



 Relief

SUPPORTING NOISE SENSITIVE PATIENTS THROUGH RECOVERY



# 01 INTRODUCTION

## ABSTRACT

Concussion is a type of mild traumatic brain injury triggered by a blow to the head, body, or fall, that causes the brain to shake inside the skull . Every year an estimated 42 million people worldwide suffer a mild traumatic brain injury (MTBI) or concussion". "Most patients do not have visible physical signs, rather disabling cognitive, physiological or behavioral impairments" that impact everyday life. With 15% of these people suffering from Post-Concussion Syndrome (PCS) , a complex disorder where symptoms persist beyond the typical recovery period of three months".

In collaboration with Kolbacken Rehabilitation Centre and Norrlands University Hospital in Northern Sweden, this document outlines the Master Thesis of James

Skeggs, a student of the MFA in Advanced Product Design programme at Umea Institute of Design and his desire to "support patients suffering from Post Concussion Syndrome through rehabilitation".

The design process is documented in several stages, from building empathy through secondary and primary research methods, problem analysis and synthesis mapping, ideation and exploration of several design directions, followed by the conceptual development of a final design direction.

The final solution Relief, consists of an audio device that reduces the discomfort of noise sensitivity, a common symptom for patients recovering from PCS or similar acquired brain injuries. Providing a

discreet alternative to current noise cancellation products and offering a modular system that adapts to each patients individual recovery. Furthermore, Relief provides medical carers with actionable data and feedback during rehabilitation to provide the most optimized treatment and provide reassurance for patients, their families and friends.



VÄSTERBOTTENS  
LÄNS LANDSTING





Nils Berginström

James Skeggs

## NORRLAND UNIVERSITY HOSPITAL

### Nils Berginström, Neuropsychologist

Several interviews were conducted with Nils Berginström, Neuropsychologist and PHD student at Norrland's University Hospital Neurorehabilitation Unit. This provided a great resource for validating initial research, learning about cognitive functions and personally experiencing current testing and consultation techniques. Please refer to Appendix 1.2 for further detail regarding interviews.

*"I do very few computerized tests because I think the face to face or pen and paper are more valid.... Then I can do the judgement as a clinical psychologist, which when I am there sitting with the computer, I miss".*

*"I am also a clinical psychologist, where we sit beside each other, and in that way it is a lot easier to explore feelings [Patients] and their tellings of the day and*

*so on. I would never be able to have a psychotherapy session like this, it would never work at all".*

*"Going out and doing observation for me is very time consuming, being able to go home with the patient without being there, testing them or reminding them would be awesome".*

*"What's important is how they are functioning in the real world".*

### KEY POINTS

- The road to recovery is never straightforward.
- Testing is a only tool to determine reactions.
- There is a disconnection between a closed environment assessment and the real world.
- Testing is a daunting experience for patients.



## KOLBACKEN YOUTH REHABILITATION CENTRE

Based in Kolbacken, the local child and youth rehabilitation centre both habilitate and rehabilitate paediatric (1-18 years old) patients affected by various conditions. In particular, research was undertaken with a multidisciplinary team dealing with head trauma referrals from Sundsvall to the far north of Sweden. Twelve different sessions were conducted through group interviews, observing/shadowing consultations, patient/family interviews and Fika. Please refer to Appendix 1.3 for further detail regarding interviews.

*“Sometimes parents have to quite their job, work half time to sit with the children in school or preschool”.*

*“You look at how big the increase of symptoms is when you work cognitively or physically, that’s how you determine when you are supposed to go back. So basically, if you are almost symptom free at home that’s*

*when you are ready to go back to school”.*

*“We have to rely on the interviews with the parents, the teacher and the people who knew the child before”.*

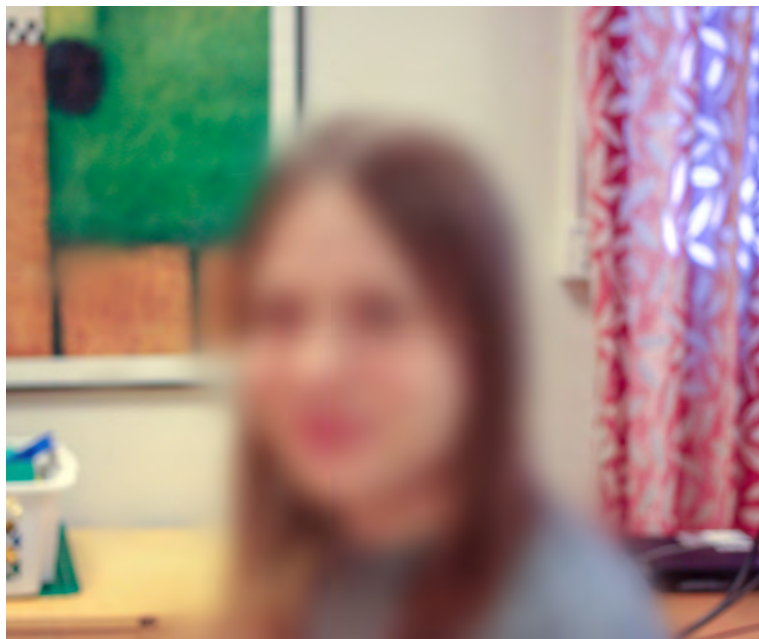
*“Too much stimulus for children can cause fatigue, their brains do not have the capacity to deal with this information during recovery. But also, we need to train these aspects, practice gradually, expose at a level the child can handle and over time”.*

### KEY POINTS

- Symptoms in pediatrics are often misinterpreted.
- Concussions affect entire families wellbeing.
- Specialists are reliant on information provided by others.
- Rehabilitation is a balance of rest and exposure.
- Paperwork can be time consuming and inefficient.

## KEY PATIENT STORIES

As a result of meeting several medical professionals working with Acquired Brain Injury, a variety of their patients were interviewed. In particular Moa, Frida and Colleen who span different stages of rehabilitation (see page 33) provided insight into how concussion effects people on an everyday scale and provided the opportunity to build empathy for the end user. The supporting imagery and text briefly describes their backgrounds and key lessons learnt. Please refer to Appendix 1.6 for more detail surrounding each interview.



### **Moa, 17 years old**

Moa grew up in Umea and attended school in Mora to play floorball. In 2015 she was struck in the head by an opponents knee while playing as a goalkeeper.

#### **Key Points**

- PCS does not require multiple concussions.
- Some coaches are not aware or accepting potential risks, influencing players mentality.
- Symptoms are isolating and affect relationships.
- Correct treatment and patient awareness can bring positive change.



### **Frida, 14 Years old**

Two and a half years ago, Frida and her father were motorbiking in the woods near Boden. This was only the third trip for Frida when she drove into a tree and was knocked out unconscious.

#### **Key Points**

- Patients and their families are feeling neglected or uninformed after leaving the hospital.
- Patients feel isolated and have trouble with others understanding their symptoms.
- Some medical professionals are misdiagnosing concussion.

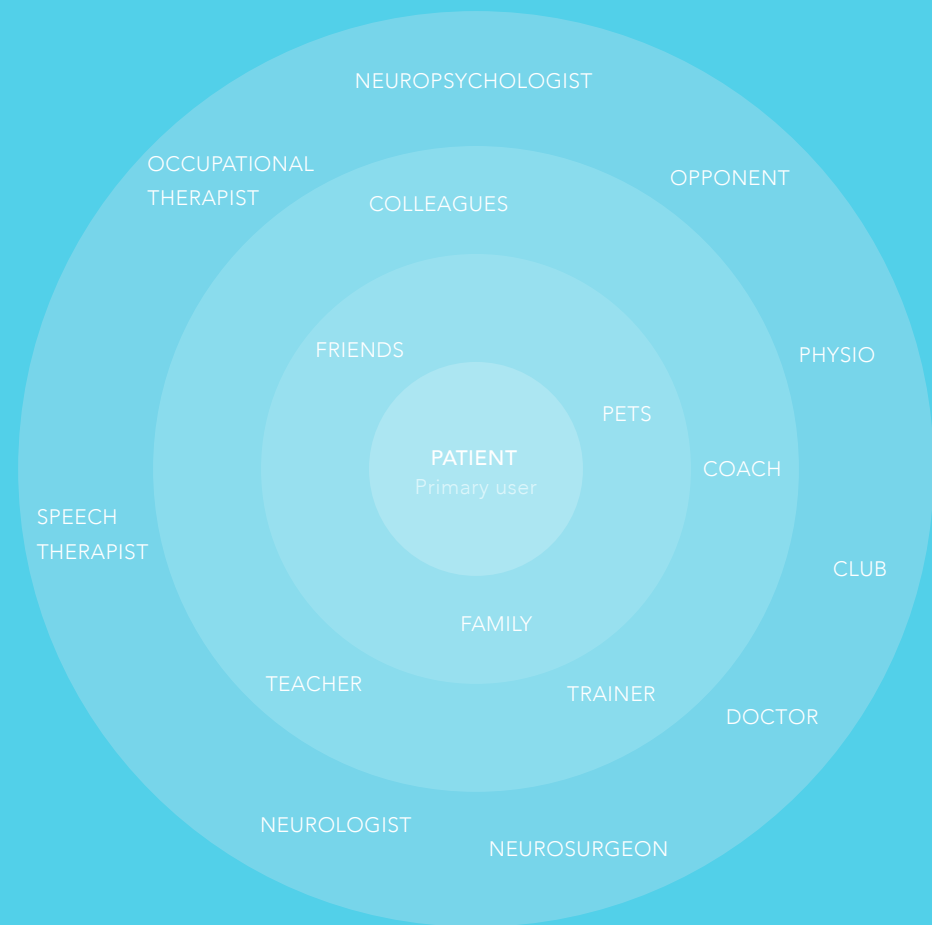


### **Colleen, 22 years old**

Colleen has suffered from 4 recorded concussions in the last 10 years playing ice hockey in Boston. Her journey through recovery has been far from straight forward but she now comfortably manages her symptoms.

#### **Key Points**

- There is a disconnection between family members, coaches and the reality/acceptance of concussion.
- Recovery journey is non linear.
- It's challenging for people to understand and relate to impact of symptoms.
- Connecting patients and sharing stories helps.



## 02 SYNTHESIS

### PROJECT AUDIENCE

Research findings have shown that a tremendous amount of stakeholders' may be involved with a concussion. Whether this is prior to the event, directly after an incident, during acute diagnosis or throughout long term rehabilitation. Similarly, a significant effort was made to personally meet and build empathy for a range of patients at stages throughout the rehabilitation journey.

This project aims to put the patient (or potential patients) at the heart of the design process. Working outwards to address relationships and effects on those close (such as family and friends), break boundaries with other established connections (such as teachers, coaches, work colleague) and support or leverage the needs of medical carers involved.

## PERSONAS

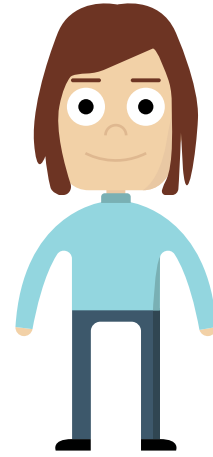


### **Frida, 14 years old. Lulea, Sweden.**

- Motorbiking with Dad in woods and collided into a tree.

- Blacked out several times + rang ambulance. - Nothing showed in tests, spent 48 hrs in hospital where *"everything was spinning"*.  
- Sent home next day with the standard info.  
- Behavior worsened in next 4 weeks and parents thought *"it was just her age"*.

- More info + reassurance after leaving hospital.  
- A way for others to understand her symptoms.

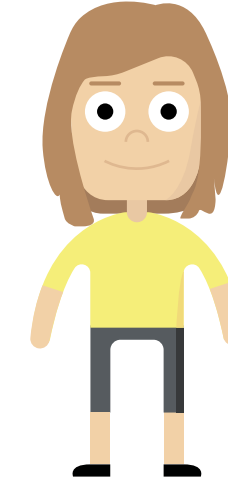


### **Moa, 17 years old. Mora, Sweden**

- In 2015 was struck in the head while playing floorball as a goalkeeper.

- Told by coach *"don't bother"* with hospital.  
- At first, thought it was *"just like being sick"*  
- Pet rabbit and knitting helped get through.  
- Eventually referred to Kolbacken where she checked up once a week to review feelings.  
- Wants to be a gym teacher + floorball coach.

- Wishes those around would not neglect PCS.  
- Support through lonely stages of recovery.

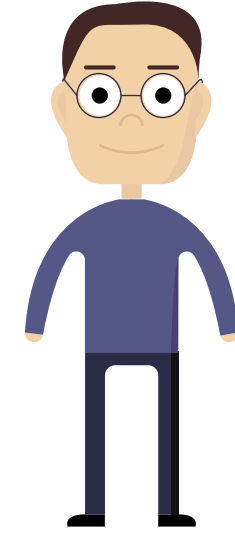


### **Colleen, 22 years old. Boston, USA.**

- Suffered from 4 recorded concussions in the last 10 years playing ice hockey.

- *At times "was perfectly fine one second, then flying into a rage the next"*.  
- Was forced to leave college *and told by on friend "your making this up, this is ridiculous"*.  
- Now in a comfortable place and sharing her story with others through blogging.

- Acceptance from friends and family about PCS.  
- Understand it's not a straightforward journey.



### **Nils, 38 years old. Umea, Sweden**

- A Neuropsychologist at Norrlands University Hospital working with PCS patients.

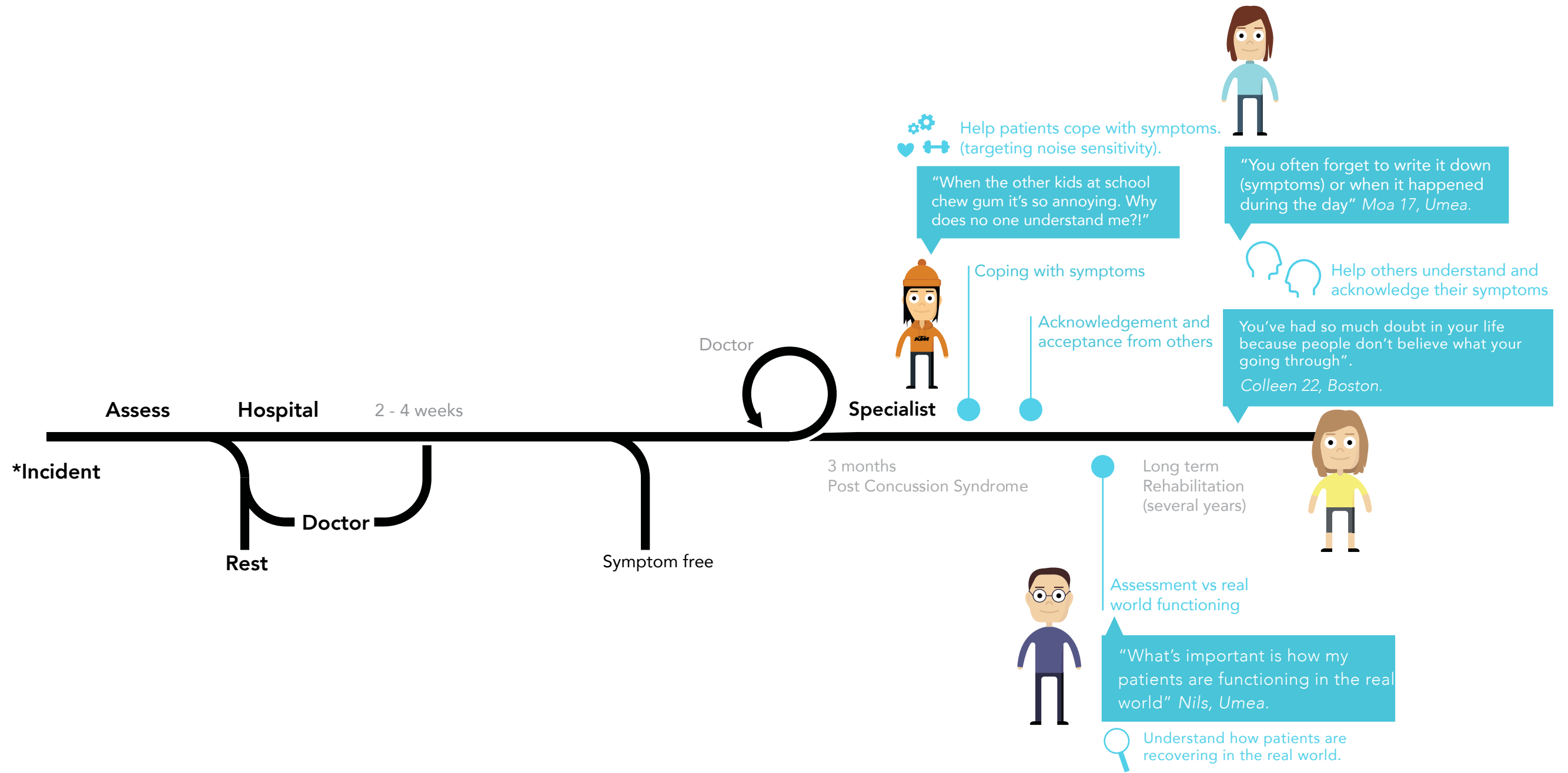
- Prefers using pen and paper testing to better understand patients reactions.  
- Wonders how his patients function in the real world and balancing rest vs exposure.  
- *"There's always those setbacks, I've never had a patient that doesn't have a relapse"*.

- Make testing less daunting for patients.  
- Better understand recovery in the real world.

## REVISED PATIENT JOURNEY

Taking the previous insights, pain points, and today's rehabilitation journey in to consideration, the following design framework was narrowed.

- Help PCS patients cope with their symptoms, focusing on noise sensitivity.
- Provide a way for others to understand and acknowledge their symptoms.
- Allow medical carers to better understand how patients are functioning in the real world.





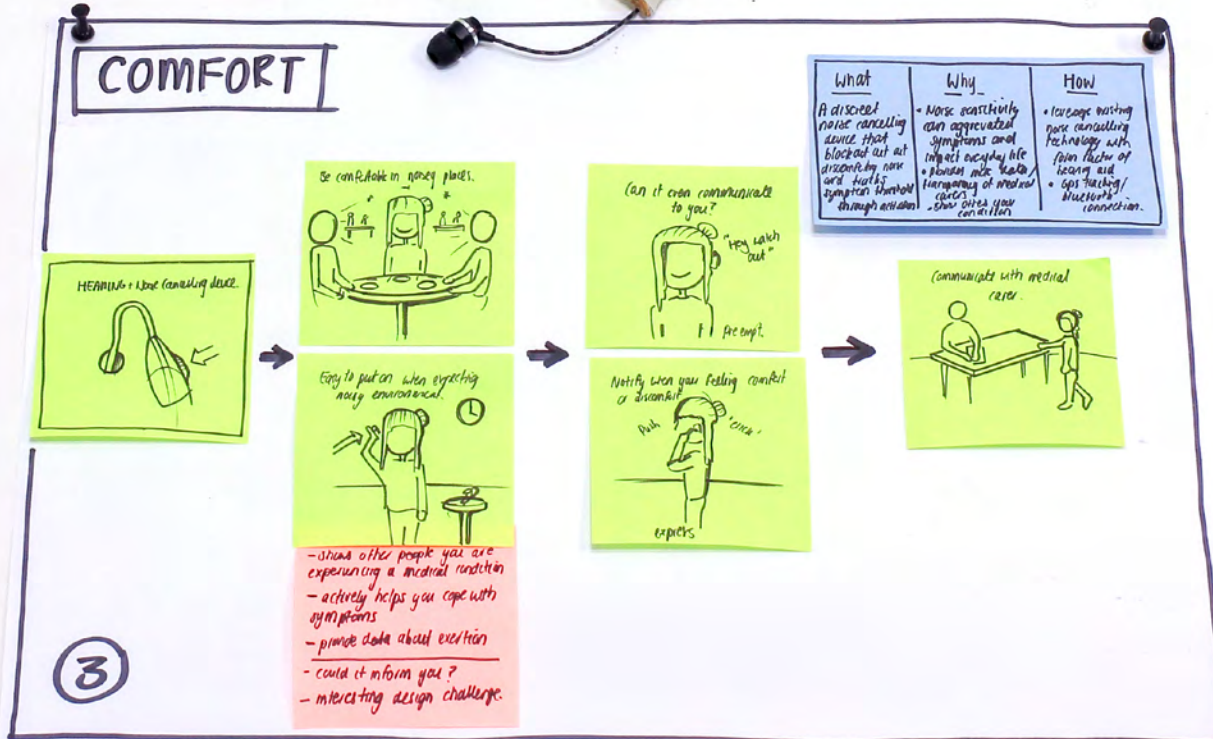
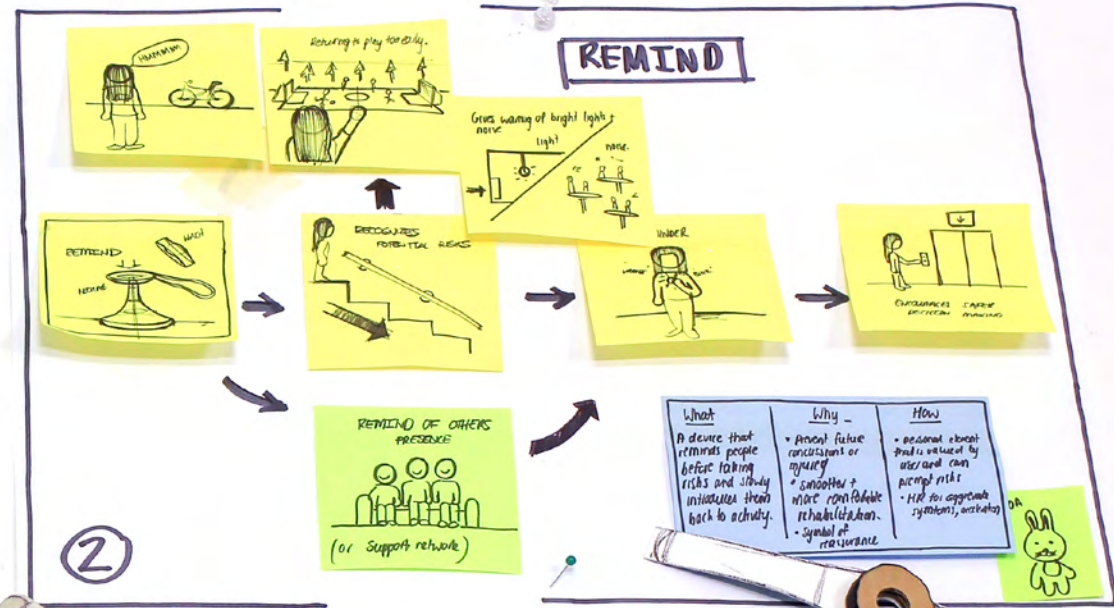
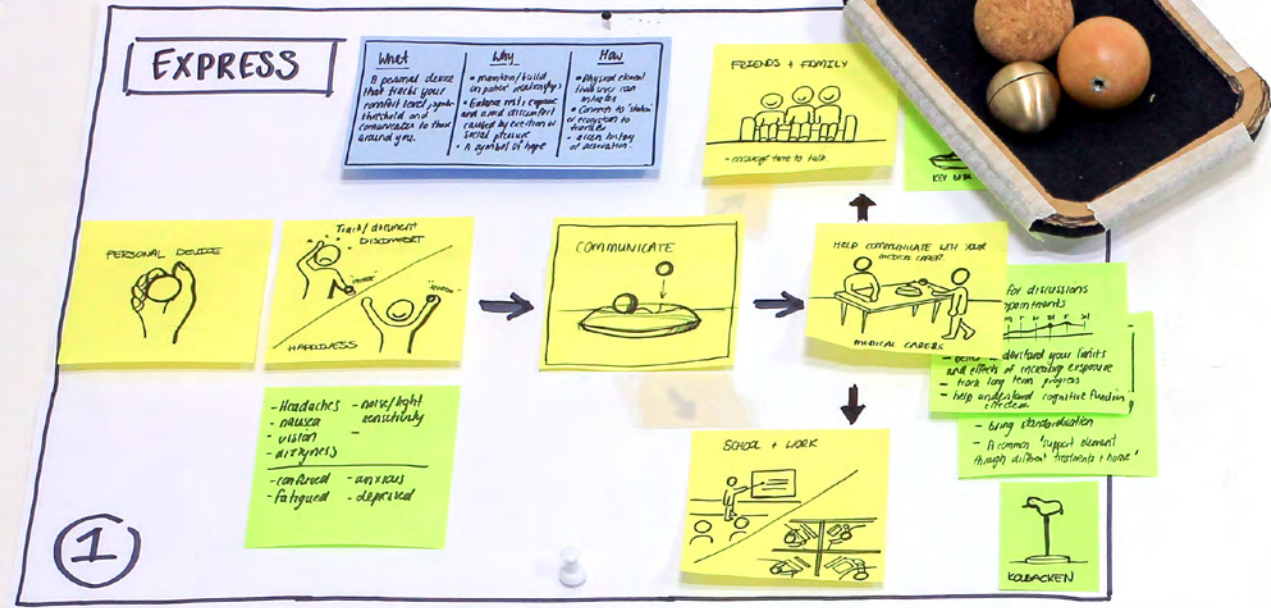
# 03 IDEATION

## IDEA MAPPING

Using the previous 'How Might We' (HMW) questions as inspiration, the next steps included 'brain dumping' all initial thoughts on paper. Letting go of constraints, such as current technology and maintaining a human perspective.

As shown in supporting image, a simplified patient journey and personas were used to provide structure and highlight rehabilitation stages. As clusters of ideas began to emerge, three key areas surrounding 'Symptom Management', 'Patient tracking + Monitoring' and 'Consultation Assistant' were developed. Formulating the basis for concepts that would be developed in later stages.





**Questions for Friday**

- What info/data do you need surrounding 'comfort/discomfort'?
- If your device could test or actively help of build your tolerance? (right)
- Understanding of other similar brain injuries

**PROPOSED SCOPE**

Support people recovering from Post-Concussion Syndrome through rehabilitation

- 1 Help people acknowledge symptoms
- 2 Understand how people are functioning in the real world.
- 3 Prevent future concussions

### INITIAL DIRECTIONS

As a result of the ideation workshop three key directions were established and developed through story boarding and mock-ups. This included:

#### Express

A companion that allows patients to track and communicate discomfort levels.

#### Remind

A personal accessory that helps patients manage their symptoms and anticipate potential risks.

#### Comfort

A discreet and reassuring noise cancelling device that allows patient to live their everyday lives.

## MOODBOARD

A collection of imagery was compiled and used as inspiration during concept development. Based on the users needs, functionality and general 'look and feel' surrounding the patient care, keywords such as 'Sooth', 'Comfort', 'Care', 'Remind', 'Express', 'Reassure' and 'Support' were established. A visual representation was then created and shown through existing products, detailing, CMF and form.

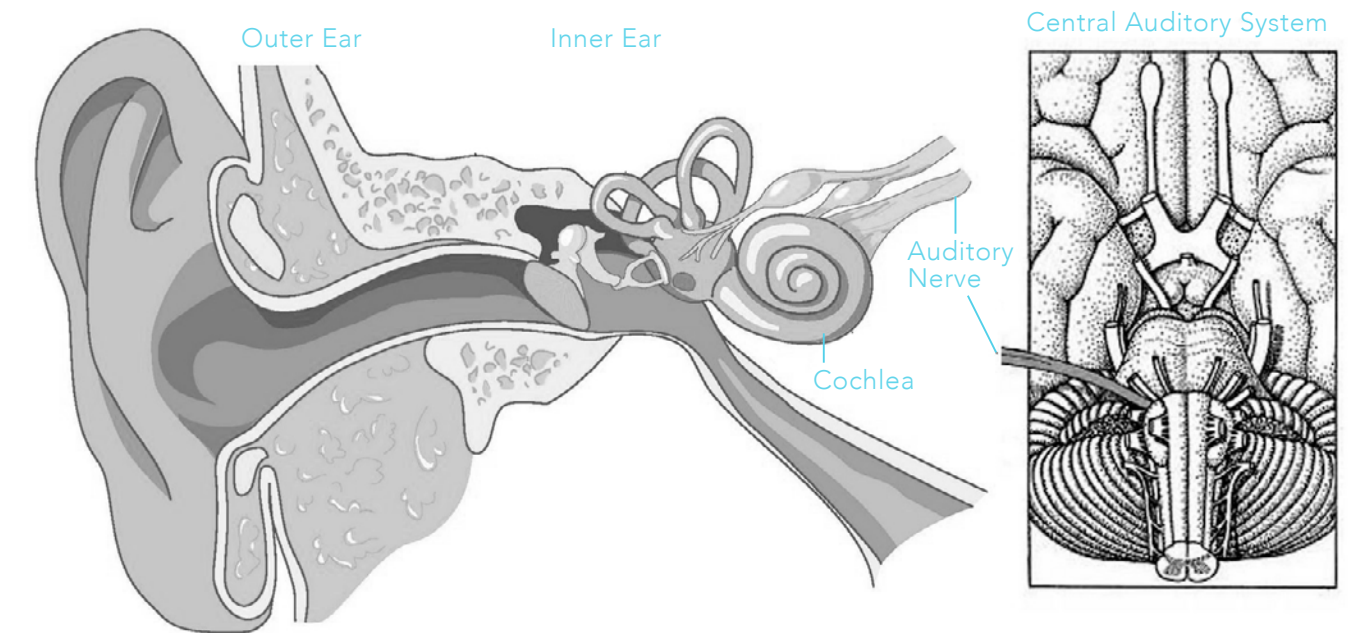


## NOISE SENSITIVITY

“After sustaining MTBI, most of the brain’s energy is diverted to basic functioning, and little is left over for filtering or censoring”. As a result, a common symptom for people suffering from concussion is hypersensitivity to sound, or hyperacusis. Meaning the “auditory system becomes very sensitive to environmental noise, and you may discover that you have great difficulty going to restaurants, the grocery store, or social gatherings”.

Patients are advised to “reduce exposure to noisy environments by choosing to sit in a quiet spot in restaurant, or far away from large tables, speakers and TV’s, or ask your dinner hosts if they can turn off the background music so you can enjoy the evening longer”. Throughout rehabilitation patients should also “be mindful to gradually increase your exposure to light and sound as tolerated, so you can eventually return to regular activities”.

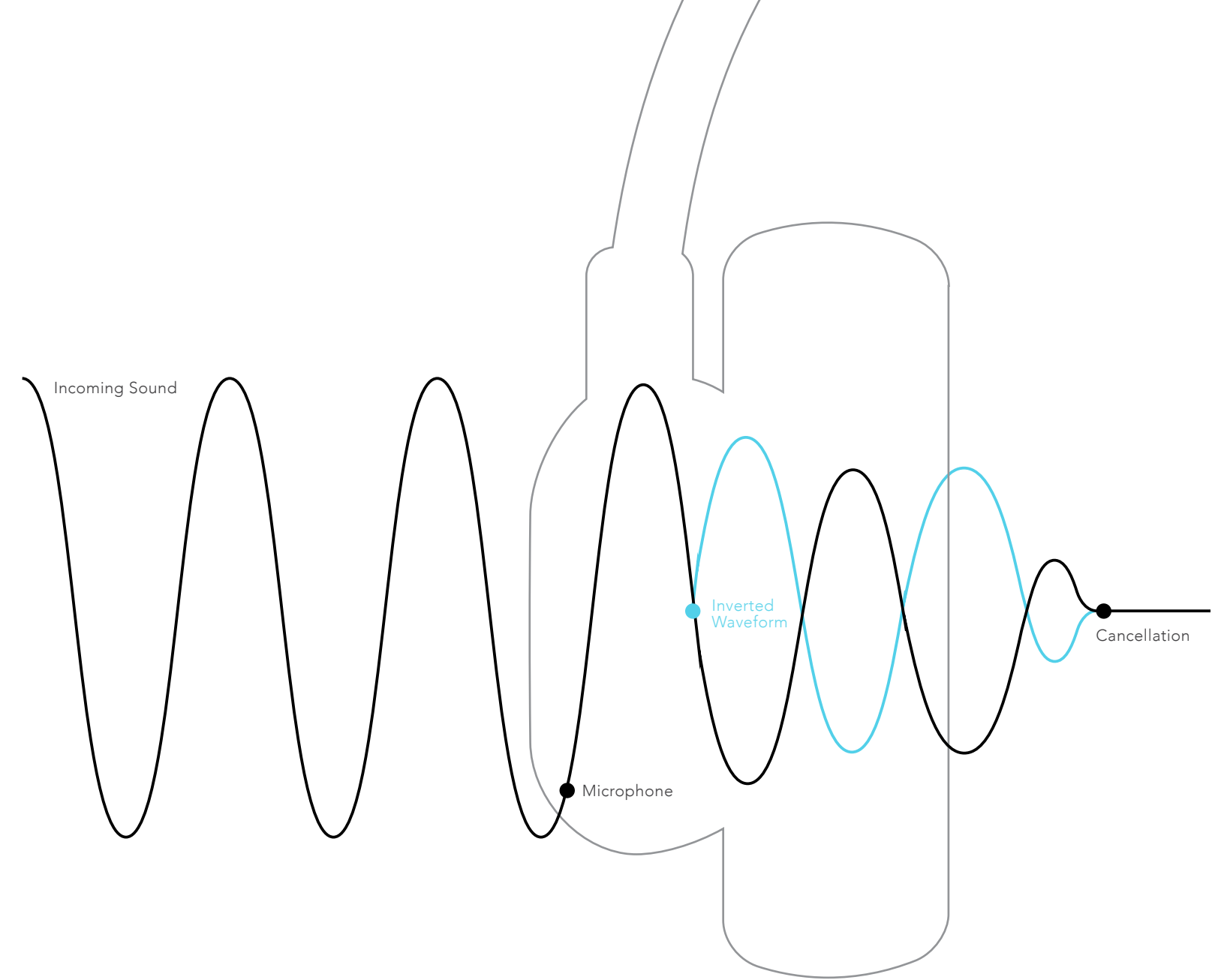
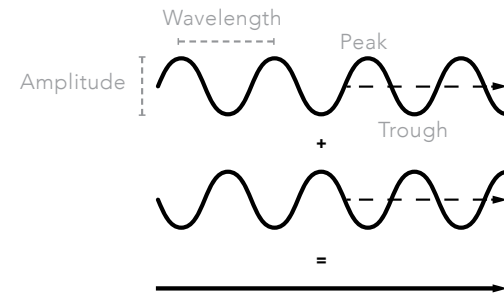
**“THE WORLD IS A VERY NOISY AND CHAOTIC PLACE WHEN THE BRAIN’S FILTERS ARE IMPAIRED...BY HELPING MY INJURED BRAIN FILTER THE AMBIENT NOISE, I WAS ABLE TO CONTINUE TO PARTAKE IN NORMAL LIFE ACTIVITIES AS I HEALED ”** Unknown PCS Patient, Murray Hearing Centre.



## NOISE CANCELLATION

Noise cancellation can be divided into two categories, passive and active. Passive reduces noise by physically covering the ears to help block out external noises. Whereas, active noise cancelling devices use small microphones to detect ambient noise (such as a refrigerator with constant wavelength and amplitude) and audio processor to electronically remove unwanted sounds without diminishing audio quality. This process of 'destructive interference' considers "sound as a pressure wave, which consists of a compression phase and a rarefaction phase. A noise-cancellation speaker emits a sound wave with the same amplitude but

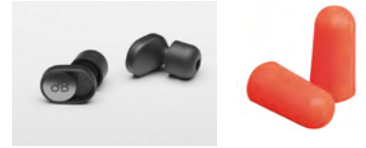
with inverted phase (also known as antiphase) to the original sound. The waves combine to form a new wave, in a process called interference, and effectively cancel each other out - an effect which is called phase cancellation". This technology is most effective for constant and low frequency sounds and will not take effect immediately (e.g. 0.3 ms).



## PRODUCT POSITIONING

Within wearable audio devices there are several product categories ranging from passive and active noise cancellation to amplification and isolation. Addressing a wide variety of different users and contexts (e.g. sport, health, safety or stage). After analyzing these existing products against their 'discreetness' it became very clear that the final solution would need to balance:

The arrangement/layout of an hearing aid and aesthetic of a consumer wireless earbud.



Passive Noise Cancellation



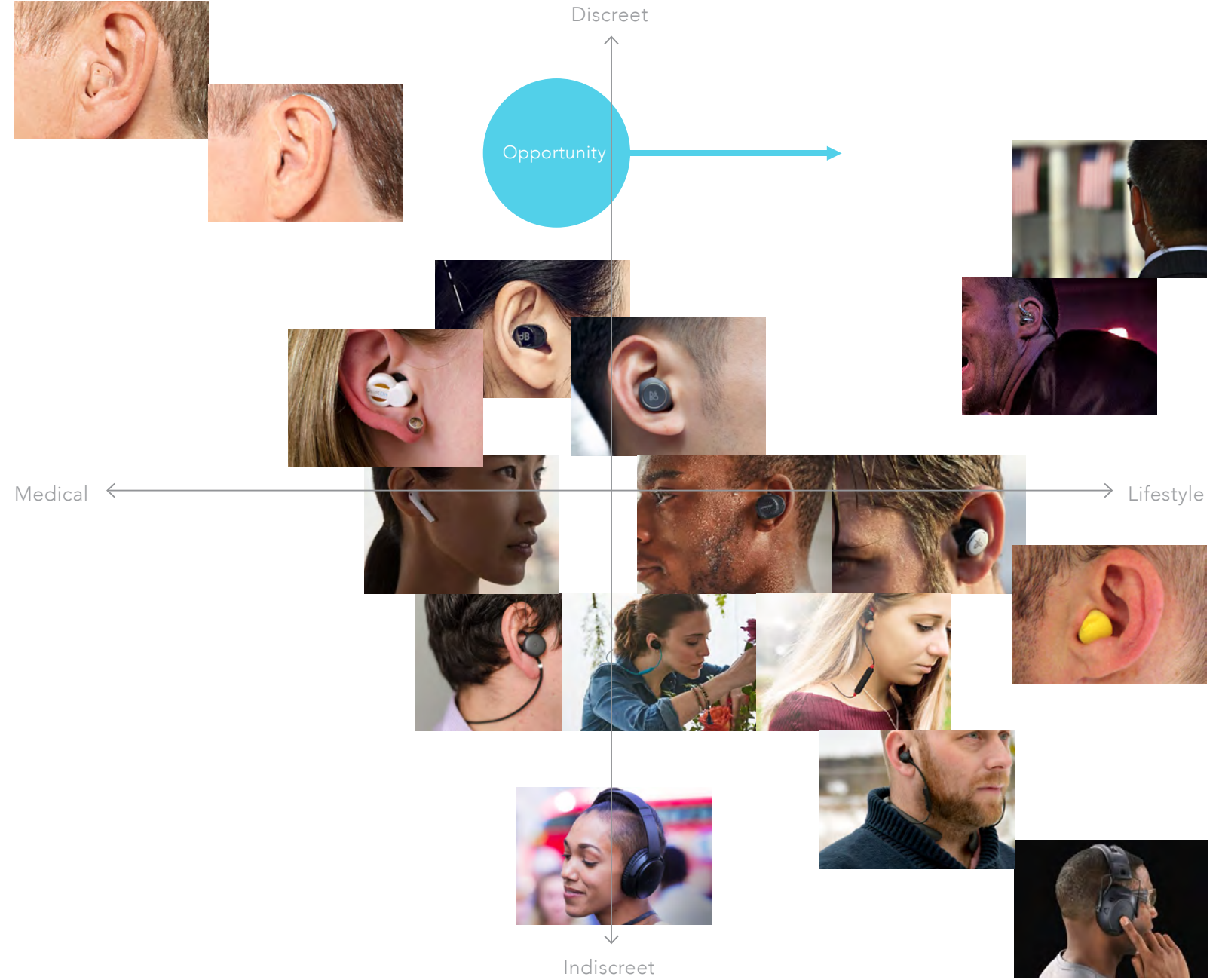
Hearing Aids + Amplification



Noise Isolation + Monitoring



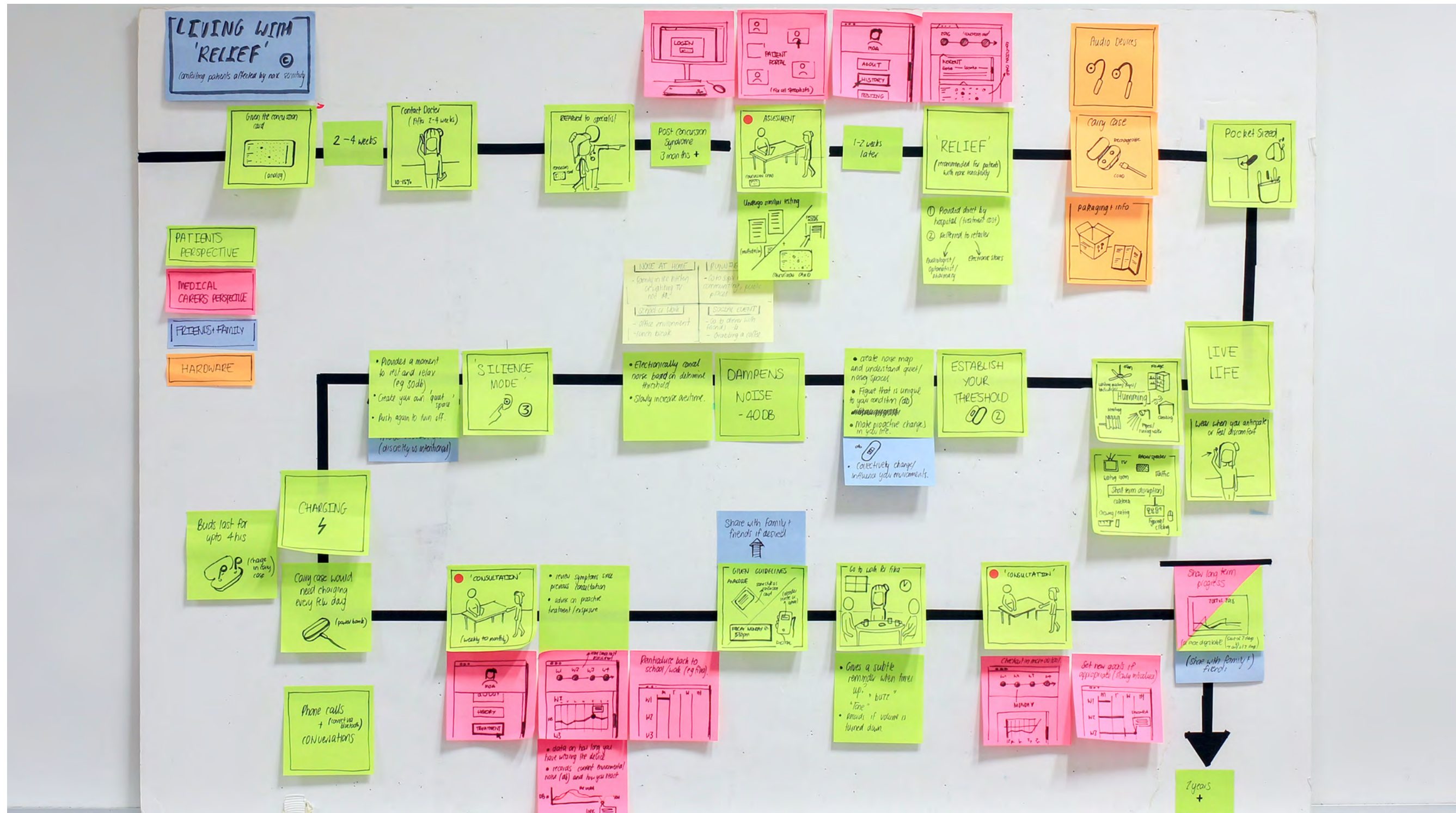
Active Noise Cancellation



## FUTURE SCENARIO

A future scenario was developed to better understand what's required in terms of hardware and software. This also helped to clarify functionality, different stakeholder touchpoints and hierarchy of needs being addressed. In summary, two audio devices, a portable carry/charging case and digital platform (most likely website) for medical providers would need to be developed.

It was also interesting to explore whether or not data should be displayed directly to the patient. However, this was not pursued as patients are often in a highly sensitive or fragile state. Rather, at the judgement of the medical carer data could be shared to patients and their family when appropriate (e.g. positive change or progress) through digital or printed output during consultation.



## DESIGN CRITERIA

A set of design criteria was established based on research findings, validation and initial concepts. This includes a list of constraints that narrow a concept direction, rank importance and ensure key insights from users are met within the final solution.

### SERVICE OFFERING

**Patients** (13 to 30 years old)  
Target teenagers + young adults with Post Concussion Syndrome.

HARDWARE



Applicable to other types of ABI, Hyperacusis patients or people desiring ambient noise cancellation.

HARDWARE

### Medical Provider

Provide software platform that standardizes treatment and provides transparency

SOFTWARE, HARDWARE ROYALTY

### Retailers

(Online or Direct)  
Consumer electronic stores, pharmacy, and Audiologist.

HARDWARE ROYALTY

### Friends + Families

Limited access to treatment data

SOFTWARE

### MUST DO

### SHOULD DO

### MUST NOT

NOISE

- Dampen ambient noise with constant low frequency.

- Provide a 'silence' mode or moment for rest.

DATA

- Create actionable data and platform for medical carers (Location, time, frequency).

- Show harmful or negative data to patient.

EXPRESSION

- Be discreet in appearance.  
- Visually celebrate act of noise cancelling or 'silence'.

- Utilize medical arrangement of hearing aid and lifestyle aesthetic of current earbuds.

- Look unapproachable or prevent conversations.

USABILITY

- Easy to put on and take off.  
- Use earbuds for half a day without charging.  
- Pocket sized charging case.

- Suitable for exercising  
- Allow for phone calls and conversations while wearing.  
- Consider weight distribution and range of percentiles.

TREATMENT

- Provide common ground between patient + family.

- Be useful after initial stages of recovery (e.g. educates or reads db levels).

PRODUCTION

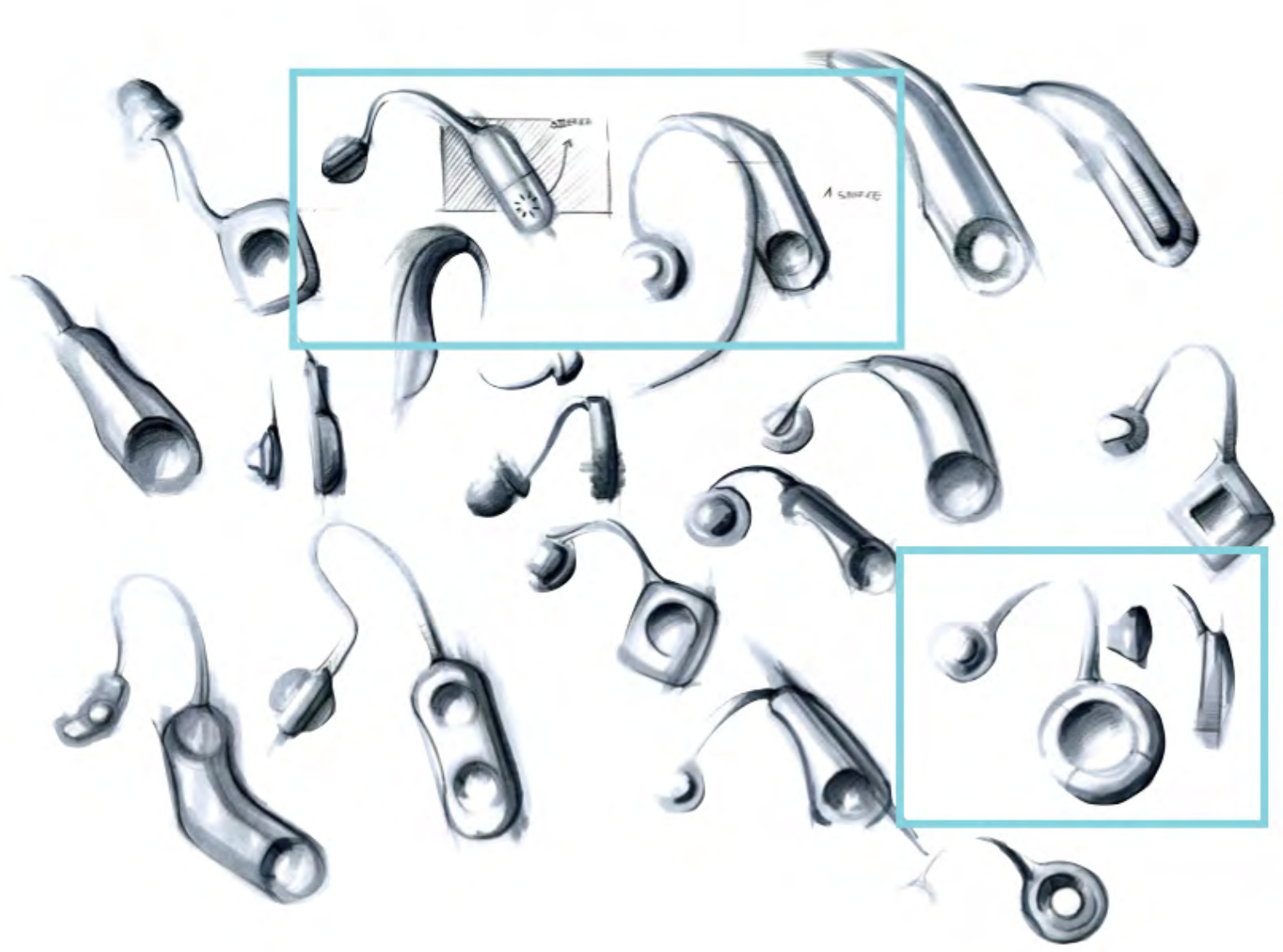
- Easily disassembled into constituent parts.  
- Avoid processes that compromise virgin materials

- Prevent overexertion and balance increased exposure

- Lifespan of entire treatment





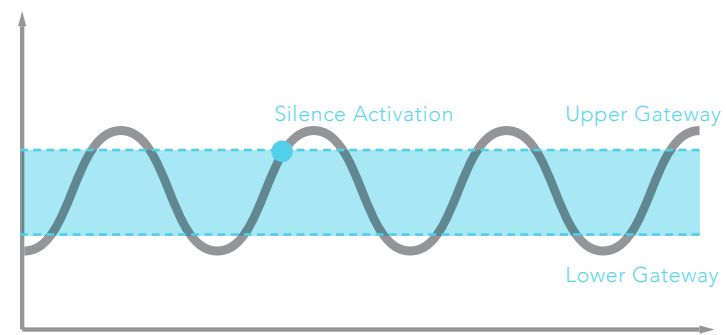


PROTOTYPING + TESTING

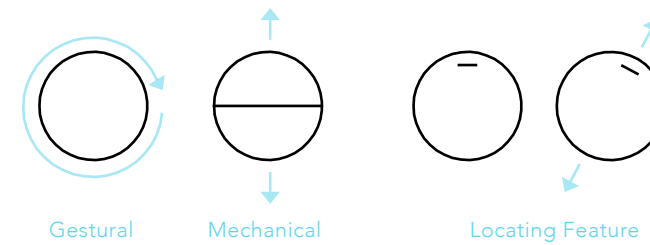


## PHYSICAL USER INTERFACE

After discussions with local sound engineer Andreas Estensen, it was suggested to incorporate 'dampen less', 'dampen more' and 'silence' functionality. This way patients can manually establish their own threshold or 'gateways' during an assessment period and adapted noise cancellation throughout long-term rehabilitation. The 'upper gateway' disables unwanted noises while the 'lower gateway' enables conversation sound if desired. The 'silence activation' would provide valuable data (e.g. history, time, location) that can be used during treatment.



In conjunction with developing the back-end, different iterations of the physical interface were explored. The two most promising scenarios included using a capacitive surface with gestural control and mechanical switch with restricted movement. As shown in the supporting imagery, gestural interactions often caused the device to move undesirably or provoked contact between the finger and ear. Therefore the latter option was taken further and eventually given a locating feature to help distinguish orientation if misaligned.



## SIZE + FIT

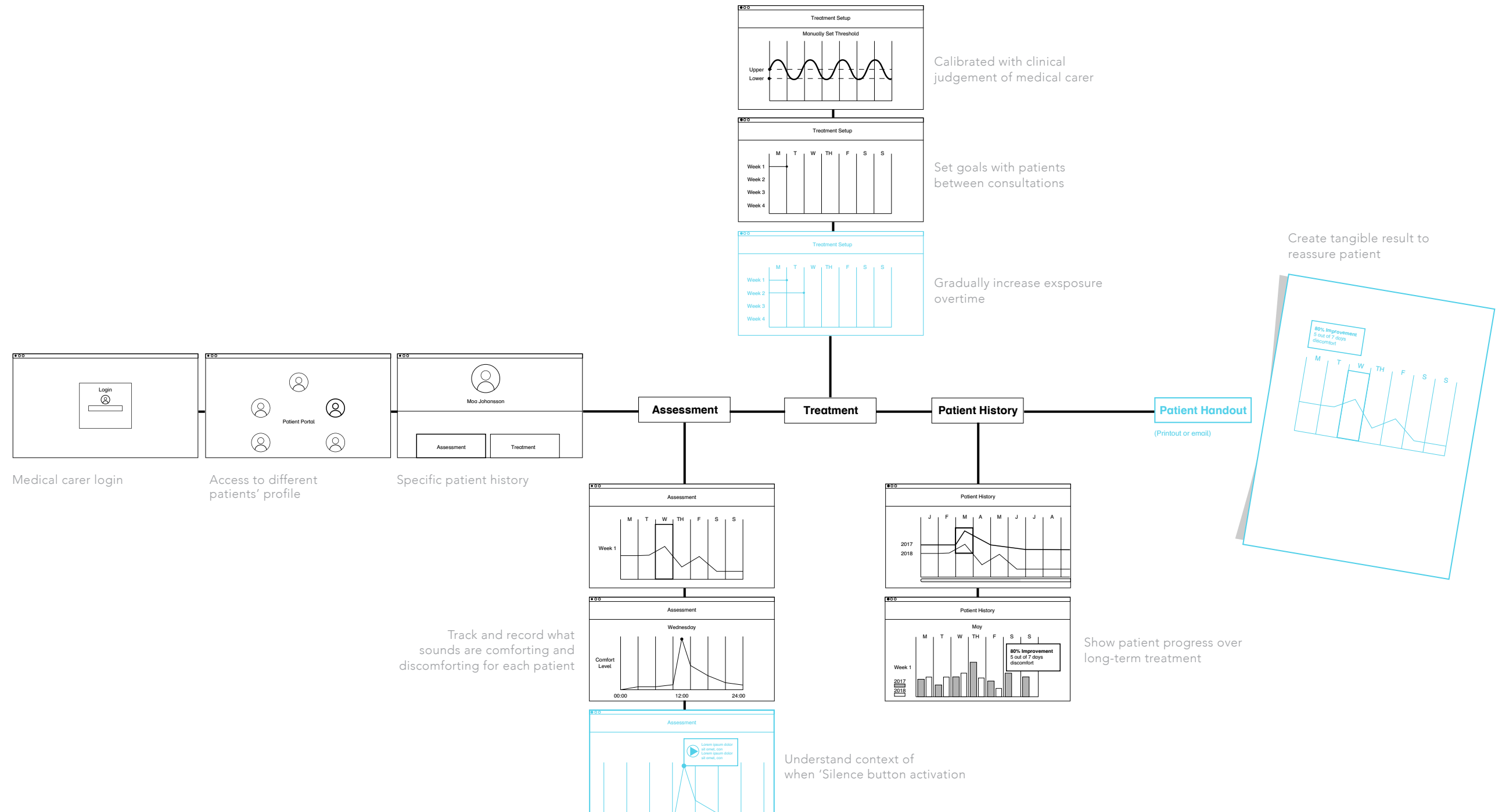
Vigorous prototyping and testing was undertaken to better understand how the device would fit across different ear profiles. The malleable wire proved an effective way to accommodate more extreme percentiles as well as scenarios with glasses or longer hair. Here, the device excelled expectations by resting more securely on the plastic frame and using an obvious concave surface to locate and mechanically control the device when hidden by hair.



## DIGITAL PLATFORM

Based on initial discussions with medical carers, a basic schematic was created to understand what information is needed in terms of a digital platform. This would include a desktop app or plug-in specifically for noise cancellation used by medical professionals. Key elements include:

- An assessment phase, where medical carers can manually set threshold perimeters based on short-term feedback and recordings of discomfort.
- A treatment phase, which allows medical carers to set goals and receive data after increasing exposure.
- A history phase, where doctors can show patients and their family members long term progress through e-mail or physical printout.



## CARRYCASE DEVELOPMENT

Based on existing wireless earbuds, a supporting carry case with charging capability was developed. Several iterations were created that explored portability, scale, orientation of device, battery life and ease of use. However, after further testing and learning about the battery capability of 'Quiet-on' (see page 100), it was decided to focus more on a docking station that directly charges individual earbuds or simultaneously through accessories (e.g. wired necklace). Compromises were also made to allow the carry case to still remain 'pocket sized' and hold a molded profile with potential for more specific versions in future development (e.g. case for earbuds, case for wired earbuds etc).





## 04 FINAL DESIGN

### RELIEF

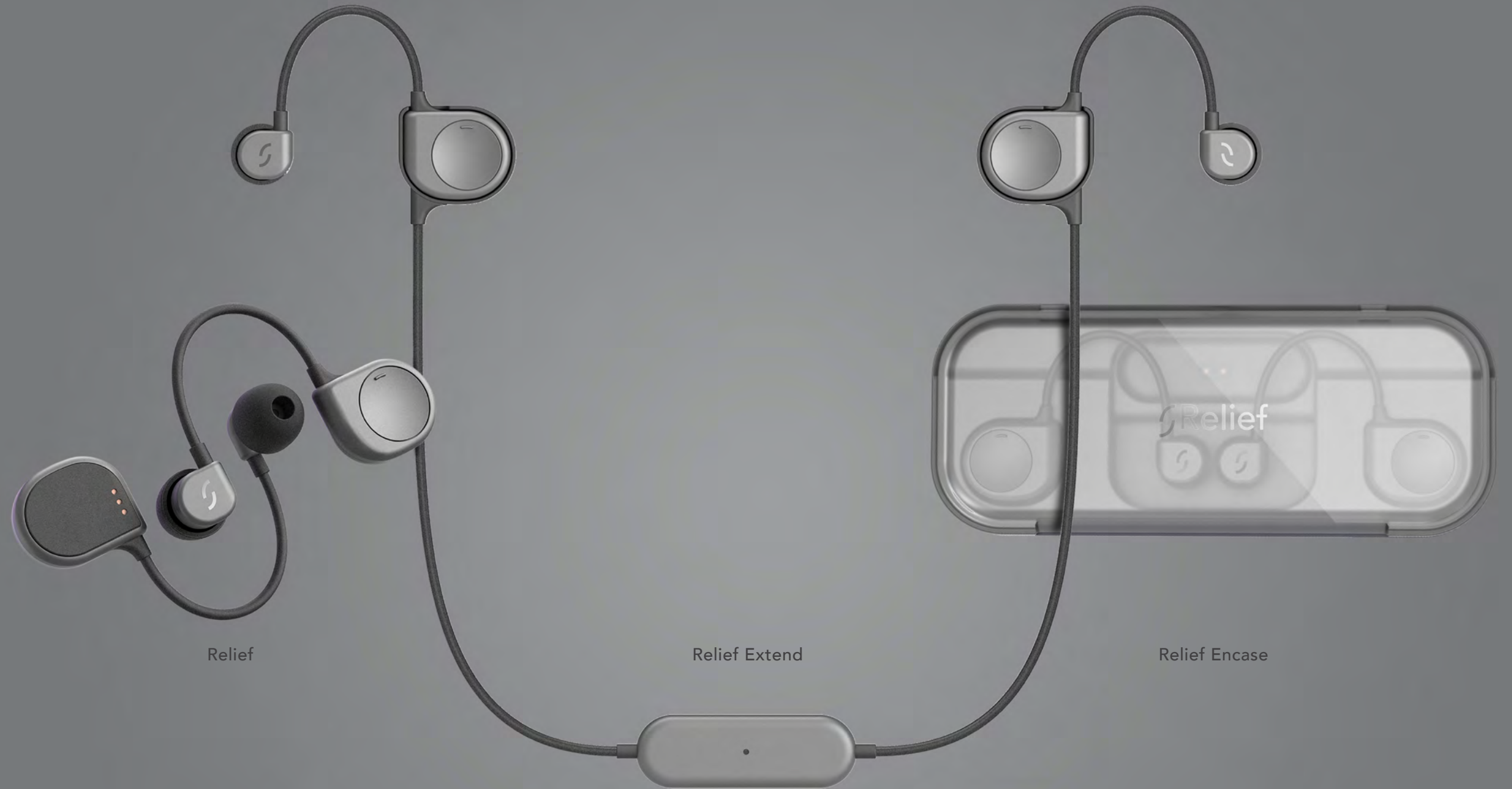
Relief is an audio device that reduces the discomfort of noise sensitivity, a common symptom for patients recovering from Post-Concussion Syndrome or similar types of Acquired Brain Injury. Providing a discreet alternative to current noise cancellation products and adapting to individual needs through a modular system during long-term recovery.

Relief will also create actionable data during rehabilitation and learn what type of sounds are comfortable for each patient while gently increasing exposure over time. Allowing medical carers to optimize treatment, bring transparency to consultations and most important provide reassurance for patients and their loved ones.



## PRODUCT FAMILY

The 'Relief' Product Family consists of three elements; The discreet 'Relief' noise cancelling earbuds, 'Relief Extend', a wired accessory for longer battery life, and a way to celebrate your treatment, and 'Relief Encase' a portable charging station that is compatible with both options as a power bank or docking station. Alongside the clinical judgement from their medical carers, patients now have access to a flexible system that accommodates different needs and adapts to change throughout long-term rehabilitation.





Prescribed by your medical professional

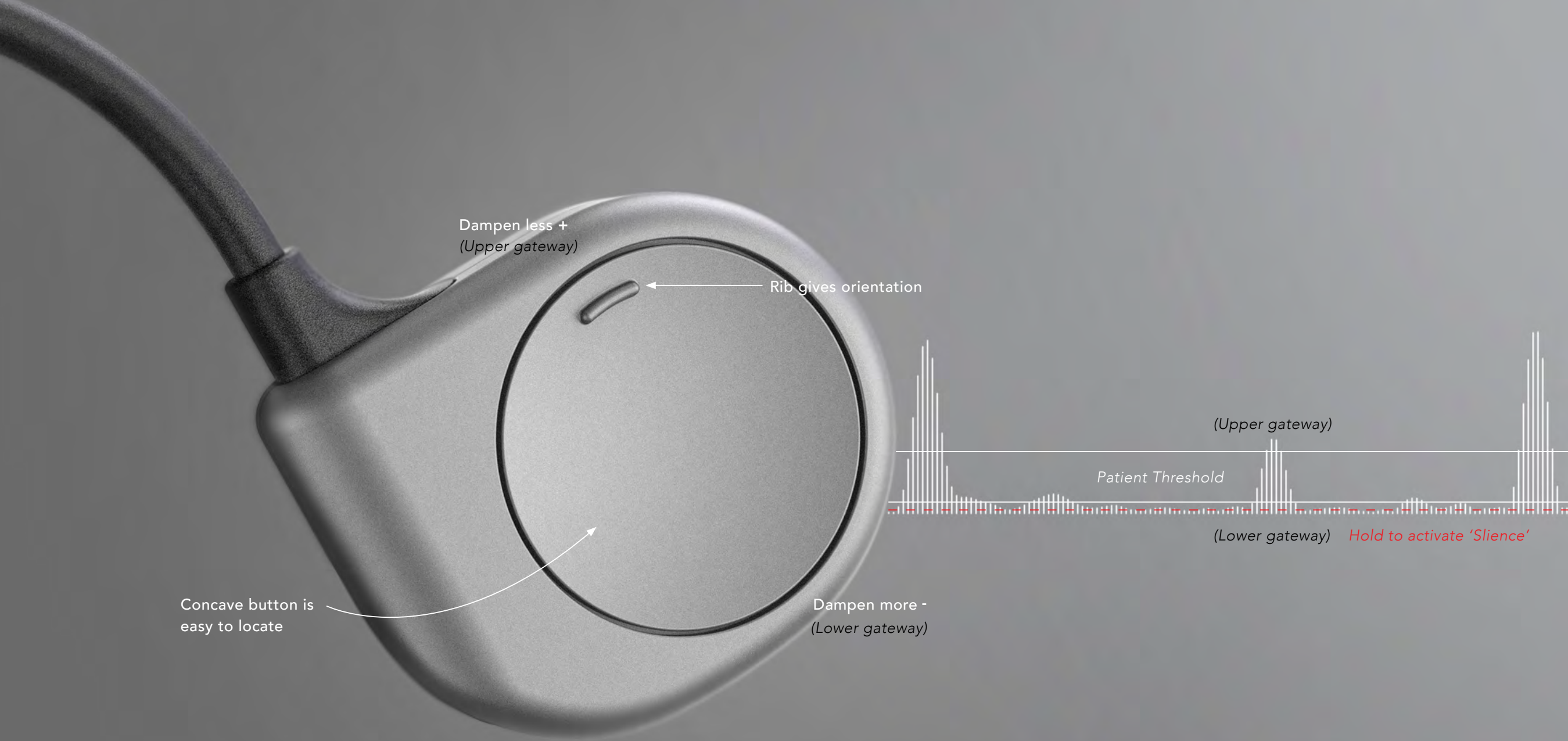


### CUSTOM FIT

Once noise sensitivity has been suspected or diagnosed by a medical professional, Relief will be prescribed, calibrated and fitted during initial consultation. Interchangeable ear tips are available in a range of sizes that are made from acoustic foam that passively cancels higher frequencies and more suitable for long-term use. The malleable wire fits snugly across a variety of ears, keeps its shape, while also allowing the device to be worn on top or below hair or alongside other accessories such as glasses.

Malleable wire adapts to different profiles





Dampen less +  
(Upper gateway)

Rib gives orientation

(Upper gateway)

Patient Threshold

(Lower gateway) *Hold to activate 'Silence'*

Concave button is  
easy to locate

Dampen more -  
(Lower gateway)

## ADAPTIVE NOISE CANCELATION

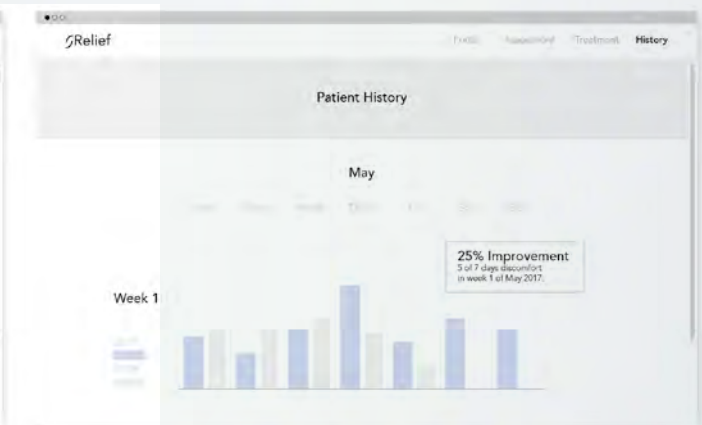
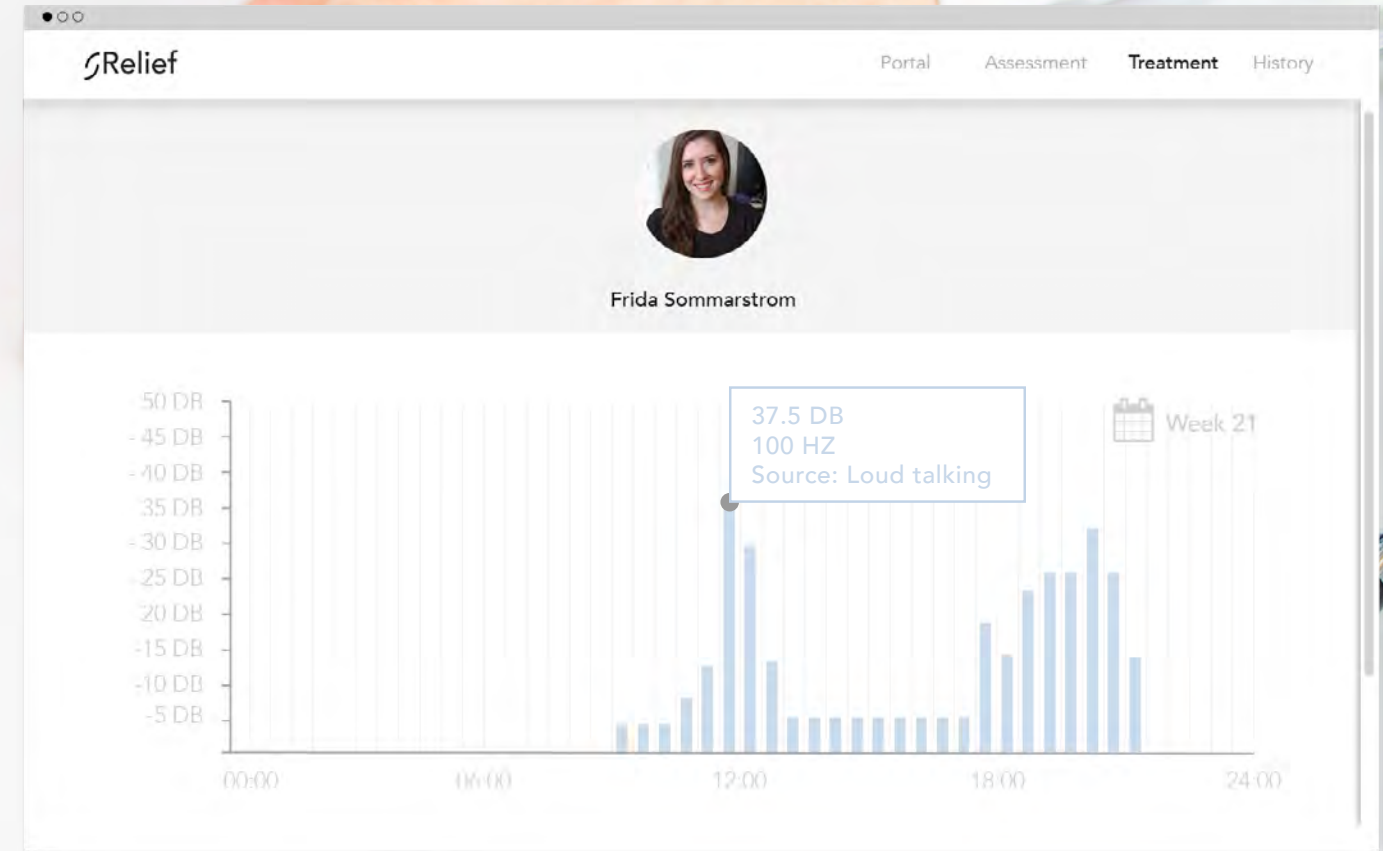
Relief will learn what sounds are comfortable and uncomfortable for each patient. Using a balance of active and passive noise cancellation technology to establish an individual threshold that slowly increases exposure overtime.

During assessment Relief will be used more frequently to establish what frequencies are distressing (pressing 'dampen more') for patients and what are manageable ('Dampen less' button). Holding down the ('Dampen more button'), or downwards for a prolonged period will activate the **silence mode**, giving patients a moment to experience a near silence effect and rest.

## CREATE ACTIONABLE DATA

Relief brings transparency to consultations, allowing medical professionals to better understand how their patients are functioning in the real world, document change and create tangible results that improves treatment.

In particular, Relief will track when the device has been activated or when the surrounding decibel level has been increased or decreased by each patient. Furthermore, providing detailed information such as time of day and type of sound if the 'silence mode' is engaged. This invaluable data provides medical professionals more context and offers new talking points and feedback during consultations. Over time patients will also be provided with tangible results and a percentage of improvement via email or printed form during long-term treatment. Providing reassurance for patients, their families and everyone involved.



## CELEBRATE OR WEAR DISCREET

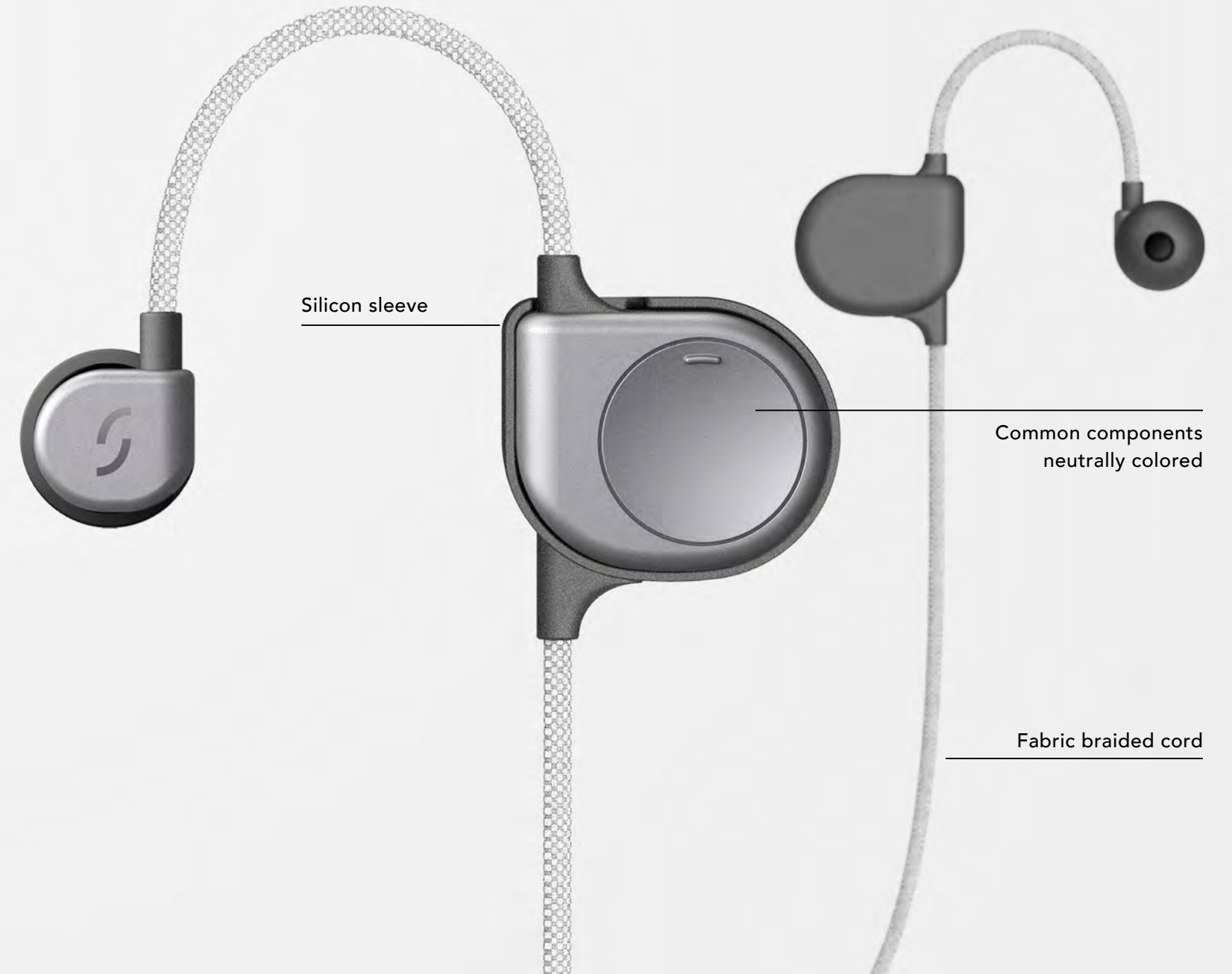
Relief is available in a variety of different CMF versions. The subtle and neutral polymer housings give patients the choice to choose from more discreet cable finish or celebrate through a variety of pastel tones. Relief's modular design easily clips into 'Relief Extends' silicon sleeve to offer extended battery life, security and a way to show treatment. This flexible system will also adapt to reflect the need of patients throughout long-term rehabilitation.



CMF Versions



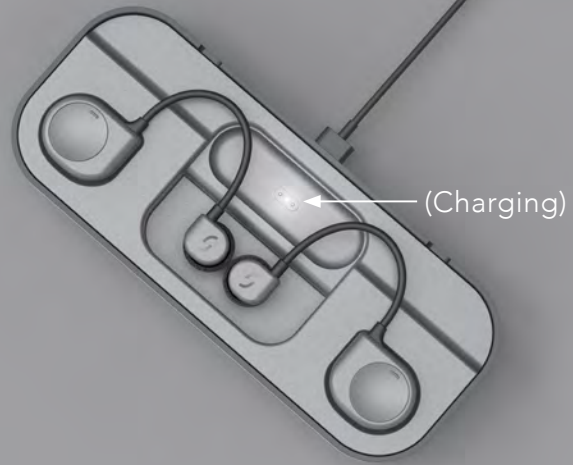
'Relief Extend'



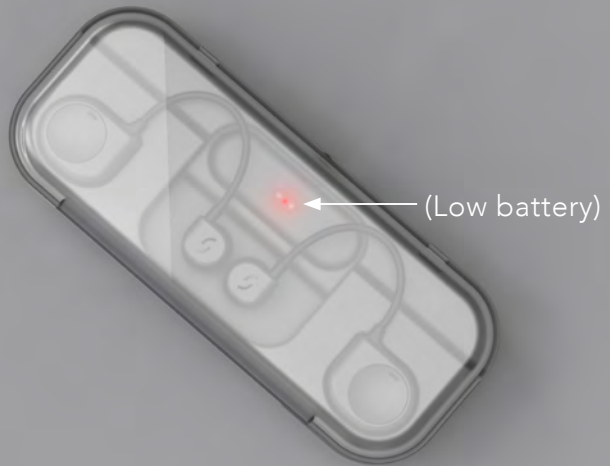
Silicon sleeve

Common components neutrally colored

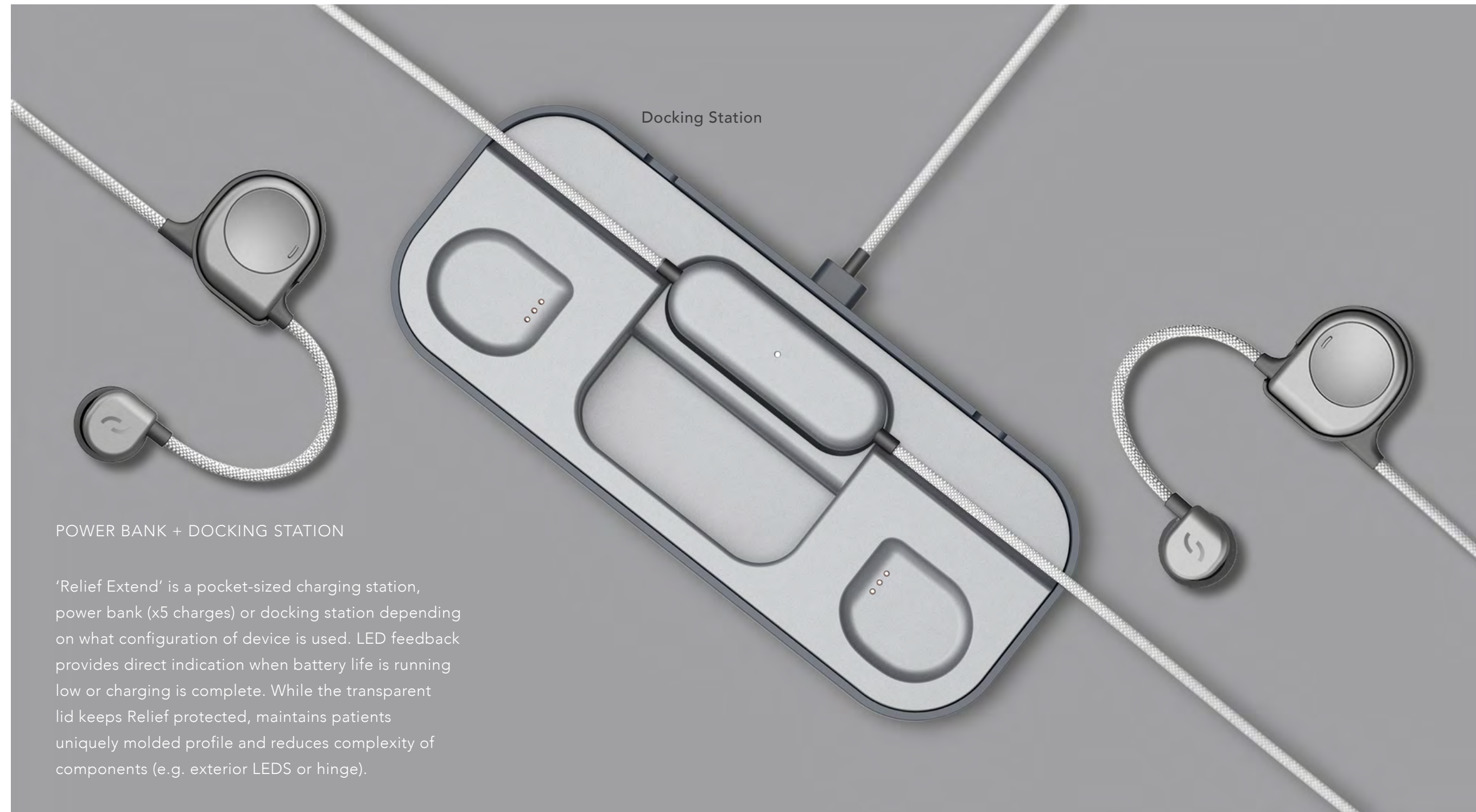
Fabric braided cord



Charging Station + holder



Powerbank + carrycase



Docking Station

#### POWER BANK + DOCKING STATION

'Relief Extend' is a pocket-sized charging station, power bank (x5 charges) or docking station depending on what configuration of device is used. LED feedback provides direct indication when battery life is running low or charging is complete. While the transparent lid keeps Relief protected, maintains patients uniquely molded profile and reduces complexity of components (e.g. exterior LEDs or hinge).