It is time to become active

Simon van Roozendaal
July 2022

Biomedical Systems and Signals (BSS)
Supervisor: dr. Femke Nijboer
Critical observer: Sefora Tunc

UNIVERSITY OF TWENTE.

Abstract

The Dutch society has a growing life expectancy, this is accompanied by a higher percentage of 'older' inhabitants. A higher life expectancy is generally positive, but it is accompanied by a negative side. While aging, quality of life increasingly relates more to the ability to function as a person. This ability to function is associated with effects of health issues like hospitalization, institutionalization, use of health resources and death. A result of these issues is a more significant burden on the healthcare sector. To prevent overstaining of this sector, the number of health-related issues must be reduced. A certain weekly amount of physical activity can counteract or postpone these issues. Sadly, most older adults do not follow recommendations regarding the weekly amount of physical activity. To reduce the expected burden on the healthcare sector, the older adults need to adapt a more active lifestyle.

This project aims to participate in motivating the older adults to this change of lifestyle by using technology. First, different ways of motivating the target group were investigated. Subsequently, research has been conducted into the requirements interactions needs for older adults to adopt the technology. Eventually, a product was designed exploiting the investigated motivational strategies whilst considering the required requirements for adoptable technology.

By applying the Creative Technology Design process, the design was created and developed in several phases after which the resulting concept was made into a prototype. First, ideas were gathered by using the creativity of fellow students. The ideas were combined into concepts, the most promising was selected by an expert. Subsequently, the concept has been developed into simple prototypes. Finally, simple prototypes were made through which the concept was subjected to user testing. The process resulted in the ultimate design of the concept, which was developed into a working prototype.

The resulting device is a working motivational clock displaying health related data of the user, equipped with remote for user input. The clock needs to be connected to a storage of health-related data, a server to which a smart wearable can be connected. The clock retrieves the data from the server and displays it by using LEDs strips and matrixes, connected to the device. This will make the user aware of their activity, and reward them when participating in enough physical activity.

Ultimately, both the process and the result are evaluated, and a conclusion has been drawn. The developed prototype works but is not yet a perfect product. By processing the information gathered from the evaluation phase, can be concluded the design must still experience (at least) an iteration of the Creative Technology Design process. In this iteration, the recommendations from the conclusion must be incorporated in the process and design. After that, a full-fledged product can be developed from the refined design.

Table of contents

1. Introduction

On January 1, 2020, Dutch society had almost 3.5 million inhabitants over the age of 65, which is equivalent to roughly 20% of the total Dutch population. In 1990 this was only 13%, it can be stated the number of elderly people has grown, and it still is growing (CBS, 2020). An older population is associated with a higher life expectancy of the inhabitants of a country, but this also comes with certain issues.

Although quality of life can be high also in older age, some health issues come up while ageing. Living your life and doing your activities of daily living can be disturbed by hospitalization, institutionalization, use of health resources and death of loved ones? (Angulo et al., 2020). Staying physically fit is important. Many of the causes of these issues can be (partly) counteracted or postponed, for example by adopting an active lifestyle. According to Phillips and colleagues (2004) the effects of getting older like functional decline, loss of independence and increased disease burden can be delayed or prevented by exercising more. A Harvard Alumni study substantiated this even further. Regular exercise and/or increased aerobic fitness were associated with a decrease in all-cause morbidity in older adults, even when these older adults only started exercising at a late age (Nied & Franklin, 2002). Additionally, mortality rates were lower in older adults who started exercising at a later age compared to adults who had been active in their younger years and stopped moving. Kohl and colleagues (2012) even state 6-10% of all non-communicable disease deaths are due to physical inactivity.

The amount of physical activity an older adult needs varies from person to person, but there are guidelines that older adults can adhere to, to remain or become healthy. Nied and Franklin (2002) state the health-related benefits of exercise follow a hyperbolic curve associated with regularity of physical activity. Their founding's indicated the most substantial improvements in health benefits can be seen in the older adults who went from zero to a little physical activity, while further increase in activity brings less significant improvement in benefits. Subsequent studies come to roughly the same, more concrete, conclusion: it is recommended for older adults to take part in at least 150 minutes of moderate intensity physical activity each week with varied exercises (Phillips et al., 2004; Bennett & Winters-Stone, 2011; Bodegom, 2018). Angulo et al. (2020) outlines categories of older adults with different conditions and intensity of activity (robust, prefrail, frail, hospitalized) and concludes 180 minutes of physical activity per week are needed. Additionally, strength training as part of the weekly activity benefits the results from this activity. Strength training prevents decline in strength, which in turn results in lower incidence of frailty, disability, and mortality.

Most older adults do not follow these recommendations. In contrast with health-promoting behaviours, physical activity declines exponentially with age (Philips et al., 2004). Many older

adults do not achieve the recommended 30 minutes of exercise 5 times a week and when they participate in exercises it usually only consists of walking. This is practical but not varied enough to achieve the desired results. Regular strength training would be important to participate in by older adults, but only 12% of persons 65 and older confirms taking part in strengthening exercises more than twice a week (Bennett & Winters-Stone, 2011). Oppezzo et al. (2021b) states that reasons for not exercising differ per older adult but are ultimately often related to the ability to move, fear of falling and fear of pain.

Older adults encouraged by a professional like a physician tend to exercise more than those without such professional help. According to Phillips et al. (2004) and Nied and Franklin (2002) the professional ensures a safe execution of the exercises and plays an important role in promoting increased activity in the long term. The professional identifies barriers to activity, setting specific goals and recruiting support from the older adult's surrounding. Bodegom (2018) confirms this and points out when the professional help is no longer given, the physical activity reverts to how it was before. This shows receiving frequent and short professional help proves to be very effective in maintaining or building an active lifestyle. In order to maintain this active lifestyle, some sort of professional coaching has to be in place.

To prevent overstaining the healthcare sector, an active and sustainable way must be found for older adults to become active. The proportion of older adults in Dutch society is growing. If these older adults do not exercise enough, they will become less fit and therefore more prone to illness or injury. This, in turn, will put more pressure on healthcare. To counteract this pressure, older adults need to be motivated to exercise more. Since professional coaching costs a lot, it may not be feasible to equip older adults with their own personal coach. Therefore, technology-supported coaching might be needed.

Whilst research shows older adults are becoming more and more accustomed to new technologies, technologies regarding physical activity are not yet adopted by older adults. Although, older adults are not unwilling to use these technologies, for many the technology is nog not accessible and available enough to be integrated in their daily life (Callari et al., 2012). Many technologies that aim to increase physical activity are not developed for older adultselderly, but for young people who have experience with "new" technology and can therefore use it more easily and integrate it into their daily lives. The barrier this entails is that older people do want to use these technologies but are not motivated to do so independently (Callari et al., 2012). If no help from another person is involved the new technology is not accessible enough for the elderly to learn to use themselves. With the help of others, this entry level is easier to achieve. Older adults do indicate that the existing activity technologies are desirable, but still require some adjustments to be truly integrated into their daily lives. This leads to the question "What requirements have to be taken into account while designing a device to adapt a more active lifestyle for older adults?"

The overarching problems are clear: a considerable part of the population of older adult's experience certain age-related problems, which in turn could lead to an overstraining of the healthcare sector. Prevention of lifestyle-related physical decline is important. One way to stimulate the older adults to adapt a more active lifestyle is encouragement by professional coaching, which is effective but too time-consuming to implement on a broad enough scale.

For younger people, technology plays a significant role in solving this problem: the professional coaching is supported or can be replaced by technological activity stimulating devices. The same physical activity motivating technologies are not accessible enough for the older adults and the technologies specifically intended for older adults are not so abundant that every older adult can have them.

To integrate a physical activity motivating technology into the life of an older person, the technology must meet requirements of older adults. Hengeveld (2021). Hengeveld (2021) held a co-creation session with older adults in which he conducted research into the method of adoptation of a physical activity motivational product. He then asked older adults about their opinion on important aspects in technology. five different themes emerged from this study that are important for technology adoption and adherence: mitigate the level of intrusiveness, acknowledgement of individuality, respect autonomy, encompassment of utility and entail usability. Hengeveld then build a clock which displayed both the time, and the process towards a daily activity goal of the user.

The goal of this graduation project is to expand the clock from Hengeveld to better motivate older adults to adopt an active lifestyle. The device will be developed with the main goal of integrating the benefits of professional coaching to the life of older adults. To ensure a simple and wide possible integration, the device must meet certain accessibility requirements approved for/by the older adults.Thus, this project builds upon the work of Hengeveld that resulted in important user requirements. Here we investigate the requirements further . The five key themes combined with information required form the literature research will form the foundation of the ideation session in the coming project. After this brainstorming session, prototypes will be developed that will then be rejected or improved after a user testing. The final product must be able to motivate the elderly to adopt a more active lifestyle. This leads us to the research questions::

1.2 Research Questions

RQ	How should a device to motivate older adults to adapt to a more active lifestyle be designed?
SQ1	What are the main means used by professional coaches regarding motivating elderly to adopt an active lifestyle?
SQ2	What are the most decisive requirements considered while designing a device to adapt a more active lifestyle for older adults?
SQ3	What experience elder adults themselves as a good motivation to adopt an active lifestyle?

1.3 Structure

The report is divided into 8 different chapters, which are subdivided into further sub-sections. The structure of the report is equivalent to the different phases of the Creative Technology design process described by (Mader & Eggink, 2014), that ultimately leads to the final product. After the introduction, the report provides research into background information in the second chapter. This starts with a literature review aimed to explore and gather information on the subtopics “professional coaching”, “motivating older adults” and “interaction technology requirements”. The chapter continues by providing information and examples on the state-of-the-art technology.

The third chapter informs on the methodology of the Designing Process, consisting of 4 phases: the Ideation Phase, the Specification Phase, the Realization Phase and the Evaluation Phase. These phases are also the topics of the next few chapters. Chapter 4 Ideation covers the Ideation Phase of the report: requirements and concepts for the final design are devised here. Chapter 5 Specifications concretized the requirements and concepts, devised in the previous chapter. Chapter 6 Realizations concludes the prototyping of the to be developed device. The first physical product will be developed on the basis of the concrete concepts that emerged from the previous chapter. The prototype(s) will be user tested in Chapter 7 Evaluation. Here the prototype produced will be used by users from the ultimate target group. The last chapter will be used to explain the results of the project and describe possible future research.

1. Background research

The background study of the report consists of 2 parts, a literature study and a state of the art overview. The aim of the literature review is to answer the sub-questions “What are the main means used by professional coaches regarding motivating elderly to adopt an active lifestyle?” and “What experience older adults themselves as a good motivation to adopt an active lifestyle?”. The state-of-the-art part will describe existing and relevant technologies. These technologies will range from smartwatches and other wearables to applications. The chapter will be concluded by drawing a conclusion from all the information gathered, which will be evaluated in a critical discussion.

1.1 Literature research

In this literature review, research is conducted into the pros and cons of professional coaching and effective motivational strategies for older adults. Additionally, it was investigated what older adults want in technology. A list of requirements was drawn up that are important when designing the device relating back to the first sub-question: “how should a device to motivate older adults to adopt a more active lifestyle be designed?”.

1.1.1 Professional Coaching

Professional coaching means the guiding of a person (in this case an older adult) on an active level by a professional. This can be done by motivating the person in question, as well as by prescribing or even guiding during exercises. The professional is someone with a job in this field, such as a personal trainer or physiotherapist.

Older adults encouraged by a professional like a physician tend to exercise more than those without such professional help. According to Phillips et al. (2004) and Nied and Franklin (2002) the professional ensures a safe execution of the exercises and plays an important role in promoting increased activity in the long term. The professional identifies barriers to activity, setting specific goals and recruiting support from the older adults surrounding. This shows receiving frequent and short professional help proves to be very effective in maintaining or building an active lifestyle. Bodegom (2018) confirms this but adds that when the professional help is no longer given, the physical activity reverts to how it was before.

Several ways in which professionals coach the older adults exist of which three are specifically elaborated below. Bennett and Winters-Stone (2011) describes multiple studies into this topic. The first elaborated method concerns research about a motivational session followed up by 15 booster calls (by phone or computer). A significant increase in physical

activity over one year was noticeable by the patients, as well as a higher percentage of participants meeting the recommended amount of physical activity compared to the control-group. The second method concerns a study examining older adult cancer survivors (Bennett et al., 2007), a similar result was found here compared with the first method. In this study, the cancer survivors were first given a session with a professional specialized in motivational interviewing, who subsequently had contacted them by telephone to increase the amount the cancer survivors exercised. In a third study nurse practitioners gave brief advice on the topic of physical activity, after which participants were regularly called by a trained motivational counsellor (Bennett et al., 2008). This resulted in increased self-efficacy for exercise.

To conclude, despite the good results of the professional coaching regarding motivating older adults, the effectiveness is difficult to sustain in the long term. The results obtained depend on both the motive and commitment of the professionals and participants, which are vulnerable for attrition (Bodegom, 2018). Additionally, the costs will cumulatively become high when an older adult goes through a long process with a professional. Furthermore, the availability of the professionals must also be considered. When more older adults require coaching, the overall availability of the professional will decrease (Bennet and Winter-Stone, 2011). Ways of coaching in which the older adults are still motivated but with reduced time-consumption for the professionals, would be more sustainable.

Alternative and more sustainable coaching styles for older adults are being explored. Examples of alternatives are online, phone based and peer coaching, of which the latter was most promising according to Bodegom (2018). The alternative should not be time-consuming for the professional but should increase motivation in the older adults. To get a better idea of what requirements make an alternative effective, investigation on the motives of the older adults must occur.

1.1.2 Motivating the older adults

Motivation is defined as the forces acting on or within a person to initiate a behavior (Phillips et al., 2004). Motivating older adults to adopt an active lifestyle, concerns trying to influence the behavior of the older adult in such a way they become more active in their daily lives. Both intrinsic and extrinsic factors influence this change in behaviour (Oppezzo et al.,2021). Intrinsic factors are factors taking place in the person's head: motivating thoughts that lead to that person wanting to exercise. The thought “I remembered how important it is to be physically active” is an example of an intrinsic motivation because it tries to persuade the thinker to become active. Extrinsic factors are factors outside the person. Imagine something or someone that prompts a person to be more active e.g., using walking the dog to become more active.

To effectively motivate the older adults, solutions must be sought to make possible age-related barriers as insignificant as possible. Oppezzo et al. (2021) states these barriers differ per older adult but are ultimately often related to the ability to move, fear of falling and fear of pain. Some older adults are no longer physically able to do certain exercises they were

used to, which could have a demotivating effect. Additionally, these older adults often consider themselves frail, which makes the fear of hurting themselves during an exercise also a barrier (Oppezzo et al., 2021). Finally, Oppezzo et al (2021) mentioned the fear of the neighbourhood as another barrier to physical activity: the older adults indicate not always feeling safe enough to go outside alone to get their share of physical activity. In order to motivate these older adults as effectively as possible, it would be optimal to counteract these barriers before they fully develop.

There are several ways to overcome these barriers, examples are theory-based interventions. Providing the older adults with sufficient information about fitting exercises in relation to their abilities and how they should be performed, is a possible solution to overcome these barriers. Chase (2014) states theory-based interventions are significantly more effective compared to interventions without a theoretical base: the older adults have a better understanding of why they carrying-out certain activities and whether it is a correct and an effective way. Besides interventions to be counselled or educated about the topic of physical activity, interventions targeting strategies to accomplish behaviour change is also essential.

Strategies on how to motivate older adults to participate in physical activity can be categorized in 3 types: internal, external, and other strategies. All three types of strategies are methods to motivate people to become more active which can be applied in everyday life. Oppezzo et al (2021) conducted research into these strategies in older women, with the aim of analysing different methods of motivating these persons. Subsequently, Chase (2014) research points out interventions regarding physical activities are similarly effective regardless of whether the subjects are female or not. The research of Oppezzo et al (2021) stated that internal strategies are often associated with the amount of physical activity. External strategies were associated with the amount of, and additionally, the intensity of physical activity. (Figure 1-1)

Internal	
Intrapsychic	Trying to adopt a certain mindset; Setting goals
Avoid Bad	Thought: "if I don't excercise, I will become too fat to fit into my clothes"
Approach Good	Thought: "if I run more often, my condition improves and I will feel better"
External	
Manipulate	Putting tennis shoes by the door; Writing a note as member to run in the morning
Capitalize	Walking the dog; Doing groceries by walking to the supermarket
Other	
Just do it	Thought: "I forced myself"
Passive	The doorbell rang so someone has to walk to the door
Nothing worked	-

Figure 1-1: Motivational strategies and examples

Internal strategies appeal to internal motivation: influence thoughts about physical activity. This can again be divided into certain sub-categories: intrapsychic, avoid bad and approach good. The “intrapsychic”-strategy relates to anything a person is telling oneself. The “avoid bad”-strategy focuses on avoiding a negative consequence in the future or focusses on what will happen when something is not done. A degree of fear of a bad result in the future is used as motivation to do something in the present. Finally, there is the “approach good” strategy, where achieving a positive outcome in the future is the motivation to do something in the present. (Figure 1-2)

External strategies appeal to external motivation: influence the surrounding to motivate physical activity. Two sub-categories can be defined: manipulate and capitalize. The “manipulate”-strategy is manipulating or changing the world around someone in order to motivate them to do something. The “Capitalize”-strategy is taking advantage of things or events already about to happen anyway, to accomplish the desired result. (Figure 1-2).

Other strategies appeal to remaining strategies, which are not linked to a real motivation and almost can’t be named strategies. The other strategies can be divided in sub-categories: just do it, passive and nothing worked. The “just do it” strategy is about someone not needing motivation, but just accepting it must be done. The “passive” strategy consists of things that happen by chance and must be done. The last subcategory of other is “Nothing worked”, here no motivation could be found (figure 2).

Although there is a difference between the strategies, no clear best strategy can be chosen. Oppezzo et al (2021) demonstrates different strategies worked well for a variety of participants. The approach good strategy here seemed slightly more effective in comparison to the other strategies, reminding about how things worked out well last time also work

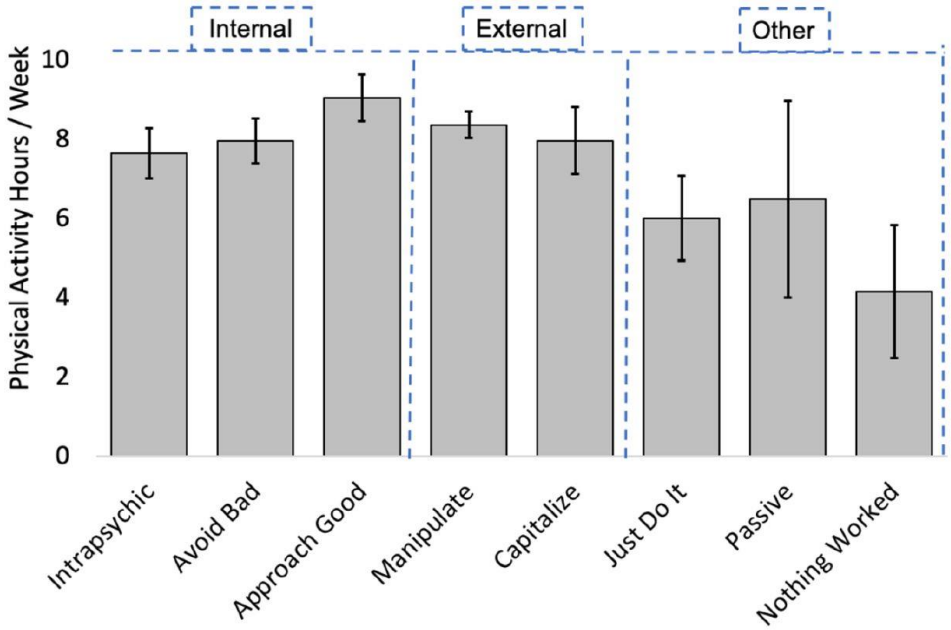


Figure 1-2: categories of motivational strategies against physical activity hours each week. (Opezzo et al., 2021)

especially well. Campbell et al (2001) claims a comparable conclusion. Older adults prefer

motivational messages focused on the progress of the exercises, instead of messages focused on the health-related outcomes of the physical activity. For instance, “to feel mentally alert” was ranked higher by older adults than “to improve or maintain health” Oppezzo et al (2021, p.2).

While overcoming the barriers not only the kind of strategy used is important, both the number of strategies used and way the intervention takes place have effect on the effectiveness of the intervention. Opezzo et al (2021) state the number of strategies applied is more influential than the choice of strategies. More specifically, when three of the given strategies are practiced simultaneously the effectiveness was highest. Chase (2014) argues pecifically a combination of both internal and external strategies would have an even more significant impact on the improvement of physical activity related behaviour. The way in which this intervention takes place also influences effectiveness. An intervention with both an audio and a visual part works better than just one of both, or none (Chase, 2014). (Figure 1-3)

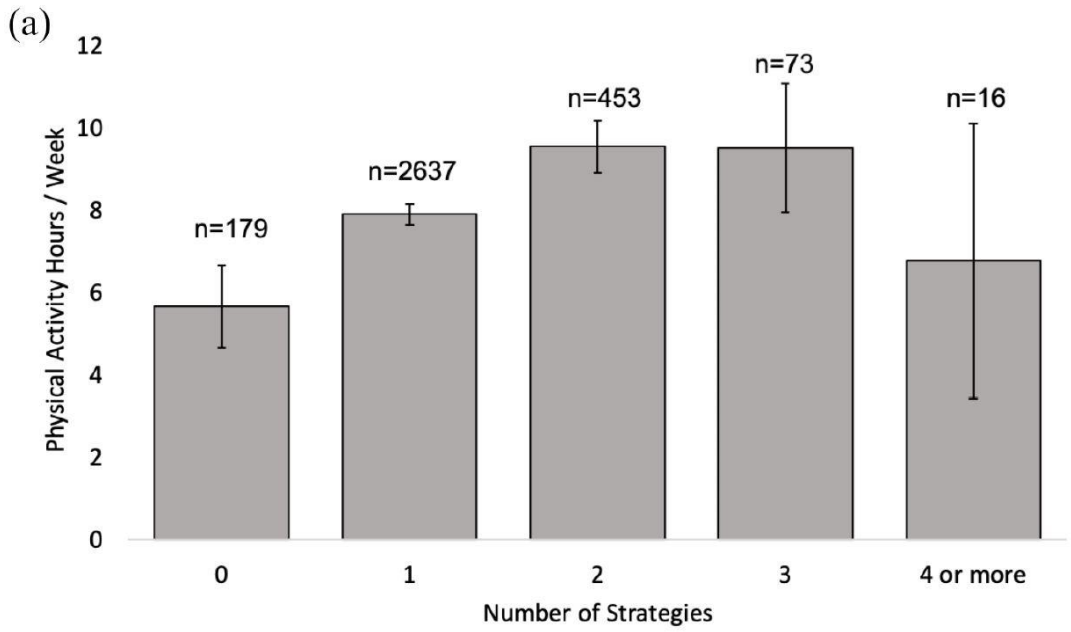


Figure 1-3: Number of motivational strategies used in relation to hours participated in Physical Activity each week (Opezzo et al., 2021)

1.1.3 Guidelines for Motivational Interaction Technology

A way to counteract the disadvantages of professional coaching while still maintaining their motivational strategies is using technology. If a device could take over from a professional, it will cost less man hours and thereby less money. Take the example of Bennet and Stone (2011): a motivational session followed up by 15 booster calls (by phone or computer). If the booster calls are automatized, it will save the time of 15 calls but yield the same effect: the older adult still has a reminder and therefore incentive that they must be physical active. Another option is to develop a device replacing instead of automating the current tasks them. A standalone device which uses three motivational strategies, both intern en external, to motivate the older adult. In order to relive the professionals, a device has to be developed to take over certain responsibilities.

To make the older adults to successfully interact with a device, certain design requirements for this device must be met. In a previous graduation project by Hengeveld (2021), research has been conducted to gather insight regarding the attitude and opinion of older adults towards interaction with digital technologies and physical activity. This insight was obtained through a Co-creation session as described by Sleeswijk-Visser and colleagues (2005). This Co-creation session consisted of two phases and was participated in by seven older adults. The first phase consisted of a booklet. containing various assignments on how older adults encounter technologies. The booklet was sent home to each participant to be completed individually. The second phase continued the booklet and was held in person between the researcher and each participant. The meeting was composed of a creative session in which a participant was expected to perform several small creative tasks. The tasks eventually revealed information and opinions on the physical activities the participants took part in in life. The results of the sessions were analyzed from which five key themes emerged.

The five key themes together form guidelines to be considered while designing interactive technologies concerning physical activities for older adults. The five themes are: mitigate the level of intrusiveness, acknowledgement of individuality, respect autonomy, encompassment of utility and entail usability. When these themes are considered when drawing up the requirements for a device, it will increase the likelihood of being successful in the motivation of physical activity.

Intrusiveness

The intrusiveness concerns the extent to which a device is present in the life of the older adult. Older adults indicate to prefer to decide for themselves the extent to which a device is used in their lives. For example, interrupting notifications or that are constantly visible often lead to frustration. Additionally, a smartwatch is deterrent because it is present on the body all the time. A smart ring, on the other hand, turned out to be less extreme due to its small size. (Hengeveld, 2021)

Individuality

The individuality concerns the extent to which a device distinguishes an individual from others and thereby provides appropriate interaction. Individuals require different amounts of physical activity (Angulo et al., 2020). Consequently, they require different approaches and intensity to be motivated to perform the physical activity (Oppezzo et al., 2021a). While one needs to be motivated once a day, the other can only do that once a week. In addition, the research of Opezzo et al. (2021b) state different types of strategies work better for certain older adults compared to others. In order to be accessible for older adults, they will have to be able to differentiate between these categories Hengeveld (2021).

Autonomy

The autonomy concerns the amount or to what extent an older adult can utilize the device by themselves. Additionally, it concerns the way and amount of interaction to utilize the device. Callari et al. (2012) identifies one of the barriers to use new technologies for the older adults, is the inability to learn to use it themselves. When no help from another person or professional is involved, the new technology is often not accessible enough for the older adult to learn to use themselves. Lee & Coughlin (2014) claims the lack of independence of a device can result in poor adoption among older adults. To counter this, fitting modes of control, feedback, and instructions must be provided.

The amount of interaction and time the device needs to be used properly and takes to be used effects usability for the older adults as well. A smartwatch satisfied the needs of the older adults by always being capable to display results and information. On the other hand, the device was seen by the older adults as obligation to be worn constantly in order to receive the proper effects. (Hengeveld, 2021)

Utility

The utility concerns the quality or state of being useful profitable, or beneficial. The usefulness is primarily expressed in the type and clarity of the information displayed to the user. The older adults in the research of Hengeveld (2021) indicated an excess of information quickly becomes unclear. Less but concrete information was appreciated more. Lee & Coughlin (2014) elaborates this even further and states a technology has to provide clear benefits to the current lifestyle. Older adults are generally withholding regarding devices they cannot clearly see the advantages of. They are more inclined to adopt a device or technology when it they understand its usefulness and possible effectiveness, rather than for novelty's sake.

Usability

The usability concerns the measure of how well a specific user in a specific context can use a product/design to achieve a defined goal effectively, efficiently, and satisfactorily. The older adults in the research of Hengeveld (2021) were asked the simplified version of this question: does the technology that I interact with does what it is supposed to do, and do I understand what it is trying to say? The older adults highlighted the importance of the obviousness of the functions of the device. An excessive amount of extra functionality would only cause difficulties and confusion. Lee & Coughlin (2014) agrees, and state interfaces should remain simple, the features of a device should look familiar and natural language should be used where possible. Additionally, interactions should not require physical cleverness or considerable cognitive processing.

To conclude, a device must be developed using the benefits of professional coaching to motivate older adults to adopt a more active lifestyle. This device must apply three motivation strategies, consisting of both internal and external factors. Additionally, to successfully make older adults interact with this device, certain design requirements for this device must be met. These design design requirements must be drawn up from the five themes.

1.2 State of the Art

To develop new technologies, the current state of the technology first has to be investigated. The aim of the investigation is to gain insight in the existing technologies and their (dis)advantages. The devices and technologies emerging from this research will provide inspiration for the ideation process. At the end of the State of the art, an overarching conclusion will be drawn from the usefulness of different aspects of the described technologies. Ultimately, various requirements for the final design will be determined based on this conclusion.

1.2.1 Process

A general assessment of the technologies and devices will first be given, after which the individual types will be discussed in more detail. The technologies in this chapter are subdivided into several categories, of which a general consideration is given based on the five themes (Table 1-1). Additionally, a few individual technologies are examined so a picture can be formed of the type of product. The products are selected based on familiarity: these products are widely used frequently. The pros and cons arise from reviews of the products, and the researcher's personal experience with the products.

Theme	Assessment	Score
Intrusiveness	The extent to which a device is present in the life of the older adult.	
Individuality	The extent to which a device distinguishes an individual from others and thereby provides appropriate interaction	
Autonomy	The amount or to what extent an older adult can utilize the device by themselves and of interaction to utilize the device.	
Utility	The quality or state of being useful profitable, or beneficial.	
Usability	The measure of how well a specific user in a specific context can use a product/design to achieve a defined goal effectively, efficiently, and satisfactorily.	

Table 1-1: example of the considerations based on the five themes

1.2.2 Activity or health Trackers

An activity tracker or fitness tracker, also known as fitness-wearable, is a compact electronic device for measuring and processing fitness and health related information. Physical activity related wearables have functionalities to collect and process information about the human body, such as activity and heart rate. These devices exist in a variety of forms, capabilities, and complexity.

1.2.2.1 Smart Wristbands

Smart wristbands are smart and compact electronic devices worn on the arm or wrist, in contact to the skin. These health trackers have functionalities like a heartrate- and pedometer built in. More expensive devices often feature displays and functionalities to visualize the measured data to the user. Additionally, the wristbands also take over certain functionalities of a watch like the ability to show the current time, a stopwatch, etc. Due to their placement on the body, they can perceive a lot of health-related data even though they are not prominently present on the body. The combination of display, placement on the wrist and only a few important features like a heartrate monitor and pedometer makes them generally to be seen as simple to use (Lee & Coughlin, 2014).

The wearables are often not capable of storing a lot of user data, limiting the saved performance history. Additionally, these devices often do not have the ability to process information by themselves and require an external device to use the full capabilities. Usually, the activity trackers transmit information about the wearer to a mobile application. This application processes and stores the information. Subsequently, the device can retrieve the information from the application again, to display it to the wearer. As a result of this division of labour, the device itself needs less capacity. This can result in a more compact device and thereby lowering the intrusiveness. Additionally, the cost of these devices is generally lower compared to other wearables like the smartwatch, due to the lesser capacities.

Wristbands		
Intrusiveness	Relatively small device strapped around the wrist, presence not constantly noticeable	+
Individuality	Does not distinguish between individuals, is possible through external technologies (e.g. application)	-
Autonomy	Works properly without attention (tracks activity on its own), but must always be around the body for it to function properly.	+/-
Utility	Concise number of varying and useful functions	+
Usability	Considered simple to use	+

Wristbands

Table 1-2: the FitBit charge 5 (Fitbit Charge 5, 2022)

Fitbit Charge 5

- https://www.fitbit.com/global/us/products/trackers/charge5
- https://smartwatchgraph.com/smartwatches/fitbit-charge-5-full-specifications-features-and-price/

- ☑ GPS
- ☑ Heart rate monitor
- ☑ Sleep tracking
- ☑ Distance tracking
- ☑ Simple to use
- ☒ pricy (+ €100,-)
- ☒ no onscreen workout
- ☒ no fall detection
- ☒ extra device needed

Table 1-3 the Xaomi Smart Band 5 (Mi Smart Band 5, 2013)

Xiaomi Mi Band 5

- https://www.mi.com/nl/mi-smart-band-5/
- https://smartwatchgraph.com/smartwatches/mi-band-5-full-specifications-features-and-price/

- ☑ Cheap +/- €30,-
- ☑ Heart rate monitor
- ☑ Sleep tracking
- ☑ Distance tracking
- ☑ Simple to use
- ☒ no onscreen workout
- ☒ no fall detection
- ☒ extra device needed

1.2.2.2 Smart Strap

Smart straps come in different shapes and sizes, but are generally similar to, but have less functionality than Smart Wristbands. The Smart Straps are attached to or around a body part where the heart can be properly monitored. This can vary from the upper arm to the chest. The device monitors the hart and stores the data or forwards it to another device it is connected to. No data can be visualized on the smart strap itself. In general, the straps have a more accurate measuring of the heartrate and other hearth related functionalities compared to the wrist strap.

Smart Strap		
Intrusiveness	The large band around the chest makes the user almost constantly notices its presence	-
Individuality	Does not distinguish between individuals, is possible through external technologies (e.g. application)	-
Autonomy	Must always be around the body for it to to function.	-
Utility	Very high utility regarding a small number of features	+
Usability	Small amount of possible features makes it simple to use	+

Smart Strap	
	**Polar H10 Heart Rate Monitor Chest Strap** - *https://www.polar.com/us-en/products/accessories/h10_heart_rate_sensor* ☑ Heart rate monitor ☑ Bluetooth connection ☒ pricy (90,-) ☒ extra device needed

Table 1-4: Polar H10 Heart Rate Monitor Chest Strap (Polar H10, 2022)

	***Garmin HRM-Pro*** - https://www.garmin.com/nl-NL/p/682155 ☑ Heart rate monitor ☑ stores movement dynamics ☑ Bluetooth connection ☑ also stores data local ☒ pricy (130,-)

Table 1-5 the Garming HRM-Pro (Garmin & or, 2022)

1.2.2.3 Smart Shoe Sensors

Health or activity trackers connected to or around the feet can be classified as Smart Shoe Sensors and gather data centered around leg or feet related activity. The trackers can be attached to or are built into the shoes of the user. The devices only collect data that is displayed on an external screen. Often this is an app on a smartphone used to provide information on the way the user moves. The trackers themselves do not have any built-in visualization functions.

Smart Shoe		
Intrusiveness	Prescence almost unnoticeable	**+**
Individuality	In itself the device does not distinguish between individuals, only through its own input or external technologies this is possible.	**-**
Autonomy	Always must be attached to the feet for it to function properly, but everyday utensil so will already be so.	**+/-**
Utility	Very high utility regarding a small number of features	**+**
Usability	Useable by almost everyone	**+**

Smart Shoe

Table 1-6: the Polar Stride Sensor (Polar Stride Sensor, 2022)

Polar Stride Sensor Bluetooth Smart

- https://www.polar.com/nl/producten/accessoires/Stride_sensor_Bluetooth_Smart

- ☑ Attachable to most shoes
- ☑ Distance tracking
- ☑ Stores movement dynamics
- ☑ Bluetooth
- ☒ pricy (€70,-)
- ☒ extra device needed

1.2.2.4 Smartwatches

A smartwatch is a wristwatch with the limited functionallities of a smartphone. The devices are equipped with similar functions as activity or health trackers along with a larger display. This display can be used to show various applications. These applications make it possible to provide the carrier with more information. As a result, the device can be seen as a replacement for the extra device that an activity or health tracker does need o display certain statistics. The larger display enables the device to show certain graphs and statistics only available for the smartwristbands on an external device with application. The display also makes for higher utility. Unfortunately, these extra options also come with drawbacks. The additional functionalities could become confusing and thus make the device harder to use.

Smart watch		
Intrusiveness	Small device strapped around the wrist, presence not constantly noticeable	**+/-**
Individuality	Does distinguish between individuals and can calculate suggestions based on data	**+**
Autonomy	Works properly without attention (tracks activity on its own) but must always be around the body for it to function properly.	**+/-**
Utility	Vast number of varying and useful features	**+**
Usability	Considered hard to use due to the amount of features	**-**

Smart Shoe

Apple Watch Series 7

- https://www.apple.com/nl/apple-watch-series-7/

- ☑ GPS
- ☑ Heart rate monitor
- ☑ Sleep tracking
- ☑ Distance tracking
- ☑ Big display
- ☑ No extra device needed

- ☒ pricy (€500,-)
- ☒ no onscreen workout
- ☒ no fall detection

Table 1-7: the Apple Watch Series 7 (Apple Watch Series 7, 2021)

Samsung Galaxy Watch4 Classic

- https://www.samsung.com/nl/watches/galaxy-watch/galaxy-watch4-classic-black-bluetooth-sm-r890nzkaeub/

- ☑ GPS
- ☑ Heart rate monitor
- ☑ Sleep tracking
- ☑ Distance tracking
- ☑ Big display
- ☑ No extra device needed

- ☑ GPS
- ☑ Heart rate monitor
- ☑ Sleep tracking
- ☑ Distance tracking
- ☑ Big display
- ☑ No extra device needed

1.2.3 Applications

A technological interaction consists partly of interaction with the device itself, but additionally with the software connected to the device. Both activity or health trackers and smartwatches can often connect to applications on an additional device. This connection with the application can have different functionalities: e.g.: sending reminders that the user needs to move or providing information about the amount of physical activity the user has participated in. The application stores and process the health and activity related data collected by all devices linked to the same person and visualizes this in an overview of the data that has been collected about the wearer. Drawing conclusions from this data could be a useful for the approach and process of influencing the choice and design of motivational strategies. For example, estimates can be made of the number of motivational messages/impulses the user requires. The main usage of the applications is storing and clearly presenting health-related data collected about the user.

1.2.3.1 Apple fitness+

The Apple fitness+ applications is designed for usage on products related to or developed by Apple Inc., such as the previously mentioned “Apple Watch series 7”. The fitness app can be installed on products from Apple inc. such as the different generations from the iPhone series. In addition to storing the data collected by all the devices connected to one person (or one Apple Account), the application provides a variety of features. It provides suggestion on type of exercises or whole workouts, onscreen workouts itself and tracks advances in these workouts.

Apple tries to motivate the user to become more physical active by attending the user on their progress in three different areas of activity. These three categories are the amount a person has stood, moved and trained in a given time frame. The amount that must be reached can be set by the user himself, whereby he gets advice from the application how much this should be according to their personal goals and data (Figure 1-4). Additionally, Apple tries to motivate the user to become more active by reminders to move and suggested workouts.

Figure 1-4: Progress bar of Apple Fitness+

1.2.3.2 Google fit

The Google fit applications are designed for usage on products capable of running multiple operating systems like Andriod, IOS, windows, etc. The application can be connected to a variety of devices regardless of the brand or developer of the device. The main functionality of the application is to be a storage and visualization place for data collected by all the devices connected to one person (or one Google account). The google fit app makes users aware of progress towards preset goals in 2 categories (heart points and steps) through a similar kind of progression bar as the Apple Fitness+ application. Although the Google fit+ application can be connected to more different types of devices than the Apple variant, the fit+ application has fewer features to use.

Figure 1-5: google fit startscreen

1.2.4 Conclusion: platform to connect technologies is lacking

All types of technologies bring (dis)advantages making it impossible to select a clearly "best" technology type, what matters is the preference of the user. Within each category a difference between the designs of different products exists, but the overarching advantages and disadvantages remain most decisive. For example, the versions of the discussed smart straps have different specifications, but the decisive advantages and disadvantages for the user remain the same. A heart rate monitor strap is simple to use but always noticeable when worn. On the contrary a smart shoe, it is barely noticeable when worn, but it does not contribute individuality by itself. It is important to equip the final product of this project with the compatibility with different devices, this allows the user to choose a product of own preference.

A method to equip the product with compatibility for different technologies is by means of an application. Research into the applications shows the functionality as bridge between different devices. This bridge also solves some of the flaws of physical devices. For example, a disadvantage of a smart wristband is the limited individuality involved. By connecting the wristband to an application like google fit, new functionalities can be unlocked. These new functionalities could be used to add additional individuality to the device An application connected to several types of technologies should be used to give the user the choice of the physical device preferred to use.

1.3 Conclusion: background research

Receiving frequent and short professional help proves to be effective in maintaining or building an active lifestyle, the downside being here the eventual high cost and labour hours. This can be reduced by an initial contact moment with a professional followed by periodic reminders. This has been found to motivate older adults to take part in physical activities more regularly and thereby adopt a more active lifestyle. In the initial contact moment, the professional can counsel the older adult about fitting exercises according to their abilities and explain how they should be performed. The periodic reminders can then be used to further support and motivate the older adult. These reminders (or interventions) are best conveyed in an audio-visual way and consist of both internal and external factors. The internal factors being thoughts that lead to that person wanting to exercise. The thought "I remembered how important it is to be physically active" is an example of an internal factor. Extrinsic factors are factors outside the person. Imagine something or someone that prompts a person to be more active e.g., using walking the dog to become more active.

When training motivative strategies, a variety of internal and external strategies should be used. Where the approach good strategy or positive feedback aimed at the performance already achieved is seen as effective, in order to receive the most influential effect three

different strategies have to be adopted. If these strategies are learned, the older person will be better able to maintain the active lifestyle. This would result in less dependency on the professional help, so that the professionals have to spend less time with these older adults.

Older adults can be stimulated to participate more in physical activities by a combination of professional coaching and a variety of motivational strategies. Practice shows professional coaching helps older adults to adapt an active lifestyle, but this is not sustainable. When professionals teach the older adults a combination of three internal and external strategies, these can be used to adopt a more active lifestyle. As a result, the older adults will participate in more physical activities.

When the professional coaching and motivational strategies are integrated in interactive technology, this technology must be developed according to certain guidelines. The guidelines are divided into 5 so-called themes. When all these 5 themes are taken into account, the chance of older adults incorporating these technologies into their lifestyle will increase. This will result in more motivation for physical activity and thus a more active lifestyle. The 5 guidelines are:

- **Intrusiveness**: the extent to which a device is present in the life of the older adult.
- **Individuality:** the extent to which a device distinguishes an individual from others and thereby provides appropriate interaction.
- **Autonomy**: the amount or to what extent an older adult can utilize the device by themselves and of interaction to utilize the device.
- **Utility**: the quality or state of being useful profitable, or beneficial.
- **Usability:** the measure of how well a specific user in a specific context can use a product/design to achieve a defined goal effectively, efficiently, and satisfactorily.

In the state of the art, different technologies emerge which can serve as examples and inspiration in the coming ideation process. Besides, the research suggests a combination of multiple technologies could prove advantages compared to a single technology. For example, various wearables are not advantages compered with a number of the five themes. Linked to an application, the wearables resolve the shortcomings. At last the research suggest all technologies contain advantages and disadvantages, the choice of what is important is ultimately to the user. Using an application is once again a method to respond. The application can connect to different technologies and thus give the user the choice of the wearable.

To conclude, a device must be developed using the benefits of professional coaching to motivate older adults to adopt a more active lifestyle. This device must apply three motivation strategies, consisting of both internal and external motivations. Additionally, to successfully make older adults interact with this device, certain design requirements for this device must be met. These design design requirements must be drawn up from the five themes. Finally, the final product must be able to be combined with other technologies. Also, the choice of which additional device must be the choice of the user. Below is an overview of requirements.

User Requirements		
Requirement	***Description***	***Priority***
Periodic reminders	The device should make use of periodic reminders	Should
Internal factors	The device must make use of internal factors	Must
External factors	The device must make use of external factors	Must
Motivational Strategies	The device must make use of three motivational strategies	Must
Audio visual way	The device should make use of an audio-visual way to convey the motivational strategies	Should
Intrusiveness	The device must mitigate the level of intrusiveness	Must
Individuality	The device must distinguish an individual from others and provide appropriate interaction	Must
Autonomy	The device must be usable without a permanent utilization	Must
Utility	The device must have a certain level of profitability	Must
Usability	The device must be easy to learn and use	Must
Compatibility	The device must be compatible with different categories of external devices (like wearables)	Must
User preference	The device compatible devices must be chose able by the user	Must

2. Methodology

The background research has conducted research into answering the first two sub-questions, the following chapters will address the sub-question “What are the most decisive requirements considered while designing a device to adapt a more active lifestyle for older adults?” and answer the main research question. This will be done on the basis of the Creative Technology Design Process, a way of designing described by (Mader & Eggink, 2014). This process will consist of four phases, each with their own chapter: the Ideation Phase, the Specification Phase, the Realization Phase and the Evaluation Phase.

2.1 The Creative Technology Design Process

The device will be developed with the focus of integrating the benefits of professional coaching and motivational strategies to the life of older adults by using the Creative Technology Design Process. This process is described by (Mader & Eggink, 2014) and consists of four iterable phases, each of the phases continues the results of the previous phases. All phases have a different purpose; the Ideation phase aims to emerge different guidelines, ideas, and concepts for the eventual solution. The specification phase explores this by creating prototypes, each of which exploring a solution for a specific idea. These prototypes are simple and will only cover a small aspect of the bigger picture. All information emerging from the testing of these smaller prototypes will be combined and realized in the Realization Phase. Different prototypes are developed by considering the problems and solutions arising from the previous phase. These prototypes will thus combine the solutions for different aspects of the problem into one whole. These combined prototypes will be subject to user testing in the Evaluation phase.

The process frequently makes use of Divergence and Convergence models and Spiral models. Divergence is the process of first approaching a problem or design choice in a broad way, many ideas or solutions have to be released. A brainstorming session in which the participants are given the opportunity to report everything they find relevant, could be an example of a diverging process. Subsequently to this process, different design choices are selected from this broad pool of ideas, which is part of the convergence process. The ideation space is reduced again, and the most relevant ideas are included. A Spiral Model uses steps that each include components of problem understanding and definition, project planning, idea generation and evaluation. This involves looking back, evaluating and improving on smaller aspects of problems. In the Creative Technology Design Process, Divergence and Convergence is used in both the Ideation Phase and the Specification and

Realization Phase; the Spiral model is used in both the Ideation and Specification phase. (Mader & Eggink, 2014).

By making use of this process, space will be provided for the creativity of the researcher and the participants in various sessions. This will result in a concept in which the design has been looked at from many sides. This in turn ensures many different solutions will arise, from which the best is selected. Ultimately, a wide range of problems will be considered, and a well-thought-out solution will be found.

2.1.1 The Ideation Phase

The first phase of the design process will consist of a brainstorming session with the goal of producing an unspecified number of smaller solutions for specific aspect of the devices to be developed. Additionally, during the brainstorming session the participants will be encouraged to suggest certain combined solutions or device concepts, to provide inspiration for possible final solutions. The session will be based on the 5 themes and other information emerged from the literature research. It will be attended by several other student designers in and will consist of several phases, each of which ensures the divergence or convergence of the ideation space. By diverging the ideation space, ideas and solutions will emerge that might otherwise not have been included (Mader & Eggink, 2014), after which the convergence will reduces the pool of ideas so that only relevant things are included.

The participants will not consist of people within the target group but will be asked to empathize with the target group. Prior to the brainstorming session, the participants will receive information from the literature review on the ways to motivate the target group. Additionally, they receive information about the five themes that have been developed by, among others, the target group itself. These themes are guidelines for how a design would work well with the target group. The participants are also instructed to contact someone who fits within the target group (this could be a grandparent, for example), to empathize with their situation. This will take place prior to the brainstorm session.

A final divergence and convergence session will take place after the brainstorming session, through an expert interview. The opinion of the expert will be asked on the remaining concepts, afterwards the most promising concept will be selected and elaborated. By allowing the student designers to diverge and converge, a lot of space will be available to unleash creativity on the problem positions and provide a lot of input towards the final concept. The expert will give opinions (and sequentially ideas) about the concepts, which again has a converging effect. When the expert filters the concepts by selecting the most promising concept, a divergence will take place. The convergence and divergence cycles will iterate, hereby a variety of factors can be taken into account for the final concept.

Due to the difficult availability of the older adults, it was decided not to do the brainstorming session with the participants specifically selected from the target group. Older adults are difficult to find and are a fragile target group, thus consent must also be given for participation. To come up with the right ideas, the participants of the session will be asked to empathize with the target group, to promote ‘empathic design’. This empathizing will be

done by making the participants talk to or calling with an older adult prior to the session. The idea behind this is now the participants can better fulfill the concept of 'walk the user's walk' (Kouprie & Sleeswijk Visser, 2009). The selected participants in the brainstorming session are students with a background in, or a passion for, design.

2.1.1.1 The brainstorm session

The brainstorming session will consist of a meeting between several student designers. After an elaboration of the background of the literature research as introduction the student designers receive an explanation of the conclusion of the research (Appendix A). After a moment intended to allow the participants to ask questions about the received information, the brainstorming starts.

Prior to the brainstorming session, participants are asked to contact their grandparents or other known older adults. The purpose of this contact is to simplify empathizing with the older adults. The participants are asked to question the elderly on any comforts and inconveniences they experience with interactive technologies. As a result, they will learn more about the problems that these older adults experience in their daily life and thus which problems can be solved by means of a product.

The brainstorming session will consist of three phases: the introduction phase, the converging phase, and the diverging phase (Table 2-1). In the introduction phase, the background information will be elaborated on. The purpose of the brainstorming session will be explained by means of a few examples. The converging phase will consist of creating a mind map (Figure 3-1). In this mind map session, participants are expected to write down as many ideas and words that belong to the topic as possible. By elaborating this, they will eventually come up with concepts and guidelines. The best concepts arriving from this phase will be selected in the diverging phase. In this the vague concepts will also be further elaborated by means of adding a guideline to the mind map (by adding sticky notes).

Round		***The introduction Phase***	***Comments***
1	*Advance*	Participants are asked to contact older adults	
	Activity	Elaboration on the literature findings (5 theme's, motivational strategies)	Elaboration letter is handed out
	Afterwards	Participants can ask questions	
		The divergence phase	
2	*Advance*	Mindmap is drawn and elaborated	
	Activity	Participants are asked to are asked to tell everything they think has to do with certain themes. Any concepts will be encouraged from this.	

	Afterwards	Participants are given time to carefully study the Mindmap
The convergence phase		
3	*Activity*	Participants will select the best concepts and elaborate some guidelines
	Afterwards	The participants are thanked for their effort

Table 2-1: Phases of the brainstorm session

In the convergence phase of the brainstorming session general guidelines, solutions and concrete ideas are selected. These specifications will be taken into the next phase of the design process. To do this, they must first be collected and organised together in an orderly manner.

General guidelines

The organization of the general guidelines will happen by collecting all information, comments, arguments for and against each guideline and summarizing them briefly and concisely. This will produce a coherent list of requirements and descriptions. The possible solutions thought up by the participants of the brainstorm session are elaborated on in the last row of the table.(Table 2-2). The purpose of the guidelines is not to set rules a design must comply with, but rather things to take into account when designing.

Guidelines		
Guideline	***Description***	***Possible solution***
Name guideline 1	*Information describing the guideline and specifics to be considered*	*Example theme 1, example theme 5*
Name guideline 2	*Information describing the guideline and specifics to be considered*	*Example theme 3, example theme 5*
Name guideline 3	*Information describing the guideline and specifics to be considered*	*Example theme 4*

Table 2-2: Collection table of the general guidelines (example)

The ideas

The organization of the ideas will happen in a comparable manner as the guidelines: by collecting all information, comments, arguments for and against each guideline and summarizing them briefly and concisely. This will produce a coherent list of ideas and the concepts they are used in.

Ideas		
Idea	***Description***	***Concept***
Name idea 1	*Information describing the idea and specifics to be considered*	*Example concept 1, Example concept 4*
Name idea 2	*Information describing the idea and specifics to be considered*	*Example concept 3*
Name idea 3	*Information describing the idea and specifics to be considered*	*Example concept 2 Example concept 3*

Table 2-3: Collection table of the ideas (example)

The Concepts

The organization of the concepts will happen by collecting all information, comments, and ideas before summarizing them succinctly. The concepts will not only consist of texts, but guidelines, examples, and other visual illustrations as well. This will also all be combined and placed in a coherent list (Table 2-4). In addition to the coherent list, all the individual concepts will be elaborated on more extensive, this will cover both the features as the design ideas. This elaboration will be included in the appendix (Appendix B).

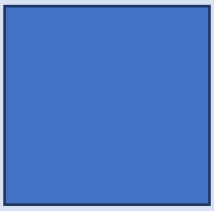
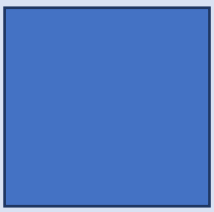
Concept 1	
	Brief elaboration of the idea
	***Guidelines*** ***Ideas***
Figure x: illustration of idea	
Concept 2	
Brief elaboration of the idea	
	Brief elaboration of the idea
	***Guidelines*** ***Ideas***
Figure x: illustration of idea	

Table 2-4: Collection table of concepts (example)

2.1.1.2 The Expert session

Subsequently to retrieving and sorting the results of the brainstorming sessions, all developed concepts will be investigated by an expert. This will be done through an interview. The expert will be asked to elaborate their opinion on each individual concept. Additionally, the expert will be asked to select the most promising concepts. This will all be substantiated and noted down and added to the elaborated concepts.

2.1.1.3 The final concept

The ideation Phase is concluded by selecting the most promising concept by the researcher. The choice will be based on the opinions expressed in the brainstorming session and the expert interview. The final concept must be approved by the supervisor. The design will be elaborated with associated possible features and functionalities.

2.1.2 The Specification Phase

The various solutions emerging from the Ideation Phase are developed into prototypes in the Specification Phase. The aim of the Specification Phase is to find a method to meet certain requirements, and then test this method by making prototypes. The prototypes will not be complicated and consists of only the solutions of a few aspects of a potential final product. The specification phase explores the requirements and solutions emerging from the ideation phase, by creating prototypes.

At the end of the Ideation Phase, all the ideas devised by the participants of the brainstorming session have been collected and organised in three different categories: the guidelines, separate ideas, and concepts. For each concept, certain ideas and guidelines should be considered. The most promising concept from the Ideation Phase with associated ideas and guidelines will be further elaborated on in this phase and tested on each aspect on.

The concept to be worked out, and associated ideas and guidelines, first must be separated into user and system requirements, and the solution or functionality to meet these requirements. A user requirement is a requirement on how the device should behave. A system describes how the system works. For example, the system should be able to be powered on a certain power supply. The focus of the testing of the concepts will be based on the user requirements. (van Velsen et al., 2009)

The MoSCoW method is used to properly classify the requirements (Table 2-5). This method was developed as a framework to help prioritize tasks during product development. This framework consists of four gradations, each of which paints a picture of the priority of a

task. These tasks can then be completed from top to bottom, so that the most important tasks are completed first (Positive Stud, 2022).

Mo	Non-negotiable product requirements that are mandatory for the team.
S	Important initiatives that may not be vital, but can add significant value.
Co	Nice to have initiatives that will have a small impact if left out.
W	Initiatives that are not priority for the current time frame.

Table 2-5: depiction of the MoSCoW method (Positive Stud, 2022)

The requirements will be divided into 4 categories in ascending order: MUST, SHOULD, COULD and WONT. MUST meaning must-have; the functionality absolutely must be included in the final design, SHOULD meaning should-have; it will have a high priority in fitting in the final design, COULD meaning could-have; it can be included if there is the availability, and WONT meaning won't-have; it can be included but no effort has to be made.

User requirements

The user requirements elaborated on in the previous chapters will be combined in a well-arranged table (Table 2-6). The requirement will be summarized in one or a few words and elaborated on further in a small sentence. Additionally, the priority of the requirement is described in the last column of the table. The requirements will be sorted on priority.

User Requirements		
Requirement	***Description***	***Priority***
Name user requirement 1	*Information describing the user requirement and specifics to be considered*	*MUST*
Name user requirement 2	*Information describing the user requirement and specifics to be considered*	*SHOULD*
Name user requirement 3	*Information describing the user requirement and specifics to be considered*	*WONT*

Table 2-6: Collection table of the User Requirements (example)

System requirement

The user requirements elaborated on in the previous chapters will be combined in a table (Table 2-7). The requirement will be summarized in one or a few words and elaborated on further in a small sentence. Examples of specific systematic requirements: the device must be able to connect to Bluetooth, the device must have a micro-USB power input, etc. Additionally, the priority of the functionality is described in the last column of the table. The requirements will be sorted on priority.

System Requirements		
Requirement	**Description**	**Priotity**
Name systematic requirement 1	*Information describing the systematic requirement and specifics to be considered*	*MUST*
Name systematic requirement 2	*Information describing the systematic requirement and specifics to be considered*	*SHOULD*
Name systematic requirement 3	*Information describing the systematic requirement and specifics to be considered*	*WONT*

Table 2-7: Collection table of the Systematic Requirements (example)

Solutions

The solutions arising from the the previous chapters will be combined in a table (Table 2-8). The solution will be summarized in one or a few words and elaborated on further in a small sentence. Additionally, the requirement the solution(s) tend to resolve are stated in the last column of the table.

Solutions		
Solution	**Description**	**Requirement**
Name solution 1	*Information describing solution and specifics to be considered*	*Name requirement 1*
Name solution 2	*Information describing the solution and specifics to be considered*	*Name requirement 2, Name requirement 3*
Name solution 3	*Information describing the solution and specifics to be considered*	*Name requirement 3*

Table 2-8:Collection table of the Solutions (example

2.1.2.1 Prototyping

A prototype is a primitive form, sample or early model of a product specifically developed for testing. It is built to evaluate a concept to enhance the design and serves to provide specifications for a real device instead of a theoretical one. Prototyping is the making of the prototype.

For each of the functional requirements, different solutions are investigated and tested. This will be done by making prototypes concerning one or a few functionalities. This protype first will be thought out and or visualized, after which it will be develop. These prototypes are meant to be simple and easy to create. One way to do this will be by developing them on or out of paper.

2.1.2.2 User Testing

Testing of the prototype will be done by means of User Testing. The prototypes have not yet been developed and need to be tested mainly at the basic level. This will result in frequent and extensive testing. To guarantee this, the participants in this phase will again not be selected by target group but based on availability. To again promote 'empathic design', the participants will be asked to empathize with the target group. This empathizing will be done by making the participants read and take on a persona (Appendix D). A persona is a sketch of a person telling his or her character traits and relevant information. The goal is for the participant in the session to fully empathize with this persona, in to make choices and comments that the persona would also make (Kouprie & Sleeswijk Visser, 2009).

User testing will take place per functionality using a form that the participant must fill in. First, the participant will be informed on the goal of the graduation project and the way the user testing will elapse (Appendix C). The questions arising will be elaborated on immediately by the researcher. Unclarities will be elaborated on immediately by the researcher. The participant will now be asked to empathize with the target group, this will be done by means of a persona.

Hereafter, the participant will receive the prototype and will be requested to operate it (if possible). The participant is asked to elaborate the first opinion on the prototype, the researcher record this opinion on the form (Figure 2-1). Now the participant receives the explanation about and questionnaire on the functionalities. Ultimately, the participant will be given the opportunity to make other comments on the prototype. The opinion and comments will first be stated for each test (Table 2-9). Eventually, the results will be organized together in an overview (Table 2-9).

Overarching name of the prototype		
Functionality 1	*First impression and comment of the participants*	
	The prototype works properly The prototype works as expected The prototype covers the given functionality The functionality seems useful The functionality adds usability to the prototype The functionality makes the prototype easier to understand The prototype is overall better with the functionality	*Examples of possible scores:* D – D – A D – N – A N – D – A
	Further remarks of the participants	

Table 2-9: Collection table of the functionality test answers

Functionality Testing – *Name of functionality*

Name of prototype:	*Name of the prototype and version*
Date:	*Day / month / year*

First Impression:

Space available to note down the first impression of the participant

Functionality questionnaire:

	Disagree	*Neutral*	*Agree*
The prototype works properly	O	O	O
The prototype works as expected	O	O	O
The prototype covers the given functionality	O	O	O
The functionality seems useful	O	O	O
The functionality adds usability to the prototype	O	O	O
The functionality makes the prototype easier to understand	O	O	O
The prototype is overall better with the functionality	O	O	O

Further remarks

Space available to note down the further remarks of the participant

Figure 2-1: Functionality testing form

2.1.3 The Realization Phase

In the realization Phase, the solutions for the requirements will be combined into full prototypes. When all smaller aspects and solutions for the various requirements have been tested, the most promising solutions will be combined into a more concrete prototype in this phase. Where the prototypes in the previous phase were simple and only intended for a single aspect of the bigger picture, in this phase they will be expanded and have full functionality.

2.1.4 The Evaluation Phase

In the Evaluation Phase, the full prototypes developed in the Realization Phase will be subjected to user tests by the target group. The participants in the Ideation Phase were not part of the target group, but participants in the Evaluation Phase will be. The User Test consist of both students taking on a persona, and participants form the target groyp. This evaluation will consist of a demonstration of the product, with an elaboration on the functionalities. After this, a questionnaire will be filled in with room for other comments.

An earlier version of this product has already been made, which consisted of a user test. This user test consisted of eight questions open questions with the goal of getting to know how the product would be received by the target audience. Additionally, the SUS score (Brooke, 1995) was calculated based on this questionnaire. To check whether the extra functionalities improve the product, the same evaluation method will be used again (partly). The results of both tests will be compared afterwards. In addition to questions from the previous user test, questions specifically aimed on testing whether various requirements have been met will also be asked.

The questionnaire will consist of eight open questions with the aim of finding out whether the product does what was devised in the previous phases (Figure 2-2). By asking specific questions on the implementation of the product, an opinion can be formed about whether the product has met different requirements. The main aim of the open questions is to obtain information on the requirements of motivation strategies and the first four themes: intrusiveness, autonomy, individuality and usability. The questions about the SUS score will show whether the requirements about utility and usability have been achieved (Figure 2-2).

The System Usability Scale (SUS) is used to rate the usability of a system so it can be compared to other systems. The method consists of ten multiple choice questions, each of which can be rewarded with one of five choices. The choices range from ‘completely disagree’ to ‘completely agree. The questions are devised such a way the usability can be measured and compared with other products, whilst takin the context in which the product is used in account (Barnum, 2021).

Calculating the SUS score results in a score between the 0 and 100, 68 is the statistical average. The method of calculating is to assign a number between one and five to the choices, one being completely disagree and five completely agree. The results of the odd questions are calculated by ‘points’ – 1 = result of question. The results of the even

questions is calculated by 5 – 'points' = result. The total SUS score is calculated by multiplying the sum of all questions by 2.5.

Questions

1. *Do you understand what the product wants to tell? Clarities/Unclarities?*

This question is taken from the research by Hengeveld (2021). The purpose of this question is to clarify whether the product's Usability is sufficient.

2. *Which internal factors does the product provide to motivate you to become more physical active?*

Whilst answering the question, the participant might have to be explained orally what an internal factor is. The purpose of this question is to find out which and how many internal motivational strategies the product entails.

3. *Which external factors does the product provide to motivate you to become more physical active?*

Whilst answering the question, the participant might have to be explained orally what an external factor is. The purpose of this question is to find out which and how many external motivational strategies the product entails.

4. *How should the product be improved to motivate you/motivate more?*

This question is taken from the research by Hengeveld (2021). The purpose of the question is to clarify the improvements the product might need to undergo when it is not sufficient in motivating.

5. *Would you view the product as an obligation to use?*

This question should result in an answer that makes it clear whether the product has the right level of intrusiveness and autonomy.

6. *Will the product hinder you in your daily life?*

This question should result in an answer that makes it clear whether the product has the right level of intrusiveness and autonomy.

7. *Do you feel like the product appeals to you as an individual?*

This question should result in an answer that makes it clear whether the product has the right level of individuality.

8. *Do you think that there is still something missing at the product?*

This question is taken from the research by Hengeveld (2021). The purpose of the question is to provide the user space for additional comments on how the product can be improved.

Evaluatie sessie

Naam van tester:	*Not a necessity*
Datum	*Day / month / year*

Vragen

Begrijpt u wat het product probeert te vertellen? Zijn er onduidelijkheden?
Op welke interne manieren zou het product u motiveren om meer fysiek actief te worden?
Op welke externe manieren zou het product u motiveren om meer fysiek actief te worden?
Wat zal verbeterd moeten worden aan het product om het u meer te laten motiveren?
Zou u het product zien als een verplichting om te gebruiken?
Zal het product u in de weg zitten in het dagelijks leven?
Voelt het voor u alsof het product u aanspreekt als een individu?
Denk u dat er nog iets missend is aan het product?

SUS score

1. Ik denk dat ik dit product frequent zou willen gebruiken.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
2. Ik vond het onnodig ingewikkeld.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
3. Ik vond het product makkelijk te gebruiken.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
4. Ik denk dat ik technische support nodig heb om het product te gebruiken.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
5. Ik vond de verschillende functies van het product goed met elkaar geïntegreerd.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
6. . Ik vond dat er te veel tegenstrijdigheden in het product zaten.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
7. Ik kan me voorstellen dat de meeste mensen snel met het product overweg kunnen.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
8. Ik vond het product omslachtig in gebruik.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
9. Ik voelde me zelfverzekerd tijdens het gebruik van het product.				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
10. Ik moest veel over het product leren voordat ik het goed kon				
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens
Overige opmerkingen:				

Figure 2-2: Evaluation Session questionnaire and SUS-score

3. Ideation

The first phase of the design process aims to emerge different concepts for the eventual end-product. Ideas and guidelines on individual aspects for a product will also emerge, which will be tested in the next phase. This Ideation Phase consists of several brainstorming sessions in which different student designers and other students receive the information of the literature review and try to emphasize with the older adults. After this they are asked to provide their vision for different concepts and ideas on the issue by means of a mind map. The goal of the Mindmap is to increase their creative thinking process to produce an unspecified number of smaller of producing an unspecified number of smaller solutions for specific aspect of the devices to be developed. During the session the participants are encouraged to suggest certain combined solutions or device concepts, to provide inspiration for possible final solutions. The sessions were held in Dutch

3.1 The brainstorm sessions

The brainstorming session consist of three phases: the introduction phase, the converging phase, and the diverging phase. In the introduction phase, the background information will be elaborated on. The purpose of the brainstorming session will be explained by means of a few examples. The converging phase will consist of creating a mind map (Figure 3-1). In this mind map session, participants are expected to write down as many ideas and words that belong to the topic as possible. By elaborating this, they will eventually come up with concepts and guidelines. The best concepts arriving from this phase will be selected in the diverging phase. In this the vague concepts will also be further elaborated by means of adding a guideline to the mind map (by adding sticky notes). The brainstorm session was held twice with different participants to ensure that enough creativity would emerge.

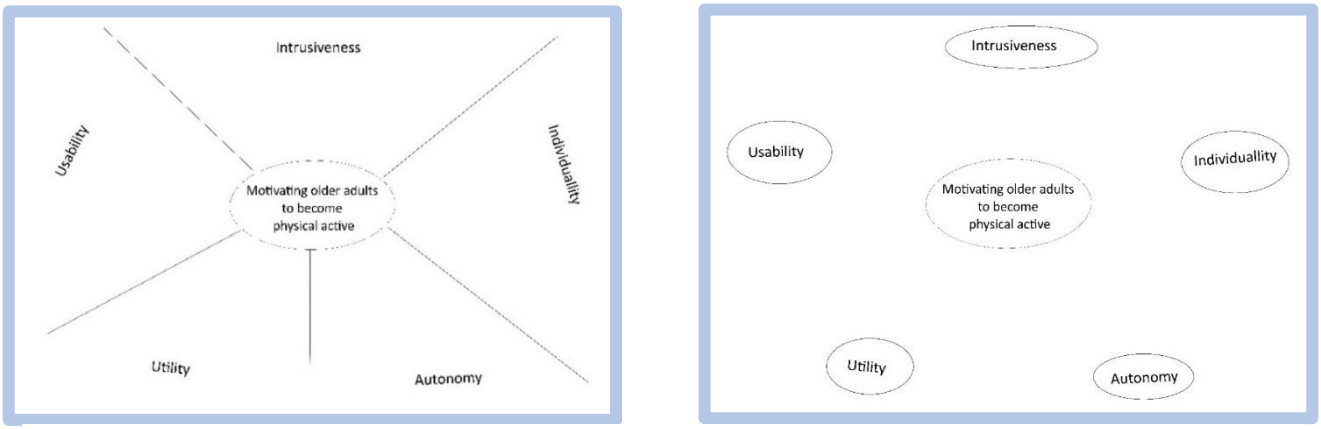


Figure 3-1: Mindmaps of Brainstorm session

Prior to the brainstorming session, the participants were informed on both the purpose of the graduation assignment and the brainstorming session. Additionally, the participants were informed on the importance and conclusion of the background research, by means of a letter of introduction (Appendix A) and oral explanation. Subsequently, the participants were requested to participate in the making of the mind map. The layout of the mind map is designed to continue on the elaboration of the background research in the introduction letter, the five themes. The A2 format paper is divided into five parts, each part dedicated to a different them (Figure 3-1).The participants were asked to come up with words and functionalities based on the five themes, preferred was the words would fit a final product. By developing the mind map session with the five themes as starting point, the final design will always take the five themes into account. The themes functioned both as starting point as well as method to create a well-functioning design.

3.1.1 First mind map session

Participants	Two design students (Industrial Design) and the researcher (Creative Technology)
Language	Dutch
Location	Study room
Time	30 minutes

After the initial elaboration on the topic only a few minor questions were asked, both participants indicated understanding of what was expected. The session started with a blank sheet of A1 paper, with the text "motivating older adults to become physical active" in the centre, surrounded by the five themes. The participants were encouraged to say as many things as possible they felt related to the themes. This started slowly: at first the participants were reluctant, and nothing was written down. After a while, the first words appeared, and it went faster and faster.
Gradually more concrete ideas and guidelines emerged. Eventually concepts for potential products emerged as well. These were written down on the sticky notes. Afterwards, the mind map was read through, and the participants were able to explain the best ideas and concepts that they had come up with.

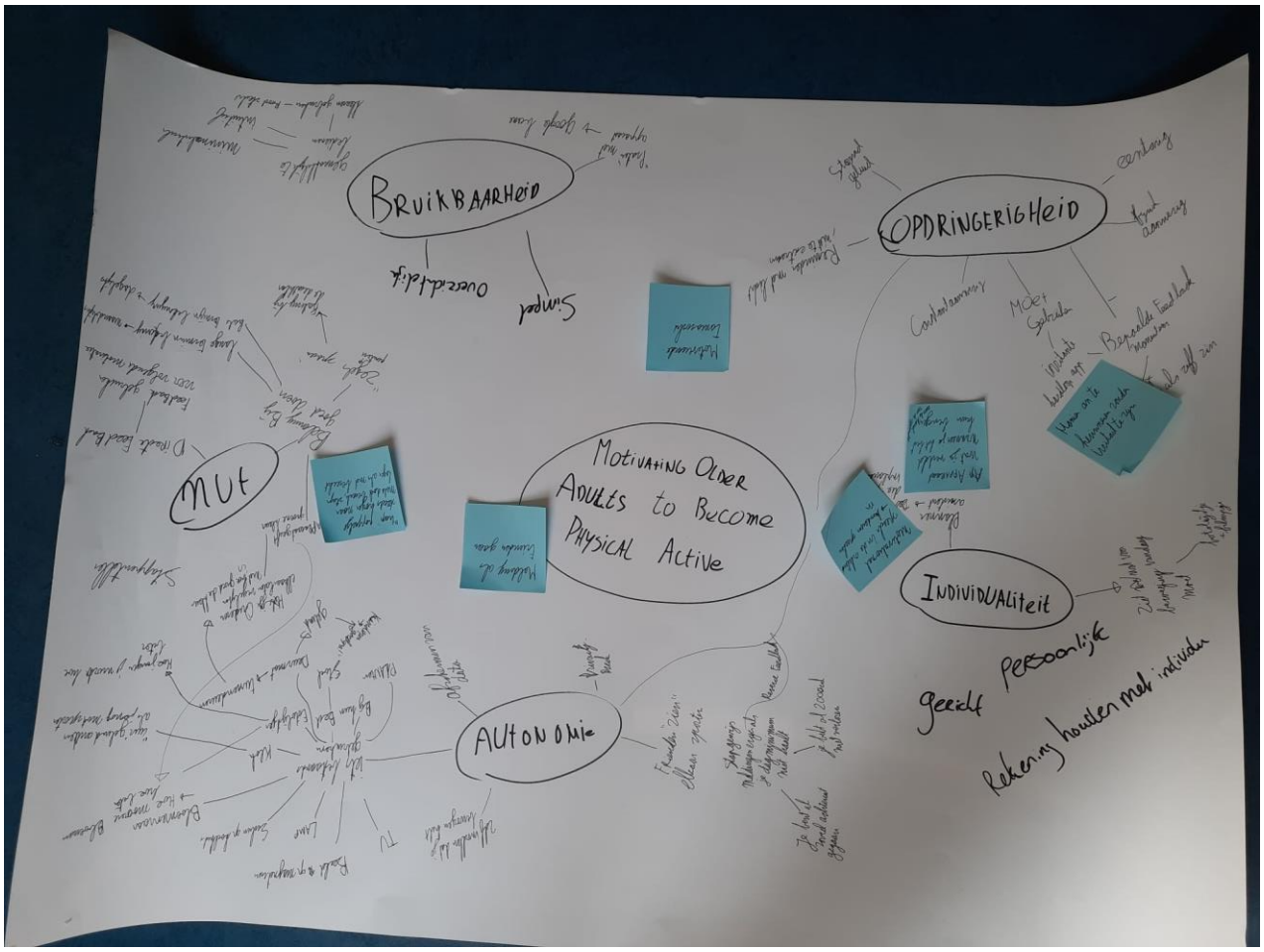


Figure 3-2 the resulting mindmap of brainstorm session 1

3.1.2 Second mind map session

Participants	Three students (2 Industrial Design,) and the researcher (Creative Technology)
Language	Dutch
Location	Study room
Time	30 minutes

The session differed from the first session. Instead of starting by writing down words appropriate to the five themes, the group immediately came up with solutions and concepts for the final product. Initially, this was steered by the researcher towards a constructive approach: first words, then guidelines and ideas and only then concepts. It became apparent the group did not find this necessary or found it less interesting. As a result, it was decided to let the group go ahead and come up with many concepts. The concepts were written down on sticky notes.

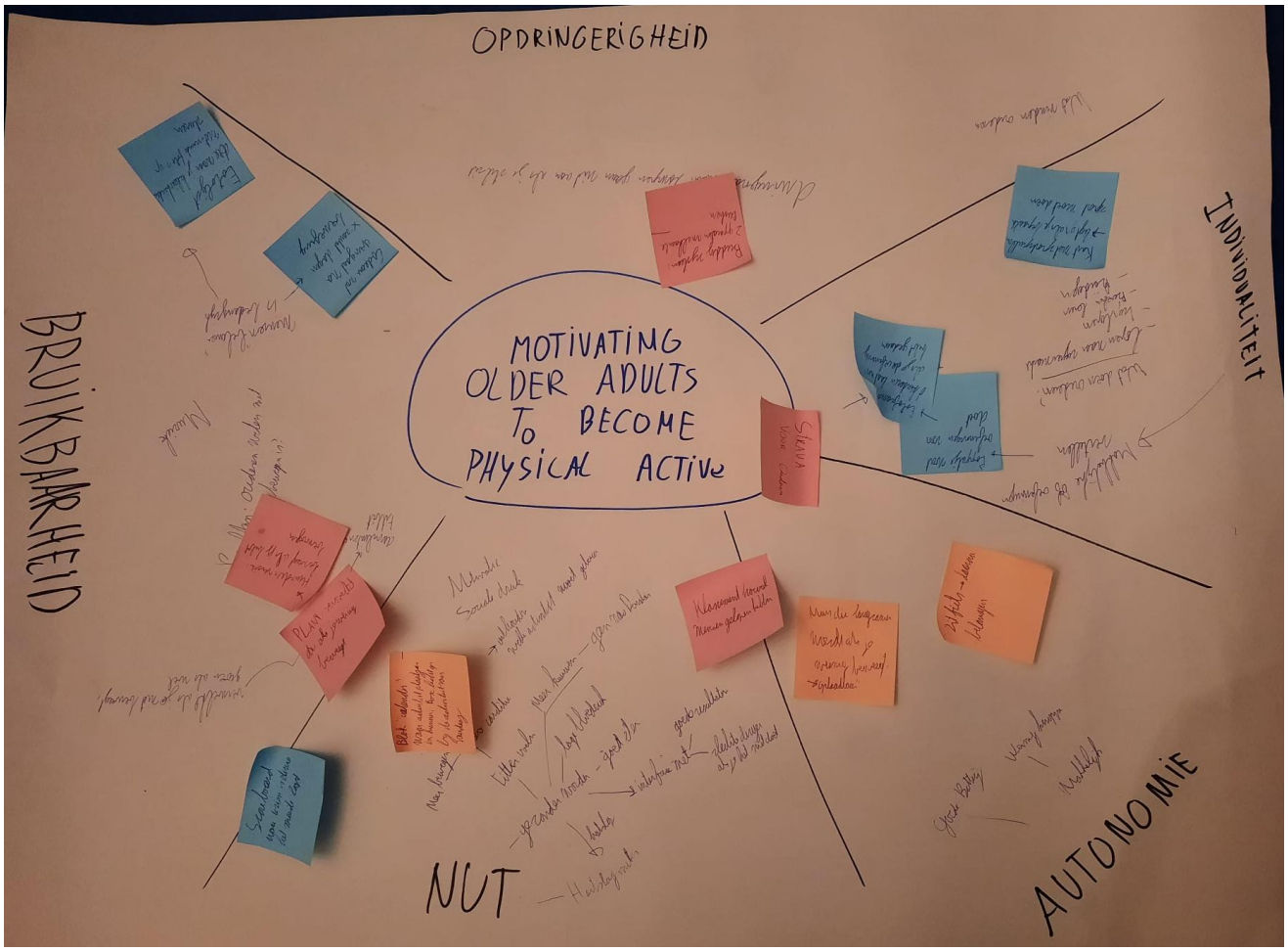


Figure 3-3: resulting mindmap of brainstorm session 2

3.2 Selecting the results

The final part of the Brainstorm sessions consisted of selecting and elaborating on different guidelines, ideas, and concepts. Participants were given the opportunity to select the most important and filter the insignificant. This choice was made after oral consultation and substantiation of what makes a concept or idea good or bad. It was also encouraged to also investigate the errors in one concept in the next concept. In this way an honest opinion was formed.
The results of this last convergence are collected in the tables below.

Guidelines		
Guideline	***Description***	***Possible solution***
Sounds	When the device is making a sound, this cannot be disruptive or monotonous	
Brightness	When lights are used, too much or bright is a deterrent.	
Obligation	there should be no obligation in use	Certain feedback moments, possibility for input at own time
Privacy	Users data should not be shared without permission	

Table 3-1: Collection table of Guidelines

Ideas	
Idea	***Description***
Agenda planner	A device/software which fits in workout time in the agenda
Motivational speech	A device which uses motivational speech (for example from family members) to motivate
Notify friends	A device which notifies when friends are sporting
Reverse feedback	Notifications gradually become more annoying/worse when minimum is not met
Own time input	Besides wearables, ability to input own progress
Integrating the existing	The device should be integrated into an existing object (lamp, picture frame, clock, vase, doormat)
Reward when participating	The device should reward when the user is active

Long- and short-term reward	Integrate both long- and short-term rewards/feedback
Direct feedback	Use the feedback to motivate the participants
Social pressure	Make social pressure to perform a motivation for the user
Social prestige	Show that you are doing well with a device, so that others see this which can be motivating.
Explain exercise	Explain exercises to the participants to make them do it
Activity reminder	Remind the user when to be active. E.g., make a sound or light flash when someone has not been active in a while

Table 3-2: Collection table of Ideas

Concepts

For each concept, the participants also indicated the relevant ideas and guidelines. The result of the most promising concepts can be seen in . A more elaborated version of all the concepts can be seen in Appendix B

Vase of flowers

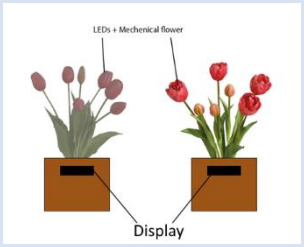


Figure x: illustration of the vase of flowers concept

A vase with a fake plant connected to an activity tracker software (e.g., google fit). The plant flourishes when certain activity goals are met, and withers when weekly goals are not met.

Guidelines
Brightness
Obligation
Privacy

Ideas
Integrating the excisting
Reward when participating
Long- and short-term reward
Social prestige
Social pressure

Picture frame

Figure x: illustration of the picture frame concept

A picture frame displaying the exercise to be participated in each day. After participating in the exercise pictures of family or friends are shown. Family or friends can send in motivational voice memos as well.

Guidelines
Brightness
Obligation
Privacy
Sounds

Ideas
Motivational speech
Integrating the excisting
Reward when participating
Direct feedback
Explain exercise
Activity reminder

Scoreboard

Figure x: illustration of scoreboard concept

A scoreboard a group of older adults (for example in a care home) uses to keep track of the "activity score". On this board the names and the number of steps or exercises are displayed.

Guidelines
Privacy

Ideas
Notify friends
Social pressure
Social prestige

Blok Calendar

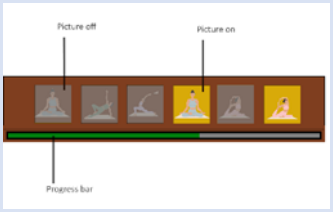


Figure x: illustration of block calendar concept

A calendar of the week consisting of blocks, where cards can be inserted. There is an exercise on each card. Each day, preset lights will illuminate which exercise the person should do.

Guidelines
Obligation

Ideas
Agenda planner
Own time input
Explain exercise
Activity reminder

Expanding the Clock with additional functionalities

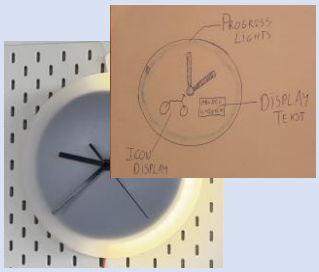


Figure x: illustration of the clock expanding concept

The mentioned ideas can also be used to expand the clock made at Hengeveld. Currently it has the function to display steps taken each day, this can be extended by displaying additional health related features.

Guidelines
Brightness
Sounds
Privacy

Ideas
Reward when participating
Integrating the existing
Activity reminder

Table 3-3: Collectino table of Concepts

3.3 The expert interview

The expert interview is intended to conduct once more a (small) convergence session concerning the concepts, followed up by the divergence of the concepts. The expert is asked to elaborate their opinion on each individual concept. The interview was conducted verbally by Microsoft teams supported by a PowerPoint on the concepts. In advance, the background information from Appendix A was explained verbally with a supportive PowerPoint.

General Comments

- To ensure the effectiveness of a motivation by means of a reward for the participants, it is necessary to work with small steps and achievable goals. When the steps are too big, the participants will not be motivated as effectively to achieve this goal.
- Direct feedback must be considered: when someone immediately notices or sees something positive while being active, this person is more likely to become motivated.
- The abilities of older adults may vary. It must be variable what a “goal” is. For example, one older adult can take many more steps per day than the next one, making a goal of 10,000 steps is feasible to achieve.
- Consider the developed devices to have functionalities for entering data manually. This ensures when someone has not used their measuring device, an estimation still can be given on the activity of the day. This prevents demotivation when wearing the measuring device is forgotten.
- A feature to be used in multiple projects the “just-in-time” function: when people have the opportunity to participate in activity, why not make them do it. Example: if you are waiting for the kettle, do a quick exercise because you have time to kill.

Vase of Flowers

- The difference must be visible, for example the drooping when withering, and growing during flowering, potentially gives more effect relative to only the LEDs.
- Instead of only weekly goals (i.e., the wilting and flower effect each week), provide positive motivation per day as well. E.g., lighting in the vase could be used for this.

Picture frame

- Everyone has a different motivation to participate in activities, make the options to vary the reward. Consider functionalities to set the different photos and videos to be shown.
- Consider creating the device so an exercise or day cannot just be skipped. This motivates because the exercise really must be done instead of being skipped. Additionally, a relation between activity and reward is created.

Scoreboard

- The score must be reset occasionally, or measure the scores the previous 10 days, for example. This prevents participants from getting too far ahead, which can have a demotivating effect on the rest.

Blok Calendar

- Provide the opportunity for both easy and difficult exercises to enable accessibility to the largest possible group possible.
- Create room for personalization of the exercise
- Here the skip button can be functional. This ensures a person also has the option of not having to do an annoying exercise.
- Feature: A “surprise me” function, which randomly selects an exercise.

Expanding the clock

- Instead of only make a LED to the side, add a small screen with extra information. When necessary, show for example what happens when the user successfully completes his tasks (or not).
- Apply smaller suggestions of moments of activities. For example, walking icon when walking is planned on that day.

Promising ideas

The most promising ideas seemed to be “expanding the clock” or the “vase with flowers”. The concepts enable the user to determine the kind of activity to be accomplished. This also ties in with a broader group than the other concepts. The concepts concerning specific exercises may make it unnecessarily inconvenient for the user.

3.4 The concept

The expert interview was followed up by a consultation with the supervisor of the Graduation Project. It was decided to continue with the “expanding the clock” idea. All individual ideas and guidelines concerning this concept have been sought out and elaborated below.

Expanding the existing Clock

The goal is to expand a device previously made in a graduation project with additional features. The concerning graduation project was developed by the aforementioned Hengeveld (2021). The device is a clock which shows the percentage of steps a user has taken towards their daily goal. The motivational strategy triggered by the clock mostly concern an attendance on the user’s progress of the day, this is an external motivational strategy. The expansion mainly focusses on adding functionalities and features concerning expanding the motivational aspects for the older adults.

The clock consists of a round back plate with hands on it. The back plate is transparent with LED lamps on all sides, so that a circle can light up around the hands. This circle is used to indicate the percentage of steps taken toward the daily goal. In Figure 3-4, three examples of situations are shown, in ascending order of the participant reaching the final goal. The device currently is compatible only with the Oura Ring.

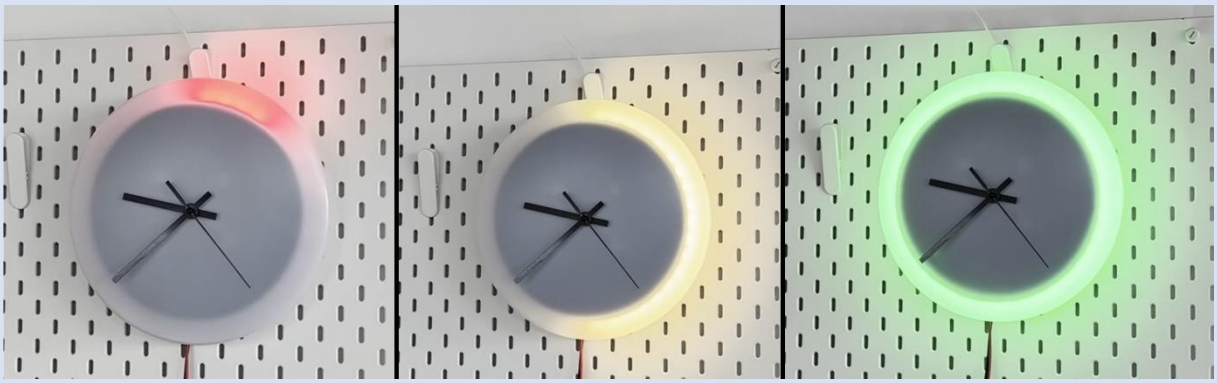


Figure 3-4: three examples of the current clock, in ascending order towards the daily goal

To create the design, requirements from previous research about the clock must be taken into account. The requirements concluding chapter two partly arise from research by Hengeveld (2021), hereby part of the requirements of the clock already have been considered in this research. This must be supplemented by additional requirements from the previous graduation project. Additionally, the recommendations on the old design must be taken into account when creating a new design.

The previous research shows:

- The device should be more noticeable when the displayed goal has not been achieved yet
- More options for controlling the device should be added
- A display with additional health related data should be added
- Continuing development should be on connectivity and interaction with the prototype
- Illumination time should be (manually) customizable
- Sounds could be added
- A possibility to change the color or intensity of the LED's would make the device more individual
- An additional display could be used to show information

Possible additional features and functions

- Displaying other health related features. E.g.: the hearth rate, (daily) active minutes, weekly goal progress, sleep score
- Remote controller. E.g.: physical controller to switch between "displays"
- Compatibility with other devices besides Oura Ring
- Show when user is active (reward user by looking nice, direct feedback)
- Reminder for user when inactive for too long
- Notification when friend is active
- Ability to adjust the goal to be achieved in a meaningful way. E.g.: target steps are connected to the mood of the person; this mood has to be inserted every day.
- Small screen with additional information
- Apply smaller suggestions of moments of activities. E.g.: walking icon when walking is planned
- Ability to enter the movement data manually
- Motivational speech could be added to sounds when (in)active
- Notification when "friends" participate in an activity
- Reminder when inactive for too long
- Progress bar of activity in shorter timespan (e.g.: hourly)

Possible guidelines

- Incorporate meaningful information. E.g.: when the user takes a step, show the moving forward of someone's dying age.
- Incorporate an extra drive or motivation. E.g.: what does it mean the user moves?. What are the effects?
- Incorporate the reason why the users has to move.
- Look to the future and past of the user
- Incorporate not only practical but emotional functionalities as well.

Work with small steps and achievable goals, motivates more effectively

4. Specification

The second phase of the design process aims to find and test solutions for the functional and systematic requirements emerging from the ideation phase. The requirements will have to be organized and adhere a priority. Subsequently, simple prototypes will be developed, each concerning a single or a few requirements at the time. These protypes will be evaluated by User Testing.

4.1 The concept

The goal is to expand an existing device with additional features and functionality. The device has been created in a previous Graduation Project of a Creative Technology student. Currently, the device consists of a clock with the functionality to connect to an Oura ring. This clock displays certain data from this Oura ring through LED lights connected to an Arduino Nano (*Arduino Nano Board*, 2022). The data is limited to the number of steps a user has taken relative of their daily goal.

The clock consists of a round back plate with hands on it. The back plate is transparent, within programmable LED-lights surround the interior of the clock. The LED lights are placed in such a way a circle can light up around the edges of the clock. This circle of LED's is connected to the Arduino Nano and is used to indicate the data.

4.1.1 User requirements

Throughout the project, various user requirements have been developed, each with a corresponding priority. The user requirement concerning the concept "expanding the Clock, are listed in the table below (Table 4-1). User requirements are requirements featuring the users' needs the product to support. These requirements describe activities the user must be able to perform, or activities performed on the user (Parker, 2012).

User Requirements		
Requirement	***Description***	***Priority***
Internal factors	The device must make use of internal factors	MUST
External factors	The device must make use of external factors	MUST
Motivational Strategies	The device must make use of three motivational strategies	MUST
Intrusiveness	The device must mitigate the level of intrusiveness	MUST
Individuality	The device must distinguish an individual from others and provide appropriate interaction	MUST
Autonomy	The device must be usable without a permanent utilization	MUST
Utility	The device must have a certain level of profitability	MUST
Usability	The device must be straightforward in usage	MUST
Compatibility	The device must be compatible with different categories of external devices (like wearables)	MUST
User preference	The device compatible devices must be choose-able by the user	MUST
Small steps	The device should work with small steps and achievable goals	SHOULD
Adjustable goals	The device should have adjustable daily/weekly goals	SHOULD
Periodic reminders	The device should make use of periodic reminders	SHOULD
Audio visual way	The device should make use of an audio-visual way to convey the motivational strategies	SHOULD
Long- and short-term rewards	The device should integrate both long- and short-term rewards/feedback	SHOULD
Social pressure	The device can make use of social pressure to motivate the user	COULD
Direct feedback	The device should reward when the user is active	COULD
Benefits	The device could show information about the benefits of physical activity	COULD

Table 4-1: Collection of User Requirements

4.1.2 System requirements

Throughout the project, various system requirements have been developed, each with a corresponding priority. The system requirement concerning the concept “expanding the Clock, are listed in the table below (Table 4-2). System requirements are requirements featuring the users’ needs the product to support. These requirements describe certain factors a user needs to perform their work (Parker, 2012). The requirements have been supplemented with additional, practical requirements.

Systematic Requirements		
Requirement	***Description***	***Priority***
Privacy	The device must guarantee good policy concerning the privacy	MUST
Buttons	The device must contain buttons for usability	MUST
Illumination	Illumination time, color and brightness must be adjustable	MUST
Power supply	The system must be able to be powered on 230 power supply	MUST
Integrating the existing	The device should be integrated into an existing object (lamp, picture frame, clock, vase, doormat)	SHOULD
Brightness	The device should have adjustable brightness	SHOULD
Compact	The device should be compact and with just one wire to plug the device in a socket.	SHOULD
Display	An additional display could be connected	COULD
Battery	The system could be equipped with a battery	COULD

Table 4-2: Collection of Systematic Requirements

4.1.3 Solution

Various solutions have been found throughout the project on how to resolve the user - and systematic requirements. The solutions are listed in the table below, along with the associated requirement (Table 4-3).

Solutions		
Solutions	***Description***	***Requirement***
Activity reminder	Remind the user when to be active. E.g., make a sound or light flash when someone has not been active in a while	Direct feedback
Rewarding when participating	When active, give the device a certain colour to show progress and reward them for doing good	Direct feedback
Enter data manual	Besides wearables, ability to input own progress	Autonomy
Notify friends	Functionality to notify designated “friends” when participating in activity	Social pressure,
Apply smaller suggestions for activity	Apply smaller suggestions for moments of activities. E.g.; walking icon when walking is planned on that day.	Small steps, individuality
Small additional display	Instead of only make a LED to the side, add a small screen with extra information. E.g.: displaying what happens when the user successfully completes his tasks (or not).	Usability
Display history	The ability to display the history of the displayed variables	Long- and short-term rewards, Individuality
Physical/remote controller	A way to control the displays manually	Usability, intrusiveness
Display health related information	Functionality to display additional health related data	individuality
Adjustable daily or weekly targets	Functionality to change the target steps or activity time each day.	Adjustable goals
Meaningful information	The meaning of the information displayed must be impactful in order to motivate the user	Utility
Application connectivity	A compatibility with certain applications (like google fit.) would result in compatibility with various wearablse	compatibility

Table 4-3: Collection table of Solutions

4.2 User Testing the functionalities

To investigate whether the selected functionalities are useful and applicable in the final product, they first will be subjected to user testing. This will be done by making paper prototypes of the clock and the specific functionalities. Subsequently, all different aspects of the concept will be tested by the user test participants. The participants are first encouraged to empathize with the target group. This will be accomplished by reading a pre-made persona, of which the identity the participants will take over (Appendix D). During and after the user testing, functionality forms will be filled in. The results of the forms will be organized in an overview, providing a clear outline of the judgments per functionality. Some user tests are successors of previous ones, they build on previously achieved results. This will be mentioned in the conclusion or introduction text for the concerning User Tests.

4.2.1 The User Test

All the User Tests will be introduced by a description combined with explanatory images. Subsequently the results will be shown, and a possible preliminary conclusion will be drawn. All user tests are listed in chronological order unless stated otherwise. The user test took place in a study room in Enschede.

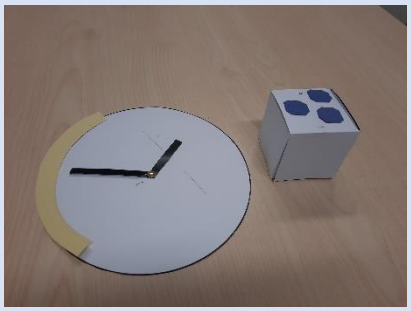
The participants were asked to assume one of three personas (Appendix D). Participants are expected to empathize with this person to the best of their ability. the judgment must be from this persona's point of view. The names at the top of the result tables are therefore those of the persona, and not those of the participant itself.

Figure 4-1: location of user test

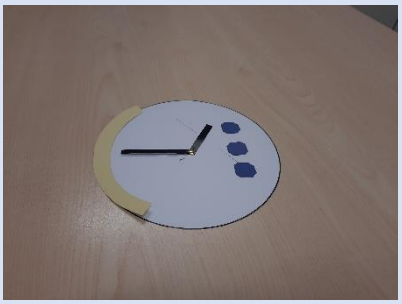
4.2.1.1 The Controls

In this user test the positioning of the controls is tested. The Ideation Phase established the clock must contain a variety of functionalities; these functionalities must be controlled by means of buttons. Solutions arising from the Ideation Phase were either a remote controller or buttons built into the clock itself, of which the remote controller was recommended. To test which solution is advantageously, two paper prototypes have been developed.

- *Buttons on the clock:* A clock equipped with buttons ().
- *Buttons on a remote:* A square box equipped with buttons, combined with a clock ().
-



4-3*: User Test Functionality: Buttons on the Clock*



4-2*: User Test Functionality: Buttons on a Remote*

If the participant presses a button, certain parts of the prototype will light up (the lights are replaced by colored paper). Simultaneously, an elaboration on the event happening is given by the researcher. This will simulate the working of the buttons. The buttons are kept simple to focus on the placement of the buttons, rather than the buttons themselves.

The user test is the first of the tests, the reason being the result matters a lot for the further development of the prototypes. The buttons and their functionalities will be tested in more depth, for this the placement of the buttons first must be clear.

Controls	
Persona: Dave-Dave-Jolanda-Angela	
Buttons on clock	- *Buttons are awkwardly placed, not close to each other, not logically placed, not next to each other. Can't always press the buttons due to the hands of the clock.* - *Everything is in one place on the clock, nothing is loose. Extra design possibility for the clock, if it are nice buttons. Have to walk there to use it. Don't lose anything. Awkward that the hands of the clock come before the buttons.* - *Buttons are nice and large, do not have to search for other stuff, just the clock, the arms of the clock block the button, nice colors, if the clock is too high, I may not be able to reach it* - *Handig alles op 1 plek, makkelijk te gebruiken, onhandig met de wijzers*

	The prototype works properly	A-A-N-A
	The prototype works as expected	A-A-D-A
	The prototype covers the given functionality	A-N-N-A
	The functionality seems useful	N-N-N-N
	The functionality adds usability to the prototype	A-D-A-A
	The functionality makes the prototype easier to understand	D-A-N-A
	The prototype is overall better with the functionality	A-N-D-A
	-	
	- *If the buttons can be on the edge (so not at the hands) this can be a good option, otherwise the other one*	
	-	
	-	
	-	
Buttons on a remote	- *Buttons correlate with the location of the light. Easy to use, no need to get up. Buttons are in a logical place.* - *Chill, don't have to walk to the clock. Lose things quickly, so that's inconvenient. Nice to take it apart.* - *Buttons are easy to press, keeps me moving if it lies somewhere else, reminds me of my tv remote which I understand to use* - *Don't have to walk to the clock, may get lost*	
	The prototype works properly	A-A-A-A
	The prototype works as expected	A-A-A-A
	The prototype covers the given functionality	A-A-N-N
	The functionality seems useful	A-A-A-N
	The functionality adds usability to the prototype	A-A-A-A
	The functionality makes the prototype easier to understand	N-D-N-N
	The prototype is overall better with the functionality	A-A-N-A
	- *I would choose this option, more logic and know how to use a remote* - *Good option* - *I prefer this over the buttons on the clock, keeps me fit and easier to use* - -	

Figure 4-4: Collection of Answers User Test: Controlls

Conclusion

The prototypes are both well received, the *buttons on the remote* are ultimately more appreciated compared to the *buttons on the clock*. An advantage of the buttons on the clock is the improbability to lose a part of the device. An disadvantage is the hands getting in the way of the buttons, or that the user is not free to hang the clock wherever they want. *Buttons on the remote* is rated far below *buttons on clock* concerning *The functionality makes the prototype easier to understand*. Orally, the participants occasionally gave a reason for this, which mainly was because it was not getting easier, but also not getting more difficult.

4.2.1.2 Different Information testing

The goal of this user test is to find the most preferable method to display different types of information on the clock. The to be displayed information will be an addition to the walking information, which is currently displayed in the luminous ring around the clock. Examples of additional kind of information are sleep score, health score. Potential solutions:

- *Data selection:* the original luminescent ring remains and can change the type of information displayed. Selecting the kind of information will be by means of the previously tested buttons. A possible addition can be to display a matching symbol on the clock.
- *Multiple rings:* the clock will be equipped with additional luminous rings instead of just the original ring. The rings each have a different color and represent different information (Figure 4-5).
-

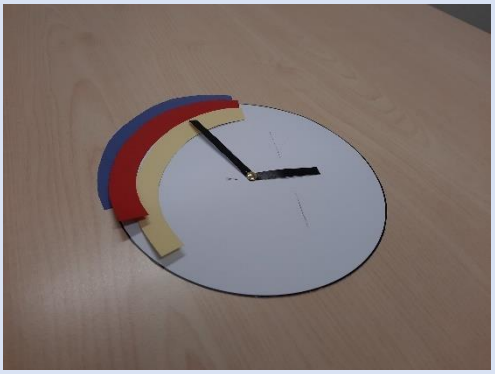


Figure 4-5: User Test: Multiple Rings

During the testing of the *data selection* solution, the participant is encouraged to press the appropriate buttons, meanwhile the researcher changes the information on the clock (ring of different colored paper). This simulates the functionality of the prototype. Prior and during to the testing, the participant receives information on the purpose of the information displayed.

Different information testing	
Dave-Jolanda-Angela-Dave	
Data selection	- *Handy for extra overview of daily goals. Easy if you're not technical. Can on a small knock. But the act of pushing the button is just as much work as changing my fitbit.* - *Maybe a bit difficult as it requires interaction, What if I make mistakes? However, less stimilu compared to multiple rings* - *Simple, clear, not as beautiful as multiple rings, but also less confusing* - *Better then multiple rings, more clear, requires extra step to see so you need to be more active*
	The prototype works properly A-A-A-A- The prototype works as expected A-D-A-A- The prototype covers the given functionality A-D-A-N- The functionality seems useful D-N-A-N- The functionality adds usability to the prototype D-N-A-D- The functionality makes the prototype easier to understand A-A-N-A- The prototype is overall better with the functionality D-N-A-A-
	- *Would personally choose the other version. Does not cost additional movement and remote can easy be lost.*

	- *This could motivate less, for instance if it is put on the heartrates mode, it would not show nor motivate my step count. But clearer then the multiple rings so prefer this one* - *Other one looks better, this is more effective and understandable* - *This one is more clear*
Multiple rings	- *Handy for extra overview, great if you don't have a Fitbit. 3 next to each other is not too busy, but the clock should not be too small.* - *Very complicated. Lots of stimuli in my living room next to my antique clock. Afraid I won't understand it* - *Very busy, not clear what is what, looks nice* - *Insightful but chaotic, functional, not disruptive present* The prototype works properly A-N-A-A- The prototype works as expected A-D-N-A- The prototype covers the given functionality A-A-D-N- The functionality seems useful N-A-D-A- The functionality adds usability to the prototype A-N-N-A- The functionality makes the prototype easier to understand A-D-D-A- The prototype is overall better with the functionality A-D-N-N- - - - -

Figure 4-6: Collection of Answers User Test: Different Information

Conclusion

In general, the multiple rings prototype was considered more chaotic and less obvious in relation to the data selection. The data selection will therefore be the final choice. However, it must be considered during the data selection that the clock will return to the step position once in a while, so that the main goal remains that the clock must motivate to move.

4.2.1.3 Activity indicator

The goal of this user test is to investigate methods of displaying activity and nonactivity in a more specific timeframe compared to the daily ring. Multiple concept ideas have emerged addressing the problem in two main ways, which could potentially be combined. The first main way is to create an activity bar. This bar fills when the user is active, and empties when inactive. The second main way is by means of an alarm. This alarm uses lights and or sounds. The alarm triggers when the user is inactive for an extended period. The possible solution is (a combination of):

- *Activity circle:* a circle of lights placed around the center of the clock. Fills up when active, empties when inactive (Figure 4-8)
- *Activity bar*: a bar of lights placed on the clock. Fills up when active, empties when inactive (Figure 4-8)
- *Alarm*: a circle of light placed around the center of the clock combined with a speaker in the clock. Lights starts to flicker more frequently, and sounds become louder the

longer the user is inactive. Alarm only starts after a certain amount of inactivity has passed.

- *Activity reward*: circle of lights around the center of the clock, green (positive) when active in the pas time, becomes redder (negative) when inactive.
- *Text displayed:* a small screen with a motivational text is displayed on the clock. Multiple sizes and placements of the display is a possibility (Figure 4-9)

Prior to the testing the testing, the participant is briefed about the purpose of the alarms. During the test the participant is encouraged to comment on the different style of activity indicators. Eventually the participant is asked to elaborate a choice on best activity indicator, or combination of. Important is the reasoning behind the choice.

Figure 4-7: User Test: activity bar-w

Figure 4-8: User Test: activity circle

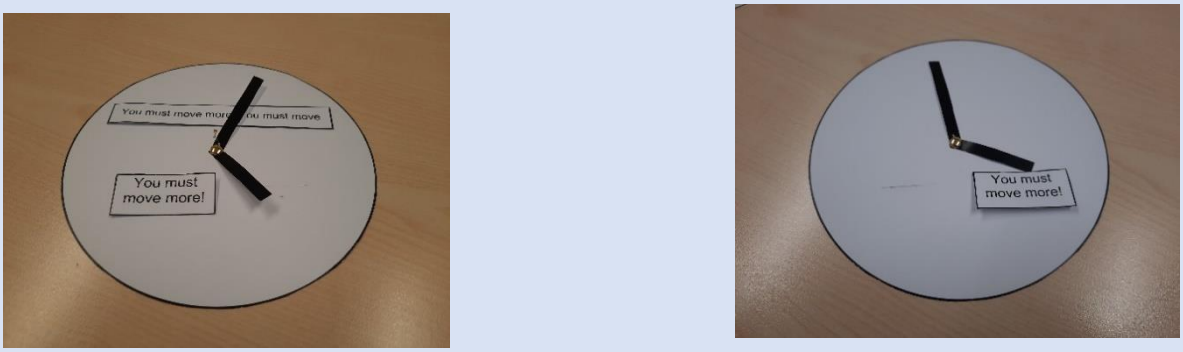


Figure 4-9: User Test: Tekst displayed

Activity indicator

Jolanda-Angela-Dave

Activity circle

- *Looks very difficult maybe a bit to negative in some way. Whenever im enjoying my horse-riding show, it would like to relax without being forced to move by the circle*
- *Don't think this will help much, wouldn't pay attention to both bar and circle. Circle looks a bit better*
- *Less visible (compared to bar). More insight in how far you are because you know how big a full circle is*

The prototype works properly	N-N-A
The prototype works as expected	N-N-A
The prototype covers the given functionality	D-D-A
The functionality seems useful	N-D-A
The functionality adds usability to the prototype	D-D-D
The functionality makes the prototype easier to understand	A-D-A
The prototype is overall better with the functionality	D-D-A

- *Easier to relate as I know when the circle would be full, compared to the bar*
- *Not a fan*
- *Would be better if better visible*

Activity bar

- *Looks very difficult maybe a bit to negative in some way. Whenever im enjoying my horse-riding show, it would like to relax without being forced to move by the bar*
- *Don't think this will help much, wouldn't pay attention to both bar and circle. Circle looks a bit better*
- *Better visible compared to the circle, where is the end?*

The prototype works properly	N-N-A
The prototype works as expected	D-N-N
The prototype covers the given functionality	D-D-N
The functionality seems useful	N-D-A
The functionality adds usability to the prototype	N-D-N
The functionality makes the prototype easier to understand	N-D-D
The prototype is overall better with the functionality	D-D-N

- *Wouldn't know where the bar ends*
- *Also not a fan*
-

Alarm

- *No thanks, my horse-riding shows are up to 2 hours of exciting visuals, I want to enjoy that! What if I forget how to turn it off? Id get crazy from the sound*
- *Nice but frustrating, would move more but not nice if you are reading a book or say sleeping during the day*
- *Annoying, forcing and not motivating. But will motivate to avoid the punishment of being inactive*

The prototype works properly	*D-A-A*
The prototype works as expected	*D-A-A*
The prototype covers the given functionality	*D-A-A*

	The functionality seems useful	*N-N-N*
	The functionality adds usability to the prototype	*D-N-D*
	The functionality makes the prototype easier to understand	*D-N-A*
	The prototype is overall better with the functionality	*D-N-N*
	-	
	- *Annoying but effective*	
	-	
Activity reward	- *Is this going to talk to me? That seems scary to me. I like rewards but how can someone talk to me when he she is not there* - Would really be rewarded by a light - *Not motivating, I'm a person who likes technology, but a simple light wont trigger me*	
	The prototype works properly	N-A-N
	The prototype works as expected	N-D-N
	The prototype covers the given functionality	N-D-D
	The functionality seems useful	N-D-D
	The functionality adds usability to the prototype	N-D-N
	The functionality makes the prototype easier to understand	N-D-A
	The prototype is overall better with the functionality	D-D-D
	- *Maybe the voice of a beloved* - *Alarm and reward both not really nice, would prefer alarm above circle, bar and reward*	
Text display	- *I cannot read from a far distance, so I do not know whether these would be visible and attracting to Me* - *Nice but unnecessary, I prefer symbols*	
	The prototype works properly	N-A
	The prototype works as expected	D-A
	The prototype covers the given functionality	D-N
	The functionality seems useful	N-N
	The functionality adds usability to the prototype	N-D
	The functionality makes the prototype easier to understand	D-A
	The prototype is overall better with the functionality	D-N
	-	
	- *Not a fan*	

Figure 4-10: Collection of Answers User Test: Activity Indicator

Conclusion

Unfortunately, except for the alarm function, none of the prototypes were enough to be incorporated into the final design. The alarm function can be considered, but also has no clear preference. Also, the text display can be changed to a symbol display.

4.2.1.4 Remote controller

The goal of this user test is to investigate options for the layout and possible functionalities of the remote controller. A requirement of the controller is the functionality to change the type of information displayed on the clock. Additionally, a functionality to scroll through the

history of the data (e.g.: show the progress of yesterday). Finally, an option to adjust the user's goal for each day must be developed. The user should be able to determine, to some extent, the daily goal.

- *Mood slide:* slider to determine the daily goal.
- *Mood buttons*: buttons to determine the daily goal. 3 moods: bad, neutral, good. When good is pressed, the hardest daily goal is set, neutral an average and bad the most easy
-

During the testing of the *data selection* solution, the participant is encouraged to press the appropriate buttons, meanwhile the researcher changes the information on the clock (rings of different colored and sized paper). This simulates the functionality of the prototype. Prior and during to the testing, the participant receives information on the purpose of the information displayed.

Remote Controller		
Jolanda-Angela		
Mood slide	- *Looks good but not really clear how I can make my mood in a slider* - *Nice, works fine but not so clear*	
	The prototype works properly	A-A
	The prototype works as expected	A-A
	The prototype covers the given functionality	A-N
	The functionality seems useful	A-N
	The functionality adds usability to the prototype	N-N
	The functionality makes the prototype easier to understand	D-N
	The prototype is overall better with the functionality	N-N
	- *Prefer the buttons, clearer what I am choosing* - *Buttons are better*	
Mood buttons	- *Clear idee, like it* - *Works good I like I have the choose between three button*	
	The prototype works properly	A-A
	The prototype works as expected	A-A
	The prototype covers the given functionality	A-A
	The functionality seems useful	A-N
	The functionality adds usability to the prototype	A-A
	The functionality makes the prototype easier to understand	N-N
	The prototype is overall better with the functionality	A-A
	-	

Table 4-4: Collection of answers User Test: Remote Controller

The mood buttons were preferred in comparison to the slider.

5. Realisation

The result is a working clock with the ability to display different categories of data, connected to a remote enabling user input for switching between the data. Additionally, a working framework is developed to request and receive real time data from the google servers. This framework is not functioning properly due to limitations of the working memory of the hardware used.

The clock itself has the functionalities:

- *To display the activity score*

The ring of LEDs at the edges of the clock functions as a progress bar of the daily activity score. The more steps the user takes towards their daily goal, the more the circle will fill up. An additional symbol is used to display the status of the progress: a heart tells the user is doing a good job, a skull tells the user the participation is not yet sufficient.

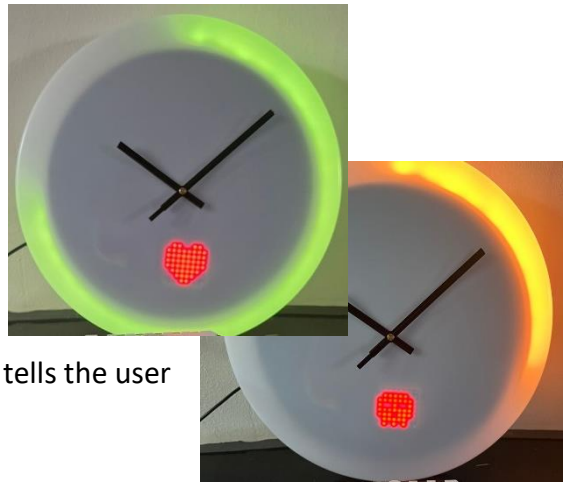


Figure 5-1: activity display of the prototype

Figure 5-2: sleep display of the prototype

To display the sleep score

The same ring of LEDs functions as a progress bar for the sleepscore of the user. The google fit application calculates the sleepscore of the user and provides a number between 0 and 100. The resulting score for each nigth is displayed on the ring, when the rotation button on the remote is set to sleepscore. The symbol of the moon indicates the kind of data displayed is sleepscore.

- *To display the current heart rate*

The ring of LEDs displays, together with the matrix, displays the current heart rate. This functionality can not display the history, only the current heart rate. An additional feature is the pulsating of the lights, this happens on the rate of the heartbeat.

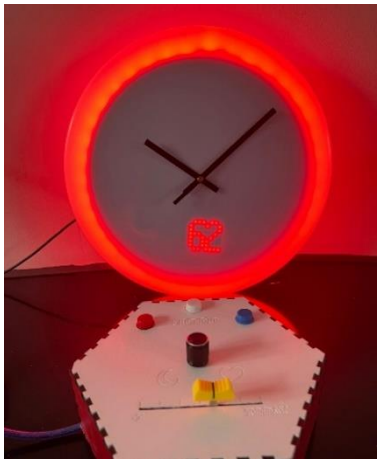


Figure 5-3: heart display of the prototype

The remote

The connected remote enables the user to manually change the display of the clock. By rotating the rotary knob in the middle of the remote, the user can choose the category of data. The knob is equipped with an indicator stripe, which has to be aimed at one of the mood symbols engraved in the upper plate of the remote (Figure 5-4).

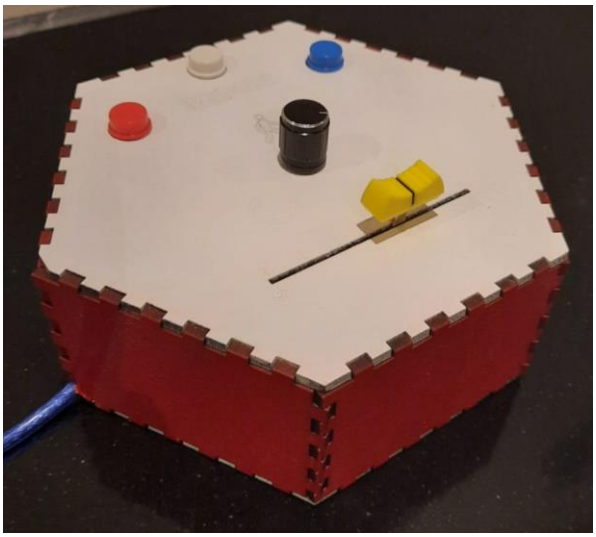


Figure 5-5: remote prototype

Figure 5-4: upside of the remote

By sliding the slider to the desired day, the history of the data can be displayed. Each stripe engraved in the upper plate of the remote counts for one day in the past, up to a total of seven days.

At last, the remote has the functionality for the user to input their mood. Based on this mood, the daily goal of steps is determined. This allows the user to influence their own daily goal.

Both the clock and the remote have a USB plug from which they receive their power. This can placed in a combination piece to fit into a 230v socket. Additionally, the clock starts up automatically: when both devices are supplied with power

5.1 Compatibility

The clock must be:

- compatible with different categories of external devices (like wearables)
- The device compatible devices must be choose-able by the user
- The device must guarantee good policy concerning the privacy
- The device must distinguish an individual from others and provide appropriate interaction

A requirement emerging from the recommendation of the previous project was an improved compatibility concerning different smart wearables, additionally the choice of smart wearable should be left to the user. Making use of an intermediary software could improve the compatibility: software which can be connect to both the product and various smart wearables. This software exists in different forms, for the realization the “Google fit. application” was chosen (1.2 State of the Art). This choice was based on the Google fit accessibility for to developers and the possibility to connect with a variety of different brands of smart wearables (REFERENCE).

5.1.1 The necessary prior knowledge.

To enable communication between our product and the Google fit application, the product must be able to connect to the internet. A microcontroller equipped with an ESP8266 WiFi module is used. This module uses a protocol which gives it functionalities to host a WebClient as well as to establish connections to the internet. The microcontroller used in this project is the NodeMCU (Overview - NodeMCU Documentation, n.d.). This controller facilitates the use of the ESP8266 WiFi module (Figure 5-6). The advantage of the NodeMCU is the simplicity of its implementation. Additionally, the NodeMCU is a cheap compared to other microcontrollers with Wi-Fi networking functionalities.

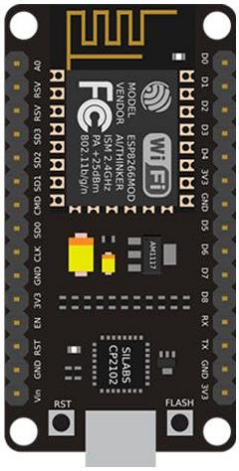


Figure 5-6: NodeMCU

A disadvantage of this microcontroller is the limited working memory, and the lack of a hard disk.

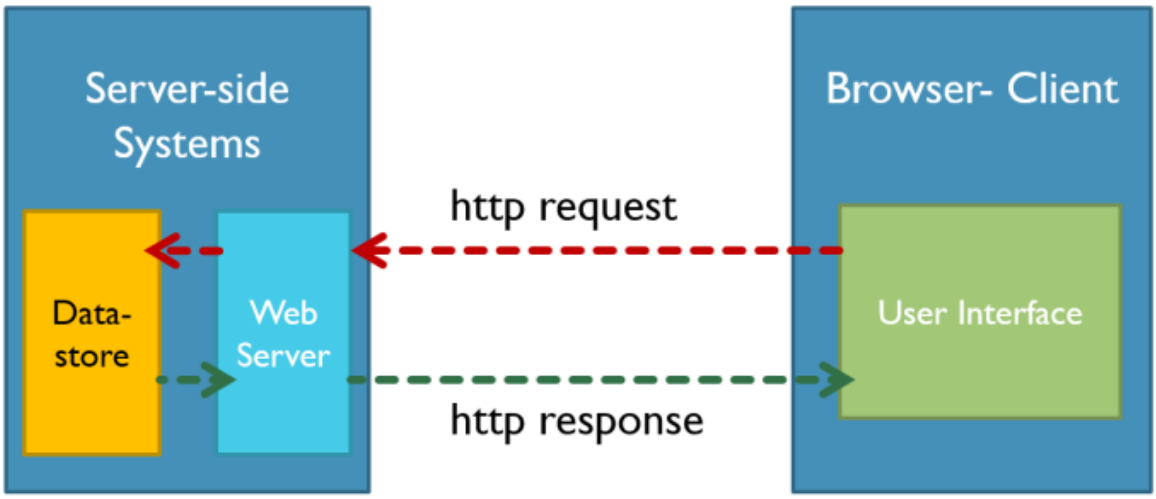


Figure 5-7: the working of an http request and response by Kereshmeh Afsari et al. (2016)

The data in the Google Fit application is stored on Google's secure servers, this data can be accessed through the Google API (Google Cloud Platform, 2020). An API is an Application Programming Interface, a program that functions as a separation between different layers of abstraction. This program should ensure different programs can use the functionalities of a more difficult program by using the API. For example, a text editing program like Word is not connected to the operating system of a printer, but needs an intermediate program to print out the text.

Figure 5-7 is a depiction of the connection between a browser and a webserver. The Google servers depicts the 'server-side Systems'. The block 'Web Server' depicts the Google API, and the 'Data-Store' depicts the Google Database. The browser client communicates with the database via the API.

5.1.1.1 Oauth2.0

The Google servers are equipped with multiple types of security, the Google Fit data required for the project is equipped with the OAuth2.0-protocol. Data not linked to a Google account, such as retrieving data from Google Maps, is secured with the API key protocol (Google Developers, 2022). An API key must be requested once and attached to the request to the server, so the Google Maps API knows request the information (Figure 5-8). This project requires privacy sensitive data. This secured with the OAuh2.0-protocol. This security protocol allows users to share and retrieve the sensitive data from an account protected by username and password (Figure 5-10) . A user needs to enter the username and password once to provide permission to the project. With this consent, an authorization code can be generated. This code enables access to the data (Figure 5-9).

```
"https://maps.googleapis.com/maps/api/js?key=YOUR_API_KEY&callback=initMap"
```

Figure 5-8: Google API authorization with API key

```
GET /fitness/v1/users/me/dataSources HTTP/1.1
Host: www.googleapis.com
Content-length: 0
Authorization: Bearer ya29.a0ARrdaM_ZoJnt-Xt_8FHZc-fA0HSV3GlJofP3p53rsBAT4RPXHnPJAGK6Lm-DXYqfjYkNg1C6YcJMn1LIpX6M4Pz-
XBMsepzCNtQEDVMog288gLMC81WZU1u7iZ9Enskt-Cj8Pq_jxHvVjUAP886SZkIr2lfw
```

Figure 5-9: Google API authorization with Oauth2.0

The Google Oauth2.0 manual provides several options to obtain an authentication code, in the project the option for 'Client-side (JavaScript) applications'' will be used. Google provides an option for "limited-input devices", unfortunately specific permission from Google is required which cannot be requested in the short term. The solution is to host a web server with the NodeMCU enabling log in functionalities via the Client-side method.

The manual prescribes to create a specific 'device-related' URL in the Google console. This URL enables a user on an external device (such as a smartphone) to log in to Google and give this project permission to use the requested data (Figure 5-10). After the permission has been given, the ESP8266 can request two so-called tokens from the Google API; an access token with which can be shown permission has been received from the user to use the data; and a refresh token to produce a new access token after the access token has expired. Due to the refresh token, the user does not have to log in every hour to provide permission.

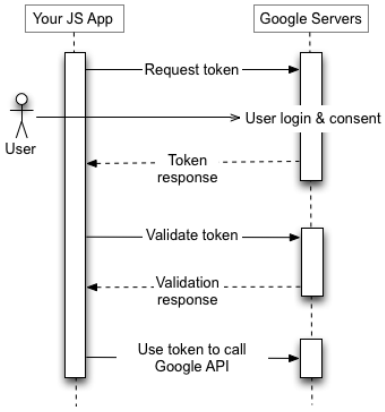


Figure 5-12: Using OAuth 2.0 to Access Google APIs: JS Application (Google Develops, 2022)

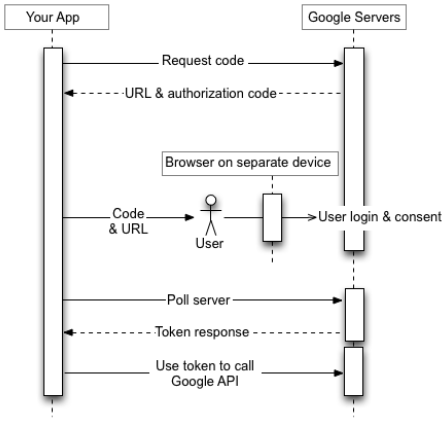


Figure 5-11: Using OAuth2.0 to Acces Google APIs: limited input devices (Google Develops, 2022)

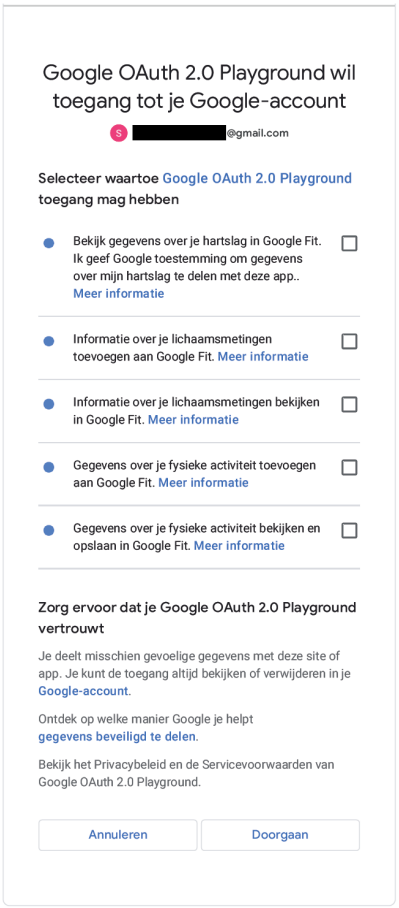


Figure 5-10: login screen for Authethication at Google

5.1.1.2 Oauth2.0 playground

The OAuth 2.0 Playground is a browser application for developers which simplifies experimentation with the OAuth 2.0 protocol and API's. The application allows developers to try out requests to retrieve data from the Google servers. The OAuth 2.0 security is added to the requests in a simple way. The application is intended to improve understanding of the protocol and learning to navigate to the correct data (Figure 5-13).

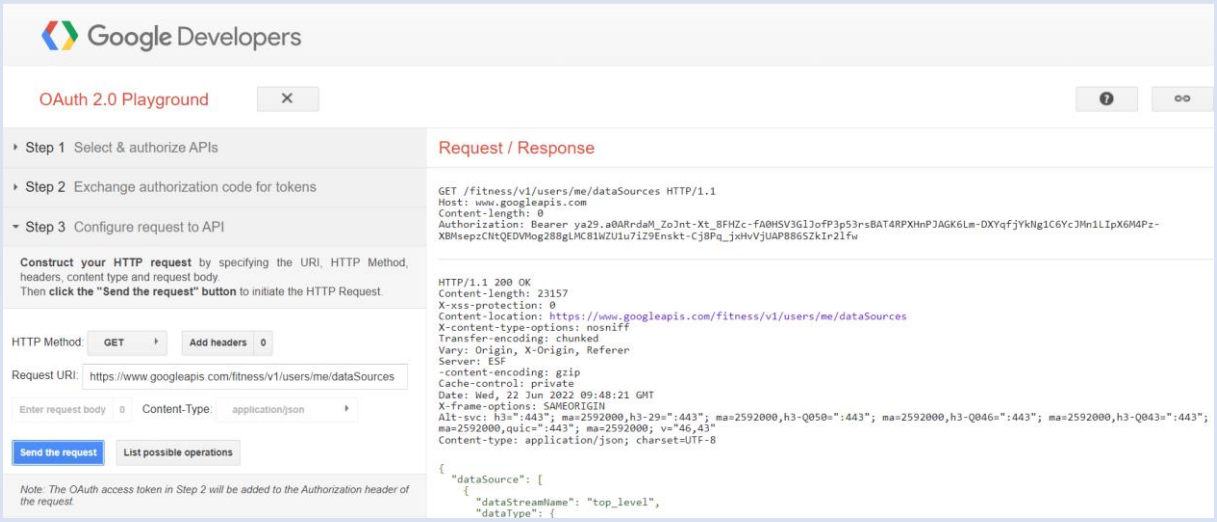


Figure 5-13: Google Developers Playground

5.1.1.3 HyperText Transfer Protocol

To communicate with the Google API, HTTP requests and responses will be used via the 'ESP8266 core for Arduino' library (ESP8266, 2022). HTTP stands for "hypertext transfer protocol" and is a way of transferring data between client devices and servers over the internet. The client (the requester) sends a query for data on the server. The server web server receives this query, searches its database for the data, and returns it by HTTP response (Figure 5-7). To work properly, the request must consist of certain parts (Figure 5-14):

- *The Request line*: The URL combined with the version of HTTP and HTTP method (in this project only GET and POST) which enables the request to be navigated to the right place on the server
- *he HTTP headers :* variables containing data needed to contact or authenticate for the servers
- *The HTTP Body:* optional information the server needs from the request

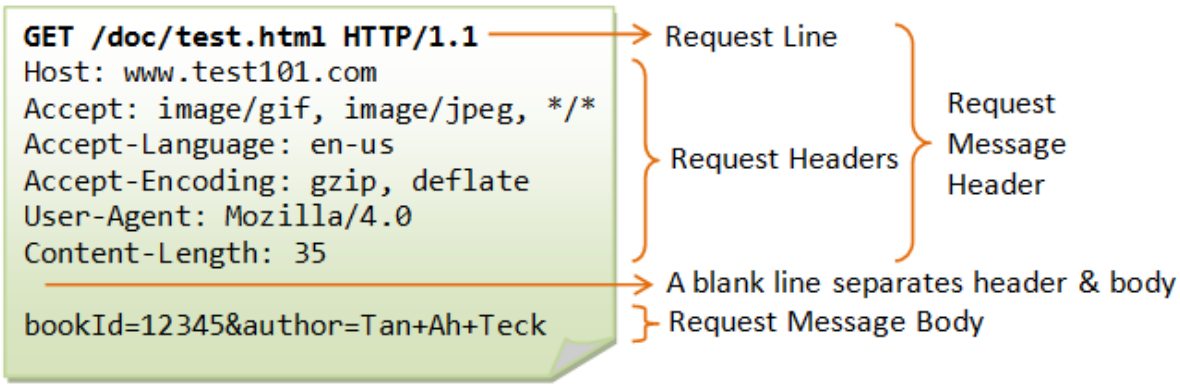


Figure 5-14: example of a GET request (Documentation Help, 2022)

The server responses contains (Figure 5-15)

- *HTTP status code* : A code stating the status of the response: OK when the request worked or another code indicating what went wrong
- *HTTP response headers*
- *HTTP response body*: the requested data

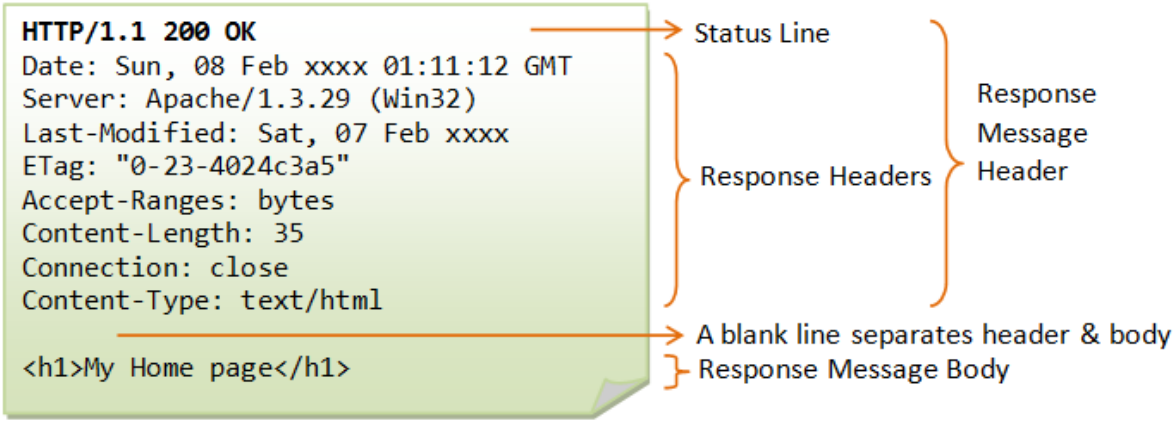


Figure 5-15: Example of a HTTP response (Documentation Help, 2022)

De 'ESP8266 core for Arduino' library allows the NodeMCU to easily produce these requests. In this project both GET and POST requests will be used.

5.1.1.4 JSON

The Google API mostly uses JSON formatted data to fill the body of an HTTP request and response. JSON, or JavaScript Object Notation, is based on the JavaScript programming language. It is a text-based data formatting method, useful for sending data over the Internet. The data is formatted by giving its contents a certain hierarchy, from which It produces a single line of code. Extracting the data from a JSON object means decomposing this same hierarchy.

```
superHeroes['members'][1]['powers'][0]
```

In Figure 5-16, an example of JSON formatted data is shown on the right, and a request to retrieve certain data from the JSON object on the left. The entire Object is called SuperHeroes. The object is navigated to by the names in red.

For example, to be able to access the members heading, “members” must be called within the Object. Note that the numbering starts at 0, when the 2nd line in a cup has to be called, use the number '1'.

```
{
  "squadName": "Super hero squad",
  "homeTown": "Metro City",
  "formed": 2016,
  "secretBase": "Super tower",
  "active": true,
  "members": [
    {
      "name": "Molecule Man",
      "age": 29,
      "secretIdentity": "Dan Jukes",
      "powers": [
        "Radiation resistance",
        "Turning tiny",
        "Radiation blast"
      ]
    },
```

Figure 5-16: JSON example

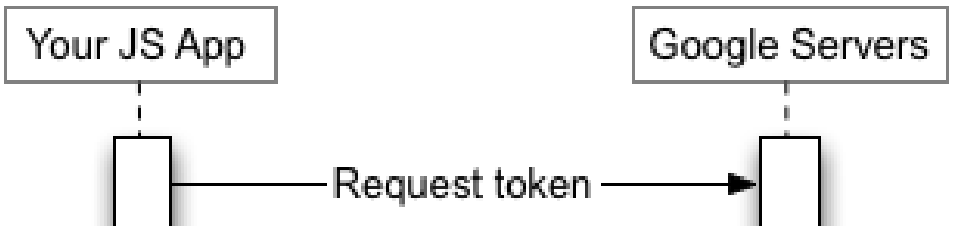


Figure 5-17: Fragment of Google Auth2.0 authentication method (1/3) (Google Developers, 2022).

5.1.2 The implementation

Implementing the prior knowledge must result in the connection of the product to the Google API by an NodeMCU, in order to retrieve the Google Fit data. The full code referenced in the next section can be found in Appendix F.

5.1.2.1 Request token and User Login and consent

The first step in the process is to create a request token to send to the Google servers (Figure 5-17). This token is usable for the whole project and has to be retrieved only once. The purpose of this token is to create a correct URL, with which the user can navigate to the Google login page with which he can give permission for the use of his data. This URL should eventuele look like this:

```
https://accounts.google.com/o/oauth2/auth?client_id=CLIENTID&response_type=code&redirect_uri=
REDIRECT URI&approval_prompt=force&access_type=offline&scope=SCOPES&state=STATE
```

Figure 5-18: URL to Google Login page for User Authentication for Auth2.0

The blue shaded areas should be replaced with the appropriate variables related to the project. These variables must be created first. First the CLIENT ID and the SCOPES will be generated, the REDIRECT URI and STATE will be created later on in the process.

Client ID

The Client ID is the ID Google connects to the project. To request this ID, a project must first be initiated in the Google console (*Google Cloud Platform*, 2020). This console is available in the web browser and is intended to provide developers with a platform to simplify the use of the Google API's. A new project must be created and new credentials for an 'OAuth Client ID' must be created in the ' credentials ' tab (Figure 5-19). The type of credential is 'web application '. When creating this OAuth Client ID there will also be an option to provide a Redirect URI, this is the same as in the URL and will be filled in later. When the Client ID is created, Google will assign an ID and a Client Secret to the project, which will be used in a future step.

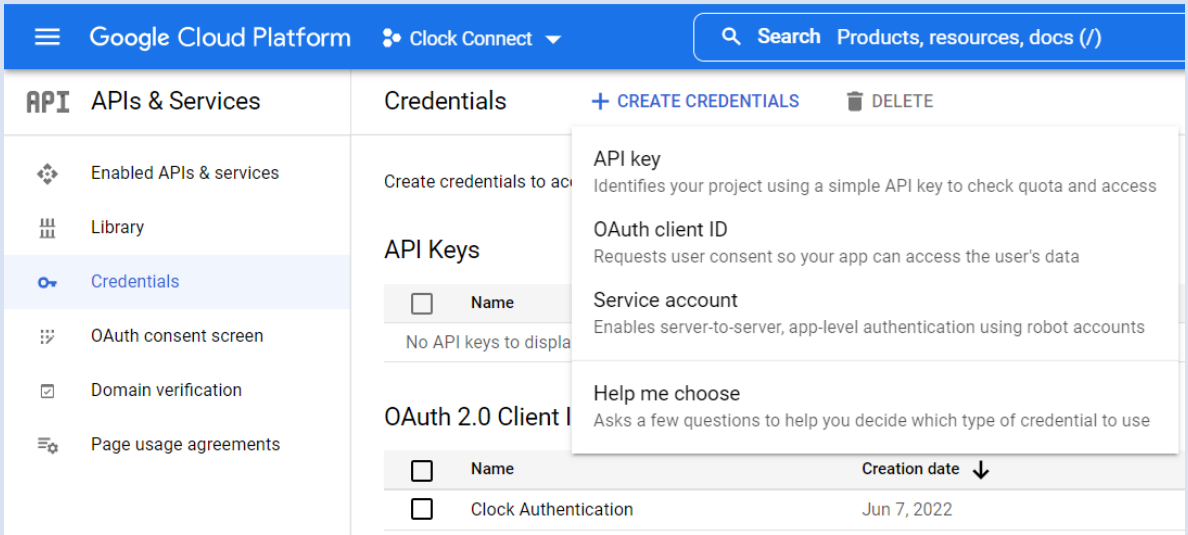


Figure 5-19: Google Console Dashboard Google, 2022)

Scopes

scopes are the categories of data the user gives permission to use. Google does not want to grant permission to every unverified project for the entirety of data on its servers. The categories must therefore be indicated. These categories can be found at "https://developers.google.com/identity/protocols/oauth2/scopes#fitness". The scopes used in this project are:

Https://www.googleapis.com/auth/fitness.activity.read
Https://www.googleapis.com/auth/fitness.sleep.read
Https://www.googleapis.com/auth/fitness.body.read
Https://www.googleapis.com/auth/fitness.heart_rate.read
Https://www.googleapis.com/auth/fitness.activity.write
Https://www.googleapis.com/auth/fitness.sleep.write
Https://www.googleapis.com/auth/fitness.body.write
Https://www.googleapis.com/auth/fitness.heart_rate.write

These scopes cannot yet be used in the URL, but must first be formatted. In this project de NodeMCU uses the code in Figure 5-20 to changes all whitespaces, slashes and double dots to their associated number codes.

```
342 String textToURL(String text) {
343   //String to store the new URL-text
344
345   String URLtext = "";
346
347   //have to covert the string to a char* so each symbol can be adressed seperatly
348   char * duplicate = strdup(text.c_str());
349
350   //loops through text
351   for (int i = 0; i < strlen(duplicate); i++) {
352
353     //converst the / symbol to text
354     if (String(duplicate[i]).equals(String("/"))) {
355       URLtext = URLtext + "%2F";
356     } else if (String(duplicate[i]).equals(String(" "))) {
357       URLtext = URLtext + "%20";
358     } else if (String(duplicate[i]).equals(String(":"))) {
359       URLtext = URLtext + "%3A";
360     } else {
361       URLtext = URLtext + String(duplicate[i]);
362     }
363   }
364
365   return URLtext;
366 }
```

Figure 5-20: Snippet of Code (Appendix F): confert Text to URL format

5.1.2.2 Initiating HTTP requests and Webserver

The following step in the process is to connect the ESP8266 to the Internet. Connection to the internet creates the ability to send GET and POST requests as well as the ability to create a web server. The webserver can be navigated to by the user on a smartphone or other device. This enables the user to receive the URL to the Google consent page (Figure 5-10).

The ESP8266 uses the aforementioned 'ESP8266 core for Arduino ' library (ESP8266, 2022) to connect to a WiFi network and create the web server (Figure 5-21). The WiFiClientSecure enables to make HTTPS requests instead of HTTP. This is a secure version of the normal HTTP request.

```
6  // Load Wi-Fi library
7  #include <ESP8266WiFi.h>
8  #include "ESP8266WiFi.h"
9  #include <WiFiClientSecure.h>
10 #include "ESP8266HTTPClient.h"
```

Figure 5-21: Snippet of Code (Appendix X): libraries

Next, the name (SSID) and password of a WiFi network must be provided (Figure 5-22). Additionally, a WiFiServer must be initiated to host the web server. The HTTPCLient and WIFIClient will be used for sending and receiving requests.

In Figure 5-24, the setup of the program can be seen together with the resulting text result (Figure 5-23). The setup provides the possibility to set up the Web server. This web server did run on 192.168.178.154. When a device connects to the same network as the NodeMCU is currently running, the device can navigate to this IP address. The NodeMCU now sends and reveices data to and from this IP adress

```
23 // Replace with your network credentials
24 const char* ssid = "*********";
25 const char* password = "**********";
26
27 // Set web server port number to 80
28 WiFiServer server(80);
29 HTTPClient httpsClient;
30 WiFiClientSecure clientSecure;
```

Figure 5-22: Snippet of Code (Appendix F): WiFi Network setup

```
-> ------------
-> ......Connected to WiFi Network
-> IP address:
-> 192.168.178.154
```

Figure 5-23: Snippet of Code (Appendix F): Serial Monitor

```
46 void setup() {
47   Serial.begin(9600);
48   delay(1000); //small delay to open up the serial monitor
49   //connect to WiFi
50   WiFi.begin(ssid, password);
51   Serial.println("Connecting to " + String(ssid) + " :");
52   Serial.println("------------");
53   //prints . when device is trying to connect to the WiFi
54   while (WiFi.status() != WL_CONNECTED) {
55     delay(1000);
56     Serial.print(".");
57   }
58   Serial.println("Connected to WiFi Network");
59   // Print local IP address and start web server
60   Serial.println("IP address: ");
61   webserverIP = WiFi.localIP().toString();
62   Serial.println(webserverIP);
63
64   server.begin();
65 }
```

Figure 5-24: Snippet of Code (Appendix F): setup

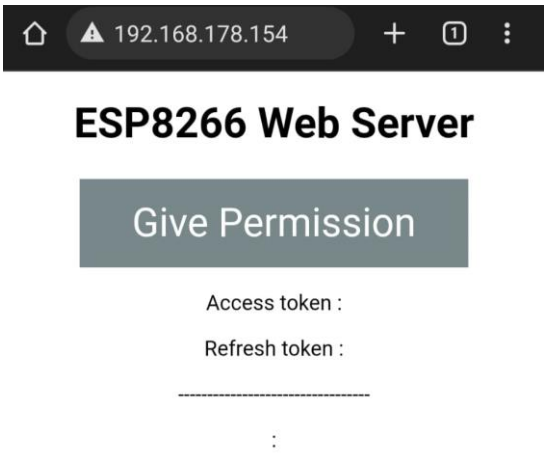


Figure 5-25: resulting web page

In the code's ' void loop()' method, a method called ' webServer ( ) is called. This method takes care of the construction of the web page. This web page will be forwarded to the aforementioned IP address and will be displayed when navigating to this address (Figure 5-25).

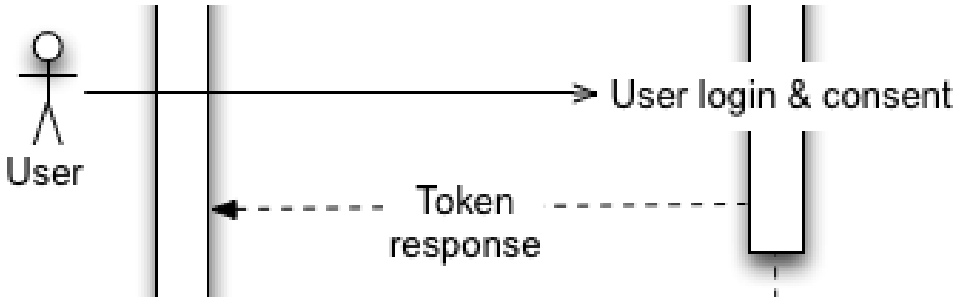


Figure 5-26: Fragment of Google Auth2.0 authentication method (2/3) (Google Developers, 2022).

5.1.2.3 Authorization of the user

Vanuit de webpagina zal de URL met daarin de Request token (Client ID en Scopes) met de gebruiker gedeeld worden, dit zal gebeuren met een doorstuur button. Wanneer er op deze knop gedrukt wordt zal de gebruiker doorgestuurd worden naar de betreffende URL (Figure 5-18). Nadat de gebruiker consent heeft gegeven moet de response tokens nog naar de NodeMCU teruggestuurd worden. Normaliter wordt dit naar de Redirect URI gestuurd uit de oorspronkelijke URL, alleen kan dit niet naar een private webserver gestuurd worden (een IP adres). Een oplossing hiervoor is om de response naar een pagina gehost door een 'echte' website te sturen, die vervolgens de gegevens weer doorstuurt. Dit zal gedaan worden door een klein PHP-script wat gerund wordt op een aparte (voor nu anonieme) website. Het adres van dit.

De response van de Google authenticatie bestaat uit de REDIRECT_URI uit de URL (Figure 5-18), met daar achter twee query's. Een query heeft de naam 'state' en bevat de 'STATE' uit de URL (Figure 5-18) de ander heeft de naam 'code' en bevat de autorisatie token. Wanneer er gezorgd wordt dat de STATE bestaat uit het IP adres waar de NodeMCU op runt, kan de autorisatie token met het PHP-script uit Figure 5-27 teruggestuurd worden naar dat IP adres.

So the redirect from google will go to: " http://www.anonymous.nl/redirectScript.php?state=http://IP_adress_from_nodemcu"

```php
<?php

$queries = array();
parse_str($_SERVER['QUERY_STRING'], $queries);

$queries['state'];

$redirectURL = $queries['state'];
$authCode = $queries['code'];

$fullURL = "{$redirectURL}?state={$authCode}";

header("Location: $fullURL");
exit();
?>
```

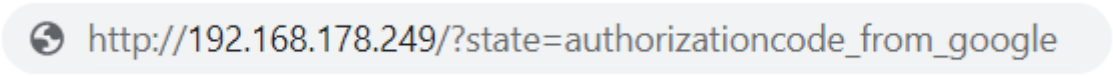
Figure 5-27: PHP script to redirect back to the Webpage of the NodeMCU

With this information the full URL can be compiled:

```
Https://accounts.google.com/o/oauth2/auth?client_id=Client ID from the google console&response_type=code&redirect_uri=http://www.anonymous.nl/redirectScript.php&approval_prompt=force&access_type=offline&scope=Combination Of All The Requested Scopes&state=IP Adress of nodeMcu
```

To enable the working this url, it must be entered as a certified redirect URI in the google console (5.1.2.1 Request token and User Login and consent).

The redirect.php will redirect the user to:



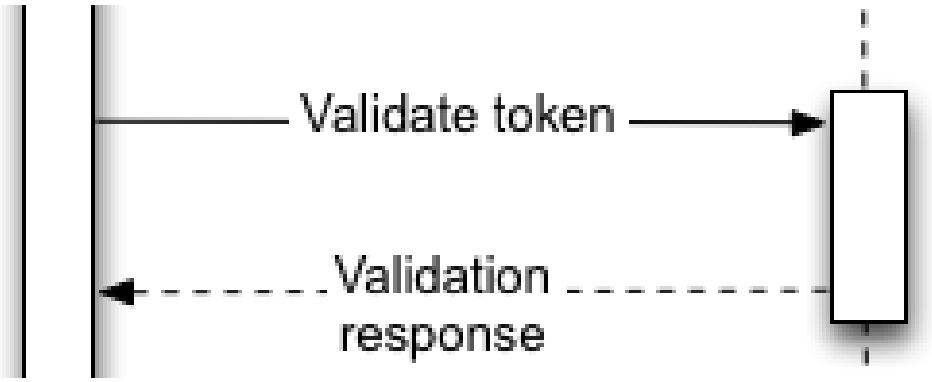


Figure 5-28: Fragment of Google Auth2.0 authentication method (3/3) (Google Developers, 2022).

5.1.2.4 Confirming the Authorization to Google

The authorization code is sent by query from the redirect.php to the URL of the IP address on which the NodeMCU runs and listens. Here in the "void webServerFunctions()" the query is split from the entire header by the "splitToQuery()" method (Figure 5-29 Snippet from code (Appendix F)Figure 5-29).

```
127 void webServerFunctions() {
128   String query = "";
129 
130   //checks if the adres contains a 'state' query (-1 if does not contain),
131   //can't dig to deep in the header
132   if (header.indexOf("state=") > 0 && header.indexOf("state=") < 20) {
133     //gets the 'state=' query from the header
134 
135     String splittedQuery = splitToQuery(header, "state=");
136 
137     // sends the authorization token to google and returns payload
138     String payload = tokenToGoogle(splittedQuery, "authorization");
139 
140     //updates the access and refreshtokem
141     updateTokens(payload);
```

Figure 5-29 Snippet from code (Appendix F)

tokenToGoogle(){

This token is sent back to the Google API in the method “tokenToGoogle()” by HTTPS Post requests. This HTTPS post request is sent to:

```
360  httpsClient.begin(clientSecure, "https://www.googleapis.com/oauth2/v4/token");
```

The HTTPS request contains two headers

```
373  //adds headers to the request
374  httpsClient.addHeader("Content-Type", "application/x-www-form-urlencoded");
375  httpsClient.addHeader("Content-Length", String(httpRequestBody.length()));
```

And a body containing the Authorization code (token), the link to the forwarding PHP (redirect_uri), the name of the project in google console (client_ID) and the client secret from the Google console (client_secret).

```
httpRequestBody = "code=" + textToURL(token) +
"&redirect_uri=" + textToURL(redirect_uri) + "&client_id=" + textToURL(client_id) +
"&client_secret=" + client_secret + "&scope=&grant_type=authorization_code";
```

Now the HTTPS request is sent as POST request. In response, the servers will send a response with status code 200 (depends whether the request is correct or not) and a response body. The body is stored in the String called 'payload', and both the code and response body are printed on the serial monitor of the arduino software (figure X). Finally, the request is terminated and the function returns the complete request body.

```
375  int httpCode = httpsClient.POST(httpRequestBody);
376
377  //gets body of the response
378  String payload = httpsClient.getString();
379
380  Serial.println("response code: ");
381  Serial.println(httpCode);
382  Serial.println("response load: ");
383  Serial.println(payload);
384
385  httpsClient.end();
386
387  return payload;
```

```
-> response code:
-> 200
-> response load:
-> {
->   "access_token": "ya29.a0ARrdaM-_1XnJsmvj0TpfnOpm32
->   "expires_in": 3599,
->   "refresh_token": "1//097rOGnPJH1z6CgYIARAAGAkSNwF-
->   "scope": "https://www.googleapis.com/auth/fitness.
->   "token_type": "Bearer"
-> }
```

(Appendix F)

The response body consists of a JSON string. This JSON string is passed in the function “webServerFunctions()” to the “updateTokens()”, a function meant to store both the refresh and the access token in the NodeMCU memory.

```
137     // sends the authorization token t
138     String payload = tokenToGoogle(spl
139
140     //updates the access and refreshto
141     updateTokens(payload);
```

Figure 5-30: Snippet of code (): updateTokens()

```
390 void updateTokens(String payload) {
391   DynamicJsonDocument doc(1024);
392   deserializeJson(doc, payload);
393   JsonObject obj = doc.as<JsonObject>();
394
395   String tAccess_token = obj["access_token"];
396
397   if (tAccess_token != NULL) {
398     access_token = "Bearer " + tAccess_token;
399     Serial.println("ACCES TOKEN UPDATED");
400   }
401
402   String tRefresh_token = obj["refresh_token"];
403   if (tRefresh_token != NULL) {
404     refresh_token = tRefresh_token;
405     Serial.println("REFRESH TOKEN UPDATED");
406   }
407 }
```

Inside the 'updateTokens()' function, the data from the payload String is put into a JSON object by functionalities of a JSON library (BenoitBlanchon, 2021). This library enables extracting data from the String. This data is used for updating the access_token and refresh_token variables.

With these tokens, data can now be retrieved by the Google API.

5.1.2.5 Requesting specific data

The access token from the Oauth2.0 enables data to be retrieved from the Google Servers through the Google Fit API. The GET and POST requests required for retreiving the proper data are found by investigating in the Google Playground (5.1.1.2 Oauth2.0 playground). To facilitate future extensions of this project, a framework will be created to allow various GET and POST requests to be sent from the NodeMCU. A necessarity for future expansion is optionality to pass variables containing search terms to navigate to the appropriate location on the google servers. These variables must be passed on to the NodeMCU by an external device. This will be done by means of a query. The POST and GET requests are constructed differently, the framework for both types will differ from a certain point. The start is the same for both frameworks.

Receiving the command

First, the variables containing the search terms must be communicated to the NodeMCU. This is accomplished somewhat like the communication to the Google API when requesting the OAuth2.0 protocol: by means of queries. This allows another device, such as a smartphone or other NodeMCU, to make a request to the IP address this NodeMCU currently hosts a server on. An example request will then look like this:

```
http://192.168.178.249/?postData=estimated_steps&bucketTime=BUCKETTIME&startTime=STARTIME&endTime=ENDTIME
```

The BUCKETTIME, STARTTIME and ENDTIME can be filled in to navigate to the right moment allowing data from a more distant past to be requested. The three variables are all set in

Epoch time: the number of seconds that have elapsed since January 1, 1970 (*Epoch Converter*, 2018).

webServerFunctions(){

This header is read by the NodeMCU and divided into variables in the 'webServerFunctions()' method, and passed to the 'searchDatabase()' method.

```
144  if (header.indexOf("postData=") > 0) {
145    String sortData = splitToQuery(header, "postData=");
146    String bucketTime = splitToQuery(header, "bucketTime=");
147    String startTime = splitToQuery(header, "startTime=");
148    String endTime = splitToQuery(header, "endTime=");
149
150    searchDataBase(sortData, bucketTime, startTime, endTime);
151  }
152  if (header.indexOf("getData=") > 0) {
153    String sortData = splitToQuery(header, "getData=");
154    String startTime = splitToQuery(header, "startTime=");
155    String endTime = splitToQuery(header, "endTime=");
156
157    searchDataBase(sortData, "", startTime, endTime);
158  }
```

(Appendix F NodeMCU code for connection with Google **)**

searchDatabase(){

The searchDatabase() method is designed to match the correct path to the entered data so it can navigat to the correct location in the Google server. This is also where the path of POST and GET splits.

```
167  if (sortData.equals("estimated_steps")) {
168    dataSourceId = "derived:com.google.step_count.delta:com.google.android.gms:estimated_steps";
169    result = retreiveAggregateData(dataSourceId, bucketTime, startTime, endTime);
170  }
171
172  if (sortData.equals("heart_rate")) {
173    dataSourceId = "derived:com.google.heart_rate.bpm:com.google.android.gms:merge_heart_rate_bpm";
174    result = retreiveGetData(dataSourceId, startTime, endTime);
175  }
```

Afterwards, the result is placed in the global array 'displayedData[]'. From this global array, the data can be retreveid and utilized .

```
177  if (result != "") {
178    displayedData[0] = sortData;
179    displayedData[1] = result;
180  }
```

(Appendix F NodeMCU code for connection with Google **)**

POST (e.g. Estimated steps)

'Estimated_steps' aims to retrieve the user's total steps a day. By passing the sourceID and variables to the 'retreiveAggregateData()' method, the data is converted to appropriate JSON format and placed in a String. This String is sent to the 'sendPostRequest()' function. This string will become the body of an HTTPS post Request.

sendPostRequest(){

The headers and the correct URL are appended to the request, along with the access_token.

```
265  httpsClient.begin(clientSecure, "https://www.googleapis.com/fitness/v1/users/me/dataset:aggregate/");
266
267  //set headers of post requeset
268  httpsClient.addHeader("Authorization" , access_token);
269  httpsClient.addHeader("Content-Type", "application/json");
270  httpsClient.addHeader("Content-Length", String(httpRequestBody.length ()));
```

And finally the request is sent and the response is retrieved.

```
272  //post the request with given body (json string), httpCode is returned
273  int httpCode = httpsClient.POST(httpRequestBody);
274
275  //retreive string from body of response
276  String responseString = httpsClient.getString();
```

(Appendix F NodeMCU code for connection with Google **)**

The response is returnd to the 'retreiveAggregateData()' method. Here the desired answer is extracted from the JSON string and returned as normal String to the 'searchDataBase()' method.

GET (e.g. heart_rate)

By passing the sourceID and variables to the 'retreiveGetData()'method, the data is converted to appropriate JSON format and placed in a String. These variables concern the time when the heart rate should be measured. Utilizing the variables, a correct URL is created and forwarded to the 'sendGetReques()'. This method assembles and sends the request. The JSON response is captured, the desired response is then extracted and the result is returned to 'searchDataBase()'.

searchDatabase(){

```
169      result = retreiveAggregateData(dataSourceId, bucketTime, startTime, endTime);
```

```
174      result = retreiveGetData(dataSourceId, startTime, endTime);
```

The result are in the global array 'displayedData[]'. From this global array, the data can be retreveid and utilized.

```
177  if (result != "") {
178    displayedData[0] = sortData;
179    displayedData[1] = result;
180  }
```

(Appendix F NodeMCU code for connection with Google **)**

5.1.3 Result

After testing the framework, the conclusion must be drawn the program is not working properly. The requests take up too much memory to process for the NodeMCU. The usable memory of the NodeMCU is full after three requests. The device resets itself; this deletes the authentication code which has to be generated again. Unfortunately, the knowledge and time were a limitation within this project to realize a solution. However, the problems have been localized and possible solutions have been devised.

The problem consists of several factors, the most important of which are the method of programming and the amount of different requests. The authentication to Google requires many different GET and POST requests, many variables have to be stored in the heap memory of the NodeMCU. The heap memory is the piece of memory an operating system reserves to work in. This heap memory fills up quickly with the current code, the variables with which the GET and POST requests work take up a lot of space. When this heap memory is full, the NodeMCU resets itself. One solution to this is to store these variables on an SD card. Firstly, this ensures the variables remain in short-term memory for a shorter period of time. A bigger advantage is that the access and refresh token are also stored. Should the device reset itself, the tokens are still saved.

The way of programming and especially the use of Strings is a more significant problem, it has led to Heap Fragmantation. A String is a way of storing data the Arduino software uses. When a String is used, the NodeMCU stores it in the heap memory, shown in the second row of Figure 5-31: illustratiof of Memory Fragmentation (Memorty Fragmentation, 2017). After String A and C are no longer needed, they are removed from the heap memory. B and D remain in the same place. Strings of a small size can be placed between B and D, but when a larger variable must be stored, it is placed after D. A small amount of variables will not be a problem, the heap of space will only be completely full after a significant amount of time. The framework works with large Strings that are often re-distributed in memory. When a large String has to be stored (with a GET or POST request), there is soon no more.

The way of programming and especially the use of Strings is a more overarching problem, it has led to Heap Fragmantation. A String is a way of storing data that the Arduino software uses. When a String is used, the NodeMCU stores it in heap memory, shown in the second row of Figure 5-31: illustratiof of Memory Fragmentation (Memorty Fragmentation, 2017). After String A and C are no longer needed, they are removed from the heap memory, while B and D stay in place. Strings of a small size would in between B and D, but larger block has to be stored after D. With a small number of variables this will not be a problem, the heap

space will only be completely full after an significant amount of time. The framework works with large Strings, often deleted from, and placed in the memory (due to the fast iterations of the program). When after some iterations a large String must be stored (from a GET or POST request), the storage wont allow it.

A method of solving this, is to use an array of Char instead of String. These can be stored dynamically so they can be relocated. In the case of an array of Chars, row three would have B and D to the left of each other. Unfortunately, converting the program to array or Char is a time-consuming task, which I have no experience with. This makes it a limitation of the research.

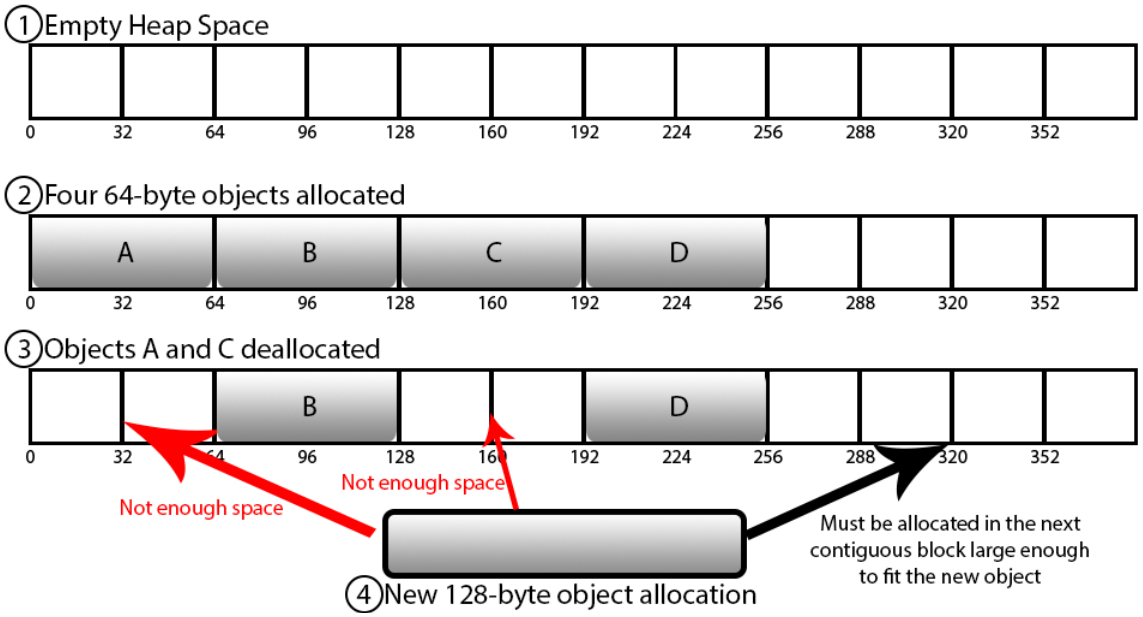


Figure 5-31: illustratiof of Memory Fragmentation (Memorty Fragmentation, 2017)

5.2 Controller

From the user test the conclusion arose the clock should not be controlled by buttons on the clock itself, but on a separate controller. The user's comments elaborated on the fear of losing the remote. The clarity of the remote control must also be considered: the user must understand the possibilities the remote delivers.

From the requirements established through the project, the controller must:

- Contain buttons
- have functionalities to adjust the brightness
- must be powered by 230v power supply
- be straightforward to use
- provide the ability to changes the displayed data

From the requirements established through the project, the controller should:

- integrate into an existing object
- be compact and only need one wire to plug into a socket
- provide the ability to adjust the daily goal

5.2.1 Hardware

The clock will be remote controlled by making use of a wireless connection between two NodeMCU's. To create a remote control, a NodeMCU will be connected to various hardware components.

NodeMCU

The nodeMCU is the aforementioned microcontroller containing an ESP8266, which is able to connect to the internet. The nodeMCU is connected to the clock through a WiFi network, and transmits the signals it receives from its own hardware components to the clokc. The NodeMCU is the central part of the remote. The other hardware components in the remote are connected to, and sending signals to, this microcontroller (Figure 5-32: NodeMCU).

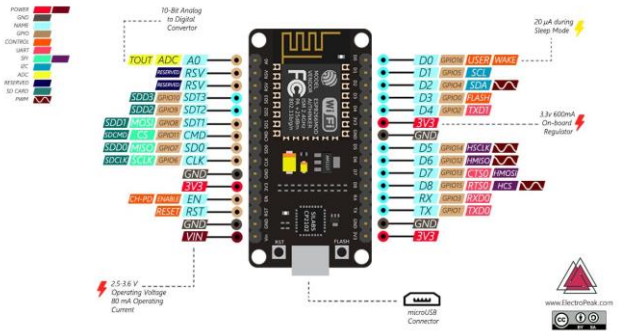


Figure 5-32: NodeMCU

Buttons

Three buttons will enable the users to indicate their mood. The buttons will be connected to three digital pins of the NodeMCU. When the buttons are pressed, they will pass a 1 to the NodeMCU, otherwise a 0 is passed on. The buttons are connected to the electrical current through a 10k Ohm resistor (Figure 5-33).

https://www.otronic.nl/a-61302611/schakelaars/drukknopje-moment-puls-12x12x7-rood/

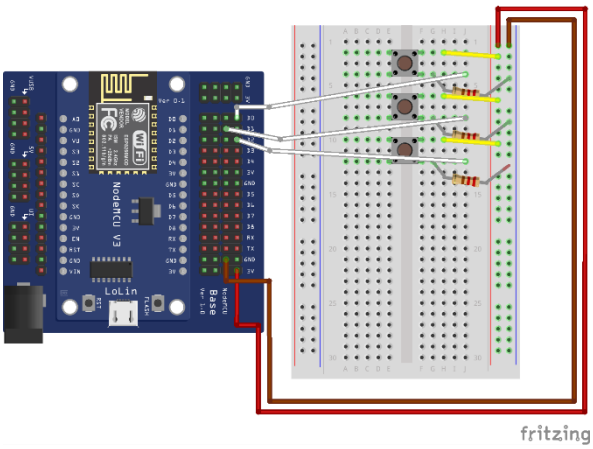


Figure 5-33: layout of Buttons and NodeMCU

Rotary

A rotator button enables the user to choose the category of data: sleep, activity or heart. The HW-040 (Figure 5-34) will be used. This rotator has five pins to connect to the NodeMCU (Table 5-1: Connection Pins Rotary Encoder). The rotatory encoder cycles once in 60 steps, with each of these steps increasing the indicated value by 1.

Figure 5-34: Rotary encoder

HW-040	NodeMCU
CLK	D5
DT	D6
SDK	D7
+	3V
GND	GND

Table 5-1: Connection Pins Rotary Encoder

https://www.otronic.nl/a-61302481/schakelaars/rotary-encoder-hw-040-met-aluminium-dopje-voor-arduino/

Potentiometer

A slider will enable the user to choose the day to be displayed: from the current day up to 7 days in the past. A linear potentiometer module (Figure 5-35: Potentiometer) will be used. This potentiometer has a range from 0 to 1024.

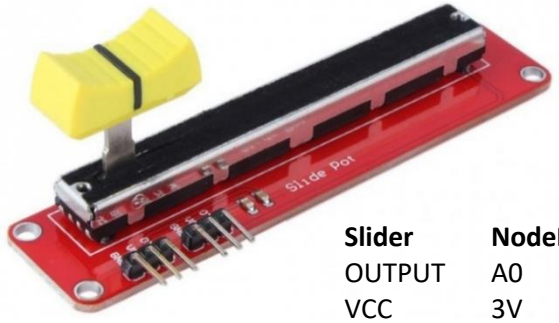


Figure 5-35: Potentiometer

Slider	NodeMCU
OUTPUT	A0
VCC	3V
GND	GND

Table 5-2: connection Pins Potentiometer

The potentiometer is equipped with the same three pins twice. The output pin has two variants: A & B. These indicate the inverse values of each other. When one pin outputs 1024, the other indicates 0 and vice versa.

https://www.otronic.nl/a-70719627/weerstanden/lineaire-potentiometer-module-dubbele-output-10k/

Layout

The setup used is displayed in Figure 5-36: Layout Remote. All parts are powered by the NodeMCU, which can be connected to the power net by USB connection.

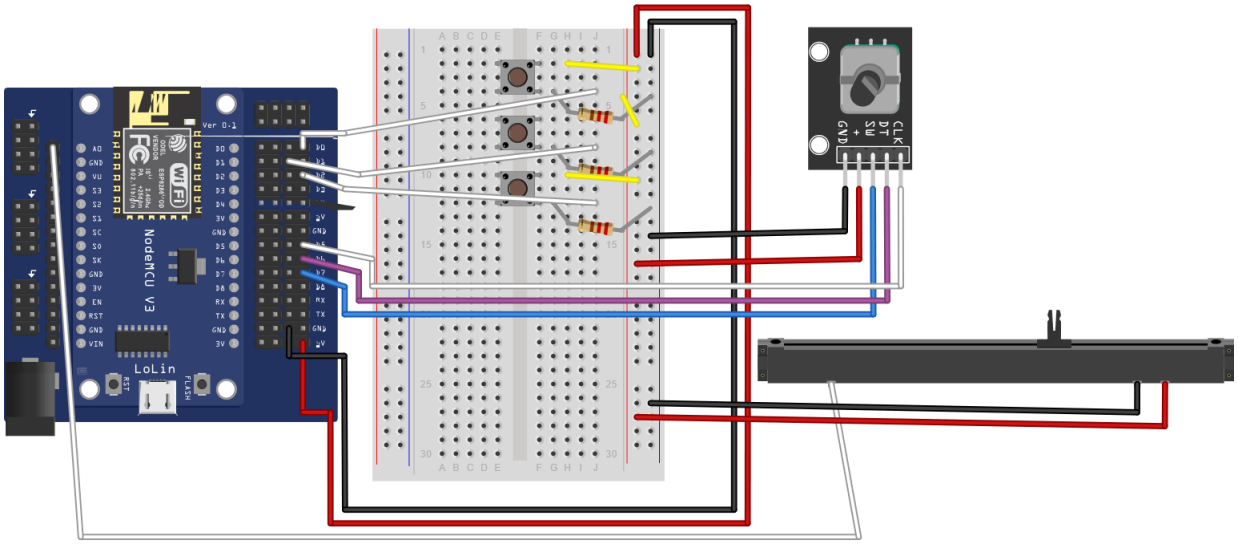


Figure 5-36: Layout Remote

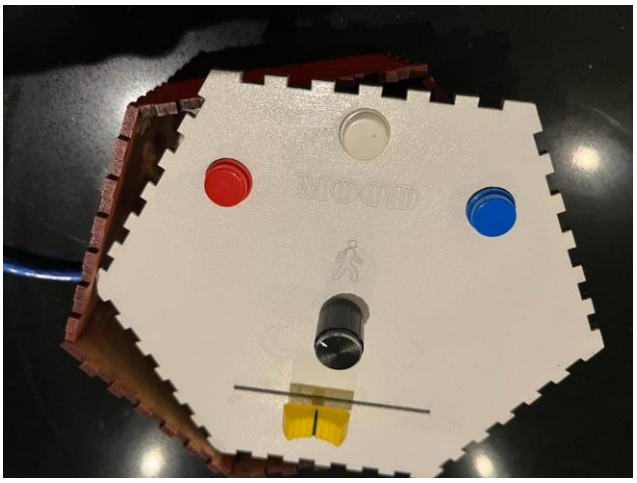


Figure 5-38: up side remote

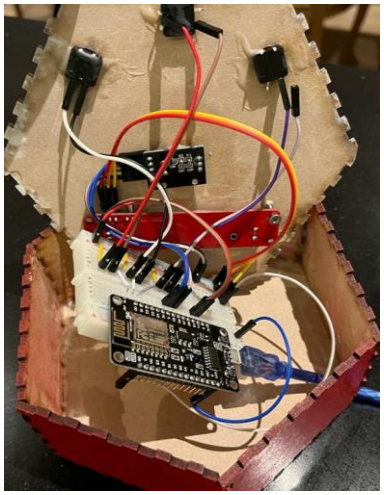


Figure 5-37: inside remote

All the interactive parts will be mounted on a box, the breadboard and nodeMCU will be placed inside the box (Figure 5-37: inside remote). This box will function as the casing for the remote. It consists of six sides, a bottom plate, and a top plate. All parts are laser cut from a 3mm thick MPF sheet. The cutting file was created by using Adobe Illustrator.

Additionally, the top plate is engraved with various symbols and text to clarify the usage. The boards are attached by cut out teeth and wood glue. The top plate is not glued, it can be

removed when maintenance is required. All plates are coated with multiple layers of spray paint. This aims to make the remote more striking and attractive.

5.2.2 Software

To enable the communication between the two NodeMCUs, a Server-Client communication will be set up. The advantage being the ability to connect by smartphone. This could be used in future expansions.

5.2.2.1 Server

The remote control will function as server of WiFi connection. The 'Asynchronous Web Server' library (me-no-dev, 2022) will be used, a library facilitating the setup of a web server. The web server will not use an existing WiFi network but will start a private. The address of the network will be given the SSID and contains an optional password protection. A device needs to connect to network to communicate with the NodeMCU.

```
27 // Set your access point network credentials
28 const char* ssid = "ESP8266-Access-Point";
29 const char* password = "123456789";
```

Figure 5-39: snippet of code (Appendix G): network verification

The server will host on port 80.

```
31 // Create AsyncWebServer object on port 80
32 AsyncWebServer server(80);
```

setup(){

The server will be initiated and on a specific IP address where it starts checking for requests.

```
59   WiFi.softAP(ssid, password);
60
61   IPAddress IP = WiFi.softAPIP();
62   Serial.print("AP IP address: ");
63   Serial.println(IP);
```

Subsequently, three possible addresses will be initiated. GET requests will be sent to these addresses for different types of data. For example, when a device connects to the WiFi network of the current NodeMCU, a GET request can be send to http://IPADRESS/latestmood. The client (sender) will receive response with status 200 and a body filled with the string, the function 'readButtons()' returns.

```
65 server.on("/latestmood", HTTP_GET, [](AsyncWebServerRequest * request) {
66   request->send_P(200, "text/plain", readButtons().c_str());
67 });
68 server.on("/displayeddata", HTTP_GET, [](AsyncWebServerRequest * request) {
69   request->send_P(200, "text/plain", readRotator().c_str());
70 });
71 server.on("/displayedday", HTTP_GET, [](AsyncWebServerRequest * request) {
72   request->send_P(200, "text/plain", readPotentiometer().c_str());
73 });
```

(Appendix G)

The functions producing the Strings for the response body consist of the return of a variable. These variables contain Strings of the data from the buttons, potentiometer, and rotator.

```
34 String readButtons() {
35   return buttonData;
36 }
37
38 String readRotator() {
39   return rotatorData;
40 }
41
42 String readPotentiometer() {
43   return analogData;
44 }
```

‘buttonData’ contains the mood that was last pressed ('sad', 'normal', 'good')

‘rotatorData’ contains the type of data the rotator is currently pointing out ('sleep', 'activity', 'heart'

‘analogData’ potentiometer the amount of days in the past the meter indicates (0 to 7).

Figure 5-40: snippet of code (): functions to send data to other NodeMCU

The Client receives the data, the Serial monitor could look like this: (Figure 5-41)

```
mood :  good
dataType :  activ
day :  2
```

Figure 5-41: Serial monitor of the Client

5.3 Clock

Concluding from the user test, the clock should make use of one single indicator LED ring, to display the different categories of data. Additionally, the activity indicators were not received well, only the possibility for a sound alarm could be integrated. A small display could be added to the clock, but displayed symbols were preferred over text.

From the requirements established through the project, the clock must:

- mitigate the level of intrusiveness
- be usable without a permanent utilization
- have a certain level of profitability
- be straightforward in usage
- have Illumination time, color and brightness
- must be powered on 230 power supply

From the requirements established through the project, the clock should:

- integrate both long- and short-term rewards/feedback
- be integrated into an existing object (lamp, picture frame, clock, vase, doormat)
- be compact and with just one wire to plug the device in a socket.

From the requirements established through the project, the clock could:

- An additional display could be connected
- The system could be equipped with a battery

5.3.1 Hardware

In order for the clock to receive and display the data, several hardware components are needed:

NodeMCU

The nodeMCU in the clock receives data from the remote and forwards it to the Arduino Nano. If the connection to Google Fit had been possible, the NodeMCU in the clock would fetch data from the servers and forward it to the Arduino Nano. Due to a shortage of bandwidth this feature cannot work properly. Nhe NodeMCU now only forwards the data from the remote to the Arduino Nano.

NodeMCU	Nano
D1	A5
D2	A4
Vin	5v
GND	GND

Table 5-3: Connection Pins NodeMCU

Arduino Nano

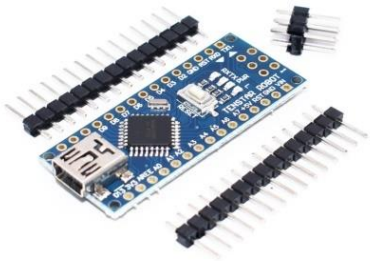


Figure 5-42: Arduino Nano

The Arduino Nano is the central part of the clock: it receives the settings from the remote through the NodeMCU. These settings are converted to specified signals towards the LEDs and Matrix to show a matching result.

https://www.otronic.nl/a-60871663/arduino/nano-v3-arduino-compatible-ch340/

LED Strip

The data on the clock will be shown by means of an LED strip. The LED strip is, just like the previous project, mounted in a circle on the inside of the clock. This allows it to show a full circle of light. The LED strip used is the WS2811b LED strip. This LED strip allows you to control all LEDs separately.

Figure 5-43: LED strip

WS2811b	Nano
Din	D3
+5V	5V
GND	GND

Table 5-4: Connection pins LED strip

LED matrix

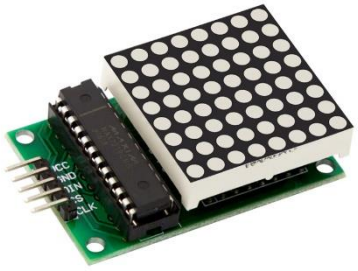


Figure 5-44: LED matrix

The MAX7219 Dot Matrix LED is used to show additional data to the user. This display consists of an 8x8 Matrix of red LEDs that can be controlled separately from each other. By turning separate LEDs on or off, numbers, letters or symbols can be formed.

https://www.otronic.nl/a-70104887/leds/max7219-dot-matrix-led-displaymodule-rood/

MAX7219	Nano
VCC	5v
GND	GND
DIN	D11
SC	D10
CLK	D13

Table 5-5: Connection Pins LED matrix

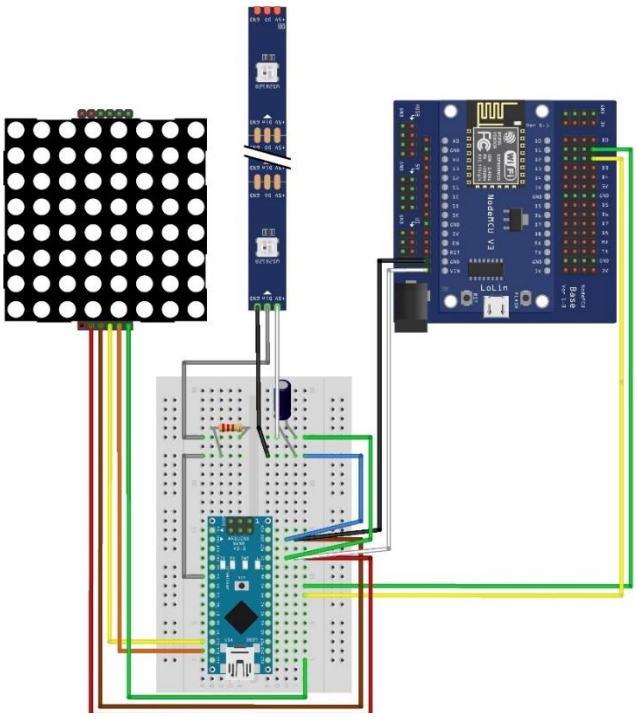


Figure 5-45: Layout of Clock

Layout Clock

Figure 5-45: Layout of ClockFigure 5-45 shows the layout of the components of the clock. All components are powered by the Arduino Nano, which itself is powered by USB.

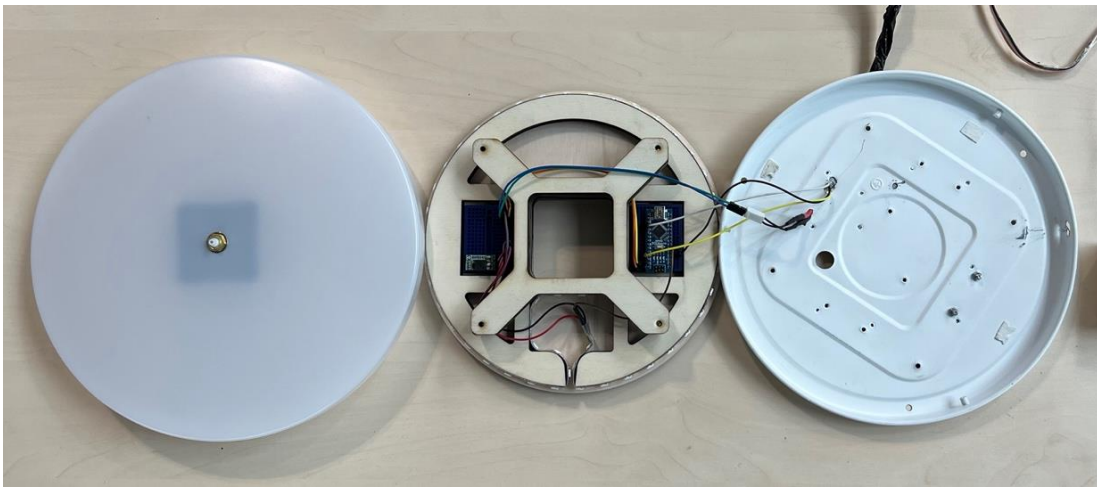


Figure 5-46: Inside of Clock (Hengeveld, 2021)

The framework of the clock is taken from the project by Hengeveld (2021), and consists of a lamp with a wooden construction. This wooden construction contains a holder for the inside of the clock and the Arduino Nano.

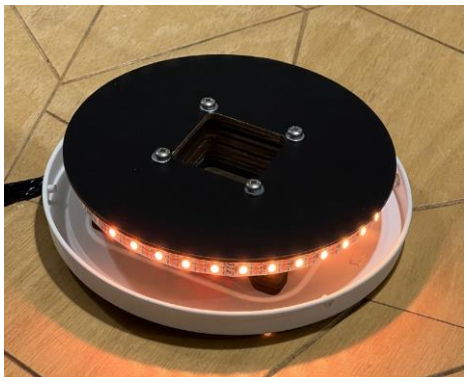


Figure 5-47 Inside of the Clock (Hengeveld, 2021)

The NodeMCU is placed in the space of the wooden construction. Subsequently, a hole was drilled in the plate through which the wires for the Matrix were drawn. For the first prototype, the matrix was held in place by tape. Later this was replaced by screws.

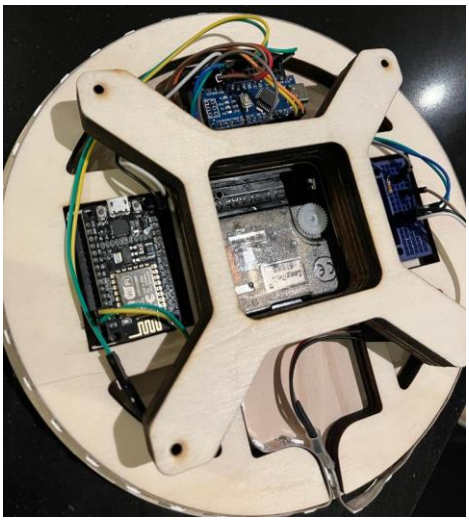


Figure 5-48: Inside of clock with additional features

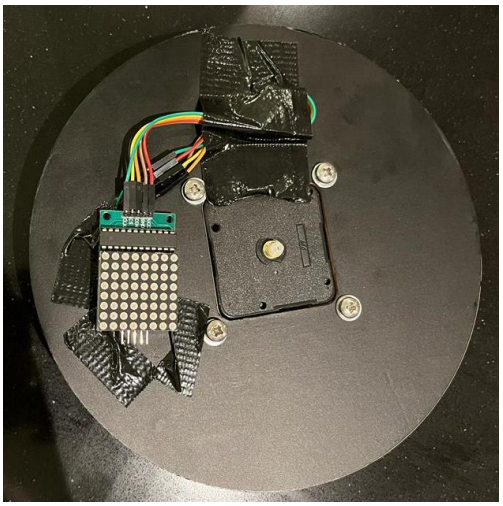


Figure 5-49: frontfase of the inside of the Clock

5.3.2 Software

The software used in consists of two parts, the operating system of the NodeMCU and the operating system of the Arduino Nano.

5.3.2.1 NodeMCU

The NodeMCU merely acts as a conduit for the data received from the NodeMCU in the remote. The remote streams data on its private network. To receive this data, the NodeMCU must be connected to the WiFi server provided by the remote NodeMCU. This connection is secured following the same methods for connecting to a normal WiFi network (725.1.2.2 Initiating HTTP requests and Webserver).

requestManager(){

Data is sent from the remote to three different addresses, this data can be obtained by sending a GET request to these addresses. The GET requests are initiated in the 'requestManager()' after which the data is put in the correct variables. For example, the method of requesting the latested pressed 'mood'on the remote can be seen below:

```
163   placeHolder = httpGETRequest(serverNameLatestMood);
164   if ((placeHolder != "--") && (placeHolder.length() > 0)) { // returns -1 if query is not part of dataLine
165     newMood = placeHolder; //change data in dataholder
166   }
```

(Fout! Verwijzingsbron niet gevonden.**)**

The 'requestManager()', sends requests to three addresses.

```
13  //Your IP address or domain name with URL path
14  const char* serverNameLatestMood = "http://192.168.4.1/latestmood";
15  const char* serverNameDisplayedData = "http://192.168.4.1/displayeddata";
16  const char* serverNameDisplayedDay = "http://192.168.4.1/displayedday";
```

```
18  String newMood;
19  String newDisplayedData;
20  String newDisplayedDay;
```

The responses are placed in the corresponding global variables.

The global variables are passed on to the Arduino Nano by making use of the Wire library.

sendToNano(){

The data is first collected in a String, after which it is placed in an array or Bytes

```
76  String data = currentDisplayedData + " " + String(currentDisplayedDay) + " " + currentMood;
77  byte dataInBytes[12];
78  data.getBytes(dataInBytes, 12);
```

This is sent, byte by byte, to the Arduino Nano. This communication takes place from the digital pins D1 and D2 of the NodeMCU, to analog pins A4 and A5 of the Arduino Nano.

```
82  for (int i = 0; i < 12; i++) {
83    Wire.write(dataInBytes[i]);
84  }
```

(Fout! Verwijzingsbron niet gevonden.**)**

5.3.2.2 Arduino Nano

De Arduino Nano zorgt ervoor dat de klok de data displayed, dit gebeurd aan de hand van de gegevens van de remote, die doorgestuurd worden door de NodeMCU. Deze gevens krijgt de Arduino Nano binnen via analoge pinnen A4 en A5, deze worden uitgelezen door de Wire library (reference). Dit gebeurt door de functie 'receiveEvent()', deze gaat in actie wanneer er data binnenkomt.

The Arduino Nano ensures the clock displays the proper data by using the data from the remote, which is forwarded by the NodeMCU. The Arduino Nano receives this data through analog pins A4 and A5, which are read out by the Wire library (reference). The function 'receiveEvent()' handles this communication and is run when data is received.

receiveEvent (){

The Wire library read out the incoming data byte for byte, and places in a character variable:

```
119  for (int i = 0; i = Wire.available(); i++) {
120    char c = Wire.read(); // receive byte as a character
```

This character is in turn placed in a variable:

```
if (i > 1 && i < 5) {
  mood = mood + String(c);
} else if (i > 5 && i < 7) {
  day = String(c).toInt();
} else if (i > 7) {
  displayMode = displayMode + String(c);
}
```

Which eventually places the data in the right global variables:

```
newDisplayedData = displayMode;
if (day > -1 && day < 8) {
  currentDisplayedDay = day;
}
```

(Fout! Verwijzingsbron niet gevonden.**)**

loop (){

In the function ‘loop()’, once every .5 seconds a request is send for new data to the NodeMCU. Subsequently the data is managed so the proper data to be displayed is placed in the global variables.

```
89  if (millis() > (checkTimer + 500)) {
90    checkTimer = millis();
91    Wire.requestFrom(8, 6);    // request 6 bytes from peripheral device #8
92    managerData();
93  }
```

(Fout! Verwijzingsbron niet gevonden.**)**

The loop functions also calls upon the ‘managerLed()’ function. This function makes sure one of three functions is runned, based upon the user input from the remote:

- ‘sleep()’
- ‘heart()’
- ‘activity()’

All three functions are structured roughly the same, each with their own color and symbol-related variations.

sleep (){

In de functies wordt allereerst berekend hoeveel LEDs op de ledstrip er aangezet moeten worden. Dit gebeurt door middel van een map. Deze map pakt de waarde van de currentSleepScore (e.g. 80), de minimale en maximale waardes die deze variabele kan hebben (0 to ‘maxSleepScore (100)), en converteerd het naar een hoeveelheid LEDs op de strip. In dit geval dus 80/100 van het totale aantal LED’s (40) is 32 LEDs.
In these functions, the amount of LEDs switched on is calculated. This is done by mapping the sleepscore into the number of LEDs.
By taking the value of the currentSleepScore (e.g. 80), the minimum and maximum values this variable can have (0 to 'maxSleepScore (100)), and convertingt this to a quantity of LEDs on the strip. So in this case 80/100 of the total number of LEDs (40) is 32 LEDs.

```
217  //maps out amount of LED's to be turned on
218  int switchedon = map(currentSleepScore, 0, maxSleepScore, 2, NUM_LEDS);
219
220  int green = 50;
221  int red = 190;
222  int blue = 255;
```

This calculated value is now used to switch on the amount of LEDs needed.

```
224  for (int i = 0; i < switchedon; ++i) {
225    leds[i] = CRGB(red, green, blue);
226  }
227  // LEDs are switched off which correspond to the area right of the slide knob
228  for (int i = switchedon; i < NUM_LEDS; ++i) {
229    leds[i] = CRGB::Black;
230  }
```

Finally a symbol is displayed by the Matrix:

```
232  //MATRIX CODE
233  printByte(moon);
```

(Fout! Verwijzingsbron niet gevonden.**)**

6. Evaluation

The last phase of the design process consists of testing and assessing the prototype produced in the Realization phase. The testing is done by means of User Test. Here, the participants will fill in a questionnaire to investigate on whether the established requirements from the Specification Phase have been achieved. A SUS score will also emerge from this questionnaire to decide whether the product is usable. The results of the test will be compared to the evaluation of the previous version of the product.

6.1 The test

The test took of by an explanation about the background research of the project and empathizing with the personas. After the initial elaboration on the topic space was given for the participant to ask questions, after which they received the questionnaire. A second moment for questions was provided. Now the prototype was shown. The participant was given the FitBit of the researcher to get a better understanding of the concept. After the participant took the time to test the device, they could ask the researcher questions. These questions were clarified to elaborate on the use of the clock.

The User Test was held with seven students pretending to be older adults by making use of the persona's (Persona'sAppendix D). Subsequently, the test was held with two older adults with the age of 57 and 56. The resulting answers were combined into the results.

6.1.1 The requirements

A general opinion and clarity on the requirements emerged from the questionnaire. The (un)achieved requirements will be discussed first. Subsequently the SUS score will be calculated followed by additional comments.

Internal factors (must)

Internal factors emerged from the test, not strongly. It was indicated the skull symbol resulted in the thought "I have to move because I don't want to die yet". The clock in general was said to be a reminder (and so motivation) the participants had to keep fit. One participant noted the device only provides visual advice, this would not motivate this person internally.

External factors (must)

External factors clearly emerged from the test. By watching the clock, participants were reminded they should take care of themselves, and whether or not they were doing well participating in activities. The external factor “the colors are beautiful, so the fuller the circle, the more beautiful the clock” additionally was provided. This is to be seen as a 'reward' for performance.

Intrusiveness and autonomy(must)

The User Test almost anonymously concluded the level on intrusiveness was negligible and considered the participation in the product as optional. The elaboration of the only participant labelling the device as obligation was the participant becoming motivated by the obligation. Another participant deemed the product "a beautiful additionality which does not cost any effort".

Individuality (must)

The product was considered to be individually appealing, provided the real-time information was working. Some participants indicated a wish for more personalized optionality displayed.

Usability (must)

Both the combination between, and the functionalities of, the remote and the clock was experienced as clear. The different colors used in the LED ring around the timepiece were specifically labelled ‘clear’. However, the mood buttons were experienced as confusing. Au contraire, the slider on the remote had to more obvious which day was indicated exactly. Additionally, participants indicated a small introduction tutorial was required to understand to remote.

6.1.2 The SUS score

The SUS score is calculated from second part of the questionnaire. This provides more clarity on the Usability and the Utility of the prototype.

The average result of the questions (OA1 and 2 are the older adults participating in the test):

SUS-score		
Angela-Jolanda-Jolanda-Dave-Angela-Jolanda-Dave-OA1-OA2	***Results***	***Average***
I think that I would like to use this product frequently	4-4-4-4-3-3-5-4-4	3,9
I found the product unnecessarily complex	2-3-2-1-2-2-2-2-2	2
I thought the product was easy to use	4-3-3-5-4-4-5-4-4	4,22
I think that I would need the support of a technical person to be able to use this product.	2-4-3-2-3-2-2-1-2	2,33
I found the various functions of this product were well integrated	3-4-4-5-5-4-4-5-5	4,33
I thought there was too much inconsistency in this product	2-2-3-2-1-2-2-2-2	2
I would imagine that most people would learn to use this product very quickly	4-3-4-4-4-4-5-4-5	4,11
I found the product very cumbersome to use	2-2-2-3-1-2-1-1-2	1,78
I felt very confident using the product	4-3-4-5-5-4-4-3-3	3,88
I needed to learn a lot of things before I could get going with this product	2-3-5-1-2-3-1-2-3	2,44
Total	SUS score of 76	

Table 6-1: Resulting SUS-Score of the user test

A SUS score of 75 out of 100 is labeled as 'good' and also statistically above average.

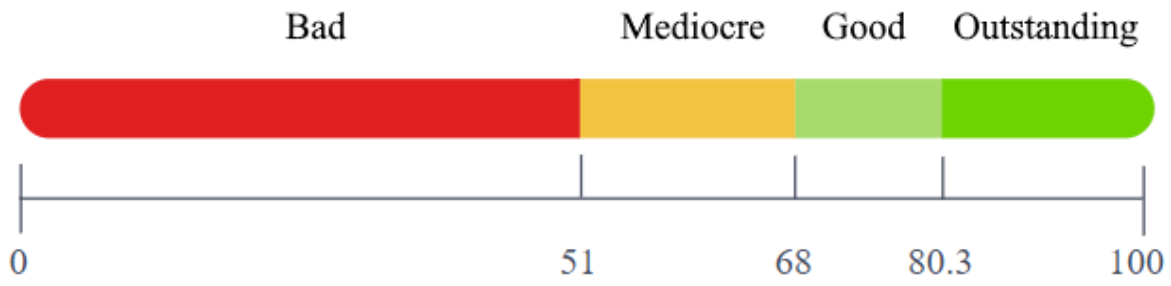


Figure 6-1: the SUS-score (UserSense, 2020)

6.1.3 Additional

Based on the questionnaire and the spoken comments, the test resulted in additional observation to be considered in the future research.

- The color of the mood buttons is confusing, green could match better by the 'good'-mood
- Inspiring text on the clock could motivate more

- Sliding knob for to select the moment in time did not work as expected
- An audio motivation should be considered
- A better separation between the age categories
- Providing feedback with more detail would be more motivational

6.2 Additional evaluation

In addition to the User Test, both the shortcomings in the design as achievements of the final prototype result will be evaluated by the designer. This will be determined based on the requirements not covered in the User Test. The requirements are filled in assuming how the prototype is intended. For example, while evaluating the requirement it is assumed the connection to the Google Fit application is working properly.

User Requirements		
Requirement	***Evaluation***	
Compatibility (Must)	The device is able to connect with different categories of external devices by making use of the Google Fit application	+
User preference (Must)	The to be connected to devices are choose-able by the user	+
Small steps (Should)	The prototype does not specifically allow for small steps with more achievable goals. However, the user can set a lower goal making it more attainable	+
Adjustable goals (Should)	By making use of the mood buttons, adjustable goals are integrated	+
Periodic reminders (Should)	N/A	-
Audio visual way (Should)	Visual, not auditory	-
Long- and short-term rewards (Should)	By showing the progression of the present day as well as that of the past, long- and short- term rewards are integrated	+
Social pressure (Could)	The symbols and the LED strip allow the user's environment to see the progression, which creates social pressure. the User test showed this would be experienced.	+
Direct feedback (Could)	By showing real time information, the users will immediately be shown how well or badly they are doing.	+
Benefits (Could)	N/A	-

Table 6-2: Evaluation of User Requirements

System Requirements		
Requirement	***Description***	
Privacy (Must)	By making use of the protection the Google servers offer, and by not storing data in the device, the product is relatively safe with regard to privacy	+
Buttons (Must)	The remote is equipped with buttons	+
Illumination (Must)	N/A	-
Power supply (Must)	Both the remote and the clock are powered by an USB-charger, which can be plugged into a wall socket (230v)	+
Integrating the existing (Should)	The device is integrated in a clock	+
Compact (Should)	Both the remote and the display only need a single wire	+
Display (Could)	A display is integrated in the clock	+
Battery (Could)	N/A	-

Table 6-3: Evaluation of System Requirements

7. Conclusion & discussion

This project aims to find a method to motivate older adults to a change of lifestyle by using technology and realize the method in a product. The lifestyle change should ensure these older adults participate in the recommended amount of exercise per week. This will ultimately ensure fitter and healthier older adults, with fewer age-related complaints. One of the final results will exist of a reduced overstaining of the health-care sector.

7.1 Literature review

The project started off with a literature review. Two types of motivational strategies emerged: internal and external. The product must integrate a combination of three of these strategies, to produce the most influential motivational effect. If successful, the product can take over from effectively working professionals and motivate a person to adopt an active lifestyle. In addition to the method of motivation, research has also been conducted into the method of delivering. This resulted in five types of requirements the product must meet if it is to be effectively adopted by older adults. These five types of requirements are characterized by five themes: intrusiveness, individuality, autonomy, utility, usability. At last, different technologies have been investigated. Concluding from this investigation is the final product must be able to be combined with a variety of technology, the type of technology must be of user preference.

Although clear requirements emerged from the literature review the product should ultimately meet, shortcomings in the study still exist. The conclusions drawn have all been assumed based on previous studies. These studies have been verified previously, but not confirmed by practical research in this project. Also, not all studies mentioned reflected the society. E.g., the research of Opezzo et al. (2021) consisted of only older women, whose average IQ also happened to be above average. A method of countering the shortcomings could have been by means of survey. Since there was no first-hand contact with older adults during the literature review, specific experiences have not been considered. Other problems many older adults encounter could have been included in the conclusion by making first-hand conversations. A survey among the older adults with open questions on this subject would have provided further insights that have not been considered.

7.2 The Creative Design Process

Several iterations have taken place in the Creative Design Process to arrive at a usable and producible final concept. By making use of the creativity and judgment of fellow students and alternating between the diverging and converging of the Creative Space, the process resulted in a concept taking many problems into consideration. In addition to the creativity of the students, the expertise of an expert was also used in selecting the right choice of concept. This concept was tested in various areas prior to the development and assembly: a user test where students pretended to be older adults ensured this.

Although the design process consisted of iterations and tests, the evaluation of the final product revealed additional points of feedback which should have been filtered out in an earlier phase. This is largely due to two obvious shortcomings of the User Test: the participants and the lack of a general test. The first User Test consisted of students who tried to empathize with the target group. These participants try to emphasize to the best of their abilities but will never be able to pinpoint the exact same problems the real users might have been able to detect. The second shortcoming is the lack of the general test: the User Test only consisted of testing different aspects of the product. This provides good feedback on these particular aspects but does not provide feedback on the product as a whole. This feedback was only received in the final evaluation.

7.3 Realization

The realization of the product has succeeded, except the finalization of the synchronized real time data. The concept has been developed in small steps, whereby most of the problems encountered have been solved immediately. The researcher did not yes possess the development skills for Arduino, this resulted in many small mistakes made in the first phase of development. These errors consisted of programming software incorrectly and connecting hardware incorrectly. The errors have been resolved in the later stages of the development.

A recommendation for a next project is to rewrite the frameworks already been built and use them to retrieve the real-time data. From several phases is concluded the real time data would be an addition. Investigation in the conversion of String variables into arrays of Char almost solves the entire problem. This would solve the problem of Heap Memory fragmentation, after which the data can easily be linked to the output (arduino nano) of the clock.

7.4 Evaluation

The evaluation of the product was conducted by both a User Test and the evaluation of the researcher of the product. In the User Test, students emphasized in older adults and provided their opinions on the product by questionnaire and SUS-score survey. In combination with the self-evaluation of the researcher, a conclusion can be drawn on whether the requirements have been met, and which areas still need improvement.

Most of the requirements regarding motivation, ease of use and integration with the target group have largely been met. Most participants experienced multiple internal and external motivational factors and indicated to be motivated by the device. The SUS score of 76 can be labeled as 'good', but is a deterioration compared to the SUS score obtained by the earlier version of the project (2.1.4 The Evaluation Phase). A recommendation is to focus on improving usability in a follow-up study.

In addition to the evaluation of the user test, most individual requirements have been met (Table 6-2). Seven out of ten user requirements are eventually met (provided the google Fit servers are connected). Only the *periodic reminders*, *audio visual* way of motivation and displaying *benefits* have not been met. Fortunately, these three factors were Should and Could priorities. The periodic reminders were investigated, but all proposed ideas were rejected in the User Test of the Specification phase. The Audio-Visual way can easily be added in a subsequent study: this can be achieved by placing a speaker in the clock. In addition, the benefits can still be shown on the display in the clock. Only two of the eight systematic requirements have not been met, consisting of the *illumination* (manual changing the brightness) and including a possible *battery*.

7.5 Conclusion

How should a device to motivate older adults to adapt to a more active lifestyle be designed?

By investigating by means of a literature study into the questions “how older adults can adopt a more active lifestyle?”, and “what requirements a device must meet in order to be picked up”. Followed by creating, developing and finalizing a concept by making use of the Creative Technology Design process, including multiple evaluations, and creative sessions. The design of a concept can be developed, which must be evaluated on and immersed again in the Creative Design process. After this, the prototype will have to be realized and evaluated again to perhaps become a fully-fledged and refined product.

Unfortunately, the last iteration was not able to take place in this project, the result is a prototype close to a fully working product. The recommendations and conclusions from this chapter will also have to be included in the next design to be able to optimize the final product.

8. Appendix

Appendix A. Elaboration for brainstormsession

How should a device to motivate older adults to adapt to a more active lifestyle be designed?

Het doel van dit afstudeerproject is om een apparaat te maken dat helpt bij het motiveren van oudere volwassenen om een actieve levensstijl aan te nemen. Het apparaat zal worden ontwikkeld met als hoofddoel om de voordelen van professionele coaching te integreren in het leven van oudere volwassenen. Voor een eenvoudige en brede mogelijke integratie moet het toestel voldoen aan bepaalde voor ouderen goedgekeurde toegankelijkheidseisen, die onder andere aan de hand van deze brainstormsessie opgesteld gaan worden. Na deze brainstormsessie worden prototypes ontwikkeld die na een gebruikerstest worden afgekeurd of verbeterd. Het eindproduct moet ouderen kunnen motiveren tot een actievere levensstijl.

Vooraf

Voorafgaand aan de brainstormsessie wordt de deelnemers gevraagd contact op te nemen met hun grootouders of andere bekende ouderen. Het doel van dit contact is om het inleven in de ouderen te vergemakkelijken. De deelnemers wordt gevraagd om ouderen te bevragen over de gemakken en ongemakken die zij ervaren met interactieve technologieën

De brainstormsessie

De brainstormsessie zal bestaan uit een aantal studentontwerpers en is bedoeld om richtlijnen op te stellen en ideeën te vergaren voor het uiteindelijke eindproduct van dit afstudeerproject. Allereerst zal er een samenvatting gegeven worden van de conclusie van het afgesloten achtergrond onderzoek. Na een vragen moment over de ontvangen informatie, zal het brainstormen beginnen.

Conclusie achtergrond onderzoek

Ouderen kunnen gestimuleerd worden om meer deel te nemen aan fysieke activiteiten door een combinatie van professionele coaching en een verscheidenheid aan motiverende strategieën. De praktijk leert dat professionele coaching ouderen helpt bij het aanpassen van een actieve levensstijl, maar dit is niet duurzaam. Wanneer professionals de oudere volwassenen een combinatie van drie interne en externe strategieën leren, kunnen deze worden gebruikt om een actievere levensstijl aan te nemen. Een interne strategie zou bijvoorbeeld een gedachten kunnen zijn die ertoe leidt dat die persoon wil gaan sporten. De gedachte "Ik herinnerde me hoe belangrijk het is om lichamelijk actief te zijn" is een voorbeeld van een interne strategie. Extrinsieke strategieën zijn strategieën buiten de persoon. Stel je iets of iemand voor die een persoon ertoe aanzet om actiever te zijn, bijvoorbeeld je tennisschoenen naast de deur zetten om te herinneren dat je moet tennissen.

Het doel van de het eindproduct gaat zijn om een apparaat te ontwikkelen wat 1 (of liever 3) van deze strategieën toe past, en daarmee de rol van de professional overneemt. Bij het maken van een motiverende technologie moet er rekening gehouden worden met 5 thema's:

De 5 thema's
Intrusiveness of opdringerigheid: de mate waarin een apparaat aanwezig is in het leven van de oudere volwassene. *Oudere volwassene willen hier graag zo min mogelijk last van hebben.*
Individuality of Individualiteit: de mate waarin een apparaat een individu onderscheidt van anderen en daardoor voor passende interactie zorgt. *Oudere volwassenen vinden veel individualiteit fijn.*
Autonomy of Autonomie: hoeveel het apparaat gebruikt moet worden om te functioneren. *Oudere volwassenen vinden een lage vereiste om te functioneren fijn.*
Utility of nut: de kwaliteit of staat van nuttig, winstgevend of nuttig. *Oudere volwassenen waarderen nuttige functies meer dan veel functies*
Usability of bruikbaarheid: de maatstaf voor hoe goed een specifieke gebruiker in een specifieke context een product/ontwerp kan gebruiken om een bepaald doel effectief, efficiënt en bevredigend te bereiken. *Oudere volwassenen willen graag dat het apparaat doet wat het lijkt te moeten doen*

Hoe dit in zijn werking gaan is uit te leggen aan de hand van een FitBit:

Intrusiveness: klein apparaat, toch aanwezig omdat het om de pols zit

Individuality: in combinatie met de app kan het apparaat individuele feedback geven

Autonomy: niet super veel interactie nodig, maar het moet gedragen worden om bruikbaar te zijn

Utility: niet veel functies, maar dekt voor de doelgroep de lading

Usability: simpel en straightforward om te gebruiken

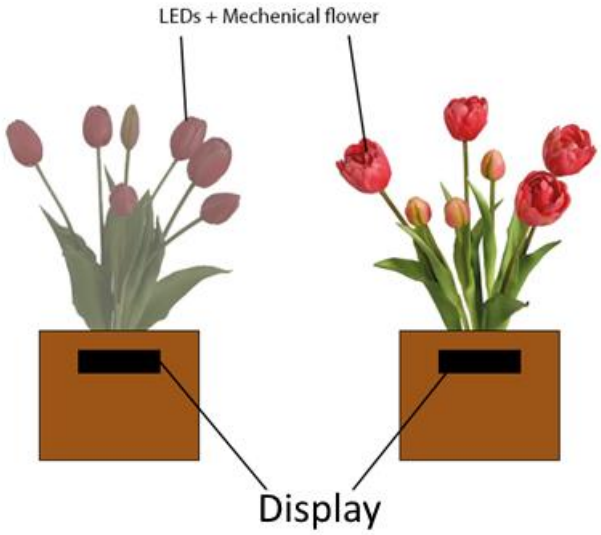
Vase of flowers

A vase with a fake plant connected to an activity tracker software (e.g., google fit). The plant flourishes when certain activity goals are met, and withers when weekly goals are not met.

The goal is to create a vase containing fake flowers that bloom each day the owner achieves the pre-set minimum amount of activity, and withers on the days this has not been achieved. The user can place the vase as decoration in a room often visited. Every time the user sees the plant, they will associate it with physical activity, and thus get an external motivation to move again. This plant will also bring an internal motivation. The owner will have a new motivation to exercise: “If I exercise more, my plant will become more beautiful”. Additionally, social motivations will also apply. The plant can be used to show to visitors whether the user has been active or. This will stimulate both the visitor and the user itself to become more active. The plant will also be able to make a sound or some other way of letting you know when the user has been inactive for too long.

Functionality

The device will consist of a physical construction in the form of a plant (kind of plant can vary), which has a connection with an application such as google fit. The application keeps track of the progress of the movement. An additional device such as a FitBit is required for this. Flowering or wilting will be simulated by means of lights (e.g. LEDs). This would be proportional to the number of consecutive days someone has met their minimum amount of activity. For example, if someone has been active enough for six out of seven days, the flower will be almost fully bloomed. If a person has been active enough for only one of the last seven days, the flower will have almost wilted. Finally, the plant can also pulse or make a sound when the google fit. app indicates that the user has been inactive for too long, for example when they have been sitting for too long.



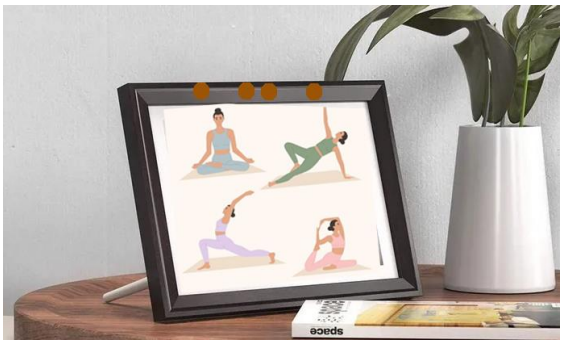
Picture Frame

A picture frame displaying the exercise to be participated in each day. After participating in the exercise pictures of family or friends are shown. Family or friends can send in motivational voice memos as well

The goal is to create a picture frame which displays various images and videos digitally. When a user has to do an exercise, the frame will give a notification and portray this exercise. Only after the user indicates the exercise has been done, the photo frame will show a photo of friends or family. The motivation is to reward the user with a nice photo when a certain task is completed. In addition, the users are also reminded when they are supposed to participate in the exercises. Finally, the users are reminded on how to perform the exercise. A possible extra functionality could be a message recorded by relatives or friends, which can be used for motivation. This could motivate the user to be even more inclined to participate in certain exercises.

Functionality

The device will consist of a display build into a frame, which runs software connected to a certain agenda containing type of exercises. The software contains the functionality to save videos and photos both exercises and personal. Additionally, the device has buttons to which are used by the user to indicate an exercise was participated in.



Frame picture: https://nymag.com/strategist/article/best-digital-picture-frames.html

Excercise picture: https://www.freepik.com/free-vector/international-yoga-day-hand-drawn-flat-yoga-poses-collection_25914493.htm#query=exersice&position=6&from_view=search#position=6&query=exersice

Scoreboard

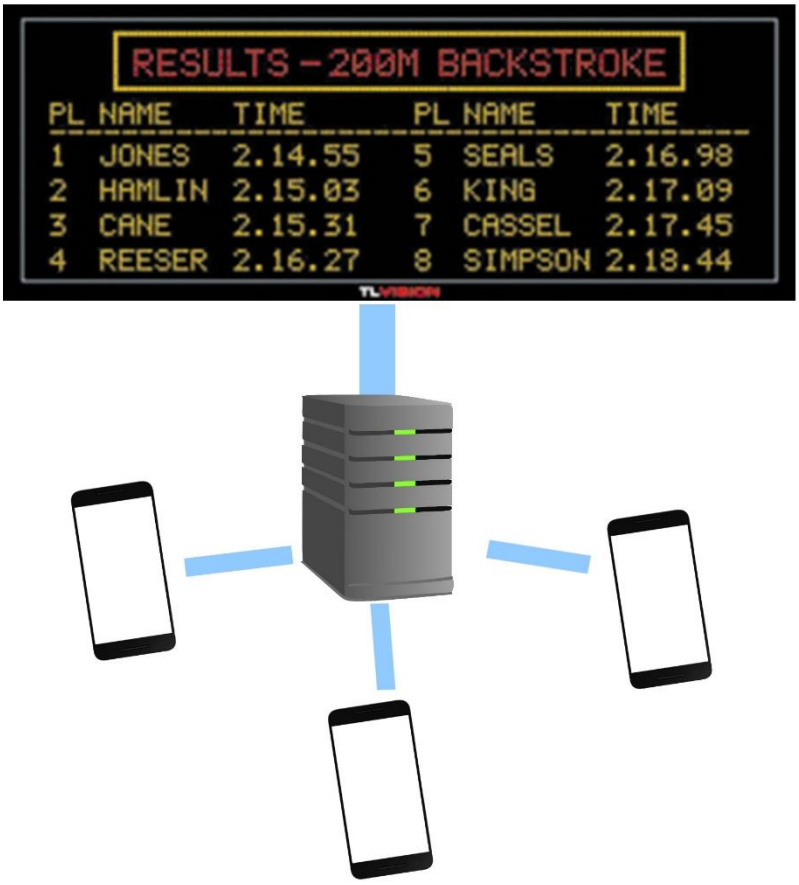
A scoreboard a group of older adults (for example in a care home) uses to keep track of the "activity score". On this board the names and the number of steps or exercises are displayed.

The goal is to create a scoreboard on which the activity score of the connected users can be shown. When users are more active, they will rank higher on the board, which can be a motivation to be more active. The social pressure and social prestige aspects are very important here. The device can for instance be hung in the hall of a care home. People passing by are reminded of the score and will also talk about it, which reminds them of becoming more active.

Functionality

The device will consist of a big display connected to software collecting the activity data of multiple connected accounts. These accounts will be connected to, for example, a Fitbit, or other devices that track a person's activity.

Scoreboard: http://www.trans-lux.com/products/fair-play-scoreboards/matrixdisplays



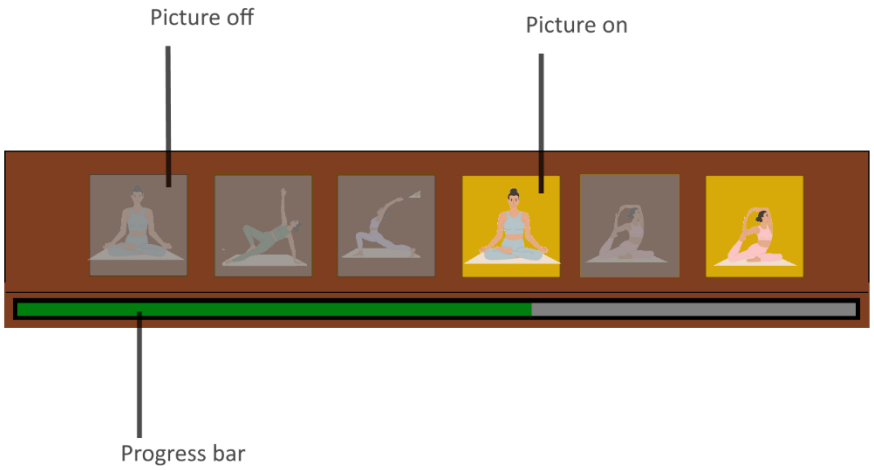
Blok Calendar

A calendar of the week consisting of blocks, where cards can be inserted. There is an exercise on each card. Each day, preset lights will illuminate which exercise the person should do.

The goal is to create a long box containing different pictures with exercises or movements, which light up based on which exercises have to be participated in for that day. The users do not have to remember which exercises to do on which day. Certain cards can be turned on or off, according to the exercises for that day. The box can also keep track of how long each exercise has to be done with a light bar. The user has to fill in this themselves when they are done with each exercise.

Functionality

The device will consist of a long box with multiple compartments intended for inserting pictures. The pictures will be printed on plastic or glass, which makes them translucent. The compartments contain lights that can be turned on and off by means of a motherboard, which in turn is connected to the internet. When the light in a compartment is turned on, the picture will light up. Because the picture consists of an image of an exercise, it will be clear that this exercise must be done. At the bottom of the box is a line of LED lights, which is also connected to the motherboard. This line will function as a timer, the lights will go out one by one after a certain time. The box will need buttons to indicate whether an exercise is being or has been done. The compartment will have to be assembled in a way the plates/figures can be easily moved in and out.



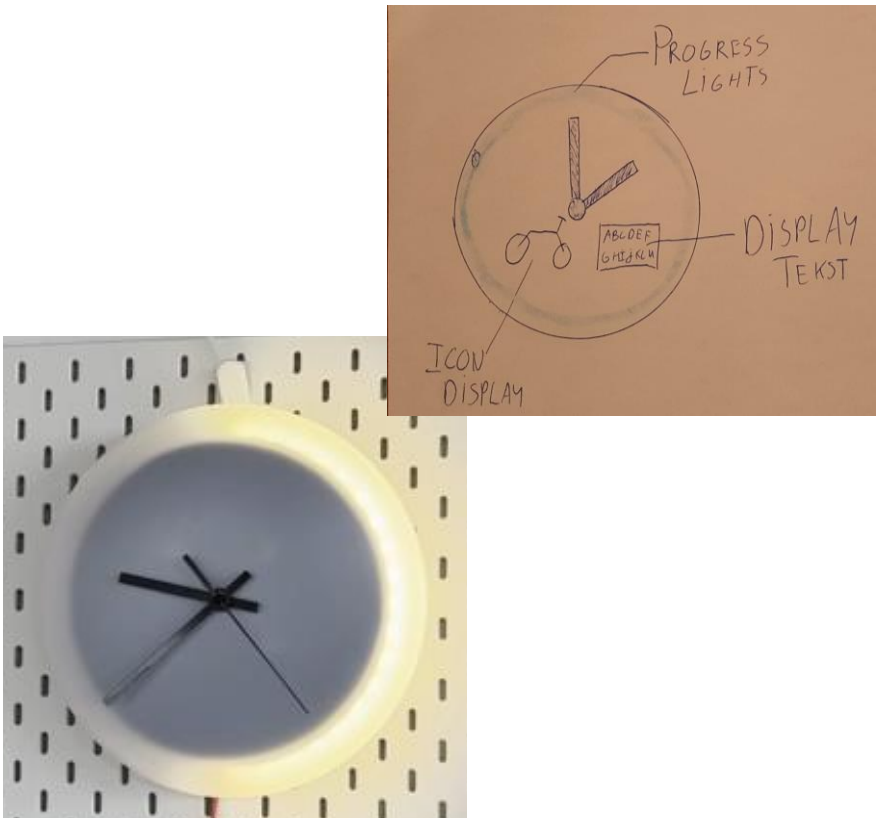
Expanding the existing Clock

Mentioned ideas can implemented on the clock made at Hengeveld. Currently it has the function to display steps taken each day, this can be extended by displaying additional health related features.

The goal is to expand the device previously made by Hengeveld with additional features. The device is a clock that shows the percentage of steps a user has taken towards their daily goal. The clock is connected to the Oura Ring. The users are attended on their progress of the day, which is a motivational strategy. Additional features could exist of additional health related information displayed, a reminder when the person is inactive for too long, a sound or notification when a “friend” is exercising, etc.

Functionality

The clock consists of a round back plate with hands on it. The back plate is transparent with LED lamps on all sides, so that a circle can light up around the hands. This circle is used to indicate the number of steps. Additional features could include displaying other features such as this person's heart rate, the number of minutes that person has been (and still needs to be) active, how far a person is on their weekly goal, and more information that the connected devices collect. An additional device can be made to remotely change the display of the device. The clock could also be made compatible with other devices besides the Oura Ring.



Appendix C. Elaboration on user test 1

How should a device to motivate older adults to adapt to a more active lifestyle be designed?

Het doel van dit afstudeerproject is om een apparaat te maken dat helpt bij het motiveren van oudere volwassenen om een actieve levensstijl aan te nemen. Het apparaat zal worden ontwikkeld met als hoofddoel om de voordelen van professionele coaching te integreren in het leven van oudere volwassenen. Het apparaat in kwestie is een al bestaande klok uitbreiden. Deze klok geeft naast de tijd ook het aantal stappen van een gebruiker per dag aan, relatief tot zijn dagelijkse doel. In het afstudeerproject zal de klok worden aangepast en verbeterd door middel van bepaalde features en functies. In deze gebruikerstest gaan we deze kenmerken en functionaliteiten in een simpele versie testen.

Voorafgaand aan de user wordt de deelnemers gevraagd zich in te leven in een specifiek persoon, dit zal gebeuren door middel van een persona. Een persona is een gedetailleerde omschrijving van iemand uit de doelgroep van het product, in dit geval oudere volwassenen. Nadat de deelnemer de persona heeft doorgelezen en voldoende ingeleefd is in de persona, zal de deelnemer de klok in zijn huidige staat te zien krijgen en even mogen gebruiken. Ondertussen zal de deelnemer verteld worden om welke functionaliteit het gaat. Alle vragen van de deelnemer zullen hierbij gelijk beantwoord worden.

De gebruikerstest

De gebruikerstest zal nu plaatsvinden. De deelnemer zal het prototype in handen krijgen en zelf mogen “besturen”. Dit kan ofwel doordat de deelnemer de functie zelf probeert te gebruiken, waarna de onderzoeker toepast wat er zou gebeuren (deelnemer drukt op het papieren knopje, onderzoeker laat de nep lichtjes branden). De deelnemer zal ondertussen aangemoedigd worden om zijn mening of het prototype uit te leggen. Nadat de deelnemer het prototype heeft gebruikt zal er tijd zijn om de gegeven vragenlijst in te vullen. Hierna krijgt de deelnemer nog de kans om zijn overige opmerkingen over de functionaliteiten van het prototype op te schrijven.

JOLANDA WILLEMS

88 jaar

FEITJES OVER MIJ

Weduwe
Gepensioneerd
Thuiswonend
Vroeger topsport dressuur

HOBBY'S

Paardrijden
Wandelen
Kletsen
Met kleinkinderen spelen

WIE BEN IK

Mijn naam is Jolanda Willems, vroeger werkte ik als verpleegster in een bejaardentehuis, waar ik zelf gelukkig nog niet in zit! Ik hield vroeger heel erg van paardrijden, maar helaas heb ik die tijd ver achter mij gelaten. Sinds dat ik daarmee gestopt ben probeer ik regelmatig te wandelen met mijn wandelclubje, maar dat lukt helaas niet elke week meer. Af en toe ga ik naar een paardrijwedstrijd om daar te kijken, maar meestal kijk ik hier fanatiek naar vanaf mijn eigen huis.

STELLINGEN OVER MIJZELF

Ik zoek manieren om met een technologie te experimenteren als ik erover zou horen

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Van mijn leeftijdsgenoten ben ik de eerste om nieuwe technologieën uit te proberen.

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Ik ben enthousiast in het uitproberen van nieuwe technologieën.

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Ik vind het leuk om te experimenteren met nieuwe technologieën.

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

TECHNOLOGISCHE VAARDIGHEDEN

Toen ik zelf in het bejaardentehuis werkte zag ik veel verveelde mensen, daarom heb ik vroeg besloten met de tijd mee te gaan. Na computerlessen zie ik mijzelf als gemiddeld vaardige gebruiker

ANGELA A. TRAM

78 jaar

FEITJES OVER MIJ

Vrijgezel
Gepensioneerd
Thuiswonend
Erg gezellig!
Fit met rugklachten

HOBBY'S

Reizen
Lezen
Wandelen
Tuinieren

WIE BEN IK

Mijn naam is Angela Annelies Tram, vroeger was ik werkende als stewardess, maar nu geniet ik al een paar jaar alleen van mijn welverdiende pensioen. In mijn eerdere jaren na mijn pensioen ging ik graag op cruises, maar de laatste jaren kan je mij vooral vinden met een goed boek in de hand. Ook wandel ik om de week met mijn vriendinnen, wat altijd erg gezellig is! Vroeger stond ik elke zondag in de tuin om mijn tulpen te onderhouden, maar helaas lukt dat nu niet meer door mijn slechte rug.

STELLINGEN OVER MIJZELF

Ik zoek manieren om met een technologie te experimenteren als ik erover zou horen

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Van mijn leeftijdsgenoten ben ik de eerste om nieuwe technologieën uit te proberen.

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Ik ben enthousiast in het uitproberen van nieuwe technologieën.

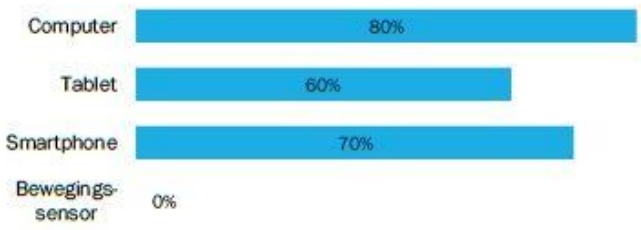
Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

Ik vind het leuk om te experimenteren met nieuwe technologieën.

Helemaal oneens	Oneens	Neutraal	Eens	Helemaal eens

TECHNOLOGISCHE VAARDIGHEDEN

Ik heb al tijden lang een computer en ben sinds een paar jaar ook mijn smartphone en tablet aan het ontdekken. Hierover valt nog veel te leren, maar ik snap ze zeker wel!



DAVE BROEKMAN

94 jaar

FEITJES OVER MIJ

Weduwnaar
Gepensioneerd
Wonend in een serviceflat
Universitair geschoold

HOBBY'S

Fietsen
Wandelen
TV-kijken
Spelletjes spelen

WIE BEN IK

Mijn naam is Dave Broekman, vroeger werkte ik als architect en daarna manager voor een groot bouwbedrijf. Na mijn pensioen heb ik een tijdlang samen met mijn vrouw in het buitenland gewoond, maar sinds haar overlijden woon ik weer in Nederland. Vroeger fietste en wandelde ik graag, maar nu zit ik liever op de bank voor de tv. Het hoogtepunt van mijn week is wanneer mijn kinderen of kleinkinderen op bezoek komen. We praten dan gezellig of doen spelletjes.

STELLINGEN OVER MIJZELF

Ik zoek manieren om met een technologie te experimenteren als ik erover zou horen

Helemaal oneens | Oneens | Neutraal | Eens | Helemaal eens

Van mijn leeftijdsgenoten ben ik de eerste om nieuwe technologieën uit te proberen.

Helemaal oneens | Oneens | Neutraal | Eens | Helemaal eens

Ik ben enthousiast in het uitproberen van nieuwe technologieën.

Helemaal oneens | Oneens | Neutraal | Eens | Helemaal eens

Ik vind het leuk om te experimenteren met nieuwe technologieën.

Helemaal oneens | Oneens | Neutraal | Eens | Helemaal eens

TECHNOLOGISCHE VAARDIGHEDEN

Om mij minder te vervelen tijdens mijn pensioen heb ik veel computerlessen genomen. Ook ben ik heel geïnteresseerd in mijn smartphone en gebruik ik een FitBit

Appendix E. Elaboration on evaluation

How should a device to motivate older adults to adapt to a more active lifestyle be designed?

Het doel van dit afstudeerproject is om een apparaat te maken dat helpt bij het motiveren van oudere volwassenen om een actieve levensstijl aan te nemen. Het apparaat zal worden ontwikkeld met als hoofddoel om de voordelen van professionele coaching te integreren in het leven van oudere volwassenen. Het apparaat in kwestie is een al bestaande klok uitbreiden. Deze klok geeft naast de tijd ook het aantal stappen van een gebruiker per dag aan, relatief tot zijn dagelijkse doel. In het afstudeerproject is de klok aangepast en verbeterd door middel van bepaalde features en functies. In deze gebruikerstest gaan we evalueren hoe deze aanpassingen hebben uitgepakt.

De gebruikerstest

De gebruikerstest zal nu plaatsvinden. De deelnemer zal het prototype in handen krijgen en zelf mogen besturen.De deelnemer zal ondertussen aangemoedigd worden om zijn mening of het prototype uit te leggen. Nadat de deelnemer het prototype heeft gebruikt zal er tijd zijn om de gegeven vragenlijst in te vullen. Hierna krijgt de deelnemer nog de kans om zijn overige opmerkingen over de functionaliteiten van het prototype op te schrijven.

Appendix F. NodeMCU code for connection with Google

```
#include <ESP8266WiFi.h>
#include "ESP8266WiFi.h"
#include <WiFiClientSecure.h>
#include "ESP8266HTTPClient.h"

#include <ArduinoJson.h>

//ID for access to the google servers
String client_id = "158513123306-
etih04etdbta86v1pglcte6fb88rb0mh.apps.googleusercontent.com";
String redirect_uri = "https://patatras.nl/redirectSvR.php";
String client_secret = "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";
String access_token = "";
String refresh_token = "";
String webserverIP = "";
String scopes = "https://www.googleapis.com/auth/fitness.heart_rate.read
https://www.googleapis.com/auth/fitness.heart_rate.write
https://www.googleapis.com/auth/fitness.sleep.read
https://www.googleapis.com/auth/fitness.body.read
https://www.googleapis.com/auth/fitness.activity.write
https://www.googleapis.com/auth/fitness.sleep.write
https://www.googleapis.com/auth/fitness.activity.read
https://www.googleapis.com/auth/fitness.body.write";

// Replace with your network credentials
const char* ssid = "Studieruimte";
const char* password = "willinksstudiepaleis";

// Set web server port number to 80
WiFiServer server(80);
HTTPClient httpsClient;
WiFiClientSecure clientSecure;

// Variable to store the HTTP request
String header;

//Variables to display the current displayed data
String displayedData[2];
int hearthRate;

// Current time
unsigned long currentTime = millis();
// Previous time
unsigned long previousTime = 0;
// Define timeout time in milliseconds (example: 2000ms = 2s)
const long timeoutTime = 2000;

void setup() {
  Serial.begin(9600);
  delay(1000); //small delay to open up the serial monitor
  //connect to WiFi
  WiFi.begin(ssid, password);
  Serial.println("Connecting to " + String(ssid) + " :");
  Serial.println("------------");
  //prints . when device is trying to connect to the WiFi
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.print(".");
  }
```

```
  Serial.println("Connected to WiFi Network");
  // Print local IP address and start web server
  Serial.println("IP address: ");
  webserverIP = WiFi.localIP().toString();
  Serial.println(webserverIP);

  server.begin();
}

void loop() {
  WiFiClient client = server.available();   // Listen for incoming clients

  if (client) {                             // If a new client connects,
    Serial.println("New Client.");          // print a message out in the serial
port
    String currentLine = "";                // make a String to hold incoming data
from the client
    currentTime = millis();
    previousTime = currentTime;

    while (client.connected() && currentTime - previousTime <= timeoutTime) { //
loop while the client's connected
      currentTime = millis();

      if (client.available()) {             // if there's bytes to read from the
client,
        char c = client.read();             // read a byte, then
        Serial.write(c);                    // print it out the serial monitor
        header += c;

        if (c == '\n') {                    // if the byte is a newline character
          // if the current line is blank, you got two newline characters in a row.
          // that's the end of the client HTTP request, so send a response:
          if (currentLine.length() == 0) {
            Serial.println("delay start");
            delay(500);
            Serial.println("delay over");
     // HTTP headers always start with a response code (e.g. HTTP/1.1 200 OK)
     // and a content-type so the client knows what's coming, then a blank line:
            client.println("HTTP / 1.1 200 OK");
            client.println("Content-type:text/html");
            client.println("Connection: close");
            client.println();

            //methods containing all the functionalities of the  server
            webServerFunctions();

            //the response to the client, this is the whole webpage
            webServer(client);

            // Break out of the while loop
            break;
          } else { // if you got a newline, then clear currentLine
            currentLine = "";
          }
        } else if (c != '\r') {  // if you got anything else but a carriage return
character,
          currentLine += c;      // add it to the end of the currentLine
        }
      }
    }
    // Clear the header variable
    header = "";
```

```
    // Close the connection
    client.stop();
    Serial.println("Client disconnected.");
    Serial.println("");

    Serial.println("end:  ");
    Serial.println(ESP.getFreeHeap());
  }
}

void webServerFunctions() {
  String query = "";

  //checks if the adres contains a 'state' query (-1 if does not contain),
  //can't dig to deep in the header
  if (header.indexOf("state=") > 0 && header.indexOf("state=") < 20) {
    //gets the 'state=' query from the header

    String splittedQuery = splitToQuery(header, "state=");

    // sends the authorization token to google and returns payload
    String payload = tokenToGoogle(splittedQuery, "authorization");

    //updates the access and refreshtokem
    updateTokens(payload);
  }

  if (header.indexOf("postData=") > 0) {
    String sortData = splitToQuery(header, "postData=");
    String bucketTime = splitToQuery(header, "bucketTime=");
    String startTime = splitToQuery(header, "startTime=");
    String endTime = splitToQuery(header, "endTime=");

    searchDataBase(sortData, bucketTime, startTime, endTime);
  }
  if (header.indexOf("getData=") > 0) {
    String sortData = splitToQuery(header, "getData=");
    String startTime = splitToQuery(header, "startTime=");
    String endTime = splitToQuery(header, "endTime=");

    searchDataBase(sortData, "", startTime, endTime);
  }
}

void searchDataBase(String sortData, String bucketTime, String startTime, String
endTime) {
  String dataSourceId = "";
  String result = "";

  if (sortData.equals("estimated_steps")) {
    dataSourceId =
"derived:com.google.step_count.delta:com.google.android.gms:estimated_steps";
    result = retreiveAggregateData(dataSourceId, bucketTime, startTime, endTime);
  }

  if (sortData.equals("heart_rate")) {
    dataSourceId =
"derived:com.google.heart_rate.bpm:com.google.android.gms:merge_heart_rate_bpm";
    result = retreiveGetData(dataSourceId, startTime, endTime);
  }

  if (result != "") {
    displayedData[0] = sortData;
```

```
    displayedData[1] = result;
  }
  dataSourceId = "";
  result = "";
}

String retreiveGetData(String dataSourceId, String startTime, String endTime) {

  String fullURL = "https://www.googleapis.com/fitness/v1/users/me/dataSources/" +
dataSourceId + "/datasets/" + startTime + "-" + endTime;

  DynamicJsonDocument responseDoc(2048);
  deserializeJson(responseDoc, sendGetRequest(fullURL));
  JsonObject obj = responseDoc.as<JsonObject>();

  String requestedData = obj["dataset"][0]["point"][0]["value"][0]["intVal"];

  //clears document
  obj.clear();

  return "requestedData";
}

String sendGetRequest(String dataSourceId) {
  //start request
  httpsClient.begin(clientSecure, dataSourceId);

  //set headers of post requeset
  httpsClient.addHeader("Authorization" , access_token);

  int httpCode = httpsClient.GET();

  //retreive response from body, place it in a string
  String responseString = httpsClient.getString();

  Serial.println("response code: ");
  Serial.println(httpCode);

  //stop request
  httpsClient.end();

  return responseString;
}

String retreiveAggregateData(String dataSourceId, String bucketTime, String
startTime, String endTime) {
  //initiate an empty json doc

  DynamicJsonDocument doc(1024);

  String requestBody = "";

  //fill the doc with parameters
  doc["aggregateBy"][0]["dataSourceId"] = dataSourceId;
  doc["bucketByTime"]["durationMillis"] = bucketTime ;
  doc["startTimeMillis"] = startTime;
  doc["endTimeMillis"] = endTime;

  //place json into String
  serializeJson(doc, requestBody);
  doc.clear();
  doc.~BasicJsonDocument();
```

```
  //send String to the post request, body of response is returned
  Serial.println("body of POST request : " + requestBody);

  String response = sendPostRequest(requestBody);

  //retreive response from body, place it in JsonDocument
  DynamicJsonDocument responseDoc(2048);
  deserializeJson(responseDoc, response);

  String requestedData =
responseDoc["bucket"][0]["dataset"][0]["point"][0]["value"][0]["intVal"];
  Serial.println("requested data is : " + requestedData);

  //clears document
  responseDoc.clear();
  requestBody = "";
  Serial.println("requested data: " + requestedData);
  return requestedData;
}

String sendPostRequest(String httpRequestBody) {

  //start request
  httpsClient.begin(clientSecure,
"https://www.googleapis.com/fitness/v1/users/me/dataset:aggregate/");

  //set headers of post requeset
  httpsClient.addHeader("Authorization" , access_token);
  httpsClient.addHeader("Content-Type", "application/json");
  httpsClient.addHeader("Content-Length", String(httpRequestBody.length ()));

  //post the request with given body (json string), httpCode is returned
  int httpCode = httpsClient.POST(httpRequestBody);

  //retreive string from body of response
  String responseString = httpsClient.getString();

  Serial.println("response code: ");
  Serial.println(httpCode);
  Serial.println(responseString);

  //stop request
  httpsClient.end();

  //returns body of response
  return responseString;
}

String splitToQuery(String authToken, String query) {
  //string to store the new query
  String splittedQuery = "";

  //have to covert the string to a char* so each symbol can be adressed seperatly
  char * duplicate = strdup(authToken.c_str());

  //checks for index of the aksed query, and make sure the variable itself is
skipped
  int startIndex = authToken.indexOf(query) + query.length();

  //loops through full query from after the '='
  for (int i = startIndex; i <= strlen(duplicate); i++) {
```

```
    // stops the for loop and returns the query when either the line stops, or '&'
is found
    if (String(duplicate[i]).equals(" ") || String(duplicate[i]).equals("&")) {
      return splittedQuery;
    }

    // adds the symbols to the String
    splittedQuery = String(splittedQuery) + String(duplicate[i]);
  }
  return "ERROR: QUERY DID NOT END";
}

String textToURL(String text) {
  //String to store the new URL-text

  String URLtext = "";

  //have to covert the string to a char* so each symbol can be adressed seperatly
  char * duplicate = strdup(text.c_str());

  //loops through text
  for (int i = 0; i < strlen(duplicate); i++) {

    //converst the / symbol to text
    if (String(duplicate[i]).equals(String("/"))) {
      URLtext = URLtext + "%2F";
    } else if (String(duplicate[i]).equals(String(" "))) {
      URLtext = URLtext + "%20";
    } else if (String(duplicate[i]).equals(String(":"))) {
      URLtext = URLtext + "%3A";
    } else {
      URLtext = URLtext + String(duplicate[i]);
    }
  }
  return URLtext;
}

String tokenToGoogle(String token, String sortToken) {
  clientSecure.setInsecure(); //sets client to insecure in order to easily connect
to the google servers

  httpsClient.begin(clientSecure, "https://www.googleapis.com/oauth2/v4/token");

  //String to store requestbody in
  String httpRequestBody = "";

  if (sortToken.equals("authorization")) {
    //converts all necessary tokens to it to URL compatible text and paste them in
the requestBody
    httpRequestBody = "code=" + textToURL(token) +
                      "&redirect_uri=" + textToURL(redirect_uri) + "&client_id=" +
textToURL(client_id) +
                      "&client_secret=" + client_secret +
"&scope=&grant_type=authorization_code";
  } else if (sortToken.equals("refresh")) {
    //converts all necessary tokens to it to URL compatible text and paste them in
the requestBody
    httpRequestBody = "&client_secret=" + client_secret +
"&grant_type=refresh_token&refresh_token=" +
                      textToURL(refresh_token) + "&client_id=" +
textToURL(client_id);
  }
```

```
  //adds headers to the request
  httpsClient.addHeader("Content-Type", "application/x-www-form-urlencoded");
  httpsClient.addHeader("Content-Length", String(httpRequestBody.length()));

  int httpCode = httpsClient.POST(httpRequestBody);

  //gets body of the response
  String payload = httpsClient.getString();

  Serial.println("response code: ");
  Serial.println(httpCode);
  Serial.println("response load: ");
  Serial.println(payload);

  httpsClient.end();

  return payload;
}

void updateTokens(String payload) {
  DynamicJsonDocument doc(1024);
  deserializeJson(doc, payload);
  JsonObject obj = doc.as<JsonObject>();

  String tAccess_token = obj["access_token"];

  if (tAccess_token != NULL) {
    access_token = "Bearer " + tAccess_token;
    Serial.println("ACCES TOKEN UPDATED");
  }

  String tRefresh_token = obj["refresh_token"];
  if (tRefresh_token != NULL) {
    refresh_token = tRefresh_token;
    Serial.println("REFRESH TOKEN UPDATED");
  }
}

void webServer(WiFiClient webPage) {

  String premissionURL = "https://accounts.google.com/o/oauth2/auth?client_id=" +
client_id + "&response_type=code&redirect_uri=" + redirect_uri +
"&approval_prompt=force&access_type=offline&scope=" + textToURL(scopes) +
"&state=http://" + webserverIP;

  // Display the HTML web page
  webPage.println("<!DOCTYPE html><html>");
  webPage.println("<head><meta name=\"viewport\" content=\"width=device-width,
initial-scale=1\">");
  webPage.println("<link rel=\"icon\" href=\"data:,\">");
  // CSS to style the on/off buttons
  // Feel free to change the background-color and font-size attributes to fit your
preferences
  webPage.println("<style>html { font-family: Helvetica; display: inline-block;
margin: 0px auto; text-align: center;}");
  webPage.println(".button { background-color: #195B6A; border: none; color: white;
padding: 16px 40px;");
  webPage.println("text-decoration: none; font-size: 30px; margin: 2px; cursor:
pointer;}");
  webPage.println(".button2 {background-color: #77878A;}</style></head>");

  // Web Page Heading
  webPage.println("<body><h1>ESP8266 Web Server</h1>");
```

```
  // button to get authorization from the google API
  webPage.println("<p><a href=\"" + premissionURL + "\"><button class=\"button
button2\">Give Permission</button></a></p>");
  webPage.println("<p></p>");
  //  webPage.println("<p><a
href=\"?sortData=estimated_steps&startTime=1654646400000\"><button class=\"button
button2\">Estimated Steps</button></a></p>");
  webPage.println("<p></p>");
  webPage.println("<p> Access token :" + access_token + "</p>");
  webPage.println("<p> Refresh token :" + refresh_token + "</p>");
  webPage.println("<p> ----------------------------------</p>");
  webPage.println("<p>" + displayedData[0] + "  :  " + displayedData[1] + "</p>");

  webPage.println("</body></html>");

  // The HTTP response ends with another blank line
  webPage.println();
}
```

Appendix G. NodeMCU code for Remote

```
#include <ESP8266WiFi.h>
#include "ESPAsyncWebServer.h"
#include "ESPRotary.h";

ESPRotary rotator = ESPRotary(14, 12); //D5 and D6

String buttonData = "";
String analogData = "";
String rotatorData = "";

int maxDays = 8;

int analogState = 0;
int buttonState[4];
int rotatorState;

int buttonName[4] = {D0, D1, D2, D7}; //last one is for potentiometer analog
int analogName = A0;

int counter;

// Set your access point network credentials
const char* ssid = "ESP8266-Access-Point";
const char* password = "123456789";

// Create AsyncWebServer object on port 80
AsyncWebServer server(80);

String readButtons() {
  return buttonData;
}

String readRotator() {
  return rotatorData;
}

String readPotentiometer() {
  return analogData;
}

// method for the rotary button
void Rotaryrotate(ESPRotary& rotator) {
  rotator.getPosition();
}

void setup() {
  // Serial port for debugging purposes
  Serial.begin(9600);
  Serial.println();

  // Setting the ESP as an access point
  Serial.print("Setting AP (Access Point)…");
  // Remove the password parameter, if you want the AP (Access Point) to be open
  WiFi.softAP(ssid, password);

  IPAddress IP = WiFi.softAPIP();
  Serial.print("AP IP address: ");
  Serial.println(IP);

  server.on("/latestmood", HTTP_GET, [](AsyncWebServerRequest * request) {
    request->send_P(200, "text/plain", readButtons().c_str());
  });
  server.on("/displayeddata", HTTP_GET, [](AsyncWebServerRequest * request) {
    request->send_P(200, "text/plain", readRotator().c_str());
```

```
  });
  server.on("/displayedday", HTTP_GET, [](AsyncWebServerRequest * request) {
    request->send_P(200, "text/plain", readPotentiometer().c_str());
  });

  bool status;
  // Start server
  server.begin();

  Serial.println("server has started ");
  Serial.println("--------------------");
  Serial.println("");
  // initialize the pushbutton pin as an input:
  pinMode(buttonName[0], INPUT);
  pinMode(buttonName[1], INPUT);
  pinMode(buttonName[2], INPUT);
  pinMode(buttonName[4], INPUT); //click rotator button
  pinMode(analogName, INPUT);

  //rotary button
  rotator.setChangedHandler(Rotaryrotate);
}

void loop() {
  updateRotaryState();
  updateButtonState();

  updateAnalogState();
  rotator.loop();
}


void updateAnalogState() {
  counter = counter + 1;

  if(counter == 50){
    analogState = analogRead(analogName);
    counter = 0;
  }
  //  int analogState = 0;
  Serial.println(analogState);

  if (analogState < 64) {
    analogData = String("7");
  }  else if (analogState > 73 && analogState < 219) {
    analogData = String("6");
  } else if (analogState > 219 && analogState < 365) {
    analogData = String("5");
  } else if (analogState > 365 && analogState < 511) {
    analogData = String("4");
  } else if (analogState > 511 && analogState < 657) {
    analogData = String("3");
  } else if (analogState > 657 && analogState < 803) {
    analogData = String("2");
  }  else if (analogState > 803 && analogState < 949) {
    analogData = String("1");
  } else {
    analogData = String("0");
  }
}

void updateRotaryState() {
  //  buttonState[4] = digitalRead(buttonName[4]);
  //  Serial.println(buttonState[4]);

  if (rotator.getPosition() > 0) {
    rotatorState = rotator.getPosition() % 60;
  } else {
```

```
    rotatorState = 60 + (rotator.getPosition() % 60);
  }

  if (rotatorState < 20) {
    rotatorData = "sleep";
  } else if (rotatorState < 40) {
    rotatorData = "heart";
  } else if (rotatorState < 60) {
    rotatorData = "activity";
  } else {
    rotatorData = "--";
  }
}


void updateButtonState() {
  buttonState[0] = digitalRead(buttonName[0]);
  buttonState[1] = digitalRead(buttonName[1]);
  buttonState[2] = digitalRead(buttonName[2]);


  if (buttonState[0] == 1) {
    buttonData = "good";
  } else if (buttonState[1] == 1) {
    buttonData = "normal";
  } else if (buttonState[2] == 1) {
    buttonData = "bad";
  }
}
```

```
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <WiFiClient.h>

#include <ESP8266WiFiMulti.h>
ESP8266WiFiMulti WiFiMulti;

#include <Wire.h>

const char* ssid = "ESP8266-Access-Point";
const char* password = "123456789";

//Your IP address or domain name with URL path
const char* serverNameLatestMood = "http://192.168.4.1/latestmood";
const char* serverNameDisplayedData = "http://192.168.4.1/displayeddata";
const char* serverNameDisplayedDay = "http://192.168.4.1/displayedday";

String newMood;
String newDisplayedData;
String newDisplayedDay;

String currentMood = "good";
String currentDisplayedData = "--";
int currentDisplayedDay = 0;

unsigned long previousMillis = 0;
const long interval = 5000;

void setup() {
  Serial.begin(9600);
  Serial.println();

  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("Connected to WiFi");


  Wire.begin();
}

void loop() {
  unsigned long currentMillis = millis();

  if (currentMillis - previousMillis >= interval) {
    // Check WiFi connection status
    if ((WiFiMulti.run() == WL_CONNECTED)) {

      requestManager();

      updateCheckers();

      Serial.println("mood :  " + currentMood);
      Serial.println("dataType :  " + currentDisplayedData);
      Serial.println("day :  " + String(currentDisplayedDay));


      // save the last HTTP GET Request
```

```
      previousMillis = currentMillis;

    } else {
      Serial.println("WiFi Disconnected");
    }
    delay(500);

  }
}

void sendToNano() {

  String data = currentDisplayedData + " " + String(currentDisplayedDay) + " " +
currentMood;
  byte dataInBytes[12];
  data.getBytes(dataInBytes, 12);

  Wire.beginTransmission(11);

  for (int i = 0; i < 12; i++) {
    Wire.write(dataInBytes[i]);
  }

  Wire.endTransmission();
}


//---------------------------------------
// below are the functionality methods
void updateCheckers() {
  if (!newMood.equals(currentMood)) {
    moodChecker();
    sendToNano();
  }
  if (!newDisplayedData.equals(currentDisplayedData)) {
    displayChecker();
    sendToNano();
  }
  if (newDisplayedDay.toInt() != currentDisplayedDay) {
    dayChecker();
    sendToNano();
  }

}

void moodChecker() {
  //checks the current mood given by the remote
  Serial.println("newMood :");
  Serial.println(newMood);
  if (newMood.equals("good")) {
    currentMood = "good";
    return;
  }
  if (newMood.equals("normal")) {
    currentMood = "normal";
    return;
  }
  if (newMood.equals("bad")) {
    currentMood = "bad";
    return;
  }
  return;
}

void displayChecker() {
  if (newDisplayedData.equals("sleep")) {
    currentDisplayedData = "sleep";
    return;
```

```
  }
  if (newDisplayedData.equals("heart")) {
    currentDisplayedData = "heart";
    return;
  }
  if (newDisplayedData.equals("activity")) {
    currentDisplayedData = "activ";
    return;
  }

  return;
}

void dayChecker() {
  currentDisplayedDay = newDisplayedDay.toInt();
}


//--------------------------------------------------------
//Below are the system methods

void requestManager() {
  String placeHolder = "--";

  placeHolder = httpGETRequest(serverNameLatestMood);
  if ((placeHolder != "--") && (placeHolder.length() > 0)) { // returns -1 if query
is not part of dataLine
    newMood = placeHolder; //change data in dataholder
  }

  placeHolder = httpGETRequest(serverNameDisplayedData);
  if ((placeHolder != "--") && (placeHolder.length() > 0)) { // returns -1 if query
is not part of dataLine
    newDisplayedData = placeHolder; //change data in dataholder
  }

  placeHolder = httpGETRequest(serverNameDisplayedDay);
  if ((placeHolder != "--") && (placeHolder.length() > 0)) { // returns -1 if query
is not part of dataLine
    newDisplayedDay = placeHolder; //change data in dataholder
  }

}

String httpGETRequest(const char* serverName) {
  WiFiClient client;
  HTTPClient http;

  // Your IP address with path or Domain name with URL path
  http.begin(client, serverName);

  // Send HTTP POST request
  int httpResponseCode = http.GET();

  String payload  = "--";

  if (httpResponseCode > 0) {
    Serial.print("HTTP Response code: ");
    Serial.println(httpResponseCode);
    payload = http.getString();
  }
  else {
    Serial.print("Error code: ");
    Serial.println(httpResponseCode);
  }
  // Free resources
  http.end();
  return payload;
```

Appendix I. Arduino Nano code for Clock

```
#include <FastLED.h>
#include <MD_Parola.h>
#include <MD_MAX72xx.h>
#include <SPI.h>

#define DATA_PIN 3
#define LED_TYPE WS2812
#define COLOR_ORDER GRB
#define NUM_LEDS 40
CRGB leds[NUM_LEDS];
#define FRAMES_PER_SECOND 120
uint8_t gHue = 0;

//Connection to the NodeMCU
#include <Wire.h>

//MATRIX
#define HARDWARE_TYPE MD_MAX72XX::FC16_HW
#define MAX_DEVICES 1
#define CS_PIN 10

// Create a new instance of the MD_Parola class with hardware SPI connection:
MD_Parola myDisplay = MD_Parola(HARDWARE_TYPE, CS_PIN, MAX_DEVICES);


int MaxBrightness = 50;

long maxStepsCurrentDay = 10000;
long maxStepDisplayedDay = 10000;
long currentDisplayedSteps = 7531;

int currentDisplayedDay = 0;

long currentSleepScore = 11;
long maxSleepScore = 100;

long currentHeartRate = 67;
boolean pulse = false;
int fader = 0;
long pulsTimer = 0;

long checkTimer = 0;

String newDisplayedData = "activ";


const uint8_t F_HEART = 1;
const uint8_t W_HEART = 9;
const uint8_t PROGMEM heartSymbol[F_HEART * W_HEART] =  // beating heart
{
  0x0e, 0x11, 0x21, 0x42, 0x84, 0x42, 0x21, 0x11, 0x0e
};



void setup() {

  //setup to receive data from the nano
  Wire.begin(11);        // join i2c bus (address optional for master)
  Wire.onReceive(receiveEvent);


  Serial.begin(9600);
```

```
  FastLED.addLeds<LED_TYPE, DATA_PIN, COLOR_ORDER>(leds,
NUM_LEDS).setCorrection(TypicalLEDStrip);
  FastLED.setBrightness(MaxBrightness);

  // moet deze er nog bij fso>? Misschien werkt hij?
  //  pinMode(DATA_PIN, OUTPUT);

  // Intialize the object:
  myDisplay.begin();
  // Set the intensity (brightness) of the display (0-15):
  myDisplay.setIntensity(map(MaxBrightness, 0, 255, 0, 15));
  // Clear the display:
  myDisplay.displayClear();
}

void loop() {

  if (millis() > (checkTimer + 500)) {
    checkTimer = millis();
    Wire.requestFrom(8, 6);    // request 6 bytes from peripheral device #8
  }

  managerData();
  managerLED();

  FastLED.show();

  //    Serial.println("LEDSTRIP STARTS HERE :");
  //    for (int i = 0; i < NUM_LEDS; i++) {
  //      Serial.print(String(leds[i]));
  //      Serial.print(" - ");
  //    }
  //    CRGB tempColor = leds[1];
  //    Serial.println();
  //    Serial.println(FastLED.getBrightness());
  //    Serial.println(String(tempColor.red) + "-" + String(tempColor.green) + "-"
+ String(tempColor.blue));
  //    Serial.println("LEDSTRIP ENDS HERE :");

}

//function which triggers when data is received
void receiveEvent(int howMany) {
  String displayMode = "";
  String mood = "";
  int day = 0;

  String response = "";

  Serial.println("start wire   :   ");
  for (int i = 0; i = Wire.available(); i++) {
    char c = Wire.read(); // receive byte as a character

    Serial.print(c);

    response = response + String(c);

    if (i > 1 && i < 6) {
      mood = mood + String(c);
    } else if (i > 6 && i < 7) {
      day = int(c);
    } else if (i > 7) {
      displayMode = displayMode + String(c);
    }
  }
  Serial.println("|" + displayMode + "----" + mood + "----" + day);
  newDisplayedData = displayMode;
```

```
  Serial.println("response : " + response);

  if (day > 0 && day < 8) {
    currentDisplayedDay = day;
  }

}

void managerData() {

  if (newDisplayedData.equals("sleep")) {
    if (currentDisplayedDay == 0) {
      currentSleepScore = 80;
    } else if (currentDisplayedDay == 1) {
      currentSleepScore = 60;
    } else if (currentDisplayedDay == 2) {
      currentSleepScore = 30;
    } else if (currentDisplayedDay == 3) {
      currentSleepScore = 40;
    } else if (currentDisplayedDay == 4) {
      currentSleepScore = 70;
    } else if (currentDisplayedDay == 5) {
      currentSleepScore = 20;
    } else if (currentDisplayedDay == 6) {
      currentSleepScore = 60;
    } else if (currentDisplayedDay == 7) {
      currentSleepScore = 10;
    }

  } else if (newDisplayedData.equals("heart")) {
    currentHeartRate = 30;

  } else {
    //HUIDIGE DAG MET FUNCTIES
    if (currentDisplayedDay == 0) {
      currentDisplayedSteps = 5000;
      maxStepDisplayedDay = maxStepsCurrentDay;
    } else if (currentDisplayedDay == 1) {
      currentDisplayedSteps = 7531;
      maxStepDisplayedDay = 10000;
    } else if (currentDisplayedDay == 2) {
      currentDisplayedSteps = 6671;
      maxStepDisplayedDay = 7000;
    } else if (currentDisplayedDay == 3) {
      currentDisplayedSteps = 3113;
      maxStepDisplayedDay = 5000;
    } else if (currentDisplayedDay == 4) {
      currentDisplayedSteps = 8890;
      maxStepDisplayedDay = 7000;
    } else if (currentDisplayedDay == 5) {
      currentDisplayedSteps = 3134;
      maxStepDisplayedDay = 5000;
    } else if (currentDisplayedDay == 6) {
      currentDisplayedSteps = 3432;
      maxStepDisplayedDay = 5000;
    } else if (currentDisplayedDay == 7) {
      currentDisplayedSteps = 5001;
      maxStepDisplayedDay = 7000;
    }
  }
}

void managerLED() {

  if (newDisplayedData.equals("sleep")) {
    sleep();
  } else if (newDisplayedData.equals("heart")) {
    heart();
```

```
  } else {
    activity();
  }
}

void sleep() {
  //maps out amount of LED's to be turned on
  int switchedon = map(currentSleepScore, 0, maxSleepScore, 2, NUM_LEDS);

  int green = 50;
  int red = 190;
  int blue = 255;

  for (int i = 0; i < switchedon; ++i) {
    leds[i] = CRGB(red, green, blue);
  }
  // LEDs are switched off which correspond to the area right of the slide knob
  for (int i = switchedon; i < NUM_LEDS; ++i) {
    leds[i] = CRGB::Black;
  }

  //MATRIX CODE
  myDisplay.setTextAlignment(PA_CENTER);
  myDisplay.print("Sleep");


}

void heart() {
  int red = 255;

  fader = fader + (MaxBrightness / 5);

  if (millis() > (pulsTimer + (60000 / currentHeartRate))) {
    pulsTimer = millis();
    pulse = true;
  }

  if (pulse) {
    fader = 0;
    pulse = false;
  }
  //  Serial.println("fader : " + String(fader));
  FastLED.setBrightness(MaxBrightness - fader);

  // all leds are pulsating
  for (int i = 0; i < NUM_LEDS; ++i) {
    leds[i] = CRGB(red, 0, 0);
  }


  //MATRIX
  myDisplay.setIntensity(map((MaxBrightness - fader), 0, 255, 0, 15));
  myDisplay.setTextAlignment(PA_CENTER);
  myDisplay.print(String(currentHeartRate));

}


void activity() {
  // maps the steps in comparison to the daily goal to the amount of LEDs
  int switchedon = map(currentDisplayedSteps, 0, maxStepDisplayedDay, 2, NUM_LEDS);
  //gradiant of Green and read are given through
  int green = map(currentDisplayedSteps, 0, maxStepDisplayedDay, 0, 255);
//hoeveelheid groen 1 led in zich heeft
  int red = map(currentDisplayedSteps, 0, maxStepDisplayedDay, 255, 0);
//hoeveelheid rood 1 led in zich heeft
```

```
  delay(100);
  // dit is t feesie als het doel gehaald is
  if (currentDisplayedSteps > maxStepDisplayedDay) {
    EVERY_N_MILLISECONDS( 10 ) {
      gHue++;
    }
    fadeToBlackBy( leds, NUM_LEDS, 10);
    int pos = random16(NUM_LEDS);
    leds[pos] += CHSV( gHue + random8(64), 200, 255);
    FastLED.delay(20);
  }
  else if (currentDisplayedSteps > maxStepDisplayedDay) {
    for (int i = 0; i < switchedon; ++i) {
      leds[i] = CRGB(0, 25, 0);
    }
  }
  else {
    // 3) Light up the LEDs
    // Only LEDs are switched on which correspond to the area left of the slide
knob
    for (int i = 0; i < switchedon; ++i) {
      leds[i] = CRGB(red, green, 0);
    }
    // LEDs are switched off which correspond to the area right of the slide knob
    for (int i = switchedon; i < NUM_LEDS; ++i) {
      leds[i] = CRGB::Black;
    }
  }
  myDisplay.setSpriteData(heartSymbol, W_HEART, 1, heartSymbol, W_HEART, 1);
  myDisplay.displayText(heartSymbol, PA_PRINT, 50, 1000, PA_SPRITE, PA_SPRITE);
  myDisplay.displayAnimate();
}
```