BLINKIE

THE INCORPORATION OF GESTURE TECHNOLOGY INTO THE SMART HOME

MSc Product Design Engineering

Project Summary

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THE GLASGOW SCHOOL OF ART

opportunity

Society is constantly changing

Everything from politics to the weather has an impact on people, and in every possible aspect. These changes may be negative as the result of a decline in quality of life, however technological advancements and human centred design are always trying to fill the gaps that societal changes may produce.

Insights

Increasing number of visually impaired

2 Million people in the UK as of 2020 live with some kind of sight loss[1], 360K of which are completely blind. These numbers are expected to grow, as a global increase of 64% has been recorded in people with some kind of visual impairment due to diabetes alone between the years of 1990 and 2018.

Besides the physical, there is also a strong negative mental impact on these groups as a consequence of their conditions, as injury from falling often results in them losing their sense of independence and motivation.

Increased popularity in remote working

A 159% increase in remote workers[2] has been noted over the last few years, and is expected to continue to grow. Despite the obvious advantages such as time saved from traffic, flexbile schedules and not being physically tied down to a location, loss of productivity from distractions is a major downside for most.

When it comes to remote working the positives are not only felt by the individual, as estimates have shown that the reduced greenhouse gas emissions produced during commuting can be cut my 54 million tons per year[3] when working from home for half of the week.

Globally ageing population

As healthcare and medicine become more available and affordable the average global age increases, resulting in 2018 being the first year in recorded history where more people are over the age of 65 and below the age of 5[4]. The increasing number of elderly and visually impaired (and the overlap in between) has contributed to a 30% increase in fall related injury[5] and deaths at home in the US from 2007 to 2016, implying more people are forced into living with temporary or even permanent movement impairment as well.

The takeaway? **People are spending more and more time at home**, and **smart home technology** is slowly making its way into every home in the world to make every day life easier.

The problem? Almost all manufacturers make use of mobile applications to let users control their smart homes.

Using an application to control smart devices requires the user to physically access their phone/tablet and shift their focus onto it, which greatly reduces the immense potential smart homes have to increase efficiency and multitaskability. This also limits the usability of movement impaired users whose upper bodies are already occupied, such as those in wheelchairs or crutches.

Improved efficiency not only makes the lives of its users easier, but reduces water and energy consumption as well. Homes account for 25.4% of all energy consumed[3], so increased efficiency not only benefits society as a whole but alleviates some of the financial burden on the homeowner as well.

Although the elderly could strongly benefit from smart homes, the learning curve they encounter with any modern interface immediately puts them off it, so much so that 87% of people aged 75+ have never been online[6].

The **intended users** are those people who can't reach the potential that smart homes can have to improve their quality of life, while being the ones that can benefit from it the most, such as the visually impaired, movement impaired, and the elderly. However preoccupied remote workers can also benefit, as well as anyone who wishes to change the way they interact with technology around their homes.

The goal:

To improve the way in which people interact with their smart homes.

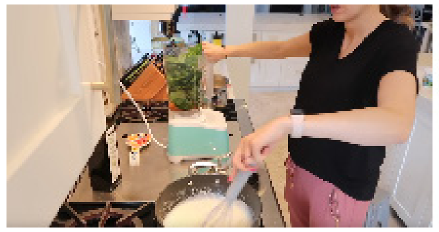
user research

Interviews with visually impaired users have shown that there is an overall strong disinterest in cooking, mainly due to their impairment. The dangers associated with heat and sharp objects, as well as mess, often put them off it, especially when turning off hot appliances[7].

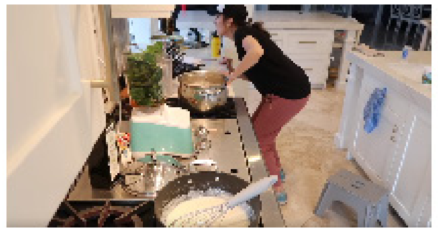
The cost of buying ready made food delivered to your door is a lot higher than grocery shopping and preparing it yourself at home, however people with disabilities struggle with grocery shopping alone and often depend on someone else to help or do it for them. The actual process of cooking is seen as a dangerous one, however the employment rate of disabled persons is half that of the average, and significant difference can be noted in wages as well. This leads to a conflict where avoiding the risk of injury when cooking is met with the financial burden of having ready made food delivered.

Since visually impaired people depend so much on the physical sensation of touch, appliances are chosen to have physical knobs and discrete clicks for different settings, however manufacturers once again are now opting for touch screens instead, making tactile interfaces harder to find.

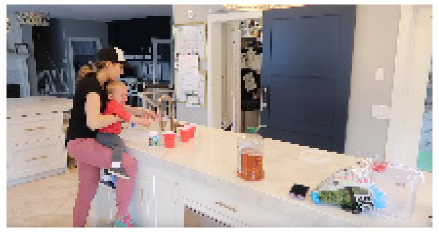
An extract from a vlog on the daily struggles of caring for young children while doing chores.



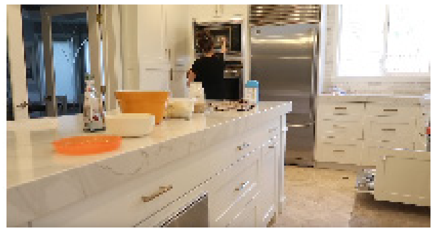
Simultaenously handling 2 pans while also operating a blender, minimizing the time spent leaving children unattended.



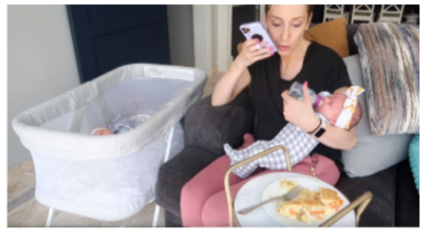
Hears her child crying from injury, and immediately goes to tend to them, leaving food exposed and burners unattended.



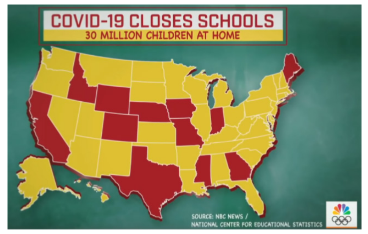
As she comes back into the kitchen to clean the wound, the food and burners are still unattended.



She must now care for the young children while simultanously finishing off the food preparation.



Even the simple process of eating requires multitasking, and answering any work or duty related phone calls requires her to divide her attention and capacity once more.



Due to Covid-19, 30 Million children were forced to stay at home as a result, meaning this scenario became far more common and parents were forced to juggle between working from home and caring for their children.

Among the very few systems that attempted to bridge the gap between disabled persons and the use of smart homes through applications , is the incorporation of voice commands. This means the user is no longer limited by his impairments and is now empowered through speech, however this is far from an ultimate solution. Besides the inability to understand intent and distinguish between different users leading to accidental commands, the dependence on voice inhibits the user from carrying out conversation without interruption. The variation of languages, accents and dialects also complicates the recognition capability of this technology, implying its usability varies from user to user[8].

This helped in determination of the **general design criteria**:

- **High acceptability,** it should work regardless of disability, nationality or age.
- **High usability,** basic enough that anyone can reach its full potential.
- **Low learning curve,** it should be intuitive and easy to understand.
- **Physical feedback**, it should communicate with the users.
- **Make multitasking easier**, the attention it takes away from other tasks should be minimized.

gestures
a solution to digital interfaces

Gestures are a natural, intuitive way to communicate, and have the potential to change the way we interact with technology. They have the ability to transcend language barriers, further showing their potential for enhanced incusivity.

Improving acceptability and usability

The recent emergence of touch screens are a clear sign that allowing people to act as the tool for interaction is the way forward, since navigating with physical buttons has now been replaced with finger microgestures. However giving users the ability to interact directly with the selected device rather than through an application will not only simplify and but make the overall process more efficient.

It will also help those like the visually impaired and movement impaired who find more difficulty in performing every day tasks than the average user, since the ability to control the various devices around the smart home from a distance will reduce some of their burden.

Studies have already shown that using gestures to interact with technology has had great success with the elderly. In fact, gaming systems like the Nintendo Wii have been found to have a strong positive impact on their physical and mental health while also promoting socializing, the difference with regular gaming systems being the incorporation of handheld gesture recognition devices[9].

A more hedonistic approach

Besides the obvious pragmatic benefits that replacing digital interfaces with physical gestures may bring, there is the added potential for making the interaction more engaging. When a keyboard and mouse interface was replaced with a gesture controlled one, despite the reduced performance due to the still developing system, the overall user experience was still rated as more enjoyable than the traditional more effective keyboard and mouse setup[10].

Products that use gestures as the interface

WiSee

This technology uses disturbances in a WiFi signal to recognize gestures within the receivable vicinity of a transmitter, allowing the user to control devices from a distance without a wearable. The main drawback is that initiating and performing a command took too long[11].

Myo armband

This wearable worn around the forearm makes use of EMG signals produced by the muscles used to produce finger and hand movements and translates them into commands. Besides the main drawback of it lacking any specific purpose and appearing as more of a novelty than anything else, it also got uncomfortable to wear quite quickly[12].

Fibaro SWIPE

This pad uses proximity sensing to recognise hand movements and uses them to control smart appliances. Although it's functionality is mainly focussed on ON/OFF commands, it does so reliably and quickly. Despite this, it can only recognize motion up to a few centimetres above the screen, and the pad occupies a considerable amount of space[13].

SinceCue

This SingleCue is another non-wearable technology that makes use of a camera to track hand movements and translate them into commands, mainly to control a TV. Although overall the system worked well, its use was only limited to the vision of the camera, and it was only applied to the control of televisions[14].

Logbar Ring

The Logbar ring was capable of detecting the motion pattern of the finger using accelerometers, and using that data to control an application. Other than its uncomfortable fit and size, and the limitation of needing the application to be open to use it, it was only successful around 10 - 20% of the time[15].

Market research on the pros and cons of the available products led to more **detailed design criteria:**

- **Low response time;** ideally an immediate reaction once a command is performed.
- **High success rate;** the more attempts required the more frustrating it will be to use.
- **Comfort;** regardless of its capability, if it is uncomortable to wear it won't be worn.
- **Low restrictiveness;** the more limitations it places on the user, such as location or the ability to perform other tasks, the less likely it is to be accepted.

concept development

Ideation; Visualizing context through video ethnography

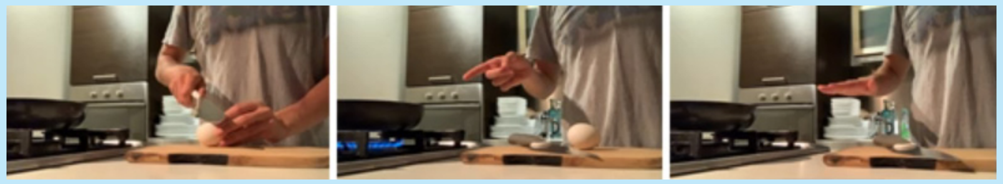
WHAT IF wheelchair users could open and close doors with their hands.

WHAT IF wheelchair users could control lights through shrugging.

WHAT IF pre-occupied users could turn on/off appliances in another room by blinking.

WHAT IF one could open/close their fridge while carrying food by tapping their feet.

WHAT IF the temperature of the room could be changed by shrugging shoulders individually.



WHAT IF the hob could be turned on/off without touching it, by pointing.

Initial concept development

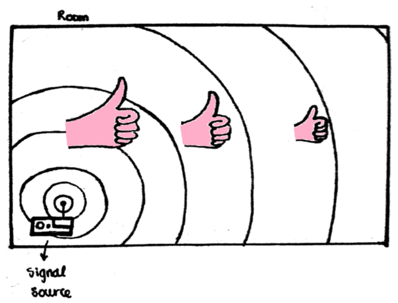
Once I understood who my users are, what problems and limitations they encounter, and how gestures could help, I could begin focussing my design and making decisions to converge into a final point. Visualizing some context helped spark some ideation on what the system could potentially be capable of doing, while the technical side could begin in parallel.

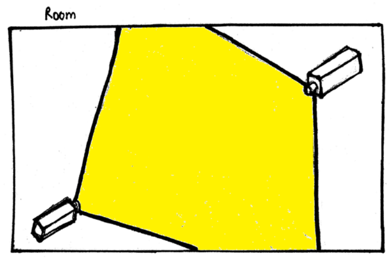
Phase 1 - Will it be wearable or not?

The starting point was the main division between different types of gesture recognition technology:

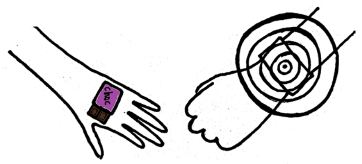
- Non-wearables

For the purposes of this project they are defined as those products which recognize gestures without physical contact from the sensing technology. These are usually short range, long range, or vision based. The short and long range could make use of radar and ultrasound in different configurations, whilst the vision based could make use of infra-red or visual light to analyze live footage. With these technologies there is a constant battle between the responsiveness of the system, and the area in which it is effective. The closer to the transmitter the user is, the more responsive the system, and vice versa, which is why some manufacturers opt for a short range system like the Google Soli.





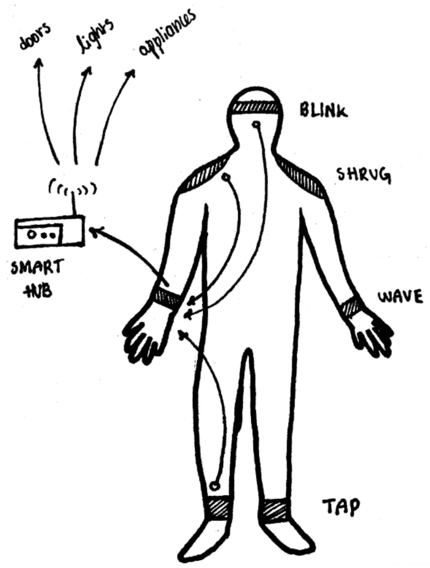
Adding more transmitters for the WiFi system could work in principle but it would increase complexity and cost, as well as the amount of hardware. Adding more cameras increases detectable area but has the same downsides as the WiFi system, while also being adversely affected by low light conditions.



A short range radar may have the advantages or responsiveness and reliability, however it still requires the other hand to use it, which may be preoccupied.

- Wearables

For the purposes of this project they are defined as those products which recognize gestures from direct physical contact with the sensing technology. This type usually makes use of accelerometers, which are very common but limited in their ability to detect, or some sort of biological monitoring, which can be far more complex yet more capable. The main disadvantages of wearables are the risk of discomfort since it will be worn on the body, and the need for batteries. It will also have to house all the communication electronics and any auxiliary technology for its functionality, which may make it bulky. Since they are so close to the user they more often than not obtain information of the gesture quickly and reliably, and with the potential of not limiting the user to a specified direction or location. Considering what a high priority these qualities are, a wearable design will be taken forward.



concept development
Refinement

It has thus been determined that the most favourable solution is a wearable. Converging the design further will require deciding which gestures will be used for recognition.

Phase 2 - Which gesture?

Since gestures use different parts of the body and require different amounts of attention and effort to perform, this is an important aspect of the design for the users given their different impairments or limitations. Choosing the gesture to be recognized for commands will be based on the aforementioned critera, particularly high acceptability and minimized intrusiveness with regards to the attention and effort required to perform it.

All of the body parts for gesturing were checked against the different user groups and graded based on how normally available that body part is considering their main impairments or limitations. If given a **2** then it is easy and available to use, if given a **1** then it is met with medium difficulty and not always available, and if a **0** then it is very difficult if not impossible or always unavailable.

			User Groups					
			Movement impaired		Visually impaired	Elderly	Remote worker	Sum
			Wheelchair bound	Upright assisted				
Part of the body to be used for gesturing	Head	Eyebrows	2	2	2	2	1	11
		Eyes	2	2	2	2	1	11
		Mouth	1	1	1	1	1	6
		Neck	2	2	2	1	1	10
	Upper Body	Hands	0	1	1	1	0	3
		Fingers	0	1	1	1	0	3
		Shoulders	2	2	2	2	2	12
	Lower Body	Leg	0	0	2	1	0	4
		Foot	0	1	2	1	2	7

Rather than producing the sum of all the different permutations and immediately going for the one that scored the highest, this table acted more as a representational guide to compare the overall usability of different gestures against the different user groups. It exposed how using hands and fingers results in the lowest scores, since they are most often the parts of the body that are already preoccupied due to their impairments or other duties, such as with wheelchair users and remote workers respectively. Despite this, all of the products shown in the market research previously all used hands and fingers to gesture. It is easy to understand why this is so considering the numerous permutations possible with 10 fingers and 2 hands, as well as the fact that they are our most versatile tool for both gesturing and non-gesturing related activity, but with regards to acceptbility it is far from the best option. Although eyebrows and shrugs also scored high there are social connotations that come with their out-of-context use that may put off users from using them. **Since blinking with one's eyes is subtle, unobtrusive, and available to most user groups, it will be the gesture of choice.**

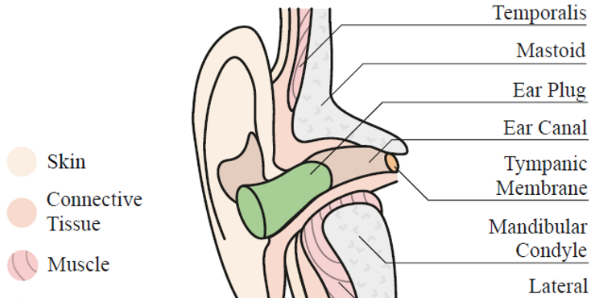
Phase 3 - How will the gesture be detected?

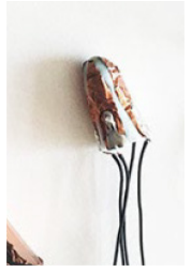
The final phase to determine the functionality of the product is the type of technology that will be used to recognize blinking. This technology must be applicable to a wearable, and ideally maximizes the aforementioned detailed design critera of low response times, high success rate, and low restrictiveness.

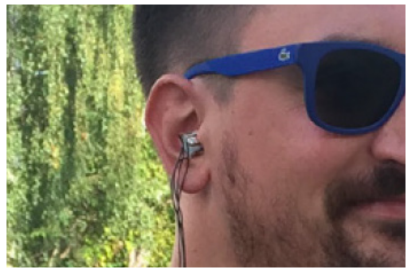
Research has led to the discovery of 2 major technologies that have the potential to meet these criteria, which are the following:

Electromyography (EMG)

This technique uses the electrical signals transmitted from muscles when they contract and relax, which can be detected, analysed, and with the appropriate software correlated to the specific muscle movement performed. The EarFieldSensing uses an inner-ear plug to detect and differentiate between different facial expressions, including blinking. It makes use of the different muscles involved when forming facial expressions that cause deformation of the ear canal, mainly due to the temporalis, the biggest muscle in the human head. This muscle also contributes to blinking, which found the highest success for detection among the different facial movements[16].

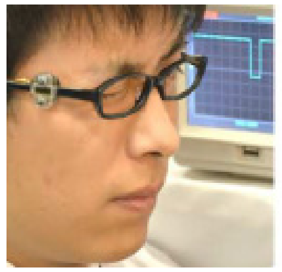


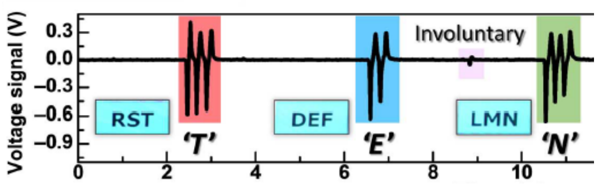




Triboelectric NanoGenerators (TENG)

These sensors make use of very subtle micro-deflections on the surface of the skin that result from muscle movements. What makes these sensors special is the high signal strength they produce from deflections under 1mm, capable of around 750mV as compared to a typical 100mV from EMG. Since the deflections themselves are what induce the signal they are essentially self powered, and can be extremely compact since they are composed of a thin film made up of multiple layers totalling a thickness under 0.5mm. A concept was developed where these sensors were placed on the temples by mounting on the arms of sight glasses, where blinks were used to select letters to form sentences, and even to control different appliances like a lamp and a fan[17].





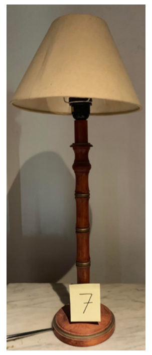
Infusing these 2 concepts into a single design could combine the pros of both concepts: the ideal placement of the EarFieldSensing device by utilising an ear plug in the ear canal to detect deformation of the ear canal, and the high performance, compact nature, ability to be self powered, and proven capability of the TENG to differentiate between voluntary and involuntary blinks.

working principle

Device selection

An efficient means for selecting devices incorporates a binary numbering system, where short and long blinks act as 0's and 1's. Taking 3 short or long blinks will allow for a total of $2^3 = 8$ devices to be incorporated, the permutations of which can be seen in the table below.

Blink Sequence	Binary equivalent	Appliance number
Short, Short, Short	000	1
Short, Short, Long	001	2
Short, Long, Short	010	3
Short, Long, Long	011	4
Long, Short, Short	100	5
Long, Short, Long	101	6
Long, Long, Short	110	7
Long, Long, Long	111	8



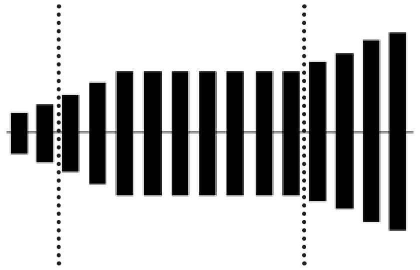
This solution requires a very simple and low cost setup, allowing the user to control any device within the effective network regardless of their location or orientation. Despite this its effectiveness depends on the user's ability to memorize the sequences for each individual device, which becomes more difficult with the addition of more devices. Keeping the user groups in mind, such as the elderly who may have issues with remembering such sequences of blinks, a simpler but less efficient method is simply allocating each device a number that corresponds to the number of short blinks to be performed after the "wake up". Although more time consuming it may prove to be easier to execute, especially if the number is visible on or next to the device it is allocated to.

False positive prevention

With any gesture recognition technology for human to computer interaction it is crucial that the system can determine if a gesture was intentionally performed for a command or not. Capturing the intent of the user will always be a challenge, but the fact that the TENG technology is capable of distinguishing between voluntary and involuntary blinks is a good start. Voluntary blinks can be used to "wake up" the system and show the user they intend on performing a command, which are unlikely to be performed accidentally. Despite this, accidental triggering is not impossible, such as how many people close their eyes when they yawn. To remedy this, some sort of haptic feedback should be provided. This will do 2 things: it will let the user know the "wake up" was performed correctly when intentional, and alert the user of false triggering when unintentional, allowing them to inhibit the rest of the comand from taking place. Following the "wake up" it will also indicate wether the command was performed succesfully or not.

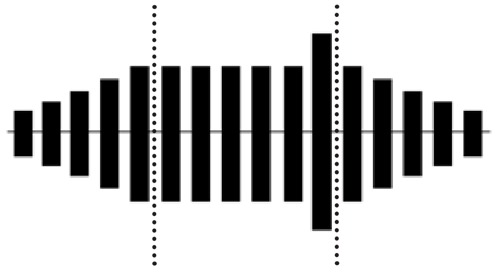
Delving into the world of interaction design for haptics led to the development of the following 2 haptic profiles, for successful and unsuccessful commands.

Successful



If a long blink is performed intentionally it will initiate the "wake up" and the strength will begin ascending. What follows is a number of intentional blinks, during which the strength will remain constant. Once completed succesfully, the strength will ascend once more and stop completely.

Unsuccessful



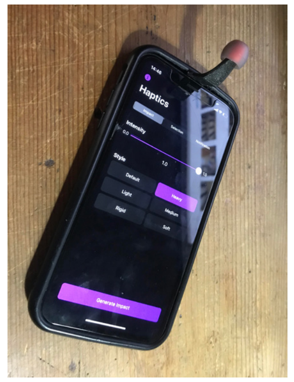
If a long blink is performed unintentionally it will still initiate the "wake up" but the user is made aware by the ascending strength. If a few seconds go while at constant strength without any subsequent blinks the system will interpret it as a false trigger, stagger to indicate the sudden termination of the command and descend in strength implying an unsuccessful attempt.

Ascending strength implies the beginning of a task.

A flat/constant strength implies action is being performed succesfully.

Descending strength implies an incompleted event.

A stagger in strength implies a sudden change.

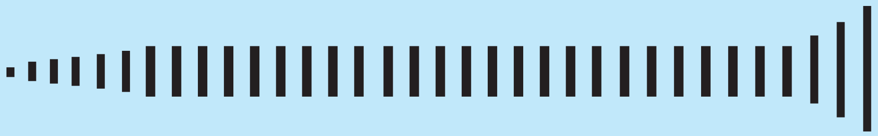


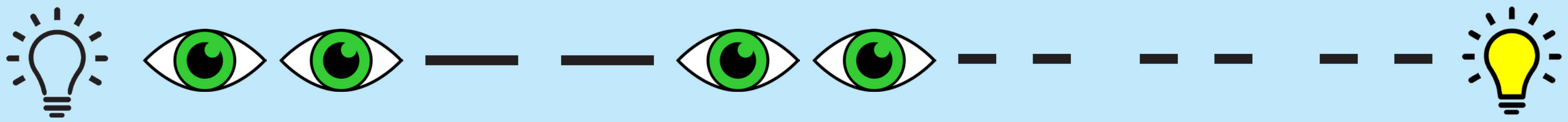
The incorporation of haptics into a wearable was briefly explored using a haptics control app made for developers and a 3D printed piece with an ear plug attached, just to explore the sensation, which was found to effectively grab attention without causing discomfort.

Functionality

Intentional

Haptic feedback



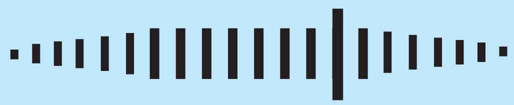


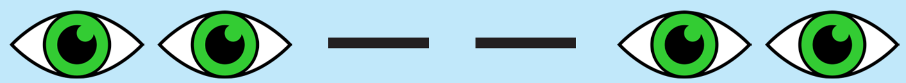
Once the device to be switched on/off is chosen the user performs a long blink to show the system they intend on performing a command.

When the long blink is over the haptics come into play and the system receives the number of short blinks allocated to that device, and thus switches it on/off.

Unintentional

Haptic feedback

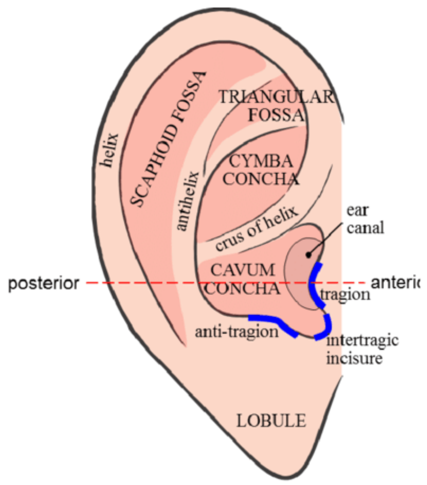


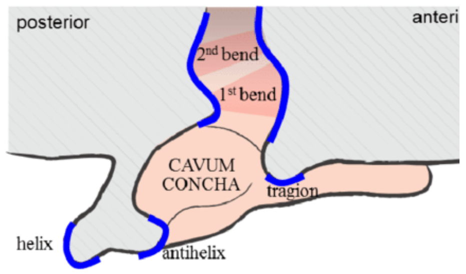


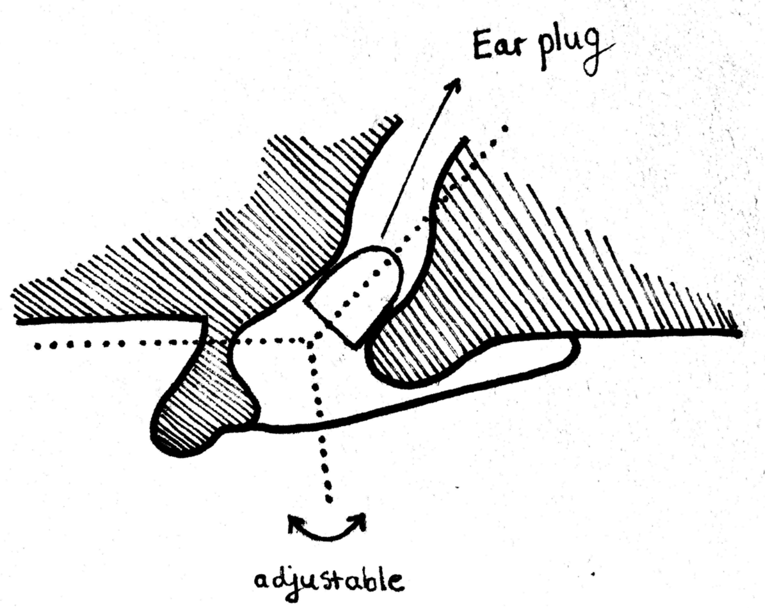
The user accidentally performs a long blink and activates the system. To prevent an unwanted command from taking place they keep their eyes open until it realizes the activation was unintentional, and ends the command.

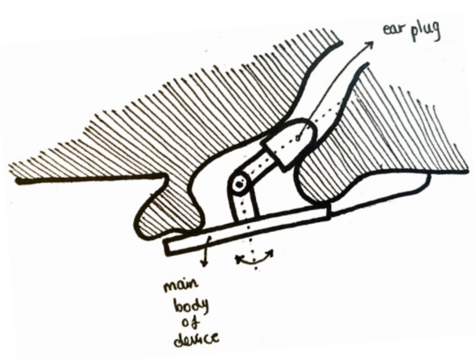
Eyes open | Long blink | Short blink

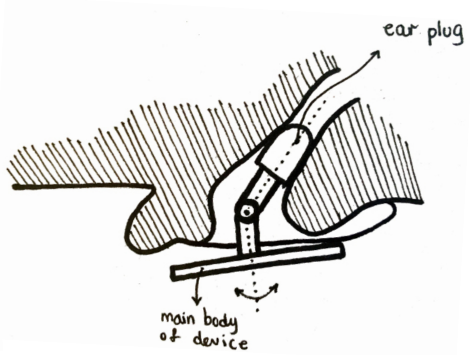
anthropometrics







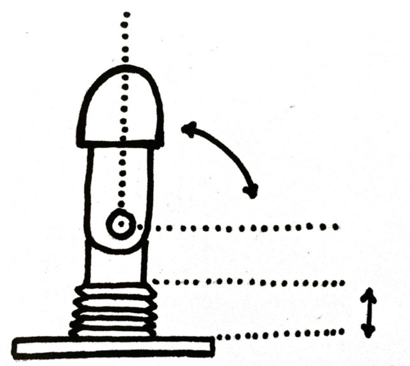


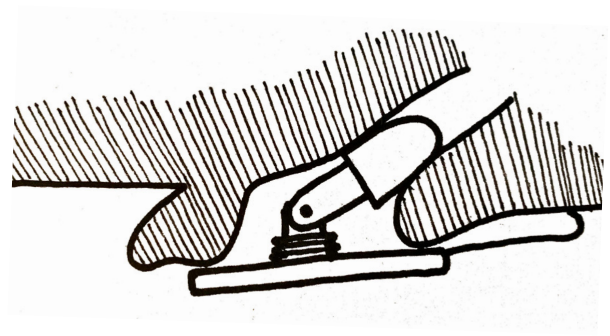


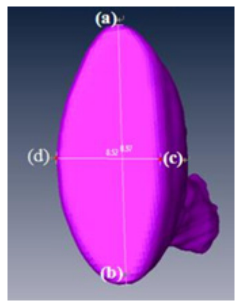
Making use of diagrams and anthropometric data of the ear helped for inclusive design with regards to the sizing and adjustbility that the product allows. This data revealed that the angle the ear canal entrance makes with the side of the head tends to vary significantly in the horizontal plane, which led to a design opportunity[18].

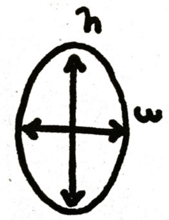
Making the angle between the ear plug and the main body outside of the ear adjustable allows for high inclusivity and reduced discomfort related issues.

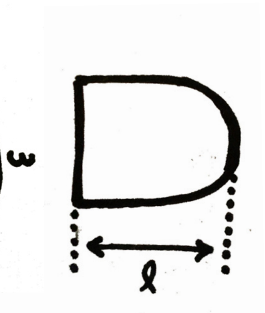
However, this adjustability doesn't account for differences in ear canal length or different angles which may leave the device protruding out of the ear. A higher degree of support is provided if the device is not left to dangle but rather lightly pressed against the ear, so the overall length of the device was also made adjustable.











	Small	Medium	Large
Height (mm)	5.0 < X < 7.0	8.0 < X < 11.0	12.0 < X < 14.0
Width (mm)	X < 5.0	5.1 < X < 8.5	8.6 < X
Length (mm)	X < 7.0	7.1 < X < 13.0	13.0 < X

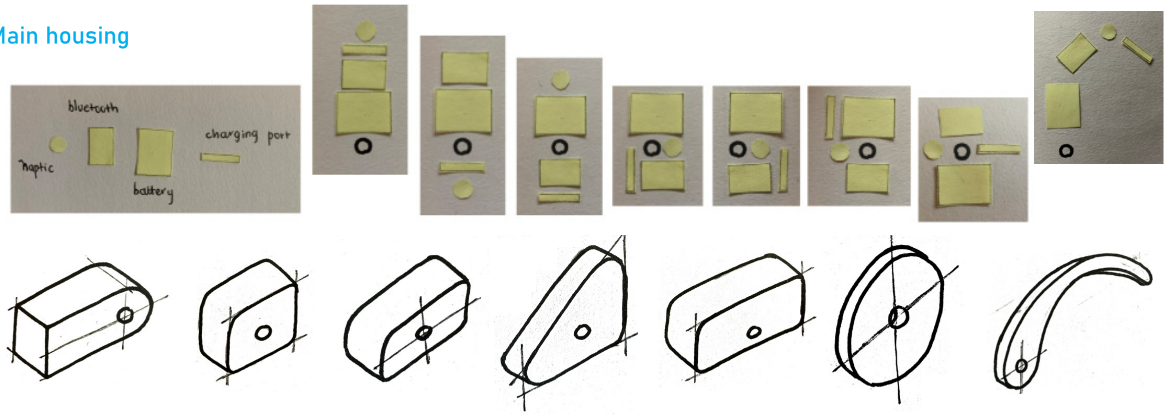
The incorporation of adjustability in both angle and length accomodates for a large number of users while eliminating the need for replaceable parts, making the device more flexible.

As a multitude of studies and 3D scans of the human ear have shown, the entrance to the ear canal is elliptical. For both optimized application of the TENG sensors and the comfort of the user, 3 ear plug sizes are offered to once again accomodate for the variations found among users[19].

design iterations

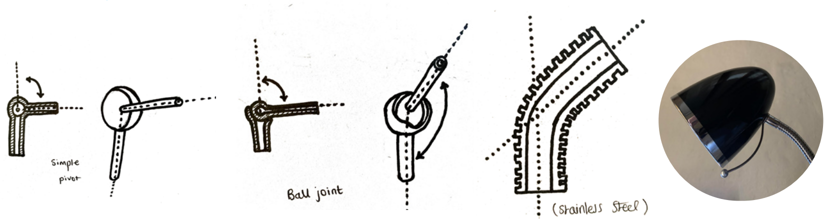
Sketching

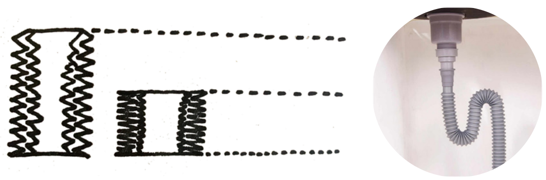
Main housing



Actual size cutouts of the components to be housed in the device were placed around the hearing hole to get an idea of the different profiles that are possible. The general profiles were then sketched in 3D to visualize them further.

Adjustability



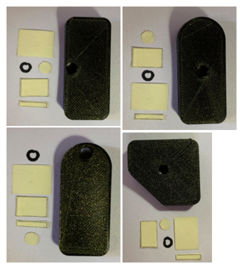


Inspiration was taken from a standing lamp for the final iteration, that makes use of a gooseneck tube construction to allow the angle of the bulb to be adjustable while holding its position. It also simplifies making the tube hollow for sound to pass through.

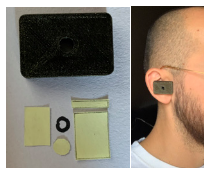
For the length adjustment inspiration was taken from the flexible tubing used in drain pipes, since the bellow-type foldable structure allows for the desired effect.

Rapid prototyping

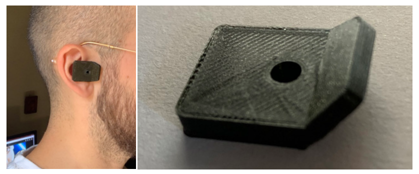
A ball joint and adjustable length mechanism was printed to better understand the possible adjustabilities. Although it was known at this point that a gooseneck tube would be incorporated into the final design, the 3D printable ball joint acted as a place holder.



The shape exploration led to 3D printing of these shapes to see how well they perform ergonomically when worn.

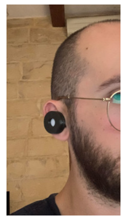


The most efficiently packed shape was the rectangle. Although very compact, one of the edges would poke into the side of the face, which did not fair well for comfort.

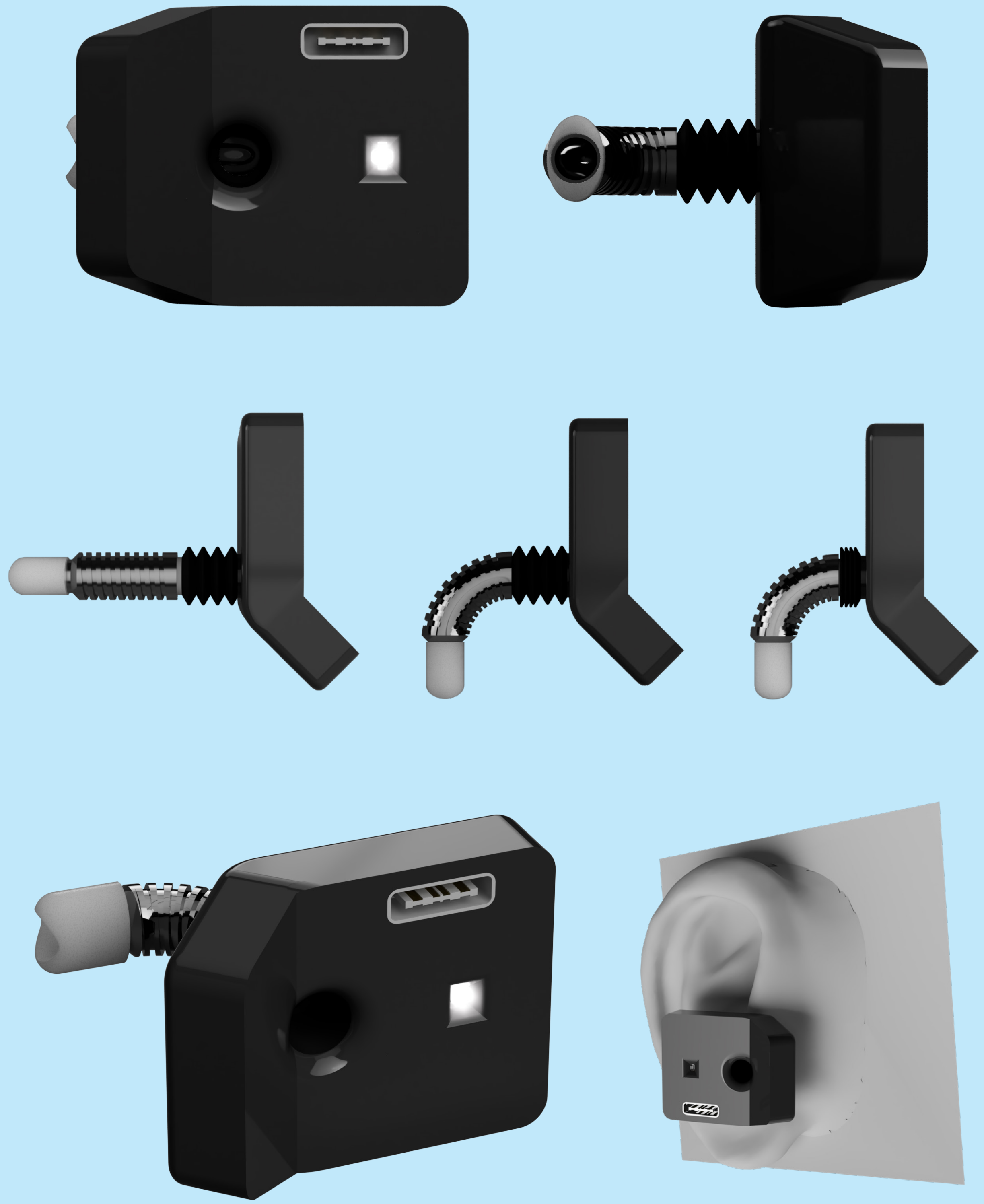


This was the most comfortable solution, which is a slight modification to the previous. The difference being the end which houses the bluetooth chip (which is of a smaller width than the battery), which tapers and curves upwards preventing the aforementioned poking.

The weight of the main housing with the components is estimated to be < 5g. This was calculated to be around $4cm^3$ of PLA, which the printed part on the right doubled in size and still felt extremely light, although bulky.



Final design



user journey

Sam, a 24 year old with an injured right foot wakes up, ready to begin his day.

He switches on the lights in his room by holding a blink for 1s, and then blinking quickly 3 times. This saves him from having to get up and switch on the lights and applying unwanted extra pressure on his foot.

He turns to the side of the bed, remembering that he has errands to do despite his injury.

Since he is about to leave the room he switches off the air conditioning to avoid wasting electricity, by holding a blink for 1s and then blinking quickly 4 times.

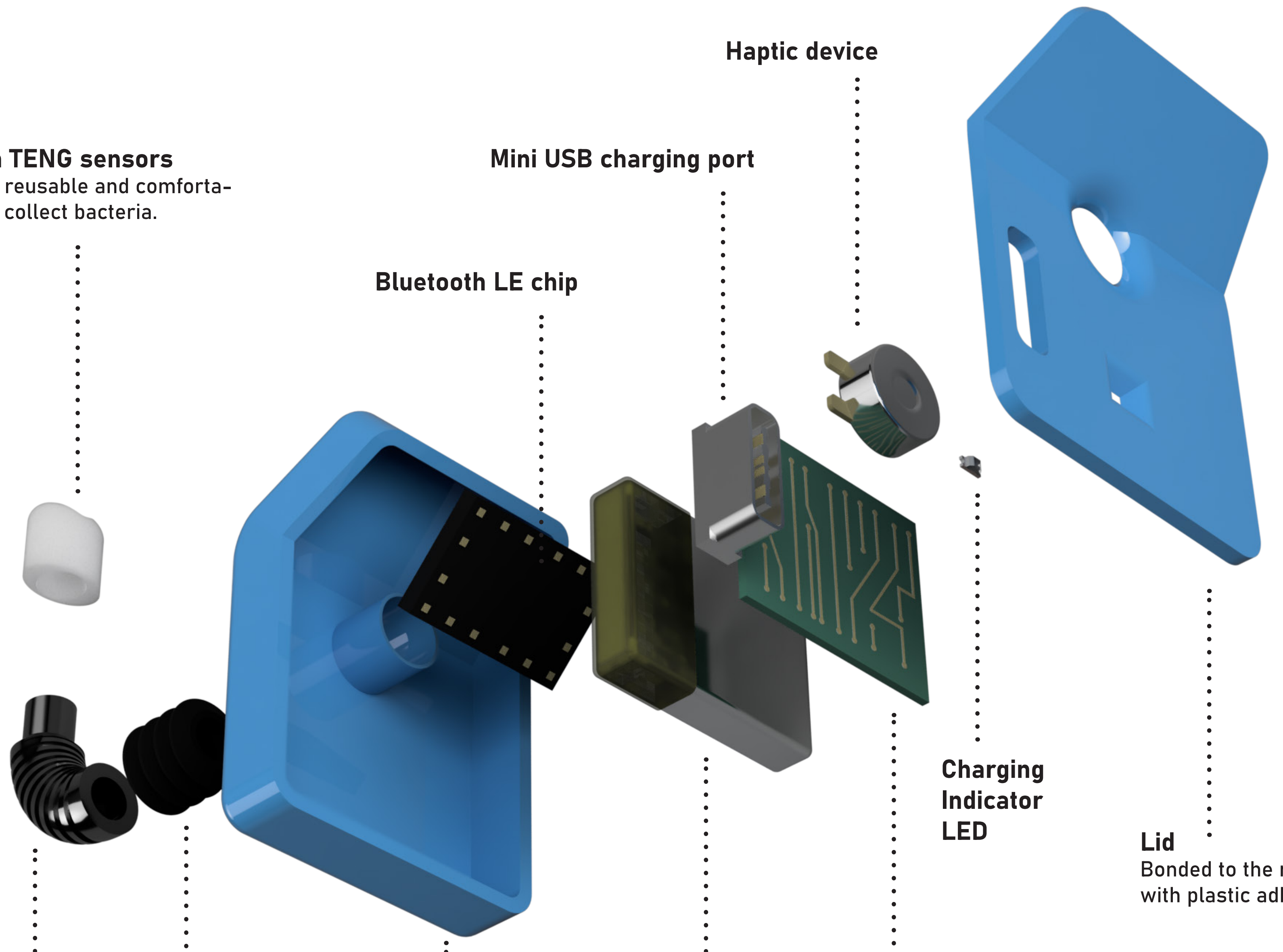
He gets up and goes to grab his bag with his left hand. Although he is walking he is doing so slowly to prevent more damage to his foot.

He grabs the other bag with his right hand, leaving both of his hands occupied with the bags.

He then looks to the door, which to open he holds a blink for 1s and blinks quickly 2 times. This saves him the struggle of having to open the door with both hands occupied and an injured foot.

Once at the doorway he switches off the lights, once again to save electricity. He does so by holding a blink for 1s and blinking quickly 3 times.

overview



Ear plug with TENG sensors
Hard silicone is reusable and comfortable, and doesn't collect bacteria.

Bluetooth LE chip

Mini USB charging port

Haptic device

Charging Indicator LED

Lid
Bonded to the main housing with plastic adhesive.

Length adjustability tube
Injection moulded polyethylene (PE).

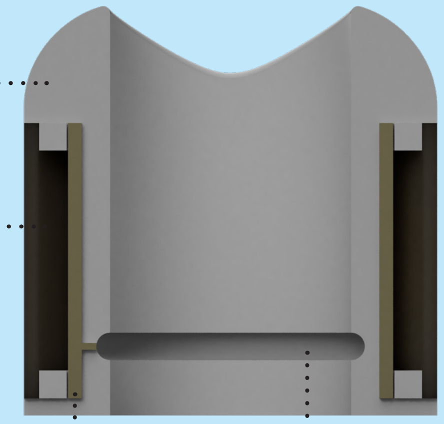
60 mAh Li-Ion battery

System on a Chip (SoC)

Angle adjustability tube
Stainless steel gooseneck tube.

Main housing of internal components
Injection moulded ABS plastic, which is commonly used for electronic enclosures and is suitable for human conditions.

Cross section of the ear plug with the TENG sensors



The sectioned model above shows that this design allows sound to propogate through the disconnected hollow tube going from the outside of the ear to the ear canal.

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