ADHKey

Final report Engineering Design (4WBB0)

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ADHkey

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1 Group effectiveness

In the group there was a lot of diversity in majors and background. There were two people from Biomedical Engineering. This was the only study represented by more than one student. For the rest of the group, there was one Mechanical Engineering student, one Computer Science student, one Data Science student, one Psychology and Technology student and one Industrial Design student. This overall gave a very varying group which meant there was usually one or more students specialized in the problem at hand.

How the strengths were used

During this project most of the group members focused on what they had already learned during their study.

The mechanical engineer made the design for the product, based on input from the group. They also made this design into a CAD model. After this CAD model was made, they 3D printed the product multiple times to get the right size. They also worked on the electronics and getting the final product to actually work. These are all things they had already done during their study or on their own out of interest. Their strengths were used to get the technical part of the product to work.

The computer scientist obviously has their strength in programming, however during the study one does not actually code that much themselves, it is mostly math. Howbeit, they have programmed in their own time a lot and has made apps before this project. The apps UI was based on a design made by another group member. Their interests and strengths were used because they created an app for our project and programmed the Arduino.

The industrial designer has his strengths in design and the design process. He created branding for the product and drew all the concept designs really professionally to show what they would look like and how they would work and move. They also created the design of the app and focused on how the product would be as user friendly as possible.

The biomedical students had a harder time using the specific knowledge from their study in this project since there were no real medical applications. They were interested in expanding their knowledge to the technical side of the project and had strengths in report writing. They worked out the concept designs using their strength with making very clear overviews. They also helped keep everyone on track because of their experience with working on group projects.

The data scientist has also written a lot of reports and had strengths in that area, they also worked on the testing part of the project since their background focuses on data analysis which is usually used during testing.

The psychology and technology student had background knowledge about ADHD from personal experience and also theory from their study. They also had experience with writing and experience with making a design that was easy to use. They also have a lot of experience with planning for group projects and made a planning for this project. Using this planning and the rubrics they also helped to keep everything on track.

Avoiding conflict in the group

During this project we did not encounter many challenges in our ability to function a group. This was avoided by actively focusing on being respectful and building a team spirit. Before the first meeting with the tutor we already met with the group to have a brief introduction. We shared our major, possibly useful skills that could be used during the project and just a more general introduction about ourselves. This little meeting before the project really started, helped to break the ice and understand each other better. It also made the first meeting a lot more productive since the introductions could be skipped. This gave us a bit of a head start and meant we never really fell behind.

Never falling behind significantly probably played a big part in why there were never any major conflicts in our group since the stress levels were never very high. Even in the week of the midterm presentation and the week leading up to it there was not a lot of stress in the group. The only time things started to become a bit tight was in the week of the final presentation since making the product work fully was a bit harder than first thought. However this still did not result in conflict because at the end of the course we knew each other quite well and could handle criticism from each other.

Being able to handle criticism from each other and being able to give this criticism without being rude is another contributor to avoiding conflict in our group. In our group, criticism was never handed out to hurt someone or bring someone down, but only to help the other person. Everyone was very open to receiving it and the person giving the criticism made sure it was well substantiated and there was a lot of positive feedback which helped balance the criticism. Another reason which helped to not get offended by criticism is the mutual respect in our group that was instantly established.

This respect was established and shown by always listening to each others contribution to the project and seeing all contributions as equally important. The people working on the technical side did not look down on the people working on more creative sides and vice versa. Actually it was usually met with a lot of excitement. This way no one felt like their contributions were useless and no conflict started rooted in feeling like you are not being taken seriously, which is often the underlying cause of conflict in groups with such different backgrounds.

Overcoming challenges as a group

As stated in the last paragraph the group never faced any major challenges. The only conflict that ever arose was the fact that the meetings always had to be very rushed since there was so much to discuss from the SSA's. This sometimes made people feel like they were not fully heard and not able to say everything they wanted to. This was never really solved with a big solution and talking everything out, but people were generally paying more attention to let everyone speak after a particularly rushed and chaotic meeting. This meant people were less inclined to interrupt others because they knew their turn to speak would come. Besides this there were no conflicts or even major disagreements.

2 Design goal

The focal area that was chosen is Health and Well-being. This is because all members of the group found the most interest in picking this focal area as opposed to the other ones provided by the course. A good starting point for the focal area is to look at one (mental) health disorder and see whether a certain target audience with a problem arises. People with ADHD struggle with many, and a wide variety of problems in their daily lives, which many others can experience as well, though usually less often. Typical struggles can include a lack of time awareness, difficulty in organizing, planning, balancing tasks and activities and forgetfulness [8]. Because of these struggles, it is worth further investigating in what ways innovation can be brought to the user in this particular focal area. Therefore, the aim is to help people with ADHD in their daily lives, or anyone struggling with similar problems. It will be narrowed down to the moment they enter the doorstep of their homes, which will soon be explained.

It is important to mention that the particular problems that relate to ADHD that are being tackled are difficulty with organizing and remembering daily tasks. The reason behind this choice is that items of organization are generally in high demand, meaning that a greater audience is reached with our product. Also, choosing to address forgetfulness is something that can impact one's daily, or at least weekly, routine. This means a quite simple product can make a big impact.

The issue with a lot of the things that are already on the market and that are targeted towards people with ADHD, or much rather targeted more broadly towards people looking for organization in their lives, is that the products are only useful when carried out in your lifestyle [2]. For instance, if a student purchases an organizer that has space for everything they need to bring to a lecture, it will only be an added value in their everyday life if they are reminded to bring the organizer and fill it with the items they need to bring with them. And the problem lies in the fact that no current product motivates its user to use it. Someone with ADHD needs to be reminded in some way to use the product otherwise, it is deemed useless. Therefore, the final product allows the user to build up a habit of using it. The action that is paid particular attention to is the consumer putting their keys away when they come home. It is again amazing to have an organizer for something, in this case for your keys, but it is vital to stimulate the behavior of using the organizer. According to a lost and found survey by Pixie [1], 28% of the survey-takers lose their keys at once a week. Which has not only cost them time but also money. 60% of the people from the same survey were late for their work because they were looking for a missing item. Others have argued with their families and others missed flights. It can even be said that losing your keys is wasteful. After all, when a key is permanently lost it has to be replaced, which costs resources. Hence, these arguments reinforce the choice of our focus.

The type of product that can resolve the chosen issue is any kind of organizing product meant for the organization of a set of keys, with the ability to actively remind the user to make use of it. It could help the target audience to keep their daily life more organized and it will motivate them to keep it that way. Not only is it something that the current market is not covering, but this problem is also suitable for our group. It is fairly simple but can be brought to more fancy upgrades, allowing for more development along the way if time is on our side. The product can be created under the given budget and in the given time, so it is the best option to go with.

From research about ADHD, it can be concluded that the struggle often lies in the fact that these people have a continuous, rambling train of thought [3]. They come home and might already be doing a bunch of things after each other and then completely forget what happened to their keys when they came through the door. This also holds for anyone who tends to be messy or forgetful. And having a designated spot for an item can help you move with more ease throughout the day. Multiple blogs created by people within the ADHD community support this claim. If you want to go out of the door, your keys should be in arms-reach. The last thing you want is to frantically search for your keys when running on a schedule or when your mind is already through that door. It can relieve the user from a lot of unnecessary stress, meaning that their overall well-being will improve. This improvement is "key" for our chosen focal area.

The user should want this product because as just pointed out it can take away the stress of looking for your keys, especially when it is bad timing. The product can prevent being in that situation in the first place. For people with ADHD, this could be a quality-of-life purchase.

3 Functional design and solutions

The next part describes a list of functions that our product can have, ranked according to the MoSCoW method. This is followed by a solution encyclopedia, which offers a set of solutions for each of our functions. Inside the MoSCoW list are discussed multiple risks, of which possible solutions are defined after the solution encyclopedia.

MoSCoW list:

Must have

- Budget (functional): The production costs of the keychain can not be more than 70 euros. This means that everything that is used for our product together must not add up to a price higher than 70 euros.
- Safety (functional): The keychain will be safe to use due to its well-designed case and the reduction of privacy risks and malfunctions. It needs to be fire-safe, but also won't hurt anyone by holding the device. The measurements that must be taken are government safety points for electrical devices on the market that follow CE marking [7].
- Well-being (functional): The device promotes well-being by helping someone create a structural habit of holding onto their belongings, which is in this case their keys. By helping the user to put their keys in a dedicated spot, they will experience less stress when leaving the house.

Should have

- Negative feedback (technical): The device has to notify the user when the keychain has not been placed in its rightful spot after an x amount of time. The negative feedback should also help the user find the keys in their house. The device should be locatable within a 10 meter radius. A second feedback route could be added to ensure the user is notified of the wrong placement, even if they're not within a 10 meter radius of the keychain. A risk is that some locatable feedback methods might limit the use of the product to people with impairments. Also, the time for feedback might be too short when the user needs the keys for longer than an x amount of time.
- Charge indication (technical): The level of charge of the battery of the keychain should be indicated by two signals, one on the device and one that's not on the device. There will be way to indicate when the charge of the battery is between 100%-50%. When the charge is 50%-15%, the device will indicate this to the user. Lastly, when the device has a charge $<$15%, there will be a third indication. A risk would be that some charge indication methods might limit the use of the product to people with impairments.
- Trackable location (technical): The device will keep track of the user's location to know when the user reaches home. It thus should have a trackable location with a maximum error of 5 meters. The risk of tracking the user's location is that it invades their privacy.
- Positive feedback (technical): When the device is correctly placed on the dock, positive feedback should be given to the user. The positive feedback should last for not more than 30 seconds, since it should be long enough to be noticeable and understood, but not too long to disturb the user's activities.
- Indicate time (technical): When the location is detected in close proximity to the user's house, the timer starts. This timer needs to be implemented in the keychain. Additionally, the timer needs to stop and reset when you leave the house again so that the product has an invariable system.
- Attachment for keys (technical): The device should be attachable to the user's keys. This attachment should be strong enough to hold the force of 1 kg since our keychain will weigh less than this.

Could have

- Rechargeable (technical): The battery used could be rechargeable at the dock, which will be connected to the main power supply. This way the device is always charged, does not need to be taken apart, and is more sustainable. Seeing as the device will be used throughout the cycle of at least 1 day, the battery life should be longer than or equal to 1 day (24 hours). A risk of a rechargeable battery is that its battery life will slowly decrease, which causes problems with the sustainability of the device.

- Phone connection (technical): The user's phone can connect with the keychain to create a two-way route for several functions, like negative feedback when the keychain is not placed on the dock in time, a timer to know when this time is over (should not have a delay longer than 1 minute to maintain matching feedback) and also to know the charge when the keychain is not close-by. This connection should be strong enough to remain connected in a radius of 10 meters with no walls blocking the signal, and in a radius of 5 meters in case there is a wall. This way the app and the device's workings should be usable in the average household [4]. The risk behind this is that the phone could have run out of battery or it could be connected to other devices which lowers its performance with the keychain.
- Diversity for dock placement (functional): The docking station for the keychain could be placed in a wide variety of interiors so that it is efficient for more people. The user could place it on a wall or on a flat structure.
- Brand (functional): Having a well-designed brand will mean more satisfaction in using the app and keychain [6].
- Sustainable materials (functional): The keychain and its compartments are built with the future of planet Earth in mind. This implies recycled, bio-degradable materials or long-lasting materials so that the environment is considered.
- Well-designed case (functional): The keychain could be a compact, comfortable, and robust case that easily fits inside someone's pocket and does not fall apart upon impact with the floor. Moreover, it should not be too heavy with a strong hook that does not break. Lastly, the case could open up for easy access when something needs to be replaced or examined. The case should have a dimension not larger than 12x6x3 cm and be strong enough to withstand a weight under 1 kg since the components will weigh less than this and the case should not break during daily activities.
- Visual weight (functional): To prevent creating the size-weight illusion (the effect when an individual under/overestimates the weight of an object based on color or material), the keychain its weight could be adjusted. This can avoid the feeling that the product is cheaply made [5].
- Encouraging effect (functional): Adding an encouraging effect could help the user create more fun in learning the new habit. It encourages the user to maintain the usage of the product.

Won't have

- Fidget on the device (functional): Since our intended target audience is people with ADHD, a fidget on the device would give the keychain more use outside of its regular use.
- A variant for the hearing impaired (functional): The device uses sound to give feedback to the user. An alternative version could be created that does not rely on sound.
- Customization (functional): The device is customizable to fit the user's taste. It has different variants for the feedback given so that it satisfies the users liking.
- Pick-up reminder (technical): The device also reminds you to not forget to take your keys when leaving the house.

Solution encyclopedia:

- Be safe to use = follow the safety measures for CE marking [7]
- Negative feedback = sound, light (or the absence of sound or light), moving scales, notification on phone, some button that has not been clicked into place if the location is wrong
- Charge indication = light (or absence of light), a pictogram of the battery level on a screen, level of charge indicated by a number on a screen, notification or indication via a phone or app, automated charge based on timing (e.g. timer switch)
- Trackable location = have GPS, connect to the home WiFi, UWB, door sensors, proximity sensor, connect to Bluetooth of a device that's home
- Positive feedback = sound, light (or the absence of sound or light), notification on phone, a pop-up feature of for example a cute character, device snaps or is stuck in the designated place

- Indicate time = digital timer, hourglass system, stopwatch, kitchen timer, winding clock, pendulum clock, electric clock, stopwatch
- Be attachable = hook, clasp, rope or fabric, magnetized system, keychain ring
- Rechargeable = rechargeable battery, USB charge, motion-powered battery (similar to a watch), dynamo, solar panel
- Phone connection = WiFi connection, Bluetooth connection, cable connection, UWB connectivity, infrared connectivity
- Diversity = a D-ring so it can be hung on a nail, sticky material like double-sided tape so that it can stick to the wall, flat bottom so it can stand on a table, hook so it can hang underneath a shelf. If the keychain is rechargeable, the dock should have a cable long enough to reach a nearby port.
- Have a brand design = attractive brand name, nice color palette, logo, font/typography, social media presence, neat app design
- Be made sustainably = long-lasting batteries, biodegradable materials, sustainable app development (for example using cloud locations), minimal waste during creation, careful design (making sure no material is wasted on bad designs)
- Well-designed keychain case = material, sizing, weight, shape, capable of being opened if needed, easy-to-grip material
- Visual weight = adding extra weight in the case, using heavier materials for the case, heavier compartments, adding magnets inside, decreasing the size of the case
- Encouraging effect = streak on the app, prizes on the app, competition with friends via the app, dopamine-releasing feature on the dock, dopamine-releasing feature on the keychain

Solutions to the described risks in the MoSCoW list:

- Locatable feedback might not be suitable for people with impairments. Therefore a combination of feedback methods can be used. Sound is locatable by blind people and light could be used for the users who are hard of hearing. The latter also aids any user who is trying to find their keys in the dark. There is no use of language or difficult actions when using the product. Therefore, cognitive or language-impaired people will have no problem using the product. People with epileptic seizures are also able to use the product if the light doesn't blink between 5 to 30 flashes per second.
- Locatable feedback can be highly annoying when the keys are needed around the house: A snooze button could be added to the keys in order for it to not blare out feedback methods whenever it is not desired. This snooze button shouldn't be allowed to work more than once, as it defeats the goal of this product if the user keeps snoozing the feedback.
- Charge indication is not readable for all users (e.g. users who are colorblind): When an app is implemented, this issue is resolved by adding a charge status that uses a percentage or filled battery icon to said app. This charge could also be spoken out for blind people if they are able to use a phone.
- Tracking the user's location can be an invasion of their privacy: This risk is the responsibility of the user. Though the product should give multiple warnings (before and after purchasing) that this is the case; the user should be well-informed about this risk.
- Battery life of rechargeable batteries slowly decreases: This problem might be neglectable.
- Performance of the phone can be poor: By sharing several functions between the app and keychain, the risk of the product not working is reduced. If one of the two malfunctions, the other functions as a backup.

4 Concept designs

Our three concept designs will be displayed using the table below. All concepts make use of interaction between a keychain and a dock, which is the designated place for the keys. The idea is that the user has to hang or place their set of keys on the dock within a certain amount of time of entering the house. When this is done successfully, there will be a sort of positive feedback. When the user does not place their keys onto the dock in the set time frame, then negative feedback will be sent out to the user, reminding them to still perform the action. This feedback stops either when the appropriate action is taken or when it is possibly snoozed. With this table, we hope to show the clear difference between our three concepts. Below that we continue the exploration of each concept.

	Concept 1	**Concept 2**	**Concept 3**
Energy	Exchangeable battery	Exchangeable battery	Rechargeable battery
Dock	The dock has a Bluetooth feature and a hook for the keychain.	The dock has a magnetic feature.	The dock charges and has a Bluetooth feature.
Phone connection	There is no connection to a phone.	There is a WiFi connection to the phone.	There is a Bluetooth connection to the phone.
Detailed app status	There is no app.	The app shows detailed status such as charge indication and location of the keychain.	The app shows detailed status such as charge indication and location of the keychain.
Location	Location is detected with Bluetooth.	Location is detected with WiFi.	Location is detected with GPS.
Charge indicator	A light on the keychain indicates the level of charge.	Both a light on the keychain and an app feature indicate the level of charge.	Both a light on the keychain and an app feature indicate the level of charge.
Negative feedback	Locatable feedback comes from a speaker.	Locatable feedback comes from a buzzer and a light.	Locatable feedback comes from a buzzer.
Location of negative feedback	Negative feedback comes from the keychain.	Negative feedback comes from the keychain.	Negative feedback comes from both the keychain and the app.
Positive feedback feedback	The feedback comes from a cute pop-up character (physical object).	The feedback comes from audio/sounds.	The feedback will come from a light.
Location of positive feedback	Positive feedback comes from the dock and the keychain.	Positive feedback comes from the dock.	Positive feedback comes from both the dock and the app.

With this overview in mind, a more detailed depiction of each concept will be given.

Concept 1

For this concept, the keychain hangs onto the dock with a hook. When using a hook, the weight of the keys is used, which could cause a cute character like an animal to pop up from the dock. This can be seen as a dopamine-inducing action for the user. An alternative can also be that the shape of an animal is illuminated on the dock once the action is done properly. The location of the keychain (and thus the user) will be known through a Bluetooth connection between the keychain and the dock; when they are in close proximity, a successful Bluetooth connection between the two will make a timer start the countdown. When the keychain is forgotten about, a speaker from within the keychain will emit a sound to indicate it has not been placed onto the dock within the 15 minutes. After the keychain is hung up on the dock, the weight of the keychain will be detected by the dock which will cause the dock to send a signal to the keychain to stop emitting the negative feedback sound. Aside from a speaker, the keychain has a light that shows how charged up it still is. It is powered by an exchangeable battery, thus when the light indicates low charge it should be replaced.

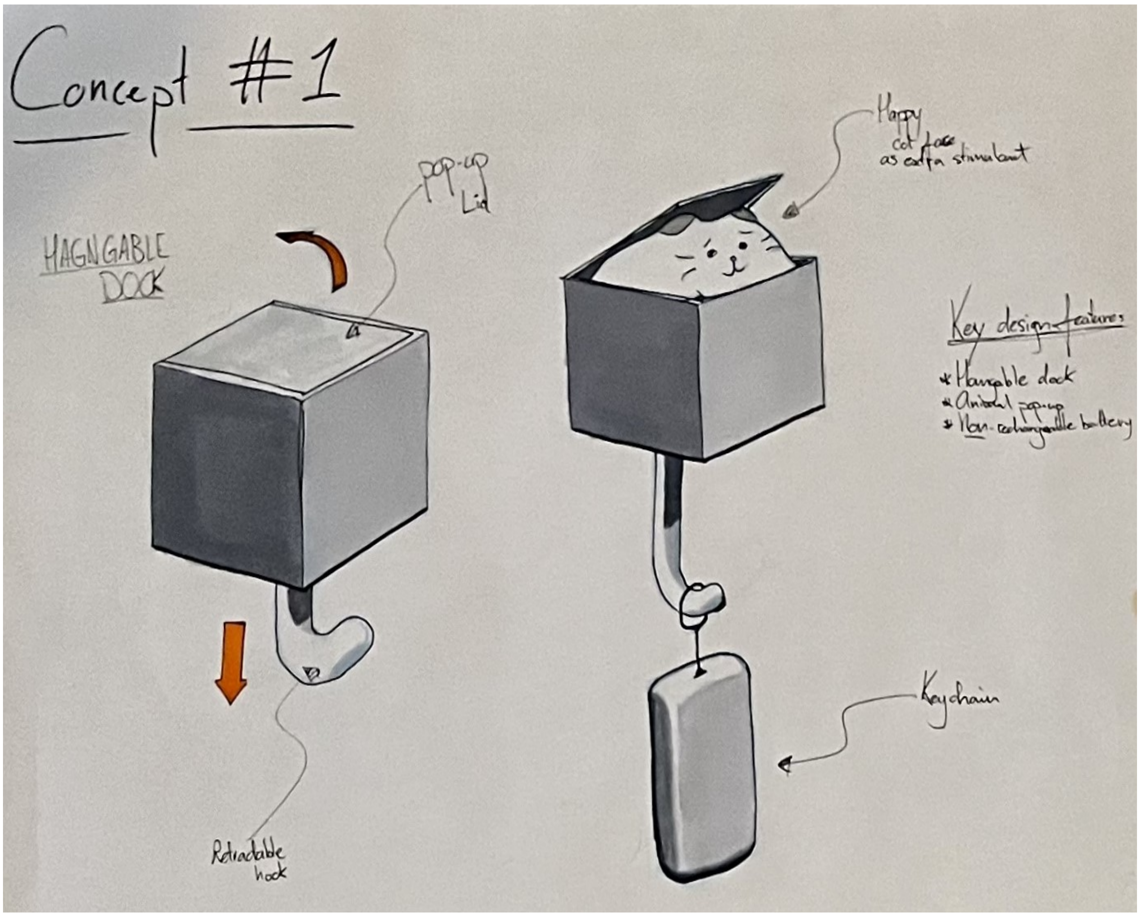

Figure 1: Sketch of concept 1

Concept 2

For the second concept, a flat dock and keychain are used, which are accompanied by an app. The tray-like dock and keychain will have magnets to connect the two. This magnetic feature can also signal the dock that the keychain is present on the dock. The positive feedback comes from the dock, which gives a reaffirming sound when the keys are placed right. The location of the keychain is known via the home WiFi, which will connect the keychain and the phone when the user arrives home. After both the keychain and the phone are connected to the home WiFi, a timer will start counting down. If the keychain is not placed on the dock after a certain amount of time, the negative feedback will start. In this case, the keychain has a light that starts blinking and a buzzer that will produce sound after the timer expires. The mentioned light is also used to indicate the level of charge. But this is not the only charge indication, as this concept will be accompanied by an app, the user can see the battery levels on there as well. The battery is again an exchangeable one. Aside from that, the app will also display the status of the keychain (if it is currently on the dock or not) and it will let the user customize the time for the timer to their liking. This way if someone needs more or less time when entering their home before they would like the timer to go off, they can modify that in the app.

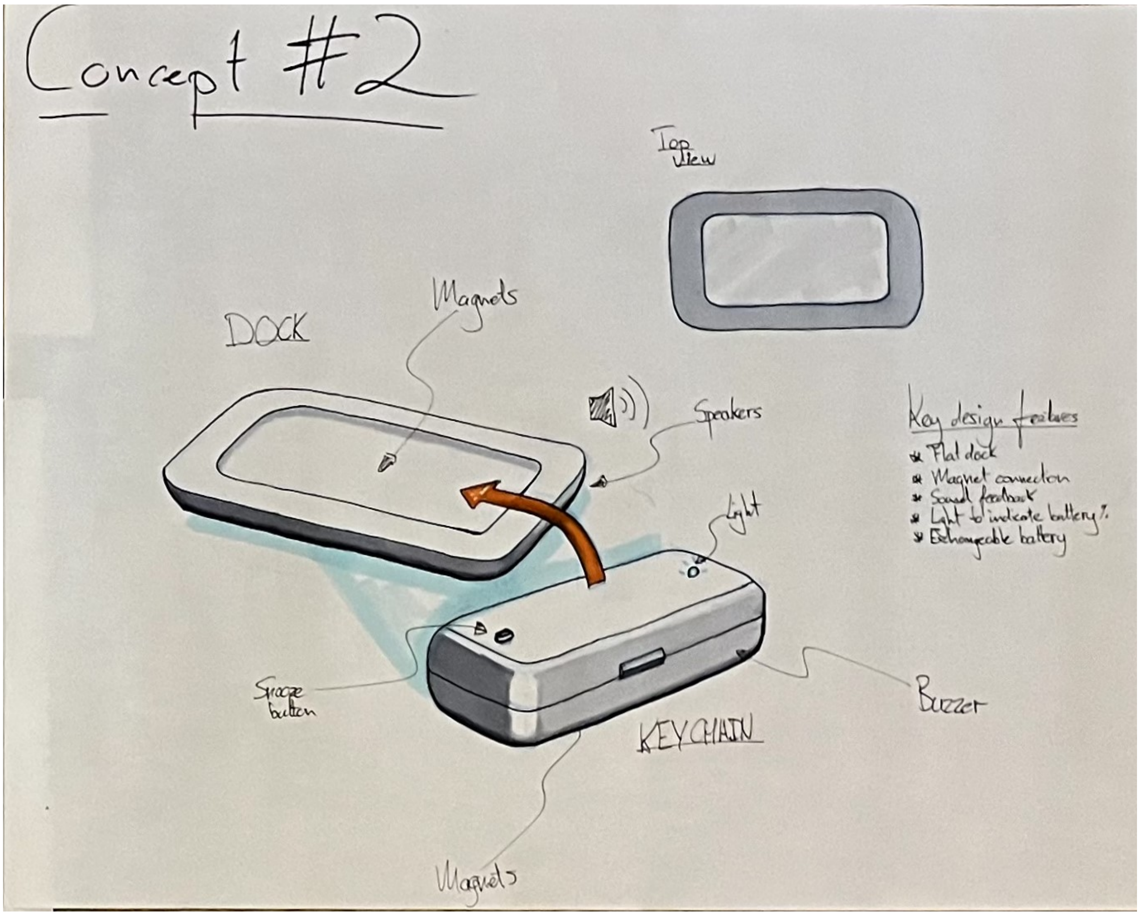

Figure 2: Sketch of concept 2

Concept 3
The last idea has a more practical exterior. As this concept makes use of an rechargeable battery, as opposed to the exchangeable batteries from the other two concepts, the keychain's battery gets charged every time it is placed onto the dock. This ensures that the keychain doesn't run out of energy. How much the battery is charged can be checked by the light on the keychain and the app. The app again shows a more detailed status, similar to concept 2. This concept makes use of the GPS of the phone and a Bluetooth connection between the phone and the keychain which allows information to be transmitted between the two. The app checks for a Bluetooth connection between the phone and keychain every x amount of time. If a connection was detected, it means the two are in close proximity of each other, and the GPS-location of the phone will update as the keychain's location on the app. If there was no successful Bluetooth connection established, the app will only display the keychain's last location, which is the location at which a successful Bluetooth connection was last made. When app detects the user is home via GPS, the timer will start counting down on the keychain as well as the phone. Feedback on the correct placement of the keychain on the dock comes from a light on the dock and a notification from the app, whilst wrong placement feedback comes from a buzzer in the keychain and a notification from the app. Th ekeychain will also contain a snooze button that resets the timer. This snooze button can be used by the user in case they are busy with something they need their keys for. The app will also contain a streak, to motivate the user to place their keys on the dock immediately when they get home.

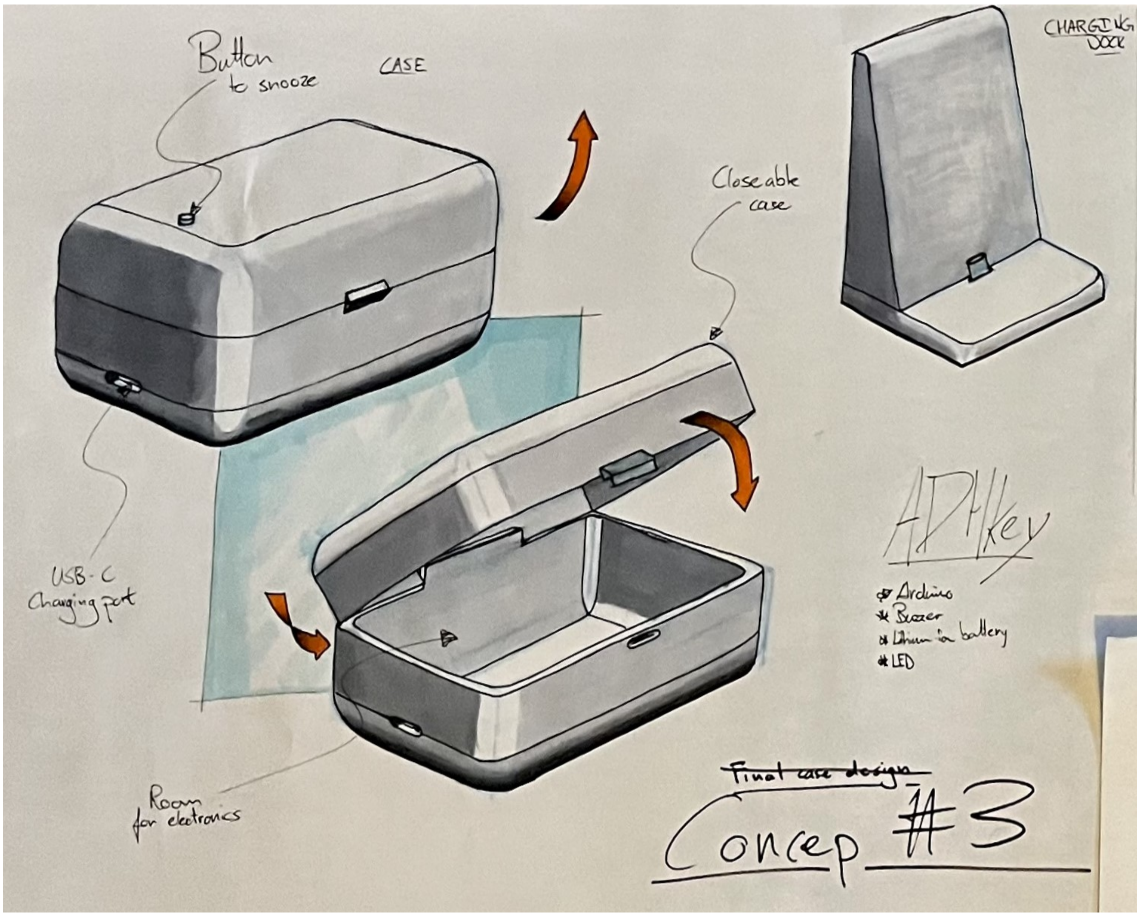

Figure 3: Sketch of concept 3

5 Final concept design

The final design concept combines features from all design concepts but it resembles concept 3 the most. The ADHkey will use a rechargeable LiPo battery. This is more favorable than using a non-rechargeable button battery as people with ADHD tend to forget to do small tasks like changing batteries [8]. The ADHDock will be connected to the power outlet and will include a male end of a charger so that the LiPo battery can be charged by plugging it into the dock. This also allows a physical connection between the dock and the keychain, making it easier to signal when the keychain is placed on the dock.

The charge of the battery is indicated on the keychain itself using a light, but the charge can also be seen on the companion app. Besides the charge of the keychain, the app will also be used to show the user the status of the keychain, i.e. if it is at home and if it is plugged in to the dock or not. The companion app will make the product more efficient for people with ADHD as the user will get notifications about the topics above, constantly reminding them if something is wrong and therefore helping against forgetfulness, one of the main signs of ADHD [8].

When the user arrives at home, the app will know this via GPS location. Using GPS location is more favorable than using Wifi or Bluetooth connection to the dock, as distance to the dock or Wifi problems won't affect the performance of the ADHkey. As this design concept also has a companion app, using GPS location is also easier to notify the keychain that the user is home rather than having a wireless connection between the keychain and the dock, like in concept 1. After the app detects the user is home, the timer will start on the app, as well as on the keychain. This will be possible due to the Bluetooth connection between the keychain and the phone. The amount of time for the timer will be 15 minutes by default, but the user will be able to change this time to their liking in the settings of the companion app.

If the timer expires, and the user forgets to place the keychain on the dock, the keychain will start beeping using a buzzer, and a light on the keychain will start blinking. The buzzer is annoying and it keeps on going until they plug the keychain on the dock. This ensures that the user will plug in their keychain as soon as possible and not procrastinate which will likely lead to them forgetting to do it in general. The light is blinking so that the keychain will be easier to find when it is darker. It also makes the ADHkey more accessible for the hearing impaired, who are not able to rely on sound to locate the keys. Besides those features on the keychain, the user will also get a notification on the app to place their keys on the dock. This is in case they are far from the keychain and cannot hear it, focused on doing something on their phone, or if something goes wrong with the Bluetooth connection between the app and keychain.

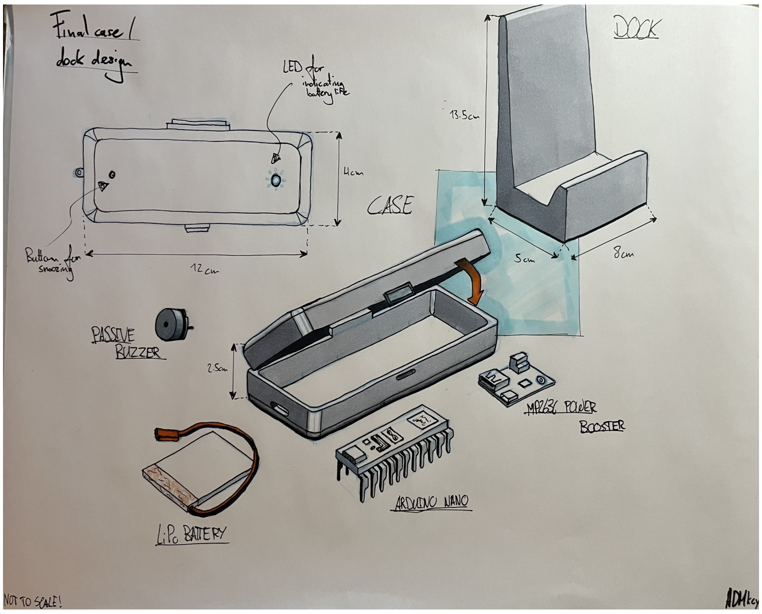

Figure 4: Sketch of the final concept

The positive feedback after the keychain is plugged in correctly on the dock would be given by a light in a certain color, different from the color of the negative feedback, and a notification on the app. There will also be a snooze button on the keychain itself. This allows the user to snooze the buzzer in case they are busy while holding their keys and need longer than the x amount of time they chose for the timer. The user won't be able to snooze via the app but only on the physical keychain. This is done to prevent the user from procrastinating to place their keys on the dock, which defeats the purpose of the ADHkey.

6 Technical specifications

Below are all Technical specifications as described earlier, in the MoSCoW list. As there were no technical specifications in the "Must Have" part of the list, only "Should have" and "Could have" specifications are described.

Should have

- Negative feedback

  The keychain uses two ways of notifying the user that the keychain is not placed on the dock. This is done by a notification on the app telling the user their keys are incorrectly placed and by having locatable feedback on the keychain itself. Having a two-way route helps the user find the device or realize the incorrect placement without having to look at the app, but also has an app that serves as a backup route when the user is not able to sense the keychain's negative feedback. For the locatable feedback, sound and a bit of light are used. The sound helps the user to realize where the keychain is in their home when it is light and dark, while the light mainly helps to locate the device in darkness or for hearing-impaired users.

  The sound is created by a Passive Buzzer 3-12V AC - 2kHz and the light by using an RGB-LED that turns into a blue blinking light. The color of the LED is chosen to be blue because it is bright enough to be seen in the dark and is a different color from our charge indicator. We also made the speed of the blinking slower than 5 to 30 flashes in one second, to prevent harm to seizure-disordered users. The buzzer chosen has a voltage range of 3V to 12V AC and a specified resonance frequency of approximately 2000Hz, which tells us it will provide a sound between 70-90 dB, assuming it functions efficiently on the 5V power supply that is used.

- Charge indication

  The charge of the keychain will be indicated in two places: on the keychain itself and on the companion app of the product. The keychain has a built-in RGB-LED that is used for different functions, among other things the charge. Because not all colors can be seen by color blind people, the charge of the keychain will also be indicated on the app, using a battery icon with a charge percentage. The color of the RGB-LED will change between 3 colors, according to the charge of the keychain. The light will stay green as long as the battery is 100%-50% charged. It will then switch to orange when the battery charge is between 50%-15%. Lastly, when the device has a charge <15%, the light will turn red, indicating the user to charge the device as soon as possible. The colors for these domains will also be represented in the app.

- Trackable location

  The companion app of the product will track the phone's location using the phone's GPS location. The app constantly follows the phone's location through GPS. Every 20 seconds the app will check for a connection with the keychain, so this is not done too often but also keeps the location pretty accurate. If the connection has been made successfully, the app will assume that the keychain is near the phone and the keychain's location will update as the phone's current location. If the connection between the keychain and the phone has not been made successfully, the app will display the location at which a successful connection has last been made as the keychain's 'last' location. The keychain's current or last location will be displayed on a map in the app. In the app, the user can assign a specific location as 'Home'. This way, when the phone's location reaches this location, the app will know the user is home.

  The home location is made by going into settings and searching for any location to be set as home. Additionally, a "set current location as home" button is added for simplicity.

  The error range for the GPS location is around 5-7 meters. This was concluded through testing. Bluetooth version 5 Low-Energy, which is the Bluetooth module used by the Arduino in the keychain, has a connection range of up to 10 meters with obstacles on the way. This concludes an error of the keychain's location of up to 17 meters.

- Positive feedback

  When the keychain is properly plugged into the dock the user will receive positive feedback in two different places: the keychain itself, and the app. The detection of the keychain being charged is done by the DFRobot MP2636 Power Booster and Charger module because when the micro-USB is plugged in, the board will detect that there is no power supply going from the battery to the USB-A port. The RGB-LED on the keychain will temporarily emit a certain color of light (not green, orange, red, or blue as these have other functions) to notify the user that the keychain was properly put on the dock.

On the app, a streak will be counted of how many consecutive days the user has plugged their keychain into the dock without having to be notified through negative feedback. So if the user places the keychain on the dock before the timer hits zero the streak will increase by one point, until a day comes when the user forgets to do so. In that case, the streak will reset to zero. The streak is there to motivate the user to build the habit of placing their keychain on the dock.

- Indicate time

  The timer that starts when the user detects the user is home, will start on two different places: the keychain and the app. This is done presupposing that the Bluetooth connection between the keychain and the app is disrupted. In that case, information can't be transmitted between the two and the two-way route of negative feedback won't be established. When the timer hits zero on the keychain, the negative feedback from the keychain will start, and when the timer hits zero on the app, the user will get an app notification. By making these independent of each other, it is guaranteed that both routes of negative feedback will go through successfully.

  The default time for the timer in the app is set to 15 minutes. This time was chosen, assuming that it takes somewhat around that time to take off your jacket, take off your shoes, and possibly bring in groceries, etc. The user can change this time in the app to any time of 5, 10, 15, 20, 25, or 30 minutes. This makes the time customizable to the user's liking.

  There might be some cases where the user arrives at home for a short while and will have to leave again quickly. To prevent the annoying buzzer from continuously buzzing, a snooze button was implemented. This button allows the timer to restart, giving the user more time to place their keys on the dock or more time to leave the house. This snooze button will only be present on the keychain and not on the app to prevent the user from being able to snooze when on their phone and not knowing where the keychain is. The snooze can only be used once by the user, as using it multiple times in a row defeats the purpose of the device.

- Attachment for keys

  The keychain should be attached by an iron ring that will be attached by creating two holes in the case and guiding the ring through. On this ring, we should be able to attach a weight of 1 kg seeing as the keys will probably be less heavy and this secures a lower possibility of your keys breaking off.

  Because of time limitation and some fitting issues that resulted in a cable being on the outside, the cable sticking out was used as the attachment for the keyring on our prototype. In future development of the product there will be no cable on the outside and the attachment for the keys will be as described above.

Could have

- Rechargeable

  We are using a Lithium Polymer (Li-Po) Battery - 3.7V 800mAh that is connected to a Power Booster. The battery is charged through the Power Booster and the components are also powered through this module. This is achieved by charging the battery through a USB-A to Micro-USB cable and charging the components with a USB-A to USB-C cable. These connections are made because charging the components directly from the battery does not supply enough voltage and does not allow charging. So, this way we are able to charge the battery and supply power to all components because the booster makes a 3.7V battery have an output of 5V.

- Phone connection

  For the features that demand a second route through an app, we have added a phone connection by using a Bluetooth version 5 Low-Energy module on the Arduino. This connection enables the use of an app and GPS on the user's phone. The functions of the app will be presenting the status of the device, such as charge and last location. The last location is determined by checking every 20 seconds if the keychain can still connect to the phone to update the last connection time on the map display. This way of determining the location has an error range of 15-17 meters.

  Next to status, the app will give a notification when the keychain's buzzer is going off by use of an internal timer that starts when the GPS on the phone detects that the user is home. The streak system is connected to this notification so that whenever the keychain is not placed correctly, the streak is lost.

  The language used for this app is Swift and the Arduino needed C++.

7 Detailing

One of the key components of the product is the mobile application. During the development of the application, the design goal was to create an intuitive, aesthetically pleasing smartphone application for the user to have besides the physical product, in order to ease the experience of the user. The initial features of the app were an alarm system that would alert the user to plug the device into the docking station through a notification, location and connectivity settings as well as a user profile with associated devices. With some prior knowledge on app development, however, with none of the team members knowing how to program an app for the iOS platform, the decision was to develop the app entirely from scratch with Xcode, so the app can be used on the iOS platform, taking upon the challenge of learning a new skillset.

Furthermore, the functional details and development process of the various application components will be discussed in great detail. The crucial role that the app is playing in the system is to check the location of the user at all times, at any moment in time when is needed. In this way, the system knows when the user arrives home and communicates this status to the keychain device so it can start the alarm if the user didn't plug the keychain into the docking station. While designing the user interface features of the app, a brilliant idea for a helpful feature has been proposed. The idea was to add another level of complexity to the communication system between the phone and the device. Essentially, if the phone can check whether the device is discoverable or not in order to send the data, then it could also display the last location of the keychain when it was connected to the app. In this way, the user will not only be reminded to place the keys in the same place when arriving home, but also to the location of the keys on a map. This has been done by making the app check repeatedly if the device is discoverable. If so, then the app stores the current location and displays it on the map as a marker for the keys. This additional feature improves the product a lot by providing the user the ability to know where the keys are.

Regarding the ability of the mobile application to know when the user arrived home, the user has to set their home location on the app. Initially there was meant to be a setting which would let the user search the home address in a searchbar and select the desired address from the results list. In the meantime, an easier implementation was found for this feature. Instead of the user having to search for the address, a button with a representative home icon was added in the main view of the mobile application (the map view with the keychain). Once the button is pressed, the app sets the current location of the user as the home address, thus improving the ease of use of the app, as well as enhancing user-friendliness. In the settings view, the user can further customize their experience by adjusting when the keychain emits an alerting sound upon arriving home. This feature allows users to select their preferred alert delay from a list of options, including 5 minutes, 10 minutes, or 15 minutes. These options were further enhanced to offer users even more flexibility. Now, the alerting sound delay settings include a range of six options, available in five-minute intervals from 0 to 30 minutes. This expanded range provides users with a wider spectrum of choices, enabling greater customization according to their specific preferences and needs. As the final project presentation was being prepared, the team recognized the need for a more concise demonstration of how the product operates. An additional option of 20 seconds was added to the app to facilitate a clearer presentation of the product's functionality. This brief interval was deemed suitable for showcasing the key features and functionality of the product during the presentation, ensuring a clear and impactful demonstration of its capabilities.

When accessing the account view, the user is presented with several sections, including 'Personal information,' 'Paired,' and 'Linked.' Within these sections, the user has the option to modify their username and profile photo. It's important to note that, during the software's development and presentation, these settings were strictly user interface elements and lacked actual functionality. In other words, selecting these elements while using the app had no practical effect. Given the time constraints of the project, the primary focus was on the core functionalities of the system. Further development is planned to provide full functionality for these settings: the 'Personal information' section would encompass fields for the username, email address, and home address, in the 'Paired' section, users could manage their paired keychain devices, allowing multiple keychains to be linked to a single user, the 'Linked' section would display a list of all keychains that have been previously connected to the mobile application, providing users with a comprehensive record of their connected devices.

As previously mentioned, the map view, serving as the primary interface of the application, offers users a 2D map displaying the last known location of the keychain when it was connected to the phone. Additionally, this view provides key information about the current status of the keychain when it was last connected. Positioned at the top of the screen, users can access essential details regarding the keychain device, including its power status (plugged in or not), home status, battery level percentage, and the last recorded address from its most recent connection.

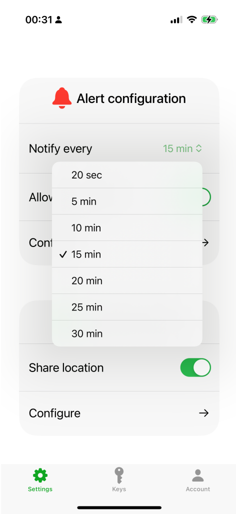

Figure 5: Settings View

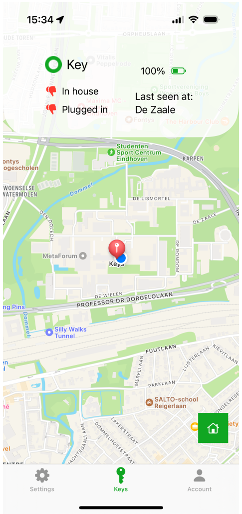

Figure 6: Map View

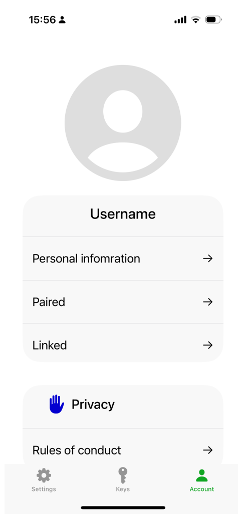

Figure 7: Account View

In the context of the keychain system, it comprises three core modules, each with a specific role. The first module is the alarm snooze system, which includes the buzzer and a button. Its functionality is as follows: when the user arrives home, a timer initiates, and when it reaches zero, the keychain emits a loud alarm-like sound to remind the user to plug the device into the docking station. Pressing the button once activates the snooze function, effectively resetting the timer. However, if pressed a second time, the sound will only stop when the device is plugged into the docking station.

The second module is the battery percentage indicator, which utilizes an RGB LED. To calculate the battery percentage, a wire was soldered to the positive terminal of the battery and connected to an analog pin on the Arduino. An algorithm was implemented to convert the battery voltage, read from the analog pin, into a battery percentage level. This value, ranging from 0 to 100, is displayed using the RGB LED, transitioning from green when the battery percentage is high, to yellow when it's medium, and to red when it's low. This feature greatly enhances the device's user-friendliness by informing users about the optimal time to recharge the keychain.

The third module involves the Arduino, which manages communication with the mobile app via Bluetooth, utilizing the integrated ESP32 module. By leveraging the BLE protocol, a connection was established between the device and the app. This connection allows for the exchange of data, including information about the device's charging status from the docking station and the current battery percentage level. This integration streamlines the user experience and provides valuable real-time information to the user.

To ensure the seamless operation of all electric components, a circuit had to be carefully assembled. At the heart of this system, the Arduino board functions as the central controlling unit, receiving data inputs from both the button and the battery voltage. In turn, it controls the buzzer and the RGB LED. All of these components are meticulously connected to specific pins on the Arduino to receive power and facilitate their respective functions.

In order to streamline the assembly phase and provide a clear visual representation of the circuit, a comprehensive circuit diagram was thoroughly designed. This diagram served as a visual guide, illustrating how the various electric components were interconnected. A software tool called Fritzing was used to generate an accurate and detailed visual representation of the circuit, ensuring that all connections were correctly established and that the system would function as intended.

Moreover, this circuit diagram played a critical role in reducing the risk of mishandling during assembly. It provided a comprehensive visualization of the circuit, minimizing the chances of accidentally frying the Arduino board or other components through unintended shorts or incorrect connections. This ensured a smoother and safer assembly process.

8 Realization

8.1 Assembly steps:

When creating the case of the product a small RPC list created that included that the case should be easy to assemble, thus the manufacturing of the case is quite an easy process. Although, the case was designed with some specifications in mind it still needed some improvisations in order to assemble it.
The first step in assembling the key chain was to 3D print the CAD models. This has been done at quite a low resolution as the outside can be rough because it does not affect the use of the product. The case is made out PLA plastic and the reason for why this material has been chosen is its relative low price along with it being light and malleable. In this phase, the first clear flaw with the CAD design appeared, as the two shafts that should've been used for the hinge were found to be quite frail. They've been cut out and replaced with one metal rod that was heated and passed through the hinge in order to create one pin rather than have two frail plastic shafts.

After the issues with the hinge were resolved the next step was to arrange the components. The top part houses the following components: the Arduino Nano, the buzzer, the RGB led, and the bulk of the cables that comes out of the Arduino. While the Arduino had already two holes, one for the reset button of the board and one for the USB-C, for the LED a 5mm hole had to be drilled in the middle of the case. This change has no effect on the structure of the case as this device is not meant to handle forces that are too high, thus there should be no bending or buckling.

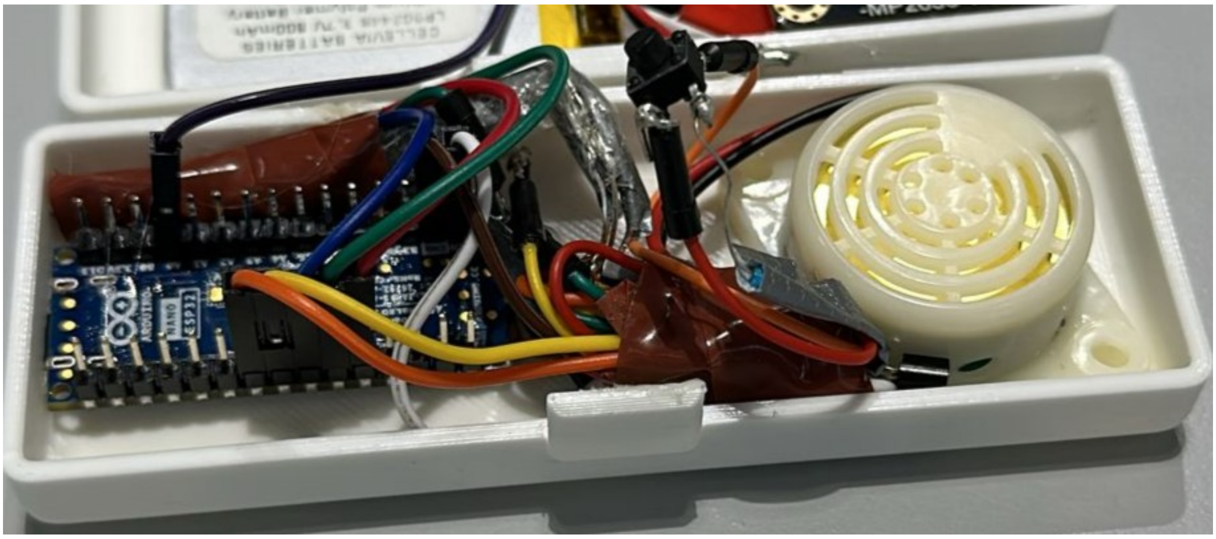

Figure 8: Top part of the case

The next step in the assembly of the product is placing the battery, the button, and the voltage booster/charging module in the bottom part of the case. It has been chosen that the bottom part of the case should not have too much wiring as this provides a more efficient way of organizing space. Again, a 7mm hole had to drilled into the case, but, again this had no effect to the structural integrity of the device.

Figure 9: Bottom part of the case

All of these components, along with the bulk of the wiring that has been wrapped with electrical tape, have been fixed with the help of the glue gun. This method of gluing the components had no effect of the workings of the key chain, as the glue was applied to spots that are less sensitive and, also, the glue does not conduct electricity.

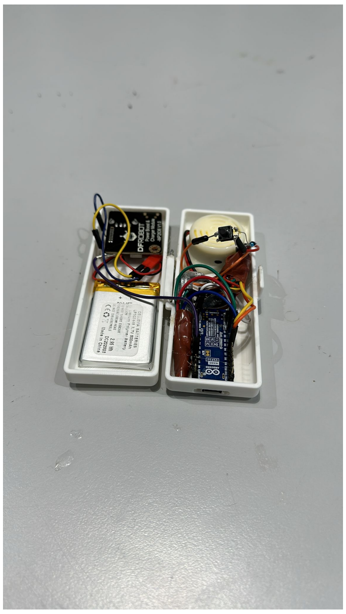

Figure 10: First iteration of the assembled case

In this stage of the manufacturing of the case, the first big problem was encountered as the wires that are coming out of the Arduino, specifically the plastic connections were too tall, and the case wouldn't close. This would not have been a problem if an Arduino that had no headers was bought in the first place so that the wires could have been soldered directly to the board.

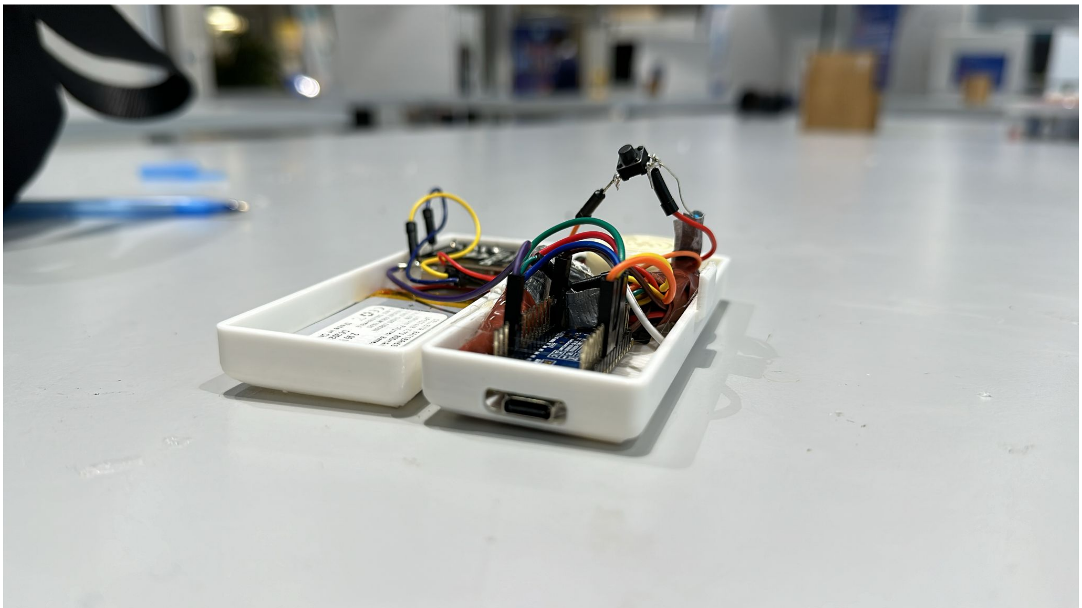

Figure 11: Headers

This problem has been remedied by printing the bottom of the case again, with bigger dimensions and repeating the steps that have been presented above. This new part was also printed with the hole for button from the start.

Figure 12: New part for bottom of the case

As this had to be done in quite a short time, the new part has been modified in such a way that no chances were took and the prototype would be ready to be shown off in the presentation, so there was a lot of extra space that was not used. In the future, this space can either be used for improvements or it can be removed so that the device would be less bulky.
As the wiring is a big part of the whole device, the connections have been made by either soldering or just using the available pins and connections. It can also be seen that in the photos above the wires are compacted with the use of tape so they would take less space. When doing this part, extra care was took so that no short circuits would appear. In order to know which wire to connect where, a circuit diagram has been used.

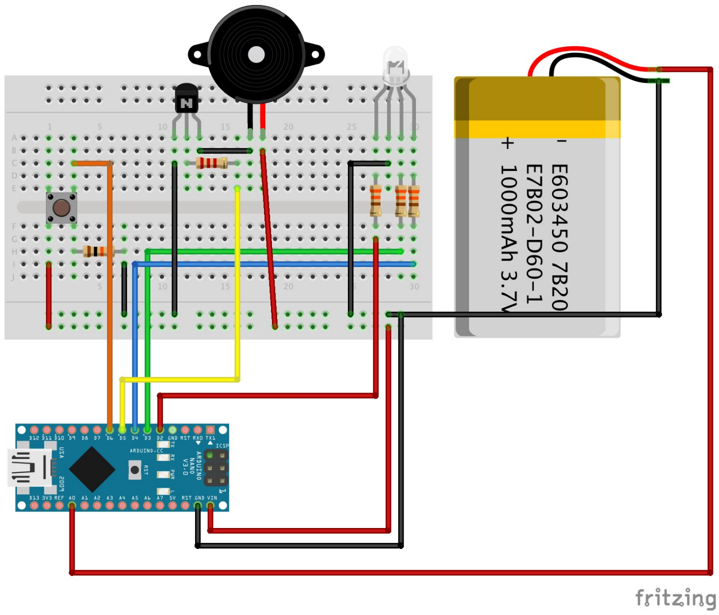

Figure 13: Wiring diagram

8.2 Preliminary and fit-tests:

As mentioned before fitting the components inside the case was not easy but the issue was resolved in time for the final presentation. In order to see the differences two manufacturing sketches are shown below. The new part has the following features that made assembling the case easier: a hole for the button, a bigger opening for the battery charging module so that the USB-A has a easier time fitting in, along with it being a lot deeper in order to acomodate the wiring so that the case of the key chain can be closed easier and without any improvisations.

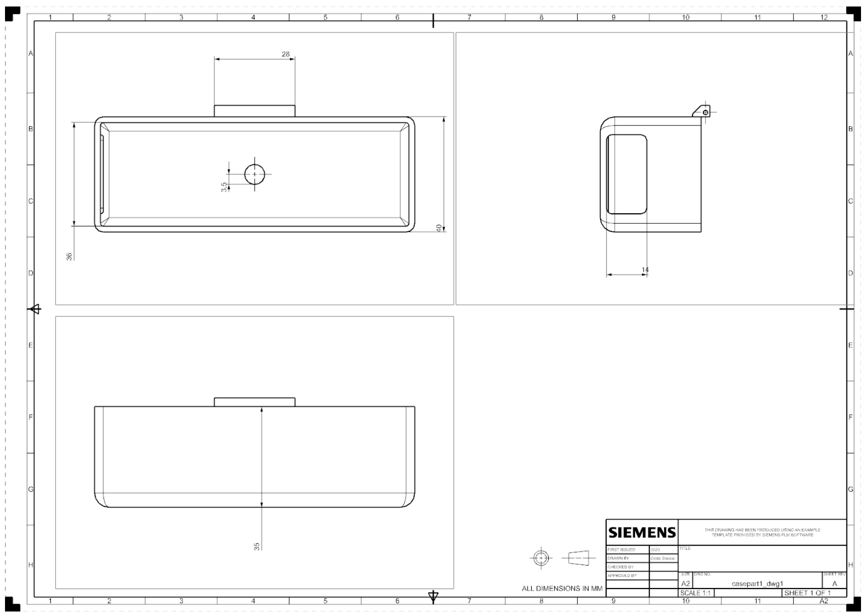

Figure 14: New bottom part

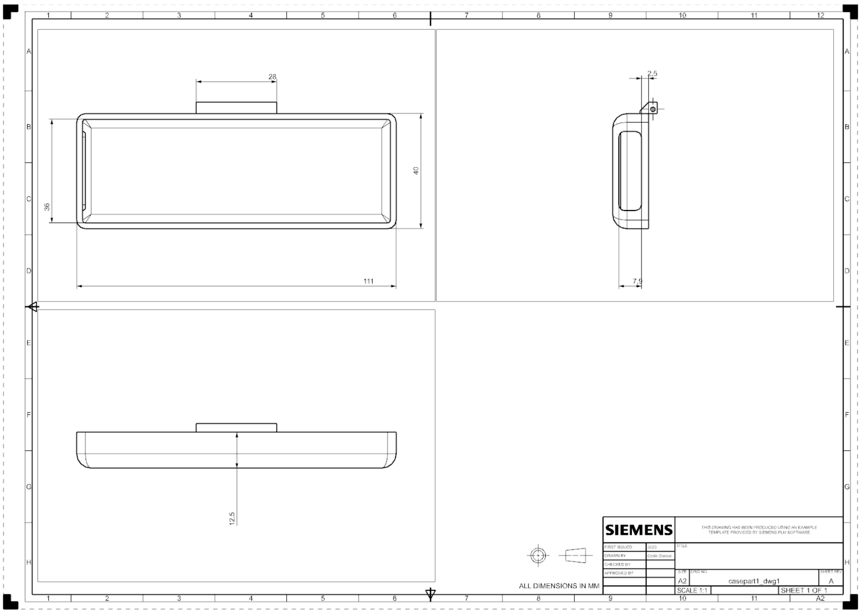

Figure 15: Old bottom part

8.3 BoM and total costs:

The list of the items that have been bought can be seen below along with the brands of the products. The total cost of the items is 38.25 euros. This does not include the PLA plastic, the button, the LED and the wires. This items were provided by the team members but in a approximation by looking at similar products they would be around 3 euros. The case needs around 30 grams of PLA plastic to be printed so that is negligible. This brings out the total cost to be 41.25 euros.

- Active Buzzer 3V-24V - Intermittent(1 euro)
- Arduino Nano ESP32 - ESP32-S3 (Arduino-22.5 euros)
- DFRobot MP2636 Power Booster and Charger Module - 2.3A (DFRobot-8 euros)
- Li-Po Battery 3.7V 800mAh (Cellevia-6.75 euros) The supplier that has been chosen is tinytronics.nl

9 Test plan

In order to realize our product, we must create a test plan. In this section, we will mention which tests should be conducted, why they are conducted and how they are done.

Pressure test
A pressure test should be conducted to measure the strength and sturdiness of the case. This test holds high relevance because it relates to having a well-designed case, which is indicated as a could on the MoSCoW list. A hydraulic press could be the instrument used to apply pressure to the shell of the case. The components should not be inside the case during testing, as the goal is to test the case. Aside from that it would also be wasteful to possibly break the components. The object should be placed in the press. Pressure should slowly be increased. Right before the case fails, the measurement is recorded. For more accurate results, the test should be repeated. With the gathered data, exploratory data analysis should be performed, as well as the accuracy of the results. The formula for pressure could be used to compute which forces the case can handle.

Drop test
This test can also ensure the strength of the case. The case should be dropped from certain heights to one (or multiple) types of surfaces. For the scope of this course it is best to keep the test simple. It is therefore best to pick one height and one surface. The best height to pick is the length from the average person's hand to the floor, as that is the most common way the product will fall. For the surface it will fall on it would be wise to pick either a generic material floors are made of in the average household. It is quite hard to perform data analysis on this test. Therefore it might be best to visually test the quality of the case. So, after dropping the case the individual testing the product should evaluate the damage to the case. This damage can be scratches, but no cracks or breaks are allowed. This is again recommended to be repeated.

Pull test
The attachment between the keyring and the case should be tested. The attachment should be strong enough in order for it to be used in someone's daily life. This can be done by hanging the ring on a hook, and increasing the weight from the case. This can be achieved by manually adding weights with hooks to the bottom of the case. These come from mass sets often used in physics. The weight can be gradually increased until right before breaking point, similar to the pressure test. For a good estimation, the test should be repeated as well.

Range of connection test
We need to test the range of the connection of the phone with the keychain in order to know when it becomes unusable. This is important because when using a Bluetooth module that connects to your phone via a signal, a value for the range should be established to be able to provide a suggestion on its usefulness in different situations. Different situations in this case are enclosed spaces, rural areas, open fields, forested areas, and so on. The most prominent locations for this project are open fields, which measure pure range without any blockage, enclosed spaces, which measure the range within a household, and rural areas that measure the range whenever the user is outside of their home. Range is measured with a surveyor wheel, that will be carried by one individual, whilst another individual stays at the start of the wheel with the phone. The phone measures the strength of the Bluetooth connection. The person with the wheel moves arbitrarily and for each certain amount of meters measured, the strength is measured as well. This data is collected pair-wise and used to build a linear regression. The correlation between these parameters will most likely give a negative correlation (as the connection becomes weaker when the distance becomes greater). More can also be determined by the statistical significance of the explanatory variable.

Location test
The accuracy of the location should be tested for the reason that it should be known how accurate the measurements of the device are. This way the error margin is shared with the user, which explains to them possible errors that occur during usage. Determining this margin can be done by using an instrument that exactly measures the longitude and latitude of the tester. Which kind of instrument this is needs to be researched. The same tester uses a phone to measure the same location. The difference between these values equates to the inaccuracy of the product. The test should be repeated to gain good results.

Light range test
The light range test is relevant because it is important to know on what level this feature is helpful for different types of users. Its helpfulness should come from the ability to detect the keychain in for example the same room, without any use of audio-aid. This would give an idea of how the hearing impaired interact with the product's negative feedback. In the scope of this course, this test can only be conducted within a dark space, as a light sensor would pick up all sources of light, and it is only meant to sense the light coming from the keychain. However, in an ideal situation, further investigation can be done to measure the light intensity and range in a well-lit room, as it is important to know how helpful the light is for the user. But in this case, the test will be conducted only

in darkness. The keychain should be placed in different locations, each with its different types of blockages, that all tell what type of placement and blockage influence the light intensity. With this data can be determined how easily the user can find the keychain in different cases.

Sound range test
Similar to the light range test, a test can be performed where sound is measured with a decibel meter for different places in a room and household. Though in this case the amount of daylight does not influence anything. The gathered data shows how easy it will be to detect the keychain when in the same room or household. This is beneficial to test since it should be validated that the use of sound is applicable to detect negative feedback and location of the keychain.

Battery life test
It is necessary to measure the battery life because the product should be able to function for at least a day, as it is integrated into an individual's routine. One can simply measure the battery life by connecting a multimeter and a stopwatch. This way we can track the voltage and amperage the battery depletes over time. When the multimeter measures a voltage of 0, the timer should be stopped. It might also be important to detect whenever a component shuts down, to determine if the previously measured battery life is longer than the time that the product remains operational.

10 Design evaluation

The intended design goal was to create a product for forgetful people, who may or may not have ADHD, and need reminders for certain parts of their daily lives. The goal was to establish this by making a device that reminds the user to not forget their keys when leaving their house and can also be a comfortable way to build up a habit of placing their keys in the same place. The device would also help the user find their keys when they lose them somewhere inside the house, and remind the user to put them back in the same spot when they get home again. However, due to time limitations, this is mostly obtained but still has some missing aspects.

The ideal keychain would not only remind the user to place their keys in the same place, but it would also remind the user to pick them up before leaving the house. The "pick-up reminder" would need a motion detector that detects whenever the user is about to leave the house without the keychain and would then remind them to pick their keys up by giving a negative feedback. This negative feedback could be the same as the negative feedback of when the user forgets to place the keychain on the dock (i.e. the buzzer) or a different one. However, due to budget limitations and lack of time, this feature was not added to the design of the product and this function remained a hole in the functional flow system.

Additionally, the keychain does not contain a very specific tracking device that always displays the exact location of the keychain in the app. The current design of the keychain checks for Bluetooth connection with the phone every 20 seconds. If a Bluetooth connection was established, the GPS-location of the phone updates as the location of the keychain in the app. If a Bluetooth connection was not established, the last location where a connection has been successfully made will display on the app as the keychain's last location. This does not help the user find their keychain in case their keys were moved from the last location where a Bluetooth connection has been made, or in case the Bluetooth connection with the phone failed for some reason. By implementing a GPS-module in the keychain, the keychain would also have a live location feature in the app, which would help the user keep track of their keys. This feature was not implemented due to budget limitations.

Lastly, for next iteration of the design cycle, it would have been nice for the user to be able to customize their ADHkey. This way users could create a more personalized keychain that they are more comfortable to use. The product would then use a speaker instead of a buzzer that allows the users to choose from multiple alarms for the negative feedback making the alarm sound personalizable to their liking. The speaker might also be able to emit an affirming sound/sentence as positive feedback. The color of the positive feedback light would also be customizable, or the dock would include a screen that displays an affirming text as positive feedback. If the product would be mass produced, there could also be multiple colors of the product available so the users can buy a color that aesthetically pleases them and they will not get bored of. By making the keychain as customizable as possible, the users would be more attached to their keychain ensuring that they will use it more often. It also makes sure that they user will not get discomforted by certain sounds/functions of the keychain. In addition, adding a fidget toy onto the keychain would satisfy people with ADHD and would give the keychain a multi-functional use. Unfortunately, these additions were not made to the product at this point of the design process as this was only a prototype and because we did not have the time or budget for this.

The three improvements above, do not add much in view of the current intended design goal, but they would improve the function product if it were to be mass produced in the future. The improvements above would also complete the functional flow which ensures the use of the product is as efficient as possible with no faults.

However, there is one issue we came across that does contradict our design goal and functional specifications which is the size of the case of the keychain. The models and sketches that were made of the keychain had the following measurements: length of 12cm, width of 4cm and depth of 2.5cm. This size does fit in most pockets and is not too bulky to be used as a keychain. In spite of those measurements, the case of the final prototype ended up being bigger than that because of last moment issues with fitting the components inside the case.
Some components that were ordered, were too big or had an unfortunate shape which did not allow us to properly stack the components inside the case. First of all, the headers on the Arduino Nano got in the way of stacking the components. By using an Arduino Nano without headers this could be avoided in further development, allowing the components to stack more efficiently inside the case and therefore reducing the size of the case. Secondly, the buzzer that was used was a bit bulky and big. A smaller buzzer was tested too, but that one was not loud enough to achieve our design goal. Due to budget and time limitations, other components, that would fit the case better, could not be ordered.
Finally, the 'power booster and charger module' (MP2636) had to be connected to the battery as well as to the Arduino, and also had to be placed at the edge of the case to be able to connect to the dock too. As we only disposed of a bulky cable to connect the Arduino and 'power booster', it did not fit into the case and that cable had to hang on the outside. This cable was used to hang the keychain on the keys, but ideally the cable would be

on the inside of the case and the keychain would hang on to the keys through a keyring that would go through small holes in the case of the keychain.
All this created some fitting issues that could have been avoided if we had more time and smaller components. The case that was used for the final prototype was bigger than expected, had a cable on the outside and did not fit into most pockets. Therefore, a reduction in the size of the case is a must for future development of the product. Nevertheless, the case of the final prototype had some space left in it which guarantees that with some smaller components and by some testing it is possible to make the case the same size as our original prototype measurements, which is small enough to fit inside the pockets of the user, or even smaller than that.

It can be concluded that the prototype that was designed could be improved on some aspects for further development but it is the close to the most that could have been done in the time and budget provided.

11 Individual contributions

The team was very organized in a way that all members had their own responsibility for the project that suited their knowledge and experience. This way, the different aspects of the project were divided over the team with always someone who could teach another member what they were doing. By doing so, the team could learn from each other's studies, personal experience, and CBL findings. This in itself enabled different visions on all the different project aspects to obtain different findings and a universal answer to our problems during the production and design process.

The division of tasks in our team is shown in the following list:
Alex: Programming of the app and the assembly of the product
Branco: Designing of the product and creating different concepts of the main design
Chelsea: Writing of the report and the test plan of our product
Costin: Modelling and assembly of the product
Daniël: Creating the brand of the product and sketching the concepts/final design
Liya: Designing of the product and creating different concepts of the main design
Tessa: Writing of the report and researching haptic perception

Each of these tasks demanded certain skills, materials, or knowledge to fulfill these tasks.

Here is an overview of the most important tasks each person accomplished.
Alex learned a new programming language (Swift) to be able to create an app, used already existing knowledge for C++ to program the Arduino, and used electrical components such as an Arduino, Power Booster, LiPo battery, and more. Combining all this knowledge he made sure the software side of our product worked. In the final week he also played a crucial part in soldering the electric circuit of the device and making sure everything worked for the presentation. He also presented the technical part in the presentation and worked on this. At the end of the course he also wrote the detailing part of the report to give more insight in what he worked on, which can be found here: 7.

Similarly, Costin started from week 1 with making the design for our product. He made CAD designs of everything very quickly and made them more and more detailed as time went on. He also 3D printed the preliminary prototype for the midterm presentation and video. After this he went on to make the final design which had to be quite a bit bigger than expected due to the components not fitting as closely as expected. This taught him more practical knowledge about making CAD models and gave him more spatial awareness when looking at them on a screen before actually printing them. In the final week he worked with Alex to make sure everything fit in the case and assemble everything. Their cooperation in this final week made it so that we had a working prototype during the final presentation. Another thing he learned for this project is soldering and connecting the wires for the final product. He learned this in the last weeks of the project while everything was coming together.

Meanwhile, Branco learned how to implement his organizing skills to keep the team on track and not forget details and important aspects of the production and designing process. During the second week he started working on the MoSCoW model. After the midterm presentation there was a lot of feedback about this which he implemented in the report, the final version of this can be found here: 3. He worked on this final version from weeks 2-6. He also worked on the technical specifications and any smaller tasks that needed to be looked at. Additionally, he learned by use of a CBL module named "Human Factors Design" the skills to create a fully thought-out product that is able to go in the practical market.

Likewise, Liya also learned how to use her cooperation skills to create an overall vision of the product by combining all the different perceptions she learned from working together with others. For example, she learned the basics of electronics to implement this perception into the concepts and design, but also use this new knowledge to define which concepts or designs are feasible or not. She also worked a lot on the design concepts that can be found here: 4. She worked on this from weeks 2-4 and kept defining them more and more. After this she also worked on the final concept design which can be found here: 5. In addition to this she worked on the final presentation and presented part of it.

Daniël learned to use his creative mind to create a brand that was used in the presentation and app. Next to this, he also developed the skill of design sketching our final product and concepts, which were used in the presentation and report. With this new knowledge, our product came to a more professional feel and look. He achieved this by creating a brand logo and brainstorming about the name of the product. Then he went on to use the colours chosen for the logo to create the design for the app that Alex later brought to life. He also did a CBL module about designing and sketching around week 6 and used the skills he learned there to create the drawings for the concept designs and the final design. This helped to make them a lot clearer. These drawings can be found here:

4. He also created the video for the midterm.

Chelsea worked on writing the report throughout almost the entire project. She stated the design goal very clearly in the second week which really helped the project along. The final version of this can be found here: 2. She also worked out the design concepts that Liya and Branco worked on and wrote about them in the report, this can be found here: 4. In addition to this she gave the midterm presentation her own and made the presentation. She also presented and helped with the presentation for the final presentation. During weeks 5-6 she completed the CBL module about testing and used this to write the test plan section of the report which can be found here 9.

Tessa joined the report writing in week 4. In the report she mostly focused on checking everything that was written to take out grammatical errors and make sure everything was written in an appropriate tone. She also made a planning for the entire project around this time and helped to keep everyone on track. This planning was a Gantt chart, which she learned about during this project when looking for a planning solution. In addition to this, she appeared alone in the first video and made the second video entirely on her own. She learned to use new editing software for this, namely DaVinci Resolve, and how to make storyboards when preparing the video.

During the project, a lot of our members learned new knowledge which got used in the final product and report.

Here is a quick overview of all the new things learned
Alex learned the programming language Swift during the beginning of the project and implemented this knowledge during the creation of the app which took place in the middle and end of the process. Next to swift, he learned to use new electrical components and used this knowledge during the end to assemble the final product.

Branco learned his CBL module Human factor design in the middle of the project and started using this knowledge from the middle till the end of the process to make the product more user friendly and accessible for more user groups.

Chelsea did her CBL in the end of the process, but did not get to use this knowledge as much as she would have liked. Due to a lot of last minute changes to the design and there not being a lot of time to get the product to work for the final demonstration. She still used some of this knowledge to write the test plan.

Costin gained a lot of knowledge about the electrical components used in the same time as Alex, because they worked together on this part of the project. He learned how to solder the electrical wires and this helped them to finish the final project.

Daniël finished his CBL for design sketching in the middle of the process and was able to use this new skill till the end of the project where the final product needed to be drawn. These drawing look very professional and were also used in the presentation to showcase the product. He also learned what software to use when designing an app in the first weeks of the course, which he used to make the app design. He finished this by week 4.

Liya got her new knowledge of the basics for electrical components and circuits because of her CBL module basics of electronics which she did in the middle of the process. She used this knowledge to help pick out what parts to use, and was able to give input into the technical part of the product. Alex also showed her how to attach wires to the Arduino, she did not necessarily help to assemble the final product, but she did learn a lot about how to do this. She also learned how to work in overleaf when working on the report.

Tessa did the CBL module haptic perception during week 6. She used this knowledge to give advice on some aspects of the final concept, however these were not specifically implemented due to there not being enough time. She also learned how to use the editing software DaVinci Resolve during the last week of the course to edit the final video.

12 Statement about use of AI

No AI was used or consulted in any type of way for the entirety of the project.

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A Appendices

None.