Engineering Design 4WBB0 Group number 130	2018-2019
Name	*Student ID*
Victor Aerts	1268120
Pietro Maschera	1220953
Paul Roelen	1255576
Stan Schuurmans	1233100
Tine Stevens	1240205
Remco Vader	1251597
Kornel Zdrojkowksi	1252836

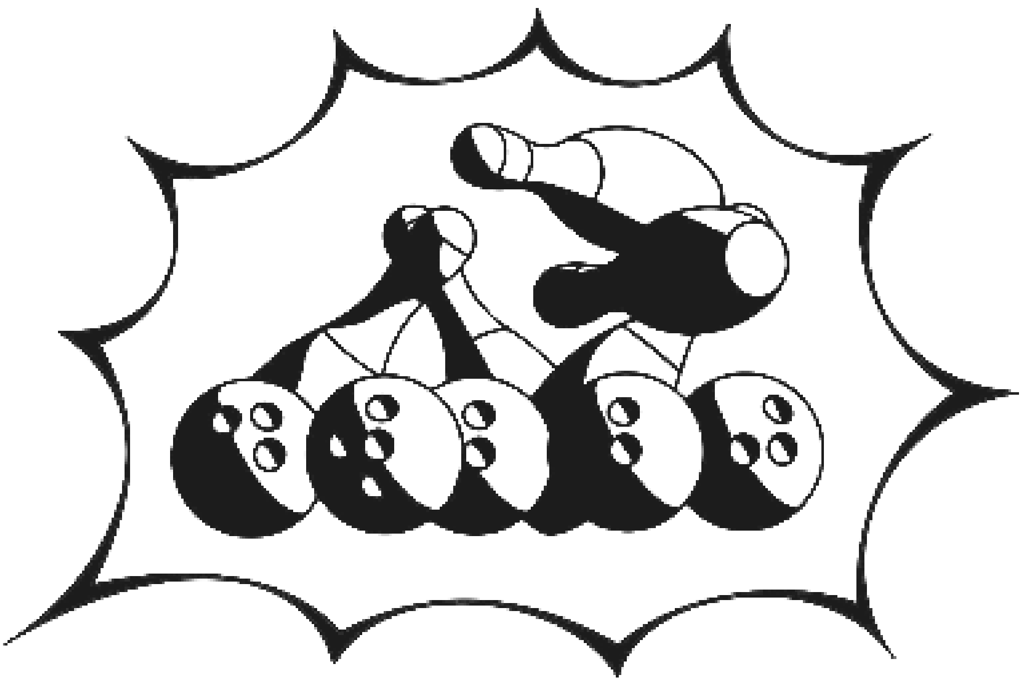


Table of Contents

1. Group Effectivity

1.1 Personal strengths & weaknesses

Victor Aerts (1268120)
I am an architecture student, meaning I've developed a design-led way of thinking and approach design problems in a creative manner. I got an average technical understanding in electronics and I can be helpful at the thinking and assembling process of the product. I'm used to planning and thinking a few steps ahead to know what is coming and how to prevent possible problems associated with that. I see myself as an inventor/artist as I am a creative, open-minded thinking person that can connect different fields to assemble a product; this is where our group can excel at. One of my weaknesses is the pitfall of getting a tunnel vision when an idea is concepted. I can easily get clamped into one idea and have troubles thinking outside of the box. This can be an issue when it comes to designing and working out (better) alternatives for problems. Another weakness is my lack of knowledge on the programming topic, as this is an essential part of the product, the concept will be influenced by the lack of these skills.

*Pietro Maschera (*1220953*)*
As a student of psychology and technology one of my biggest strengths is the interaction between the device and the user, also because I have followed the the course User Centred Design in my first year. On top of it, with my degree I have earned some programming skills, which will help our group since we do not have many people who have experiences in coding. Finally I am good at thinking out of the box which will give us a lot of different perspectives on different issues and I retain myself pretty creative. My weaknesses lie partially in the fact that I am not really good in group works. Furthermore once I am settled on a good idea I might have some difficulties on adapting to changes.

Paul Roelen (1255576)
I am studying Industrial Design which has a lot of these kinds of projects. This experience will help not only me in working efficient but also I will be able to help my teammates and steer them in the right direction. Secondly I am decent at designing models for posters or certain parts of the device. This will improve our presentation part. Secondly my models will make it easy for other group member to visualize what exactly we are doing. My weakness is that as a person I think about a lot of things at once hindering my focus.

Stan Schuurmans (1233100)
During my study of bachelor Automotive Technology I have acquired knowledge about programming and electronic components. These skills will come in handy for both the assembly manufacturing part as well as the designing part. For designing I can provide measurements and necessary components which in turn helps the people modelling it. As for the assembly part I know how to put our device together as I have some experience with soldering . My greatest weakness is communication, I get focused on my own work too much and might forget to share some important information with the group. Furthermore I know how certain things will work but my group members might not, making them feel excluded.

Tine Stevens (1240205)

During the first year of applied physics I gained knowledge about forces, torque, etc during the mechanics course, which I think could be useful in a design. I also learned how to do experiments, which could be useful during the testing of the design, and I learned to always question and check the correctness and reliability of a test result or calculation, which is important when you are making an design that is supposed to work in real life. If I had to choose I think the hunter would fit me the best. I am a realistic person and when ideas come I immediately think of practical issues such as how am I going to make that or is this something that can be done. One of my weaknesses is that I don't have a lot of knowledge about programming/software, which is unavoidable in the design. Other weaknesses are that I haven't done any practical work yet and also haven't done a lot of group work. So it's all quite new to me and something I can definitely learn from during this course.

Remco Vader (1251597)

Because of my study (Mechanical Engineering) I think I have quite a broad general knowledge about physics and math, but not too much knowledge on specific subjects such as programming and using MATLAB. However working on these types of assignments (alone or together) will only help me improve on it. During my first year as a Bachelor student I already had 2 design-based learning cases in which I worked with a group of students to create a product. Because of this experience I'm already comfortable with working in a group and having meetings and SSA's, as well as being the chairman during meetings. In previous peer reviews my stronger and weaker points were remarked by other students, so I am aware of those. I would describe myself as a very reliable group member who will live up to agreements that are made and is always on time. However, SSA's could be more in depth and I could give my opinion more during meetings. The type of creator that best fits me is the hunter because I am not necessarily good at thinking out of context, but more the type person who can switch between contexts. If I see a written code or certain functions, I can properly link those to the actual product and explain what this code or these functions do and mean. Also I am a rational person who looks for easy and logical solutions to problems instead of inconvenient solutions.

Kornel Zdrojkowski (1252836)

Industrial engineering is a study mostly focused on improving existing processes which is not as necessary while working in this small of a group.

Small things like communication and planning can be worked on thanks to the knowledge obtained during my bachelor. Furthermore, I am very open to ideas and will listen to everybody. Lastly, I am able to come up with crazy ideas due to my ability to see the different connections that are not easily spotted. My biggest weakness is the lack of expertise in designing and manufacturing products. On top of that, I have found difficulties in showing initiative in environments in which I do not feel comfortable.

1.2 Group Strengths & weaknesses

As a group we started of enthusiastic yet a bit chaotic, this was definitely noticeable in the beginning of the course project as we struggled getting to know the manual and what was expected from us. We started brainstorming immediately and came up with a lot of different ideas. From there our efficiency has been increasing as we all divided individual tasks and goals to meet our weekly targets.

We are a creative group and therefore initialised many ideas for our product. As a team, we tackle main design choices based on our individual tasks, we take the electronics, aesthetics, functionality and manufacturability all into account when working on our collaborated product.
As a group we've developed a more efficient way of working every week the project progressed. Since for most of us this was our first time working in such an environment there was a lot to learn but we caught up quickly, as we were all motivated to deliver something great.

One of our main strengths is the ability to keep thinking towards the main goal and not getting our heads stuck on one idea. This became clear in the early stage of the project as we initialised an idea and later on switched to a different concept, based on our initial idea. This shows the dynamics of the group and complements with some of the group members strengths.
A group weakness we find our self in is the lack of clear communication on what is our individual progress. During the meetings it quickly became clear we tend to become chaotic and lose track of the focus of the meeting, the group gets split up in terms of conversation and we discuss things individually; luckily this does not happen the entire meeting. Although we've been strongly improving, this still keeps to be one of our main group disadvantages. Another weakness of our group is the fact that most of the group members lack some programming skills. For this reason, we writing a very complicated code is something we'd like to prevent.

All in all we are a very lively group that works with the right mindset to deliver a brilliant product.
Although we all know what is expected every time, our lack of clear, open communication might sometimes form an obstruction in our group meetings, but remains nothing we can't resolve.

2 Project Goal

Disabilities, both mental & physical can form a tedious obstruction to a person's capability to practice a sport; varying from amateur to professional. With the Paralympics facilitating this target group a podium to compete in their sport of interest, many athletes find themselves able to express themselves again. Technology driven innovation has always been directly interwoven in this field and delivers the possibilities for practicing your sport that was impossible up until recently. Yet many sports are still in need for a fitting solution to properly integrate physically / mentally impaired sportsmen. Therefore, the importance of new technology and innovating ideas is strong as ever. The project goal is to help sportsmen to practice their sport (again).

We chose to design a product for people that are deaf or have a hearing-impairment. With a hearing impairment, physical activity is not impossible. However, many sports still form an obstruction to participate in, due to the way they are played. Something else to take into account is that for people with a hearing impairment, the barrier to have social contact with other people is higher. For these two reasons we chose to focus on a team sport.

In the world of sports, coaching is an important factor in becoming better and making correct decisions during the match. Effective coaching relies heavily on good communication between athletes, but mainly between coach and athlete. athletes and coaches that do not have any form of impaired hearing can just easily shout across the field, but for deaf athletes it becomes quite a bit harder. Because deaf athletes cannot hear others, they will need to look at the coach multiple times during the game for instructions. The team sport we chose is football on an a amateur level. This because in relaxed sports or sports with a lot of breaks, for example basketball, there are multiple occasions where the coach can give a larger instruction to a player. However, for football, there is only 1 break during the entire match. In a 45-minute during half played on a large field without the possibility for the coach to just shout at a player, coaching isn't that effortless and comprehensible.

Playing football is nothing new for deaf people, they have been participating since the founding of the sport. The first recorded game between deaf teams was played in the year 1871[1]. Research shows that there are quite a lot of deaf football associations, all focussing on playing in a fully deaf football team. They often use flags instead of a whistle and communication between players and with the coach goes via simple gestures[2]. However the integration of deaf players in normal football teams still issues to be a challenge today. As mentioned before sports also have a social aspect.

The football team often consists of friends, neighbours or other acquaintances. These acquaintances do not have to be deaf, which could raise the desire to participate in a normal football team. According to several associations for deaf football (among which the Deaf Soccer Academy[3]) deaf football players are more alert to seeing and should be able to compete in normal football games. The only real drawback is the disadvantage of more complex communication.

But if this is the case then what is stopping them, why do deaf people mainly play in completely deaf teams?

[1] https://hearinghealthmatters.org/hearinginternational/2013/football-for-the-deaf/
[2] https://limpingchicken.com/2014/06/12/footy-sign-clips/
[3] https://www.deaffsocceracademy.com/

The reason is simple; deaf athletes may have the capabilities of playing in a normal team but not enough players and coaches recognize this and are willing put in the extra effort. Deaf players end up feeling left out and missing instructions[4]. So we set ourselves the goal of designing a product that addresses the problem of communication between the coach and deaf athlete with the purpose of minimizing the disadvantages of a deaf athlete participating in a normal football match.

The problem for a deaf football player is communicating with the coach, but why exactly is this a problem? Most deaf football teams make use of gestures, which is not ideal, since every time the player has to look at the coach, it forces the player to lose focus of the ball. Moreover, the player does not know the right time to look at the coach and might thus miss important instruction or spend much time looking at the coach when it is not necessary. Iin a deaf football team everyone faces this same disadvantages and therefore all players are equal. But when a deaf player plays in a normal football team, he or she will be the only player spending extra time and attention on instructions and communication of the coach, making it a serious disadvantage.

So, there are two problems we want to overcome with our design. The first problem is that coaches are not willing to put in the extra effort of having a deaf football player on the team. The second problem being the disadvantages deaf players have due to more time consuming communication. The required solution should therefore create an easy and quickly understandable communication between coach and player.

It should be user-friendly and provide simple quick communication and affordable. Because during a football match often a limited amount of the same instructions are used, the device only needs to be able to send a few possible messages. Therefore the main focus will lie on making the messages quickly understandable and not on the amount of messages. A device that meets these requirements is not yet on the market. This is where we think our design team can make a change.

Our design group consists of people with very different backgrounds, we have a few very creative group members to come with the ideas. However, we also have a few down-to-earth practical group members which can use these creative ideas to thinks of something realistic and simple to use. This combination will be very important to come up with an innovative product, since during a football game the instruction cannot be distracting and need be quickly understandable. On the other side, the product also has to be practical in the field.
Our forward thinking abilities as a group contribute greatly to the optimization process of the design. Not getting stuck on an initial solution is a great advantage when it comes to problem solving, especially when it comes to creating a product to aid deaf people.

With our very different technical backgrounds we expect to be able to make a product that will help amateur football players to join in normal football teams.

[4] https://www.deafsocceracademy.com/

3 Functions and Solution Encyclopedia

In this chapter we will highlight a list of five functions that our device will have. Those functions will be elaborated on. Furthermore a list of solutions will be stated for each function.

The design team has set up a list of functions that should be sufficient to describe the device in general terms.

Functions

1. Send / receive information
2. Notification
3. Controlling
4. Confirmation
5. Body attachment

1. *Send or receive information*
   As the main device will need to be controlled by a controlling device, a connection has to be made to communicate between these two devices. Via this connection, information will be sent and received from the main device to the controller, and the other way around.

2. *Notification*
   The main device will need a small mechanism that notifies the athlete when a signal has been received by the device to make sure the athlete won't overlook that a new signal has been received. After this notification has been given, the mechanism with the actual signal will be put into operation.

3. *Controlling*
   There has to be a controlling device, which is controlled by the coach. This device needs to be able to connect to the main device and control it by sending signals, alerting the athlete.

4. *Confirmation*
   The main device needs to have a way to send a signal back to confirm to the controlling device that the signal has been received and processed. This way the coach knows the signal has been sent and received successfully and that the athlete understood the signal that was sent. This confirmation mechanism preferably works via a sensor to enable a quick and easy response by the athlete.

5. *Body attachment*
   The device will have to be attached to the athletes' body in such a way it is not troublesome during the sporting activity.

Solutions

Function 1 Send / receive signal	- Bluetooth - Wired - Wi-Fi - Infrared - FM – signal - AM – signal - Ultrasonic - Motions - Morse code

Function 2 Notification	- Sound - Vibration - Light - Smell - Heat - Electric - Pinching - Air - Contraction - Pressure

Function 3 Controlling	- Buttons - Touchscreen - Bracelet - Keyboard - Joystick - Paddle - Gloves

Function 4 Confirmation	- Touch - Vibration - Light - Sound - Infrared - Proximity

Function 5 Body attachment	- Glue - Sticker - Wristband - Integrated in sportswear - Gloves

4 Concepts

While keeping the RPC's and functions that had been drafted before in mind, some concept-designs are created. Each concept will be introduced and elaborated how it will operate. Highlighted is why each of the products are innovative, challenging and user-friendly, as well as the pros and cons of the concept. Out of the three concepts the best concept is chosen, this concept is defined as the preliminary design. After this design has been chosen, the concept will be fully optimized and all functions will be worked out into detail.

Prototype 1 - LightCoach

This prototype consists of two parts. The first part is the bracelet with four different colours of LEDs and the second part is the controller of the coach. The bracelet and controller need to be in contact with each other by a wireless connection (Wi-Fi/Bluetooth/etc).

The coach will have the controller with him/her (which can optionally be attached to the arm with straps). The controller consist of 4 switches, each corresponding to a LED on the bracelet, with a colour-code that indicates which colour LED will be turned on. Each colour combinations stands for a certain command that coach and athlete agree on in advance.

Making use of different colours of light makes it possible to quickly read the message. When the device is used a lot the athlete will be able to quickly translate a colour-code to the correct message. One of the challenges is to make the device small enough to keep it from being obstructive during the match. Another challenge could be to establish a good working wireless connection.



Prototype 2 - BodyCoach

The device contains 4 vibrating pads that are connected in a way that each arm has 2 pads. One on the upper arm and one on the lower arm. The vibrating pads are accompanied by a control device. The pads and controlling device need to make a wireless connection. In some way the vibrating pads need a way of notification that lets the athlete know what the coach is trying to communicate.

As for the controlling device (see picture below), there is chosen for a separate controlling device that is specifically made for the product. The device contains 4 buttons, one for each pad, that are used for creating the signal. To show the coach the athlete has received the signal, there can be a small screen that gives feedback. Alternatively, if we later decide to also create a way for the athlete to communicate back, this screen can be used for the coach to read the signal from the athlete. The screen also has 4 red dots to indicate if the device is connected to all of the pads. Because the device also needs to be turned on and off, it also has an on-and-off switch.

To receive the signals from the controller, we use 4 gloves that are equipped each with a ‘vibration device’ and 1 ‘connection receiver’. The stickers are indicated with their own code. This code starts with an S, followed by a number from 1 to 4.

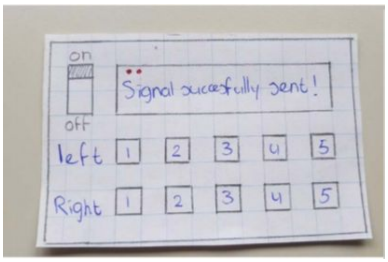
All these small contracting devices that are found in the pads are connected to the connection receive. This connection receiver will be the only part of the pads system that is connected with controlling device, and will send the signals over to the separate pads. The 2 receivers and controller will be connected via an Bluetooth connection. This way another device like a Wi-Fi router is not needed.

Because the athlete only has 4 pads on his body the device is not obstructive during the match. The coach and athlete agree on which pad stands for what message. It is easy to use. However some drawbacks could be that the athlete might miss the vibration when he is sporting intensely or that the pads might not be reusable. This is also one of the challenges how the pads are attached to body in a reusable way.

Prototype 3 - SilentCoach

The device contains 2 gloves, obviously one for each hand, and a controlling device. The 2 gloves and controlling device need to make a wireless connection. In some way, the gloves need to contain some way of notification that lets the athlete know what the coach is trying to communicate.

The controlling device contains 10 buttons, one for each finger, that are used for creating the signal. To show the coach the athlete has received the signal, there can be a small screen that gives feedback. Alternatively, if we later decide to also create a way for the athlete to communicate back, this screen can be used for the coach to read the signal from the athlete. The screen also has 2 red dots to indicate if the device is connected to either of the gloves. Because the device also needs to be turned on and off, it also has an on-and-off switch.



To receive the signals from the controller, we use 2 gloves that are equipped each with 5 ‘contracting devices’ or ‘vibrating devices’ and 1 ‘connection receiver’. The fingers in the glove are indicated with their own code.

This code starts with an L or R, representing the left or right hand, followed by a number from 1 to 5, started from the thumb. All these small contracting devices that are found in the fingers are connected to the connection receiver, indicated by L0 or R0, via wires. This connection receiver will be the only part of the glove that is connected with controlling device, and will send the signals over to the separate fingers. The 2 receivers and controller will be connected via an infrared connection. This way another device like a Wi-Fi router is not needed.

The gloves are also easy to use and with endless possibilities of messages. However this design is not preferred by our group. This because the gloves are probably hot and maybe obstructive when sporting. We also think is very challenging to make them firm enough to not break during a match.

5 Requirements, Preferences and Constraints

In this chapter the requirements preferences and constraints of our product will be stated. Firstly the requirements highlight how our product should work and what is in our mind a necessity. Secondly the preferences provide us with additional goals that will elevate our product but are not as important. Lastly the constraints are our goals which should be on the forefront ,they are not needed for device to work but guide us in designing our product. The constraint cannot be ignored or overlooked.

Requirement 1 The bracelet may not obstruct the freedom of movement of the athlete	Quantification 1 The device built in the bracelet cannot be larger than 50 x 30 x 10 millimeter (lxwxh)
Requirement 2 The wireless connection should have a reach large enough to reach any point on the football-field	Quantification 2 The reach of the wireless connection should be at least 150 meter.
Requirement 3 The received message should be quickly understandable	Quantification 3 The time to read the message cannot be longer than 1 second
Requirement 4 The battery of the bracelet should last the whole match	Quantification 4 The battery of the bracelet should at least least 120 minutes

Preference 1 The device should be elegant	Optimization 1 Round shapes around the wrist
Preference 2 The wireless connection must be at least 150 meter	Optimization 2 High quality hardware integration (costs vs performance consideration)
Preference 3 The bracelet should be as small and light as possible	Optimization 3 Make the design of the bracelet fit closely to all the electronics
Preference 4 Reading the received message should take as short as possible	Optimization 4 Easily readable display + notification method (user test)
Preference 5 The device should contain a (not visual/audio) notification device, so the athlete does not have to check for messages	Optimization 5 Building a vibrating sensor in the bracelet that notifies the athlete when he/she receives a message from the coach

Constraint 1 The device must be intended to be used in physical activity and address a physical disability	Materialization 1 The device is intended to be used by deaf amateur football players and make communication between athlete and coach possible
Constraint 2 The device must be autonomous	Materialization 2: The device contains no buttons
Constraint 3 The device should be user- friendly	Materialization 3 Easily understandable application for sending / receiving signals (mobile phone as hardware)
Constraint 4 The device has to be under 3kg and must fit in a box of 0.3x0.3x0.5 m3	Materialization 4: The wristband needs to be compact so has as little material as possible (still integrating sensors)
Constraint 5 The device needs to have some type of sensoring to which it (autonomously) responds (lights up, moves, vibrates, etc.)	Materialization 5 RGB lighting in device screen, Wi-Fi receiver (ESP) and infrared sensor.
Constraint 6 The device must be safe to use	Materialization 6 No external hardware and waterproof
Constraint 7 The connection between the bracelet and the controller should be wireless	Materialization 7 Wi-Fi receiver electronic for small distance (150 meters)

6 Preliminary design

The preliminary design is based on the prototype 'LightCoach', however we made a few improvements so it meets all RPC's we listed in chapter 5. We chose this design based on user-perspective arguments.

To come to the product decision, the other options were evaluated based on the different arguments. The gloves were not an option, as they are potentially overheating and obstructive when sporting. It is also very challenging to make them firm enough to not break during a match. Another obstruction was the wiring involved in the glove and the difficulty in processing.

The pads already had more potential, since they wouldn't be obstructive and the player would not have to lose attention from the game to get the message. However some drawbacks would be that the athlete will miss the vibration when he is sporting intensely or the pads could fall off. There is also the challenge of attaching the pads to body in a reusable way. So for that reason, the best of the LEDs-bracelet and the vibrating pads were combined in the new design.

The design is named Ludwig, after the famous deaf composer Ludwig van Beethoven, because the goal of the device is to encourage deaf people to follow their passion and not let them be stopped by their handicap.
The design is a wristband that should be worn during the football match. The wristband will have four different colours of LEDs and an infrared sensor on the outside. The coach controls which LEDs are on and which are off. Every colour of light (or combination) stands for a certain instruction the coach and athlete agree on in advance. (During a football game a limited amount of messages is needed, hence four LEDs should be sufficient. To keep the device as small as possible we decided to keep it to four LEDs). The lights will be easy to read quickly and if used on a weekly basis the colour codes will be easily translated to the correct instruction.

The IR-sensor will be used by the player to inform to coach that he received and understood the message. The sensor measures the proximity to an object that comes close. If the player touches the sensor a message is send to the coach that he received the message. We chose to use an IR-sensor for this instead of a button, because it is more user-friendly. During the game is easier to use, since it can be shortly touched with any part of the body, a button on the other hand is difficult to trigger unless you use your fingers. Another reason we chose the IR-sensor over a button is that we wanted to limit the number of parts that stick out, because when it sticks out it is more sensitive to breaking.

Inspired by the vibrating pads, the wristband will have a vibration motor on the inside (on the skin). This is built in to keep the athlete from unnecessarily losing attention from the game. When a new message is received the vibration motor starts vibrating, notifying the athlete of the new message.

Furthermore, the wristband will contain a battery that will last at least 120 minutes and a Wi-Fi receiver with a reach of at least 150m. The coach will control the lights with his mobile phone (or a laptop/tablet) that he connects to the wireless connection of the wristband via his hotspot.

7 Risk management

*During the manufacturing of the device, there are a lot of things that can go wrong. Components might be delivered late, might not work together, or might not work at all. On the other side, the device will be intensively used during a sports match, which also brings risks with it. Undergoing weather-conditions (overheating due to high temperatures / water risk) and heavy impacts (*athletes *collision / ball contact), the device asks for an all-encompassing risk analysis that clearly states possible malfunctions and how these can be precluded.*

Before the usage of the device, comes the manufacturing. The following list contains a series of topics that have to be addressed during and before the manufacturing process so the device is optimally fabricated.

Topic	**Probability**	**Impact**	**Control**
Battery shortage	high	the device stops working during the match; within 120 min, which leaves the sportsmen vulnerable	A battery with a long enough duration and that complies with the other hardware (in terms of voltage and ampere measures)
Short circuiting	high	defect of the internal electronics	optimal internal electronic placement and electrical tape.
Insufficient knowledge about writing code	high	not enough time to work on other parts of the production	gather enough knowledge about the subject/ do not spend too much time on minor details
Wires being loose	moderate	components malfunctioning/short circuit	making sure they are soldered well
ESP malfunction	moderate	non-functional device	optimize coding and solid welding of materials
Charging problem	moderate	non-functional device	easy way to change the battery / rechargeable battery
Code not working inside the device	moderate	device not receiving commands and not executing them	intensively testing the code
Ordered straps don't fitting the case	moderate	the case can't be attached to the straps	using the exact schematic of the straps during the design of the case.
Bad component fit	low	displacement of components (e.g. the IR-sensor & vibrator), leading to malfunction	solid casing that is designed to hold all components in place. Extensive work is necessary

The following list shows a series of topics that will form a risk for the device performance

Topic	**Probability**	**Impact**	**Control**
Loosening of the wristband	high	the athlete will get physically distracted from the game leaving a negative influence on the match & he/she will constantly have to re-adjust the wristband	strong yet feasible interconnection of the wristband. possible solutions can be a button system, magnetic lock, physical (watch-like) lock
Application (control device) malfunction	moderate	lost connection to the player and the disability to communicate likewise.	stable app functioning based on solid coding and a reliable connection to the device
Signal disturbance	moderate	lost connection to the coach (temporary) and negative influence on sportsman performance	usage of quality hardware that guarantees larger signal fields (than initially necessary) to eliminate possible connection losses
Loss of device	low	certain time duration loss of interaction with the coach. Player gets distracted from match.	strong connection and non-breakable / flexible material for wristband
Waterproofing fails (sweat)	low	definite defect of the device and lost connection to the coach.	waterproof design that leaves no open and especially vulnerable hardware open to water / sweat
Breakage of device	low	definite defect of the device and lost connection to the coach.	the device needs to be made out of strong yet flexible and sustainable (preferably plastic) material. This way it will be direct impact resistant and form no obstruction to the sportsmen

8 Detailing

In this chapter we will focus on three components of our device and program behind it. They represent the three most important parts: the code, the design and the electronics.

- *The detachable case (3D printed) & CAD manufacture drawings*[5]
- *The LED light device with vibration motor and proximity sensor*
- *Coding and Interface*

3D printed Casing

The 3D printed casing consists of 3 main components; the cover, the bottom & the electronics casing. The casing also includes the connection to the wristband.

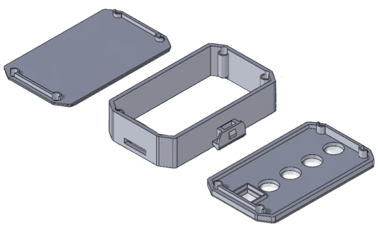
Main electronics casing

The main case includes all the electronics part including: 4 LEDs, an IR sensor, the battery holder, voltage regulator & vibration motor. They are all fitted precisely together (calculations showed at 'electronics part') so the smallest possible casing can be produced and it complies with the RPC's. Current dimensions of the casing (inside) are set to: 41 x 28 x 11.5 mm (l x b x h). The wristband connection is based on the Fitbit design as our wristband works with the same system. This way we ensured a safe & solid connection for the electronics casing to the wristband.

The wristband can be adapted to the users preferences by changing the length (and therefore overall width) of the bands. The distance between each position is marked as 10mm which ensures optimal comfort and grip; a necessity for sportsmen. The wristband is pushed into the electronic devices' connection part and automatically locks itself by the interconnection. This way the wristband can be changed to preferences (if broken or other sizes are preferred) and leaves the sportsmen with more freedom of choice

Bottom cover

The bottom cover folds over the main electronics casing and is secured in place using small bolts. This way it can be opened up again to enter the electronic compartment and change batteries when necessary (and comply with the RPC).



Top cover

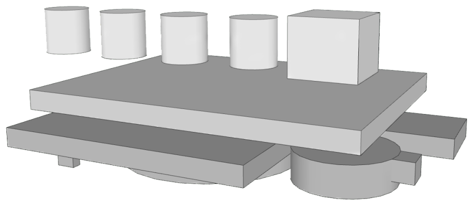
The top cover slides in the electronics case and is set using bolts. There are 5 main openings for the LEDs and the IR sensor. The design length is based on the dimensions of these components. The distance between the LEDs is kept minimal to 1mm so the minimalistic design of the product can be held.

[5] *Provided in the appendices (appendix 1) are the manufacturing drawings of the product, both assembled and seperated.*

Electronic parts

The internal electronics are placed inside the casing design to fit the components. The following electronics are included in the casing for the device to operate properly:

-	4 LEDs	7 (diameter)	mm
-	IR-sensor	7x7x6	mm
-	Wi-Fi ESP	34.3 x 25.6 x 2	mm
-	Battery	-	
-	vibration motor	20 (diameter)	mm
-	voltage regulator	13 x 8.2	mm



The 4 LEDs (5mm) are integrated in the casing using a LED case, this sticks out 1.5 mm through the top cover* of the casing so they are both visible for the player and spare space in the inside.

The LEDs are connected to the Wi-Fi ESP board which is programmed to be operated from either a mobile device or computer (see 'coding and interface'). The LEDs are soldered to the ESP.

Also the IR sensor (7x7x6 mm) is soldered to the ESP and recognized the hand of the player to confirm the received notification from the LEDs.

Underneath the ESP module the battery, voltage regulator and vibration motor are located, this design decision is based on the accessibility of the battery for charging and the possibility for the vibration motor to notify the player a signal is send and a new signal is received. The voltage regulator is directly connected to the battery and thus needs to be directly next to it.

To show how this will work, a model is built on a breadboard to test functionality (see chapter 9 - assembly).

* the placement of the 4 LEDs and IR sensor in the top cover follows the following pattern (in mm):
2.5 - 7 - 3 - 7 - 3 - 7 - 3 - 7 - 3 - 7 - 2.5 > sums up to 50 mm

---

Coding and Interface

The user is able to interact with the device with the aid of an interface on the web. The interface is divided in two options.

The first interface that is presented to the user is pretty simple and intuitive. Six buttons are located on the user's screen, four of which are for the LEDs, one is the 'buzz' (to control the vibration motor) and one to switch between the two interfaces. The buttons regulating the LEDs are shaded with the same colours of the light that they are representing (red, blue, green and yellow). The user pressing on these buttons can freely decide in which combination the LEDs are going to be turned on. The state of the LED can be understood by the colour of the buttons: if a LED is turned on the button will be fully coloured, otherwise just the edges. After the selecting all the lights the 'buzz' button can be used to inform the player in the field of a new message.

Clicking on the switch button the interface will change to the second interface. This interface is more interactive, it allows the user to choose the number of buttons placed on it (up to 15). All buttons will appear underneath each other, in a column, representing a different combination of LEDs recognizable by the coloured dots on each button. The buttons are named with default names, which are common instructions yelled by coaches during a game of football. The user can both add and subtract buttons with the aid of two black buttons ("+" and "-") at the end of the column. Like in the first interface, the "switch" and "buzz" buttons are present.

LED	**Action**	**LED**	**Action**
🔴	Attack	🔵🟡	Keep calm
🔵	Get back	🟢🟡	Stay put
🟢	Good job	🔴🔵🟢	Advance
🟡	Position	🔴🔵🟡	Offside
🔴🔵	Forward pass	🔴🟢🟡	Are you ok?
🔴🟢	Not too far	🔵🟢🟡	Change
🔵🟢	Pass to the keeper	🔴🔵🟢🟡	Shoot

In both interfaces the sentence "message received" will appear on the screen, when the player touches the IR-sensor in the bracelet.

The code was realized on the Arduino software and is the combination of C and HTML coding (seen as strings). The following table briefly describes the key features of the code in order.

Every LED and the buzz get defined on a pin on the ESP and as a bool	#define D0 16 - bool D0State = LOW/HIGH
As a bool the state of the interface is defined	bool InterfaceState = true/false
Every detail on the interface gets its own qualities in HTML code	String Header = String(".RED{border: 2px solid #f33; color: black; ...})
Every button on the interface gets the information assigned	String("<buttonclass=\"RED\"></button>");
The switch function changes the interface, therefore the InterfaceState	void interfaceSwitch(){ InterfaceState != InterfaceState}
In interface 1 depending on the LED state the button might change	if(D0State){ interface += Button0ON } else{ interface += Button0OFF }
In interface 2 for every button added the interface refreshes following a "for" loop that iterates in an array of buttons	for (int n = 0; n < j; n += 1){ interface += Btn_array[n] } (j regulates the max no. of btns to print, n the no. of btns printed)
The add() and sub() functions regulate j in the "for" loop	void add(){ j += 1} / void sub(){ j -= 1}
The buzz() function regulates the vibration motors	void buzz(){D6State = !D6State; digitalWrite(D6, D6State);delay(500); D6State = !D6State; digitalWrite(D6, D6State);...}
The toggles functions regulate the LED to be on or off (interface 1)	void toggle0(){ D0State = !D0State; digitalWrite(D0, D0State);}
Every button in interface 2 is regulated with a specific function	void red(){ D0State = HIGH;...; changeAllToState(); buzz();}
In the setup() function the pins get defined as an output, the URL-commands are established and the server begins	pinMode(D0, OUTPUT) server.on("/0toggle", toggle0) server.begin()

9 Assembly

After the detailing of all separate elements, a fit test has to be performed to check whether the design complements when all elements are brought together. After all components are confirmed, we can continue with the actual assembly and finalizing.

In this chapter, the following components are tested / explained

- *3D printed casing and wristband*
- *3D printed casing and electronics*
- *breadboard setup*
- *digital interface testing*

3D printed casing and wristband

The 3D printed case that will contain all electronics (see '3D printed casing and electronics') will be connected to the wristband by an interconnecting mechanism. The main aspects of the fit test will be: comfortability, movability, tight fit and readability & safety.

Comfortability

The wristband needs to be comfortable around the wrist, meaning it won't form an obstruction to the sportsmen during the match. The fit test of the first casing showed that the initial design was too big to fit comfortably around the wrist, the design has therefore been altered to a smaller 40 mm length so it creates a more comfortable fit around the wrist. Also the location of the connection points have been redesigned and lowered so the wristband fits tighter.

Movability

The player needs to be able to move as freely as possible so the device is designed to be as small and lightweight (PLA for case) as possible.

Tight fit

The wristband fits tightly with the casing so any risk of loosening is minimized / deleted. To assure this fit a solid interconnection is made between the two components (see appendix I).

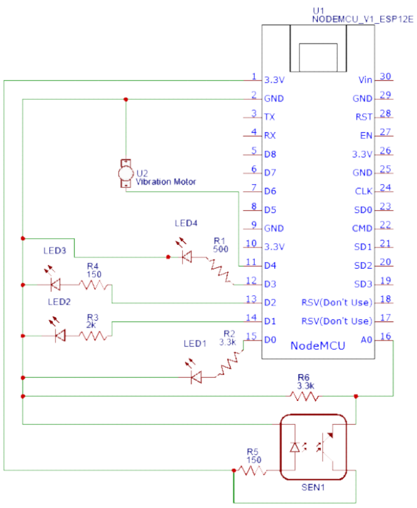
Readability & safety

The LEDs should be readable for the player so the connection should not obstruct this readability. A waterproofing test is performed to measure to amount of water that enters the casing through the openings.

3D printed casing and electronics

All electronics are first dry-fitted in the casing to validate that it will fit properly and then soldered together. Following the detail plans, the ESP and LEDs are soldered and the LEDs are held in place by using a LED holder that fits through the opening of the case. As the preliminary design did not contain the IR sensor, this has been added to the design and therefore altered the shape. It has been implemented with the LEDs in the font of the case.

[image]



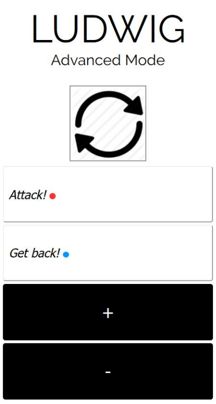
Electronic Wiring

To test the electronic wiring, all electronic components (including resistors) are put together on a breadboard with a different ESP than we eventually used for the product but functioned based on the same system.

Then, after the circuit is defined to be sufficient, all the components can be put into place and soldered together. In addition to the circuit presented in the preliminary design, an IR sensor was added, which required a slight alteration to the circuit.

All LEDs and the IR-sensor are soldered to the ESP module that receives it power from the battery (regulated by the voltage regulator) that is soldered to the power input of the ESP.

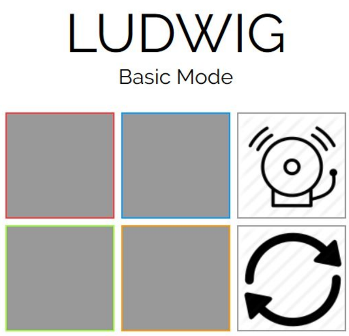
Digital Interface



In the first phase of the project there was just one interface, which had 6 simple buttons, one for each light, one to alert the player and one to refresh the page. This interface gave a better understanding of what functions would be needed.

The first idea for the new version of the interface was creating buttons on the interface and allowing each button to be customized with a label and a combination of LED's (up to 15 custom buttons with buttons for adding and subtracting on the bottom).

The problem with this plan was that it was unnecessarily complicated to make and too time consuming, therefore an interface was coded to only work with default names and pre-determined LED combinations.



10 Final Design

The final design is based on the preliminary design, which is worked out further into detail in chapter 8. After the detailing and assembling has been done, the final design is finished.

All the components that were used for the final design are listed in the table below. The table also shows the individual cost of the components, the total component cost, the total delivery cost and the budget that was available.

Component	Supplier	Cost (€)
AAA Battery	Supermarket	0,24
Battery holder for 2 AAA batteries	TinyTronics	0,80
Bouten M1,6 x 16MM per 10 stuks	MicroSchroeven	0,36
Casing and watch strap (3D-printed; PLA)	TU Eindhoven	0,00
CNY70 Vishay, Through Hole Reflective Sensor	RS Components	1,30
5mm LED Holder - Plastic	TinyTronics	1,00
LED set 5mm - 40 pieces - (Green - Red - Yellow - Blue)	TinyTronics	0,25
Moer M1,6 volgens DIN934 per 10 stuks	MicroSchroeven	0,52
Pololu 5V Step-Up Voltage Regulator U3V12F5	Floris	5,00
1KΩ Resistor (2x)	TinyTronics	0,10
150Ω Resistor (8x)	TinyTronics	0,40
Siliconen polsbandje voor de Fitbit Charge 2 - Maat S - Zwart	Bol	9,95
Small Vibration DC Motor 2.5-4V	TinyTronics	1,00
Smartphone	Coach	0,00
Wemos D1 Mini V3 - ESP8266 - CH340	TinyTronics	6,50
Total component cost		27,42
Total delivery cost		9,85
Total cost		37,27
Total budget		40,00
Budget remaining		2,73

The remaining budget after the assembling of the design is €2,73, meaning that the project was able to remain within the budget.

With these calculations, it is assumed that the coach already has a smartphone available. One might argue that it isn't fair to assign a cost of €0,00 to the smartphone. However, our design team strongly believes this is a fair assumption, since smartphones are fully integrated into present-day society. These days, almost everyone has a smartphone with them at all times, in this will probably become even more extreme in the coming years[6]. Also, the cost of the casing is assumed to be €0,00. Because the casing is 3D printed, and this service is provided by the TU Eindhoven free of charge, this is only a fair assumption.

---

[6] https://www.statista.com/statistics/201184/percentage-of-mobile-phone-users-who-use-a-smartphone-in-the-us/

For the manufacturing of the device, multiple different manufacturing techniques have been used. The table below shows what types of techniques have been used, a description of the technique and for what application the technique has been used.

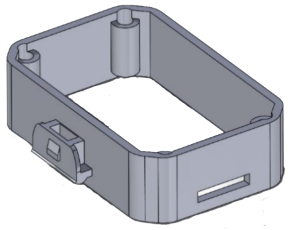
Manufacturing Technique	Application	Description of technique
3D printing	Printing the 3D casing	3D printing is a process in which a three-dimensional object can be created. This object can be designed in a computer-aided design (CAD) model and can be almost any shape or form.
Fastening / Screwing	Closing up the 3D casing	Fastening is a process where multiple separate objects can be mechanically joined together. Usually this means that the connection is non-permanent and can be disassembled. In our case, screwing is used as a fastening technique to close up the 3D casing.
Interference Fit	Fitting some electrical components together (LED pins are fitted into to the ESP)	Interference fit can be used to fasten multiple components, using friction between the components. This connection usually is non-permanent, and requires enough friction to create a tight connection.
Soldering	Soldering some electronic parts together	Soldering is a process in which multiple separate components, usually metals, are joined together by melting. This way a reasonably permanent connection between multiple components can be formed.

Chapter 9 gives a more detailed description on how these manufacturing techniques are used. None of these manufacturing techniques provides additional costs. The 3D printing is provided free of charge by the TU Eindhoven for any design group. The soldering stations in the E-lab can also be used free of charge by Industrial Design students. For the fasting / screwing and interference fit, the electrical components are used and no additional costs rise.

In the following part the final design and its components will be described and supported by images. The functions of all components will not be described here, for that we refer you to chapter 6. The final design consists of multiple parts:

- Detachable wristband;
- Casing;
- Electronics;
- Battery holder.

As shown in the pictures the device itself is not much bigger than a regular watch. Unfortunately the battery type that is used right now does not fit the casing. So, a outside holder is needed for the device. The connection between the the device and the battery is fragile, this part is not as planned and does not meet the RPC's it will thus have to be changed. The slit used for the battery wires is designed in such a way that in the future it can be used for a on/off-switch.



The device has a blocky shape but near the edges it curves a bit, eliminating sharp corners. On both sides of the casing a juncture piece is located. The wristband perfectly fits into this juncture piece. The wristband can be detached, but will not get loose by itself. This makes it easier to clean the device, but the user can still be assured the device will not fall of the wrist during the match. For further details on the casing one can look back at chapter 8.

On the top plate of the casing the four LEDs are placed in 4 LED holders, this does not only give a better design, it also makes the LEDs less vulnerable to breaking. Next to the 4 LEDs a IR-sensor is placed in a square hole. The sensor is well hidden inside the case to remove as much distortion as possible as well as protecting it as much as possible.

Inside the casing the ESP and the voltage regulator are located underneath the LEDs and IR-sensor. The casing is closed by another plate on the bottom on the inside of this bottom plate the vibration motor is placed The complete device is light weight and in it is not obstructive when actively sporting.

11 Test Plan

Testing is incredibly important in order to find out whether the device sufficiently fulfills the requirements, preferences and constraints. Based on the RPC's that have been drafted before, a set of tests has been created to test if these are actually fulfilled and what aspects of the product could be improved. Those improvements will be elaborated upon in the design evaluation.

During the manufacturing of the product, all electrical components have already been tested. This has been done to ensure that there won't be broken components that are already soldered. Every time a new component was added to the components that were already assembled and working, the completed thing was tested again. After all the manufacturing has been done, the full practical workings of the product can be tested.

Test 1

The first test will focus on user-friendliness and comfortability of the device. The RPC's state that the bracelet may not obstruct the freedom of movement of the athlete, should be as small and light as possible and look elegant.

To test these requirements the usage of the device has been brought into practice. Sadly, testing the device in an actual match wasn't possible due to time constraints. As a first test, the actual workings of the wireless connection should be tested. As the wireless connection could be set-up, it could be concluded that the connection works and Ludwig works autonomous.

Secondly, our testperson attached the device to his arm and ran multiple rounds, while turning and swaying his hands to see if the device was obstructive or not. According to our testperson the device wasn't in any way obstructive our heavy in his arms. At the end of all test that have been done, the testperson couldn't state that he had pain in his arm due to a heavy device.

Ofcourse this way of testing is partly subjective, however, our design team believes that a normal watch will always be heavier since Ludwigs casing is printed out of PLA, which is a much lighter material than all materials used for an actual watch. Elegancy is also a matter of personal opinion, but since all wiring is hidden, the casing has chamfered edges and we used LED holders, the aesthetics of the product can be considered very smooth.

Test 2

The second test will focus on the effective range connection between Ludwig and the controller. The wireless connection should obviously stay intact when the player moves over around the field. The prefered distance of the connection is at least 150 meter.

This experiment took place on an open field. Starting from the controlling device, our test-person kept walking further away until the connection was lost. When the connection isn't able to stay intact, this means that the maximal wireless distance has been reached.

Sadly, the wireless connection was lost when a distance of approximately 75 meters was reached in the three respective attempts. This distance which isn't even near the required distance, nor as the length of a football field. However, with a better Wi-Fi connection a distance of 100 meters seems reasonable.

Test 3

The third and last test focuses on the usability of the device. The messages that are received should be quickly understandable and differences between codes should be easily distinguishable. Also the vibration that notifies the athlete that a new signal has been sent should be easy to notice.

This last test was done at a moment where there was a lot of sunlight, which makes it harder to notice the different LEDs. But, despite the sunlight our testperson could conclude that the LEDs were bright enough, and because of that also easy to read.

It's also worth noticing that the battery of the device managed to did not survive the full testing period, , without any further complications popping up. So in this state the source wouldn't last more than 30 minutes which is lower than a half of a match which is unfortunate.

Out of these tests, it can be concluded that not all requirements, preferences and constraints are fully fulfilled. However, like stated before, some of these tests include some form of personal opinion. For example, one person might find the product elegant and comfortable to use, while another person might not fully agree. To reduce the chance that personal opinions influence our test results, multiple test persons could be used. Also these tests aren't done in a real match.

Testing the product in a real match, with an actual deaf athlete, might shine a light on new problems that hadn't come to mind so far. The disappointing range of the wireless connection could be a result of a bad quality hotspot that was used during the match. The distance could be longer if a proper Wi-Fi network is used. Lastly using a stronger battery Lithium or otherwise might solve the issue both on user friendliness and the required working time of the device.

12 Design evaluation

Evaluating the design is of great importance for future developments of the product. It is important to have a critical look at the final design. In this part of the report we will evaluate the our final design based on the RPC's and the tests we have done.

The assignment of this project was to create a sports aid for helping mentally or physically handicapped to people take part in sports (sports can be taken very broadly as long as it concerns a form of physical activity). Our design does serve this purpose, since it helps deaf people participating in soccer. However the project also focussed on making the most creative, innovative and user-friendly design possible. With this in mind we started with making several (design focused) prototypes and combined this to one preliminary design, the most important criticism for this was the user-friendliness of the design. Based on this we made several design decisions which we are going to evaluate in the following part.

We consider the design based on the use of LEDs for sending messages still the best option, even though it requires the player to shortly lose focus of the ball. Other options that were considered for sending messages are to probable to be missed when actively sporting. We think no further improvements are needed for the LEDs, the 4 LEDs provide enough options to send the most used instructions. However optionally there could be made a second version with more LEDs, to provide coaches and players with the option of more possible messages. To improve user-friendliness we also decided to implement a vibration motor to notify the player of new messages, this way we limited the amount of wasted time during the match. This does not need any improvements. Thirdly the wristband also contains a IR-sensor, the player touches the sensor to inform the coach he/she received the messages. This part needs some improvement, for example to account for sunny days. While working on the sensor underneath a lamp we noticed it gives false positives when exposed to too much light. Improvements on this should be done as soon as possible, since it effects the actual workings of the device. It might also be improved by adding a second sensor, since in our current design the sensor only sends 'message received' to the coach. However if a second sensor is added it is possible to make a difference between whether the message is understood or not. However we are opposed to adding a second sensor. More space in the casing would be needed for an extra sensor. Also we are not sure whether it will actually be used. Before adding such an option we would have to do more research and interview coaches and players on this topic. All in all the potential upside of the added sensor is probably lower that the advantaged gained. (The number of sensors can also be added in a later stage of the design since it is not critically for the rest of the design, but it would mean the casing would have to be changed.)

We also focussed on the comfort of our casing, we changed our 3D model several times to improve the fit around the wrist and change the size. We are quite content with the casing for the moment, however it could still be improved. A enlargement of the casing may be a future necessity although it decreases the user-friendliness of the product. With this in mind the following improvement might be a solution. The casing could be made slightly round instead of straight, this way it will better fit around the wrist. The comfort might also be improved by adding a thicker strap to the casing such that it will be attached more secure to the wrist, but this it could also decrease the comfort by obstructing movement. We will thus have to find the right balance between these two. Another problem in our current design concerning the comfort are the screws we used to close the casing, currently they are sticking out of the casing. In the future the screws should not stick out any more.

The size was one of the critical points in our design, since it had to be large enough to fit all electrical components but small enough to not be obstructive when playing soccer. This mainly was a problem for choosing the right battery. We first tried to use a coin cell battery (CR2032), because of its small size, but when testing if this would work we found out it could not provide enough power to get the wemos D1 mini we used working. The only batteries of comparable size that would provide enough power are LiPo batteries (which we were restricted from using), therefore we decided to use a battery outside the casing for the moment. In the risk assessment we already concluded that the risk of battery problems was quite high, therefore this is not a unexpected problem. This leads us to the next improvement of our current design, for actual use the battery will have to fit inside the casing, for further developments and testing of the design this should be completed as soon as possible. This will either have to be achieved by implementing a LiPo battery (although might affect the safety of the design negatively, but the casing will have to be enlarged by a few millimeter) or by enlarging the casing to fit the larger AAA batteries we currently placed outside of the casing (which will affect the user-friendliness). Therefore this is still a dilemma for which the pros and cons of both option should be weighed against each other.

Finally we had to develop a user-friendly interface to control the LEDs and send the messages. We started of with a very basic, but functional interface. However for using this interface not only the player needs to remember which colour code belongs to with instruction, but also the coach. Therefore we found the interface needed improvement. We already started on this and have a working second interface which contains buttons with the text of the instruction, which automatically turns on the correct LEDs. However because of a lack of time we haven't fully completed this interface yet. Currently the names of the buttons cannot be changed and we have given a list of names based on interviews with coaches. Our vision is to make it possible to give the buttons custom made names, potentially through an app. However this is not needed for the device to work functional and it does not need to be finished until one of the last stages of the development. Based on our risk assessment we were prepared for such problems with the coding, we decided to follow the advice we gave ourselves in the risk assessment and left it like this for now and focused on other part of our design.

The most critical step in our design process was transferring the preliminary design into an actual final design. First we had to change our preliminary design a bit, we did not implement the sensor-requirement initially. We also had to change the 3D print model several times to improve the shape and comfort of the casing, but also to make all the components fit. These problems were probably the result of our group having a to chaotic way of working. We did improve on this, so in future projects this step should go a lot smoother and result in less problems. Our product is clearly not nearly finished for actual use, but overall we consider our product a good prototype. In our opinion it has the potential to become a very useful tool in sports for deaf people, not only in soccer games but in many sports.

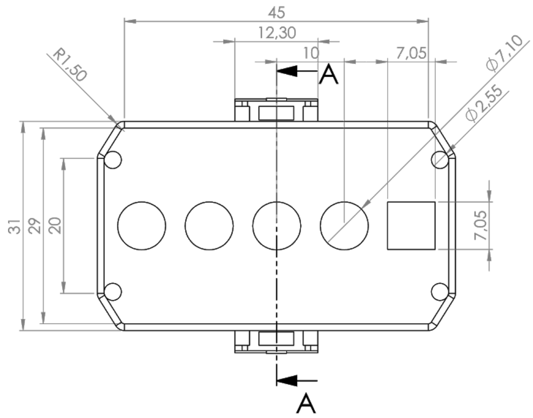
References

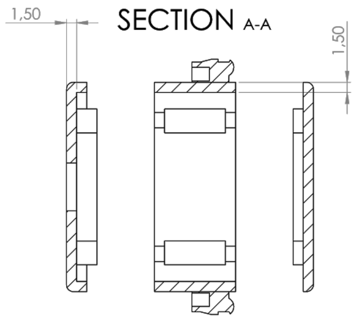
[1] traynor, R. (March 14th 2013). *Football for the deaf*. Hearing health matters. https://hearinghealthmatters.org/hearinginternational/2013/football-for-the-deaf/

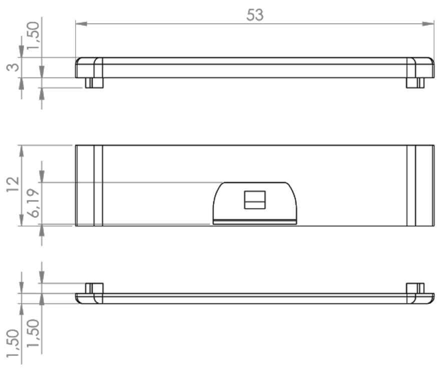
[2] gftskills. (2017). *10 different ways to use football sign language [communication advantage].* https://www.gftskills.com/football-sign-language/

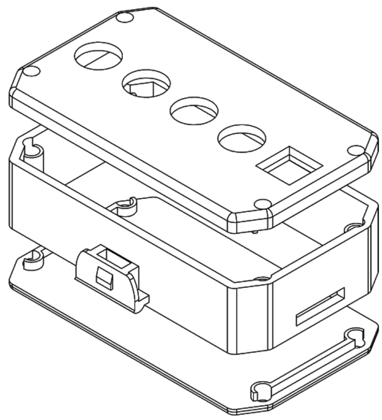
[3] Deaf Soccer Academy. (2018). https://www.deafsocceracademy.com/

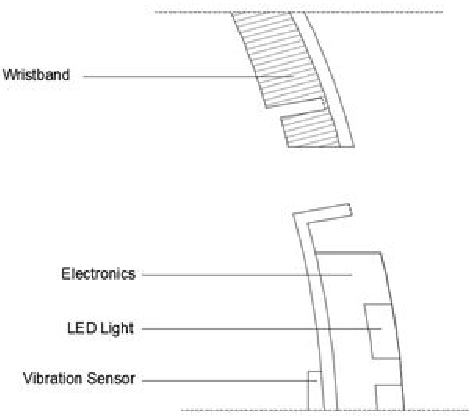
[4] Statista. (2018). *Smartphone user penetration as share of mobile phone users in the United States from 2010 to 2020.* *https://www.statista.com/statistics/201184/percentage-of-mobile-phone-users-who-use-a-smartphone-in-the-us/*

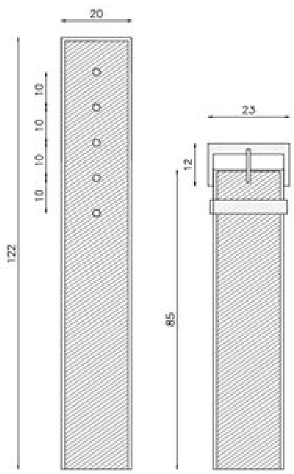

45
12,30
10
7,05
R1,50
Ø7,10
Ø2,55
A
31
29
20
7,05
A


1,50
SECTION A-A
1,50


53
1,50
3
12
6,19
1,50
1,50




Wristband
Electronics
LED Light
Vibration Sensor


20
10
10
10
10
122
23
12
85