuts because they are considered filling and healthy, but because of their high amount of calories, nuts might not be ideal. People who want to restrict their daily calorie intake should

avoid eating too many nuts. Other filling and healthy options are fruit and vegetables, with the added advantage of having a low amount of calories. These types of food will often require a refrigerator, which makes the device larger, more complicated, and more expensive. A refrigerator does give many more food options, like yogurt and cheese, which some participants would enjoy during the evening. A built-in heater would be another possible upgrade because it gives the option to dispense tea or soup. Some participants expressed a desire for snacks that "felt" more like late-night snacks, such as grated cheese, sprinkles, or a small cup of peanut butter. These participants would only eat these foods individually as a late-night snack and would be more satisfied because of this association with these foods as late-night snacks.

Location

The most popular location suggested was the kitchen, because this is where someone would go if they wanted a snack anyway, so then the device is located in the most straightforward place. Another participant argued that the kitchen would be a disruptive environment, because of all the other foods that are present there. These foods would potentially be tempting for a user and therefore the kitchen should be avoided. The living room was suggested as an alternative location.

Short-term reward

As found in Chapter 2, a short-term reward is important to make the device more engaging. A fun option could be a mascot that encourages the user when eating, similar to the Owl of Duolingo. Next to encouraging messages, this mascot could also give fun facts about snacking, nutrition, or general health, here BCT 5.1 Information about health consequences can be applied when the information informs the user of the impact of late-night snacking. The participants also expressed a desire for a satisfying sound when receiving the food, and a punishing sound when failing to reduce late-night snacking. They suggested to use a recording of the voice of the user to discourage overeating.

Long-term reward

For the long-term reward, it was immediately suggested to use a streak that the user could build up every day; when the user successfully uses the dispenser for 30 days in a row, they would get a streak of 30, similar to Duolingo. A downside that was mentioned to this system, is that if people do not want to snack at all, they might feel forced to snack from the machine because otherwise they will lose their streak. This is undesirable, as it encourages late-night snacking where the goal is to reduce it. If the machine had the ability to get certain measurements from the user, it could display encouraging statistics, such as the number of calories that were saved by reducing late-night snacking. Another idea was to create a challenge with a set amount of days. The amount of food gets slightly decreased each day so late-night snacking is slowly reduced. At the end of the challenge there can be a reward containing a tastier, less healthy snack, utilizing BCT 10.2 Material reward (behavior), by giving the person food after they performed the desired

behavior. A final long-term reward could be a random tasty snack for the user. On regular days the snack can be bland but filling and healthy, but once every week on a random day the snack will be tasty and not as healthy. The randomness can make the device more exciting to use.

Refill options

To refill the dispenser, it is important that is easy and that the refill snacks are out of sight. They could be put in a locked box that can be opened when the dispenser needs to be refilled. Another option that was suggested was to use closed cartridges that can replace the entire food-holding structure of the device. This could even include the whole top part. New cartridges would be delivered to the user's house and cannot be used without the dispenser, meaning that the user cannot eat straight from the cartridge. Used cartridges could be given back to the manufacturer so that they can be refilled and reused. This would be a subscription-based model for a dispenser, where the user pays a monthly fee to keep receiving cartridges.

General interaction

The cup mechanism was received positively, but the button should be improved upon. Now it is very small and in an awkward position, where it should be obvious and satisfying. The display can also be improved because a higher resolution looks more premium and can display more complex things. The device should remain easy to use.

6.4 Comparison with the requirements

Because of the absence of long term research it remains unknown if this solution actually reduces late-night snacking, but due to the mostly positive feedback received during the evaluation, it can be assumed that late-night snacking will be reduced. The solution is also clearly tangible, meaning that the "Must"requirements from Tabel 1 were met in this solution. According to the PQ scale of the AttrakDiff survey with a score of 1.086, the device was easy to use and the ATT scale with a score of 0.971 signals that it is also fun to use. This device can be integrated into, for example, the kitchen environment by placing it in a accessible yet unremarkable location. With these results, the prototype also meets the "Should" requirements from the design stage in Chapter 4.2.2.

The "Could" category expresses that the solution could be unobtrusive. Whether this requirement has been met can depend on the user, as some individuals will find the smell obtrusive. During the focus group the participants liked the smell and would not mind having that in their living room, making the device less obtrusive for them. This is not a solution that promotes general healthy eating, so this requirement from Tabel 1 is not met. When used as intended, the prototype will not counter other unhealthy eating habits than late-night snacking. It will also never completely stop late-night snacking because it provides the user with a replacement snack, therefore the "Won't" requirements have all been met.

7 Discussion and Conclusion

This chapter will provide an answer to the research question by presenting an overview of the conclusions that have been found in this research project. Design recommendations will be given on how both the prototype and the idea of a snacking dispenser can be improved upon, with the chapter going into more detail about four promising recommendations. Some of the limitations of the project are mentioned and suggestions are given for possible future work on this topic.

7.1 Answering the research question

In Chapter 1 the research question was posed as: how can a tangible interactive system that integrates into the surrounding environment be used to reduce late-night snacking in university students?

By having built a device that is both tangible, interactive, and can be integrated into its surroundings, it may now be possible to answer this question. Because a long term study on how participants would use the device was out of the scope of this project, it is not known how well a snack dispenser would work to reduce late-night snacking. However, there are many conclusions to be taken from this research. First of all, it was found during the empathize stage that the most important reasons, that can be tackled by a smart device, behind late-night snacking are hunger cravings. The majority of students do eat late at night regularly but do not see this as a problem that is in direct need of solving. For these reasons, the interactive system should counter hunger cravings. It should also be particularly easy to use so that the barrier to adopt this solution remains low. It has been mentioned that behavior change is much easier to implement when the change is small, which is another good reason to make the system easy to adopt.

The simplicity of the device comes from its simple interactions, where there is only one button with only one purpose: receiving the snack. The system also provides a snack that may be easier to get than how one would normally get a snack from the kitchen: by immediately giving it in a cup while it is ready to eat. Hunger cravings are addressed by the system because it still provides a small snack to replace the regular late-night snacks and because it emits the mint room spray to reduce appetite. During the evaluation, it was found that the prototype was practical, stimulating, and attractive according to the AttrakDiff questionnaire. During the focus group, participants liked the idea of the dispenser and thought the room spray was a good addition, but there were many suggestions for improvement.

7.2 Recommendations

As seen in Chapter 6.3.2 and Figure 16, many design recommendations were suggested in the focus group, with some being more practical than others. There are still possible improvements that were not mentioned in the focus group. These were constructed by the designer to get a more complete overview of the possible improvements. An overview can be seen in Figure 17.

The recommended types of snack are mostly filling snacks because these will reduce appetite. Tea and milk are added as drinks that are often desired during the evening. For the locations of the device, the idea of mounting it to a wall can save space and integrate the device better into the environment. A downside can be that it will be more effort to set it up for the user when getting started. The addition for the short term reward is that of a light that turns on or changes color to signal success. This can be done in many forms, including a tree or flower that lights up every time the snack has been dispensed. The way this tree or flower can improve the device is more obvious for the long term reward, as there could be a mechanism where the tree slowly rises or the flower slowly opens every day when the user takes out a snack. This effect mimics a streak mechanism but avoids a hard number that comes with a streak which is more confrontational to the user. Growing a tree or flower can be a great motivational mechanism to show the user progress subtly.

The simplest and current refill option would be to refill the cups manually cup by cup without opening the device. When the machine knows it is empty, the user can press the button 6 times to refill all cups one by one. This method is very simplistic and gives freedom to the user, but this freedom might not be suited for many users who will crave the food at this time. For the user interaction category, there exist many possible features in the design. There could be a countdown clock that shows the user how long is left until they receive a snack. To motivate users even more to use the dispenser another bottle of room spray can be inserted to induce appetite before the snack is dispensed. This induced appetite can increase the probability of the user using the product, but it can have the adverse effect of the user snacking even more than the dispenser snack because of their increased hunger cravings.

By combining these recommendations with those of the focus group, a large number of possible features and changes are assembled as seen in an overview in Figure 18. This mind map shows many different possibilities, not all of which will actually improve the solution. It is better to implement some good ideas than to do as many as possible. This is why a selection of the best recommendations is made so that they can be implemented in future research.

7.2.1 Built-in refrigeration

The top of the device could be transformed into a refrigerator to expand the available snacking options. During the focus group, users expressed a desire for various snacks that need to be kept refrigerated, such as milk, yogurt, and cheese. Fruits and vegetables contain many healthy nutrients, are low in calories, and are filling, but they often require refrigeration.

7.2.2 Growing a tree

A tree or flower attached to the dispenser could become both a great short and long term reward. This tree can light up every evening after the user has taken a snack, making the process more satisfying with this short term reward. This uses BCT

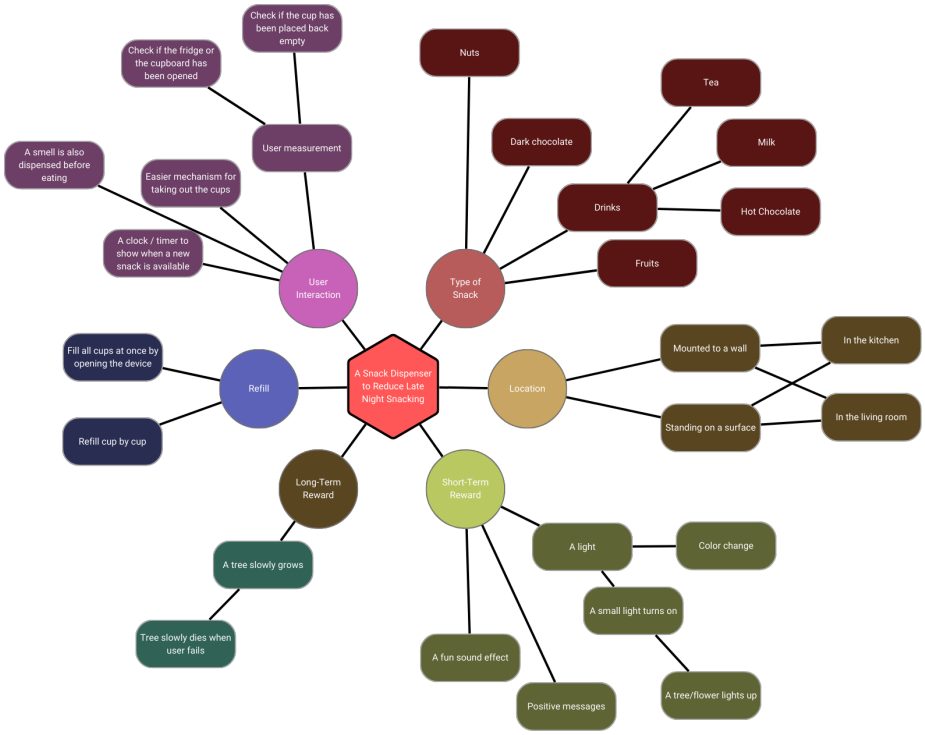

FIGURE 17: An overview of the design recommendations from the designer

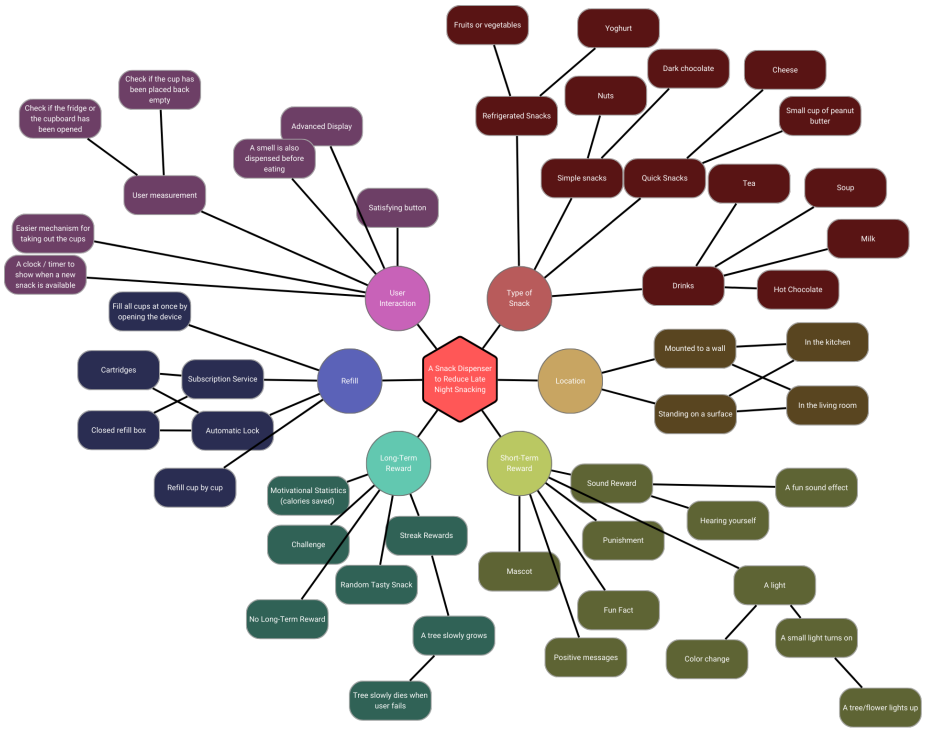

FIGURE 18: An overview of all possible design recommendations. Some ideas are more practical than others.

10.3 Non-specific reward because the flower rewards the user with something that is not material. A long term reward would be to make the tree slowly rise or grow each day the user gathers a late-night snack from the dispenser only. This growth can signal to the user that they themselves are growing as well in the improvement of their eating habits, connecting the interactive machine to the user. The tree does not punish the user when they miss a day of snacking by shrinking again and when it is fully grown it can stay that way, standing as an achievement for the user to be reminded of every day. The mechanism of growing the tree could be realized by heightening a pole with a motor that represents the trunk, leaves could expand in the process. An LED strip can form branches in a natural-looking pattern, emitting green light.

7.2.3 The cartridge subscription model

Reusable cartridges are a good way to solve the problem of refilling the snack dispenser. Having the refill snacks accessible to the user during a normal day can tempt the user to snack from this food source, which would have the adverse effect of increasing snacking. To avoid this closed cartridges can be used to be able to replace the whole food-containing part of the device all at once. A company may deliver new cartridges periodically while they also pick up empty cartridges, making the model more sustainable, while it being the easiest for the user because all they need to do is to replace the cartridge when the machine has no more food.

7.2.4 User measurements

Several sensors can be implemented to keep track of the late-night snacking habits of the user. It is useful to know when the user finishes their snack from the dispenser so the room spray emission can be timed well, as it should activate right after the snack has been finished. A sensor inside the device that can measure when the user puts back the cup can solve this issue. Another useful sensor would be one in the kitchen at the locations where snacks are commonly stored. This could be the fridge or a cupboard. The sensor could measure if a snack is being taken, so that the possible rewards provided by the snacking dispenser can be withheld. This creates a small punishment for late-night snacking, which is an extra incentive to refrain from it next to the room spray. In this scenario, BCT 2.2 Feedback on behavior is used. If a system with sensors is implemented, great care should be taken of the user's privacy.

7.3 Limitations

This project encountered several limitations due to various reasons, the most important one being time constraints. The scale of the project was not large enough for a long term study to test the workings of the prototype over the course of several weeks, this study would have given insights into the quality of the solution. Only knowing how the user reacted to the prototype based on only a short user interaction is an important limitation, as it remains unknown if the prototype would

have made an impact. What also made the evaluation weaker was the fact that there were five participants. More participants would have gotten more reliable results with a stronger conclusion. The participants who performed the evaluation were friends or acquaintances of the researcher, meaning that a slight bias could have formed in the judgment of the prototype. A group of students unrelated to the researcher would avoid this bias.

There were also limitations in the designing process of the solution. No participatory design study has been done, resulting in that the brainstorming was done only by the researcher. This limits the creativity of ideas. For a better understanding of what kind of solution would work best to reduce late-night snacking in university students, it would have been better to create multiple prototypes of different solutions so that a comparison could be drawn between them.

Finally, the prototype could have been improved by making it sturdier and more reliable. First, the stepper motor was not strong, so sometimes it would not turn the full 60 degrees it is supposed to when it carries a heavier load of food. The structure of the prototype is weak and can easily fall apart under pressure. The display has an issue where the light becomes weaker near the bottom of the screen. Finally, the structure for the room spray broke so it is no longer functional. This flawed prototype was functional for the user testing performed in this project, but should be improved before it can see actual use.

7.4 Implications

There are two contributions made by this graduation project. One of them is the prototype that may reduce late-night snacking and has features based user research. This prototype can be tailored to the user by editing the timing of the dispensing and the type of snack inside. It can already be used to reduce late-night snacking as it is functional, although not stable in certain areas.

The other contribution is that of design recommendations. Based on the focus group and on research, many recommendations were laid out in this report that can be used by future researchers to improve upon this design. Four promising recommendations were discussed in further detail in Chapter 7.2, which might inspire other researcher to pursue this topic and create an improved snack dispenser.

7.5 Future work

Future projects about this topic should address the aforementioned limitations. A new ideation phase can be performed, this time including a participatory design study, to generate ideas and design with the user. Multiple prototypes can be built with more functionality than the current one. Some prototypes should implement the design recommendations that were presented here so that the impact of them can be tested. Evaluating the prototypes should be done by comparing them to each other and seeing how different features yield different results for various users. The evaluation could still include a survey like AttrakDiff to measure the user experience, but a long term study on the impact the product has on late-night

snacking is more important because this enables the researcher to measure if the goal of reducing late-night snacking can be reached using this method.

8 References

References

[1] Unicef, "Non-communicable diseases," Nov 2023. [Online]. Available: https://data.unicef.org/topic/child-health/noncommunicable-diseases/

[2] World Health Organization, "Noncommunicable diseases," Sep 2023. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases

[3] World Health Organization , "Noncommunicable diseases netherlands 2018 country profile," August 2018. [Online]. Available: https://www.who.int/publications/m/item/noncommunicable-diseases-nld-country-profile-2018

[4] A. Budreviciute, S. Damiati, D. K. Sabir, and R. Kodzius, "Management and prevention strategies for non-communicable diseases (ncds) and their risk factors," *Frontiers in public health*, vol. 8, p. 574111, 2020.

[5] F. Al-Maskari, "Lifestyle diseases: An economic burden on the health services," *UN Chronicle. The Magazine of the United Nations*, vol. 5, pp. 1–2, 2010.

[6] K. Sollid, A. D. Webster, M. Paipongna, and K. Smith, "Food perceptions, beliefs, and behaviors amid a global pandemic: Results of the international food information council 2021 food & health survey," *Nutrition Today*, vol. 57, no. 1, pp. 26–33, 2022.

[7] S. J. Sakthivel, P. Hay, and H. Mannan, "A scoping review on the association between night eating syndrome and physical health, health-related quality of life, sleep and weight status in adults," *Nutrients*, vol. 15, no. 12, p. 2791, 2023.

[8] C. A. Crispim, I. Z. Zimberg, B. G. dos Reis, R. M. Diniz, S. Tufik, and M. T. de Mello, "Relationship between food intake and sleep pattern in healthy individuals," *Journal of clinical sleep medicine*, vol. 7, no. 6, pp. 659–664, 2011.

[9] M.-H. Kim, E.-S. Jeong, E.-J. Kim, H.-K. Cho, Y.-J. Bae, and M.-K. Choi, "Night eating status of university students in partial area of chungnam," *Journal of the East Asian Society of Dietary Life*, vol. 21, no. 4, pp. 563–576, 2011.

[10] H. M. Jaffar, W. Ahsan, K. Aqeel, R. Sajjad, M. Tariq, H. Ahmed, and N. Fatima, "Effect of late-night eating on health: A survey from university students," *Agricultural Sciences Journal*, vol. 5, no. 2, pp. 93–99, 2023.

[11] C. S. d. S. Luz, A. E. T. P. da Fonseca, J. S. Santos, J. F. Araujo, L. L. Duarte, and C. R. d. C. Moreno, "Association of meal timing with sleep quality and anxiety according to chronotype: A study of university students," *Clocks & Sleep*, vol. 6, no. 1, pp. 156–169, 2024.

[12] myfitnesspal, "Reach your goals with myfitnesspal." [Online]. Available: https://www.myfitnesspal.com/

[13] P. Glen J. Piegari, "8 reasons why it's so hard to really change your behavior," July 2017. [Online]. Available: https://www.psychologytoday.com/us/blog/neuronarrative/201707/8-reasons-why-its-so-hard-really-change-your-behavior

[14] H. Brombacher, S. Houben, and S. Vos, "Tangible interventions for office work well-being: approaches, classification, and design considerations," *Behaviour & Information Technology*, pp. 1–25, 2023.

[15] A. Kinsey and M. Ormsbee, "The health impact of nighttime eating: Old and new perspectives," *Nutrients*, vol. 7, no. 4, p. 2648–2662, Apr 2015.

[16] S. Suri and R. Pradhan, "Assessment of night eating syndrome among late adolescents," *Indian Journal of Psychological Medicine*, vol. 32, no. 1, p. 71–72, Jan 2010.

[17] A. Geliebter, H. McOuatt, C. B. Tetreault, D. Kordunova, K. Rice, G. Zammit, and M. Gluck, "Is night eating syndrome associated with obstructive sleep apnea, bmi, and depressed mood in patients from a sleep laboratory study?" *Eating behaviors*, vol. 23, pp. 115–119, 2016.

[18] H. S. Driver, I. Shulman, F. C. Baker, and R. Buffenstein, "Energy content of the evening meal alters nocturnal body temperature but not sleep," *Physiology & behavior*, vol. 68, no. 1-2, pp. 17–23, 1999.

[19] D. Duan, C. Gu, V. Y. Polotsky, J. C. Jun, and L. V. Pham, "Effects of dinner timing on sleep stage distribution and eeg power spectrum in healthy volunteers," *Nature and Science of Sleep*, pp. 601–612, 2021.

[20] M. Hibi, A. Masumoto, Y. Naito, K. Kiuchi, Y. Yoshimoto, M. Matsumoto, M. Katashima, J. Oka, and S. Ikemoto, "Nighttime snacking reduces whole body fat oxidation and increases ldl cholesterol in healthy young women," *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, vol. 304, no. 2, pp. R94–R101, 2013.

[21] K. P. Kelly, O. P. McGuinness, M. Buchowski, J. J. Hughey, H. Chen, J. Powers, T. Page, and C. H. Johnson, "Eating breakfast and avoiding late-evening snacking sustains lipid oxidation," *PLoS biology*, vol. 18, no. 2, p. e3000622, 2020.

[22] A. W. McHill, A. J. Phillips, C. A. Czeisler, L. Keating, K. Yee, L. K. Barger, M. Garaulet, F. A. Scheer, and E. B. Klerman, "Later circadian timing of food intake is associated with increased body fat," *The American journal of clinical nutrition*, vol. 106, no. 5, pp. 1213–1219, 2017.

[23] R. An, Y. Shi, C. Clarke, and S. Zhang, "Night-time eating and body weight status among us adults, 2007–2016," *Journal of human nutrition and dietetics*, vol. 32, no. 6, pp. 754–764, 2019.

[24] J. R. Soliz-Rueda, R. López-Fernández-Sobrino, H. Schellekens, C. Torres-Fuentes, L. Arola, F. I. Bravo, and B. Muguerza, "Sweet treats before sleep disrupt the clock system and increase metabolic risk markers in healthy rats," *Acta Physiologica*, vol. 239, no. 3, p. e14005, 2023.

[25] S. A. Alahmary, S. A. Alduhaylib, H. A. Alkawii, M. M. Olwani, R. A. Shablan, H. M. Ayoub, T. S. Purayidathil, O. I. Abuzaid, and R. Y. Khattab, "Relationship between added sugar intake and sleep quality among university students: a cross-sectional study," *American journal of lifestyle medicine*, vol. 16, no. 1, pp. 122–129, 2022.

[26] T. A. Madzima, L. B. Panton, S. K. Fretti, A. W. Kinsey, and M. J. Ormsbee, "Night-time consumption of protein or carbohydrate results in increased morning resting energy expenditure in active college-aged men," *British journal of nutrition*, vol. 111, no. 1, pp. 71–77, 2014.

[27] P. T. Res, B. Groen, B. Pennings, M. Beelen, G. A. Wallis, A. P. Gijsen, J. M. Senden, and L. J. van Loon, "Protein ingestion before sleep improves postexercise overnight recovery," *Medicine & Science in Sports & Exercise*, vol. 44, no. 8, pp. 1560–1569, 2012.

[28] B. Gardner, M. A. Arden, D. Brown, F. F. Eves, J. Green, K. Hamilton, N. Hankonen, J. Inauen, J. Keller, D. Kwasnicka *et al.*, "Developing habit-based health behaviour change interventions: twenty-one questions to guide future research," *Psychology & health*, vol. 38, no. 4, pp. 518–540, 2023.

[29] J. Clear, *Atomic habits: Tiny changes, remarkable results*. Avery, 2018.

[30] B. Verplanken and J. Sui, "Habit and identity: Behavioral, cognitive, affective, and motivational facets of an integrated self," *Frontiers in psychology*, vol. 10, p. 452537, 2019.

[31] M. Wehrle, "'bodies (that) matter': the role of habit formation for identity," *Phenomenology and the Cognitive Sciences*, vol. 20, no. 2, pp. 365–386, 2021.

[32] S. Michie, M. Richardson, M. Johnston, C. Abraham, J. Francis, W. Hardeman, M. P. Eccles, J. Cane, and C. E. Wood, "The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions," *Annals of behavioral medicine*, vol. 46, no. 1, pp. 81–95, 2013.

[33] C. F. Moore, V. Sabino, G. F. Koob, and P. Cottone, "Habitual overeating," in *Compulsive Eating Behavior and Food Addiction*. Elsevier, 2019, pp. 83–95.

[34] Y. Dong, A. Hoover, and E. Muth, "A device for detecting and counting bites of food taken by a person during eating," in *2009 IEEE International conference on bioinformatics and biomedicine*. IEEE, 2009, pp. 265–268.

[35] J. L. Scisco, E. R. Muth, Y. Dong, and A. W. Hoover, "Slowing bite-rate reduces energy intake: an application of the bite counter device," *Journal of the American Dietetic Association*, vol. 111, no. 8, pp. 1231–1235, 2011.

[36] M. L. Wilson, J. N. Salley, and E. R. Muth, "Are you committed cathy, reluctant rita or negative nancy? defining user personas for a technology-based wrist-worn eating monitor," in *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 58, no. 1. SAGE Publications Sage CA: Los Angeles, CA, 2014, pp. 1429–1433.

[37] Smart Plate, "Live without limits." [Online]. Available: https://www.getsmartplate.com/

[38] C. A. Pellegrini, D. E. Conroy, S. M. Phillips, A. F. Pfammatter, H. G. McFadden, and B. Spring, "Daily and seasonal influences on dietary self-monitoring using a smartphone application," *Journal of nutrition education and behavior*, vol. 50, no. 1, pp. 56–61, 2018.

[39] J. S. Ingels, R. Misra, J. Stewart, B. Lucke-Wold, S. Shawley-Brzoska *et al.*, "The effect of adherence to dietary tracking on weight loss: using hlm to model weight loss over time," *Journal of diabetes research*, vol. 2017, 2017.

[40] D. Ryan, C. Parkin, W. Longley, J. Dixon, C. Apovian, and B. Bode, "Efficacy and safety of an oral device to reduce food intake and promote weight loss," *Obesity Science & Practice*, vol. 4, no. 1, pp. 52–61, 2018.

[41] P. A. Brunton, J. Ratnayake, H. J. Bodansky, L. Mei, A. Veerasamy, and R. Hall, "An intraoral device for weight loss: initial clinical findings," *British dental journal*, pp. 1–6, 2021.

[42] M. Young, "The cookie jar grows up," *New York Times*, August 2022.

[43] NOZNOZ, "How does noznoz™ work?" [Online]. Available: https://noznoz.com/how-it-works/

[44] I. D. F. IxDF, "What is design thinking (dt)?" [Online]. Available: https://www.interaction-design.org/literature/topics/design-thinking

[45] R. F. Dam, "The 5 stages in the design thinking process." [Online]. Available: https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process

[46] I. D. Foundation, R. F. Dam, and T. Y. Siang, "What is design thinking and why is it so popular?" 2021.

[47] W. C. Adams, "Conducting semi-structured interviews," *Handbook of practical program evaluation*, pp. 492–505, 2015.

[48] A. Hudaib, R. Masadeh, M. H. Qasem, A. Alzaqebah *et al.*, "Requirements prioritization techniques comparison," *Modern Applied Science*, vol. 12, no. 2, p. 62, 2018.

[49] M. Hassenzahl, M. Burmester, and F. Koller, "Attrakdiff: Ein fragebogen zur messung wahrgenommener hedonischer und pragmatischer qualität," *Mensch & Computer 2003: Interaktion in Bewegung*, pp. 187–196, 2003.

[50] I. Díaz-Oreiro, G. López, L. Quesada, and L. A. Guerrero, "Ux evaluation with standardized questionnaires in ubiquitous computing and ambient intelligence: a systematic literature review," *Advances in Human-Computer Interaction*, vol. 2021, no. 1, p. 5518722, 2021.

[51] Omnivision Solutions Ltd, "Transcript.lol." [Online]. Available: https://transcript.lol/

[52] Y. Sun, S. Rong, B. Liu, Y. Du, Y. Wu, L. Chen, Q. Xiao, L. Snetselaar, R. Wallace, and W. Bao, "Meal skipping and shorter meal intervals are associated with increased risk of all-cause and cardiovascular disease mortality among us adults," *Journal of the Academy of Nutrition and Dietetics*, vol. 123, no. 3, pp. 417–426, 2023.

[53] K. Nakamura, E. Tajiri, Y. Hatamoto, T. Ando, S. Shimoda, and E. Yoshimura, "Eating dinner early improves 24-h blood glucose levels and boosts lipid metabolism after breakfast the next day: a randomized cross-over trial," *Nutrients*, vol. 13, no. 7, p. 2424, 2021.

[54] Y. Miyazaki and J. Kawahara, "Wearing a mint-scented face mask reduces appetite," 2021.

[55] H. F. Zoon, C. De Graaf, and S. Boesveldt, "Food odours direct specific appetite," *Foods*, vol. 5, no. 1, p. 12, 2016.

[56] P. Morquecho-Campos, K. de Graaf, and S. Boesveldt, "Smelling our appetite? the influence of food odors on congruent appetite, food preferences and intake," *Food Quality and Preference*, vol. 85, p. 103959, 2020.

[57] Listerine, "Listerine® pocketmist® fresh breath spray cool mint®." [Online]. Available: https://www.listerine.com/on-the-go-oral-health/listerine-pocketmist-spray-cool-mint

[58] Liberating Structures, "Introduction." [Online]. Available: https://www.liberatingstructures.com/

[59] Liberating Structurs, "1-2-4-all." [Online]. Available: https://www.liberatingstructures.com/1-1-2-4-all/

A Interview results

Table 4 shows the results in a short summarized format for the coded categories.

Nr	Living situation	Dinner time	Snack time	Sleep time
1	student house of 6	19:00	24:00	0:00
2	parents	18:30	22:30	1:00
3	student house of 5	19:00	-	1:00
4	student house of 10	18:30	0:00	0:00
5	student house of 2	20:00	-	0:00
6	student house of 4	18:30	22:00	0:00

Nr	Reason	Regret	Problem
1	Social reasons, not very hungry	Not	No
2	Social reasons, feeling cold, sometimes hunger	Not	No
3	Drunk or peer pressure, otherwise not	Regret	Sometimes
4	Hunger cravings, previously medical reasons	Regret	Yes
5	Social reasons	Not	No
6	Habitual eating or stress	Not	Sometimes

TABLE 4: Interview results late-night snacks

B Arduino code

This is the code that was used during the evaluation session. One change that was made was the time it took to use the dispenser. The changes from phase three to four and four to five were made only six second so that the testing could be faster. The change for one cycle was made 30 seconds instead of one day.

```
#include <LiquidCrystal_I2C.h>
#include <Stepper.h>
#include <Servo.h>

LiquidCrystal_I2C lcd(0x27, 24, 4);
int stepsPerRevolution = 32;

Stepper dispenser(stepsPerRevolution, 9, 11, 10, 8);
Servo servo;

unsigned long startMillis;
unsigned long currentMillis;

int state = 0; //0 is setup,
//1 is button can be pressed for food,
//2 is button has been pressed for food,
//3 is the short period for eating,
//4 is after,
//5 is wait until next day
int buttonState = 0; //0 means pressed, 1 means released
bool buttonHasBeenPressed;

void setup() {
  Serial.begin(9600);
  pinMode(2, INPUT_PULLUP); //button pin
  dispenser.setSpeed(600);
  servo.attach(5);

  lcd.init();
  lcd.clear();

  state = 1;
}

void loop() {
  displayWords();

  if (state == 1) {
    buttonState = digitalRead(2);
```

```
    delay(10);
    if (buttonState == 0) {
      buttonHasBeenPressed = true;
    } else if (buttonHasBeenPressed) { //if button has been released
      state = 2;
      buttonHasBeenPressed = false;
    }
  } else if (state == 2) {
    startMillis = millis(); //timer starts when button has been pressed
    dispenser.step(2048 / 6);

    state = 3;
  } else if (state == 3) {
    const long stateThreeLength = 1000*60*10; //10 minutes
    currentMillis = millis();
    if (currentMillis - startMillis >= stateThreeLength) {
      state = 4;
    }
  } else if (state == 4) {
    const long stateFourLength = 1000*60*20; //10 more minutes
        servo.write(255);
    delay(1000);
    servo.write(80);
    currentMillis = millis();
    if (currentMillis - startMillis >= stateFourLength) {
      state = 5;
    }
  } else if (state == 5) {
    const long stateFiveLength = 1000*60*60*24; //1 day
    currentMillis = millis();
    if (currentMillis - startMillis >= stateFiveLength) {
      state = 1;
    }
  }
}

void displayWords() {
  if (state == 1) {
    lcd.clear();
    lcd.backlight();
    lcd.setCursor(2, 0);
    lcd.print("Press the button");
    lcd.setCursor(2, 1);
    lcd.print("to eat some food");
    lcd.setCursor(9, 3);
    lcd.print(":)");
```

```
  } else if (state == 2 || state == 3) {
    lcd.clear();
    lcd.setCursor(2, 1);
    lcd.print("Enjoy");
    lcd.setCursor(2, 2);
    lcd.print("your food!");
  } else if (state == 4) {
    lcd.clear();
    lcd.setCursor(2, 1);
    lcd.print("Now go and");
    lcd.setCursor(2, 2);
    lcd.print("Brush your teeth!");
  } else {
    lcd.clear();
    lcd.noBacklight();
  }
}
```

C AttrakDiff results

Table 19 shows the responses all the participants gave to every item in the questionnaire, including an average of all five responses.

	1	2	3	4	5	Average
technical - human	2	-1	1	-2	-1	-0,2
complicated - simple	2	2	0	0	2	1,2
impractical - practical	2	-1	1	1	2	1
cumbersome - strightforward	0	1	2	2	1	1,2
unpredictable - predictable	2	-1	1	1	3	1,2
confusing - clearly structured	2	1	2	1	2	1,6
unruly - manageable	1	3	0	2	2	1,6
Isolating - connective	1	-2	0	-1	-1	-0,6
unprofessional - professional	0	2	0	0	1	0,6
tacky - stylish	1	1	-1	0	-1	0
cheap - premium	-1	-1	0	-1	-1	-0,8
alienating - integrating	1	-1		1	0	0,25
separates me - brings me closer	0	-1	-2	0	-1	-0,8
unpresentable - presentable	1	1	-1	0	2	0,6
conventional - inventive	1	3	2	2	1	1,8
unimaginative - creative	1	3	2	2	1	1,8
cautious - bold	1	1	1	0	-1	0,4
conservative - innovative	1	2	2	1	0	1,2
dull - captivating	-1	2	2	1	2	1,2
undemanding - challenging	0	2	0	0	-1	0,2
ordinary - novel	0	3	3	1	1	1,6
unpleasant - pleasant	1	2	0	2	1	1,2
ugly - attractive	-1	1	0	-1	0	-0,2
disagreeable - likeable	3	0	1	2	2	1,6
rejecting - inviting	1	2	1	1	2	1,4
bad - good	1	1	1	2	2	1,4
repelling - appealing	1	1	-1	1	2	0,8
discouraging - motivating	1	1	-2	1	2	0,6

FIGURE 19: Data from the AttrakDiff questionnaire

D Interview consent

Interview participants gave informed consent with the consent form in Figure 20. With this consent form came the information letter in Figure 21. Both the consent form and the information letter were approved by the Ethics Committee Computer & Information Science of the University of Twente.

Consent Form for Using everyday space as in interface for reducing Late Night Snacking

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 14/03/2024, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves an audio-recorded interview that will be recorder with a smartphone. The recording will later be transcribed as text, after which the recording will be deleted.	○	○
Use of the information in the study		
I understand that information I provide will be used for creating a prototype to reduce late night snacking and for writing a thesis on the subject	○	○
I understand that personal information collected about me that can identify me, such as personal information in the interview answers, will not be shared beyond the study team.	○	○
If you want to use quotes in research outputs then add extra question: I agree that my information can be quoted in research outputs	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

Study contact details for further information:

Jonathan Jeuring

j.v.jeuring@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

UNIVERSITY OF TWENTE.

FIGURE 20: The consent form for the interviews

Information Letter for Using everyday space as in interface for reducing Late Night Snacking

This graduation project is all about assisting people in creating healthy habits. More specifically, the focus lies on the reduction of late night snacking. This research will be used to create a tangible device that is able to reduce late night snacking while blending into the environment.

During this interview session you will be asked several questions about some of your habits and the reasons behind them. This will take about 30 minutes. This project has been reviewed by the Ethics Committee Information and Computer Science. There are no real risks involved. There will be no compensation.

Withdrawal of consent or withdrawal from the study can be done at any time. You do not have to give a reason. Your data will be then deleted.

No personal information will be collected. The interview will be recorded and transcribed. After the interview has been completed your data will be anonymized as your name will be removed and the recording will be deleted.

The raw data will not be published or stored on the long term, as it will be deleted after the completion of the project, which should be before the end of July. The data will only be accessible to me (Jonathan Jeuring) and my supervisor (Champika Epa Ranasinghe).

Contact information

Jonathan Jeuring: j.v.jeuring@student.utwente.nl

Ethics Committee Computer and Information Science: ethicscommittee-cis@utwente.nl

FIGURE 21: The information letter for the interviews

E Evaluation consent

The participants in the evaluation session consented to both the AttrakDiff questionnaire and the focus group with the consent form as seen in Figure 22. No information letter was provided because all details were explained verbally. This consent form was approved by the Ethics Committee Computer & Information Science of the University of Twente.

Consent Form for Using everyday space as in interface for reducing Late Night Snacking

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves a survey, and that written notes will be taken on my input	○	○
Use of the information in the study		
I understand that information I provide will be used for a graduation project	○	○
I understand that personal information collected about me that can identify me, such as my name, will not be shared beyond the study team.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Jonathan Jeuring

j.v.jeuring@student.utwente.nl

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

UNIVERSITY OF TWENTE.

FIGURE 22: The consent form for the evaluation session