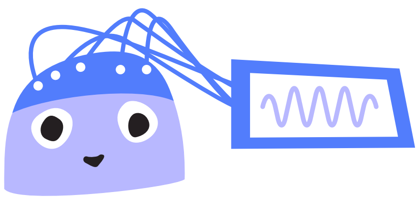
Enhancing Curiosity to Create a Child-Centered EEG Experience



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Executive Summary

Wavy is an interactive experience for children getting an EEG to become more engaged in their healthcare by exploring what the EEG does and creating a moment to ask questions and have conversations.

The goal of this project is to design a new EEG experience for children visiting the Child Brain Lab at the Sophia Children's Hospital. The Child Brain Lab will be a new space to do pediatric research for different neurological and psychological disorders. In this space there will be stations where children will do different brain tests, and one of these stations is the EEG station.

The initial goal of this project was to improve experience for children 6-12 years old by enhancing curiosity when going to the EEG station, to allow them to learn more about the EEG on their own terms, empowering them with knowledge about their own healthcare.

To achieve this goal, literature and observational research was done to learn more about the different stakeholders and the context of the EEG. The focus of the research was on identifying moments of boredom, anxiety, and curiosity for the children in the EEG space. In addition, the moments of interaction between the child-patient and the parent and lab technician were looked at in relation to these emotions.

The observational research led to detailed patient journey maps to be created for four patients who were doing an EEG test regarding the three emotions identified and the interactions between the users.

The main insights found were that patients are usually prepared for the procedural side of the appointment but not really about what the EEG test does. This is due to the EEG test being difficult to understand, even for parents, and it becomes assumed that it is too abstract for children to grasp.

Factors for how to spark curiosity were also identified through literature research: creating a safe space, building up anticipation, allowing children to predict what will happen, and integrating novel colors, sounds, or other effects.

The insights from the research lead to many ideas through sketches and low fidelity prototypes to be developed during and after the research process. Different feedback sessions with patients, parents, and healthcare providers help define the concept direction: an interactive

Figure O.1: Wavy integrates projector and physical pieces to create an interactive experience

experience that children can play during the EEG to help them learn about what the EEG does on their own terms.

The final design is Wavy, see Figure O.1, an integrated experience that utilizes a projector and interacts with physical pieces to create a virtual and physical environment for children to explore 'What an EEG does' and to introduce parts of the procedure for children. The Wavy character shows the steps that will happen as the child goes through the procedure: measuring their head and picking the EEG cap. Then after the cap is placed on their head and while the lab technician is preparing the rest of the appointment, the child can play the EEG game.

Wavy shows how doing different activities affects the EEG reading. By placing electrodes pieces, children create brain waves and a brain wave network, similar to how many electrodes are used to get the EEG reading. An activity knob allows children to change the activity, changing the brain waves patterns.

The design has been evaluated through interviews with child-patients, their parents, lab technicians, and neurologists (n=14). For the evaluation, a virtual interactive prototype was created to test with the child-patients (n=3) and parents (n=5). Lab technicians and neurologists (n=6) liked that the game is helping the child be more actively a part of the EEG appointment.
During the prototype evaluation, children asked questions to their parents about the game and EEG, and were able to relate the Wavy experience to their own EEG experience.

Table of Contents

Glossary

CBL	Child Brain Lab
EEG Test	Electroencephalography Test
VBHC	Value Based Healthcare

Guide to this Report

Important are highlighted like this

Insights

- **Main insights are found in text boxes like this**

Introduction

Problem Definition
Project Approach

Sophia Children's Hospital Child Brain Lab is looking to improve child-patient care by taking the patient's perspective in an innovative new care space. This project is in collaboration with the physicians of the Sophia Children's Hospital Child Brain Lab and the Play Well Lab at the TU Delft. The Child Brain Lab will be a new space to do pediatric brain testing, a room with several different testing stations, such as electroencephalogram (EEG) and gait analysis (Erasmus MC, n.d.a). Children visiting the lab have different brain disorders, such as epilepsy or with varying neurological or behavioural developmental levels. This project is centered around creating a child-centered EEG station experience for not yet existing CBL, for children of the developmental ages of 6-12. The EEG station is one project for the CBL and there are two other graduation projects related to improving child-patient care at the CBL.

Sophia Children's Hospital CBL is implementing value-based healthcare in their new care space. Value-based healthcare takes the patient's perspective, increasing value for the patient by focusing on areas where the patient's health and experience can be improved while keeping costs minimal (The Boston Consulting Group, 2018).

The goal of the hospital for the CBL is to create a space to do repeatable brain testing of children of various ages and disorders in order to do clinical diagnosis for patients and to use the research to learn more about cross diagnosis and treatments of different disorders (Erasmus MC, n.d.a). The hospital envisions a space that is welcoming to the various patients that will visit the CBL and enhance patient understanding to improve patient care. This project looks from the child-patient's point of view to improve the comfort, understanding, and experience while getting an EEG test.

Problem Definition

In creating a child-patient centered EEG testing experience that delivers on value-based healthcare principles, several problem areas are encountered that relate to child anxiety, communication with children, the variety of cognitive and physical abilities of the patient group, parent involvement and feasibility for hospital staff.

Child-patients are often anxious and apprehensive about doing EEG tests as it is confusing and the results are given in a form that is not digestible to them. Anxiety can increase before arriving at the hospital, during periods of waiting, and times of boredom, where the patient's mind has time to wander (Muskat et al., 2015; Paasch et al., 2012). After the EEG test, patients are relieved that the test is not painful, but still don't understand it. Children fill gaps in knowledge with their own wild assumptions which can cause more anxiety. One co-creation session showed that children thought that the EEG would suck the thoughts out of their head (Gielen, 2019). At the same time, children are also curious about what is going on and these moments are opportunity areas for learning. In hospital settings, children often are found to have a passive role as parents and doctors communicate with one another (Coyne, 2008).

The project aims to be inclusive of the different kinds of children that will visit the CBL, such as brain developmental disorders and behavioural issues. They have individual needs and flexibility in treatment can have a large impact on patient care (Muskat et al., 2015).

Sometimes patient behaviour is hard to identify as a healthcare provider, especially for patients with lower developmental levels. Parents are experts in their child's behaviour and know the baseline of the child-patient's mood, for example how anxious a child is normally (Muskat et al., 2015; Paasch et al., 2012). Parents' mood also has a large effect on the child, if parents are anxious, the anxiety can be reflected in the child (Cameron et al., 1996). These factors make the parental interaction important to account for.

The EEG station needs to fit into the workflow of the lab technicians, should not add significant workload or inhibit performing tasks. The EEG station should consider interactions moments in which the specialist can help the child learn about the EEG test.

Although these problem fields are identified from several sources, it is still an open question how they can be addressed coherently in the design of a novel EEG testing station.

Project Approach

The approach to this project follows the double diamond method, Figure 1.1. In the initial Discover phase, knowledge about the CBL, child-patient experiences, EEG tests, and curiosity will be explored. As a basis of knowledge is developed, observational research and interviews with child-patients, parents, lab technicians, and doctors at the EEG station in the Sophia Children's Hospital will help affirm or challenge learnings and assumptions from the literature research. The observations and interviews will develop patient journey maps and lead into the Define phase. In the patient journey maps, key moments of boredom, anxiety, and curiosity will be identified, as well as moments of reassurance or comfort from the parent or lab technician. During these first two phases, ideation will be done to capture initial ideas.

The research learnings and insights help redefine a new problem statement and lead into the Development phase. Ideation through sketches and clustering develop into concepts with low fidelity prototypes. To have a useful and implementable design, validation sessions with experts, doctors and lab technicians from the hospital, and with child-patients and their parents will improve the design during the Refine Phase. The process zooms in and out, as different parts of the project are explored then defined. Figure 1.2 shows the design process, its explorative nature, and is at the beginning of each section.

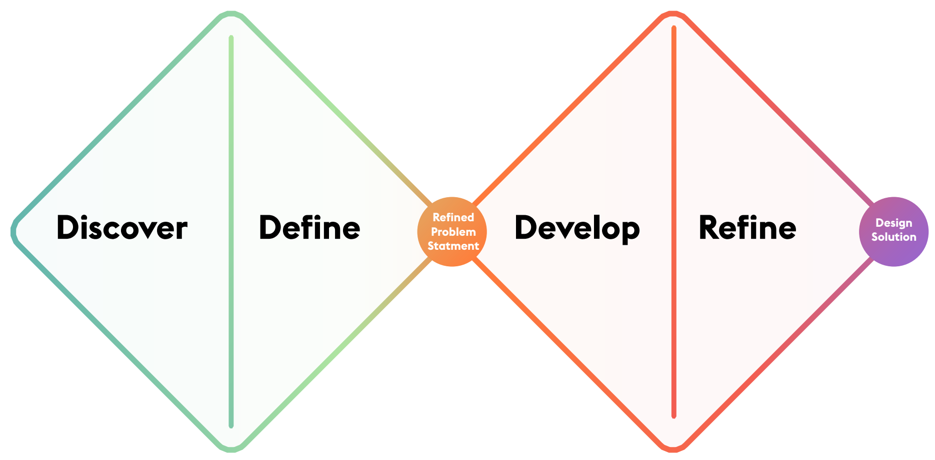


Figure 1.1: The design

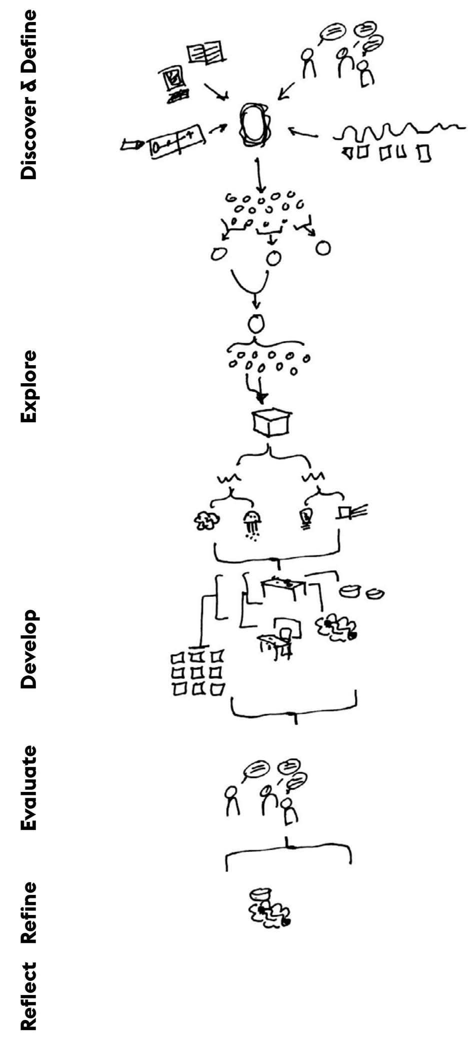


Figure 1.2: The explorative design process

Discover & Define

This chapter contains the Discover & Define phase, the research done and the analysis created.

The goal of the initial Discover phase of the project is to identify research objectives and discover different factors that will impact designing for the EEG space: learning about the context, different stakeholders, and empathize with the needs of the different users. First the research objective, questions, and approach are identified.

In the Define phase, after the research is done, patient journeys are created and the insights analyzed to create the design vision. An initial List of Requirements is made to help focus on the needs of the users.

Discover & Define

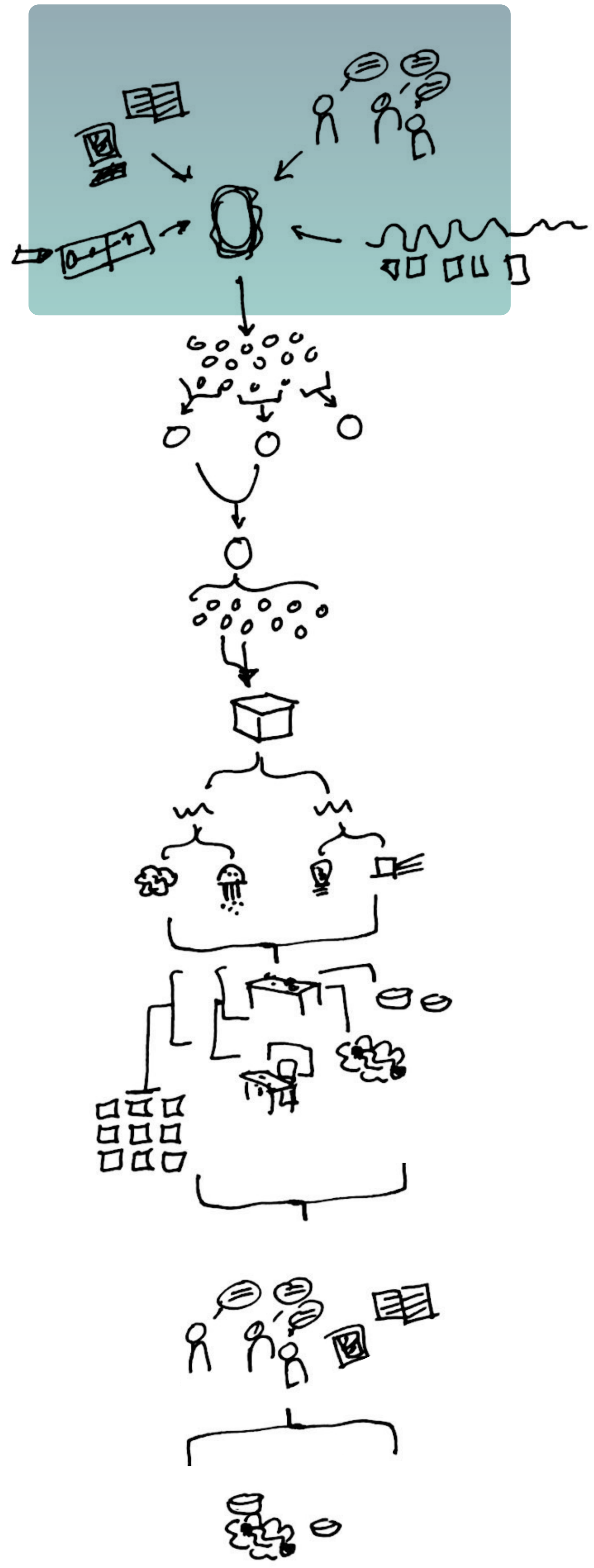
Explore

Develop

Evaluate

Refine

Reflect



Research Approach

Research Objective

To design an EEG station for the CBL that utilizes curiosity to engage children visiting the lab and meets the needs of its stakeholders, the research focuses on: the Child Brain Lab, the EEG test, children's experiences in hospitals and curiosity.

First the goal, structure, and stakeholders of the CBL are defined. Then what happens during an EEG test is explored and after the difference between a traditional EEG and one at the CBL is described.

The children's needs in hospital settings are explored, focusing on key moments of boredom, anxiety, and curiosity and the interaction between the child-patients and the healthcare providers and parents.

The objective of the research is to learn about the EEG experience process, the similarities and differences in the Child Brain Lab and a traditional EEG, the needs of the direct stakeholders: child-patient, the parents, and the EEG lab technician, and about how curiosity can be sparked in play.

Research Questions

1. What are moments during the EEG testing that the child-patient experiences **boredom**, **anxiety**, and **curiosity**?

2. When are moments that the child-patient's need **comfort** or **reassurance** from their peers, parents, or specialists?

3. What are ways to create an **inclusive** testing station for the variety of patients visiting the Child Brain Lab?

4. How to provide patients information about the EEG test **by utilizing their own curiosity** in an understandable and playful way?

Research Approach

The research approach is initially through literature research to learn more about the specific areas of interest, that leads to insights and assumptions that are then used to help make the basis of the observation and interviews of the direct stakeholders during the EEG test at the Sophia Children's Hospital. After, patient journeys are developed to compare the different experiences and an analysis of these patient journey's lead to insights for the List of Requirements for the future development of the design.t

The Child Brain Lab

How will the CBL work and who are the main stakeholders?

Structure & Goal

The CBL will be developed in the Sophia Children's Hospital within the Erasmus Hospital in Rotterdam, a figure of the CBL structure can be seen in Figure 2.1.

The main children visiting the lab will be of 'normal' developmental cognitive levels, but others could be tested as well. All of the children visiting the lab are hospital veterans and have previous experiences being in the hospital, for reasons such as brain surgery, epilepsy, or other neurological or psychological disorders (Erasmus MC, n.d.a).

Although this project focuses on children 6-12, children from 0-18 will visit the lab.

This space is being developed to do a number of brain tests with children including the EEG test and also gait analysis, eye tracking, and other neurological tests. There will be a set circuit of these tests that will be done to help build a research database to compare and research with the results. Over time the CBL hopes to identify signs of disorders and diseases earlier on so that they are able to be treated earlier. Because of the research focus of the CBL, repeatability is very important for the lab.

The space is open for design, an image of the room can be seen in Figure XXX.

Stakeholders

A visualization of the stakeholders can be seen in Figure 2.2. The direct stakeholders for designing the EEG test experience are children visiting and doing the test, the parents that will accompany them, and the lab technicians that will guide the child and parent through the process. The doctors and researchers will use the information that is gathered for better understanding the brain. Indirect stakeholders are the future patients that will benefit from the research that is gathered from the lab.

Figure 2.2: The empty room where the CBL will be located

Insights

- **Mostly 'cognitively normal' children will be visiting the lab**
- **The children are all hospital veterans and have previous experiences as the hospital**
- **Children of all ages will visit the CBL**
- **Repeatability is important for the testing of the CBL**
- **The EEG test will be one of several tests that the child will do in the CBL circuit**
- **It is an open space for design**

Structure of the Child Brain Lab

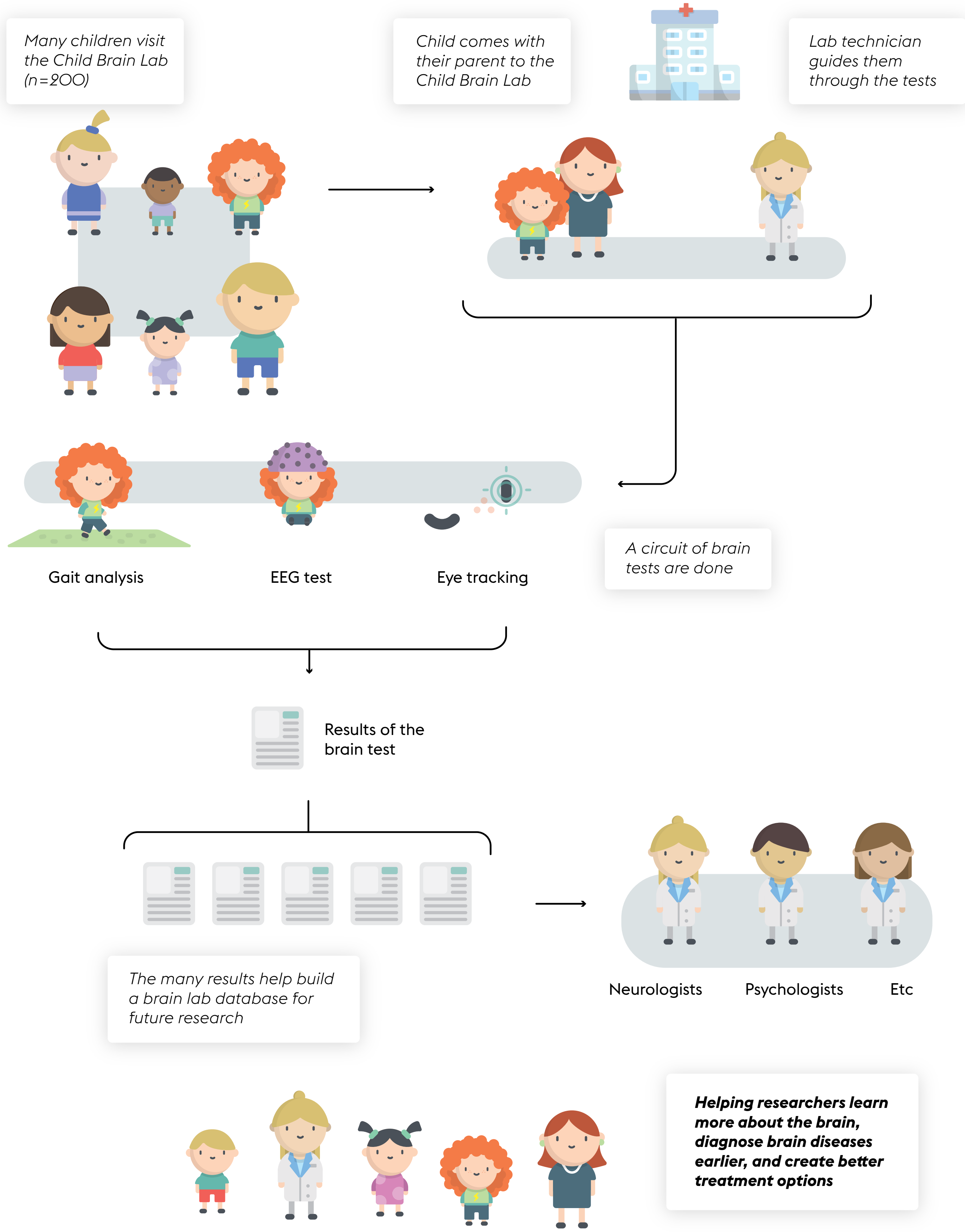


Figure 2.1: Structure of the Child Brain Lab

EEG Test

Understanding what happens during an EEG test and how this may differ in the CBL.

What does an EEG Test do?

The brain is made up of billions of neurons that produce electrical currents when they operate (Erasmus MC, n.d.b). The EEG measures these electrical signals in the brain by placing electrodes all over the head and comparing the electrical currents between the electrodes (Jeremy Moeller, 2014). Figure 2.3 shows a child with the electrodes, prepared for an EEG.

In Figure 2.4, the green electrodes are shown on the outer part of the head picking up an electrical signal that is apparent in one electrode and not another. The comparison between the electrodes allows the EEG to produce the brain's electrical signal. The electrical signals in the brain can be thought of as similar to a rock being thrown into a pond and the rippling effect that it creates, but as the brain is globe shaped, the electrodes can only measure the electric signals on the outer part of the brain (Mike Batashvili, 2013).
While doing an EEG test, hundreds of electrical signals are measured per second (Epilepsy Society, 2019). The electrical signals that the EEG test measures create a wave pattern, which are brain waves (Epilepsy Society, 2019). Brain waves are used to identify the brain activity of a patient, diagnosing epilepsy or a variety of brain development orders (Epilepsy Society, 2019).

Because the EEG picks up even small signals from movement or muscle tension, it is important to be very relaxed when taking the test. Blinking, hand clenching, or eating can set off the electrodes and signals on the EEG (Jeremy Moeller, 2014).

Figure 2.3: A lab technician placing electrodes on a child at the Sophia Children's Hospital

Image from Sophia Children's Hospital

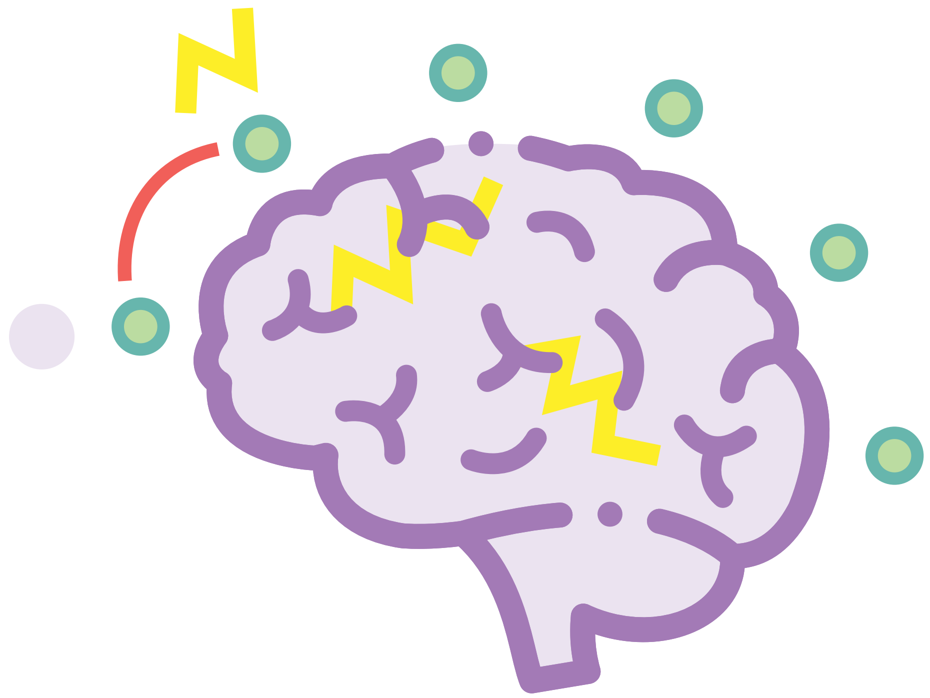


Figure 2.4: Visualization of how electrodes read electrical signals in the brain

Traditional EEG Test Procedure

In Figure 2.5, a simplified verion of the patient journey for getting a traditional EEG is visualized, based on observations of EEGs at the hospital and from literature research. The test procedure is also described step by step in Appendix B.

Usually the patient is prepared by their parents or caregiver before coming to get the EEG by having an abstract explanation of the procedure given to them (e.g. "A video of your brain") (Epilepsy Society, 2019).

At the hospital waiting room, the patient and parent are greeted by a lab technician and the child gets to choose a movie to watch when arriving at the EEG room, Figure 2.6 shows the room.

Throughout the EEG process, the lab technician makes simple, clear explanations of the process and what steps they will be doing.

The lab technician first measures and marks the patient's head, then places 24 electrodes on the patient's head using Q-tips, gritty gel, and tape to attach them, Figure 2.7 (Epilepsy Society, 2019). This can be the most time consuming physically uncomfortable parts of the EEG test.

Once the electrodes are placed, a series of exercises is done to measure the brain activity or to try to trigger a elplietic seizure. These exercises include closing and opening eyes, hyperventilation activity, and looking into a flashing light.

After the EEG test, the lab technician removes the electrodes with warm water and combs out the patients hair. The patient gets to choose a toy at the end of the EEG test before going home. Usually the preparation for the EEG and test lasts about 1 hour or it may be overnight for a 24 hour EEG. For EEGs, it is important to have the patient be relaxed and not stressed, so other tests and diagnosis with a doctor do not usually happen on the same day.

Insights

- **A lab technician guides the parent and child through the process, giving simple, clear explanations and demonstrations**
- **It is important for the patient to be relaxed during the process to not affect the EEG test results**
- **Children will be in an upright, seated position for the CBL EEF**
- **Flexibility is necessary depending on what kind of testing and research will be done**

The CBL EEG Test Procedure

In the CBL, the EEG test procedure will be different from the traditional testing experience. Instead of placing each electrode individually, a cap will be used to reduce time and uncomfortableness of the activity. Also, an eye tracking exercise will be used in addition to a couple of the traditional exercises (the open/close eyes exercise). Because of the eyetracking, the child will usually be in a chair, rather than the lying position that is typical for traditional EEGs. The overall time of the CBL EEG would be reduced to 30 minutes.

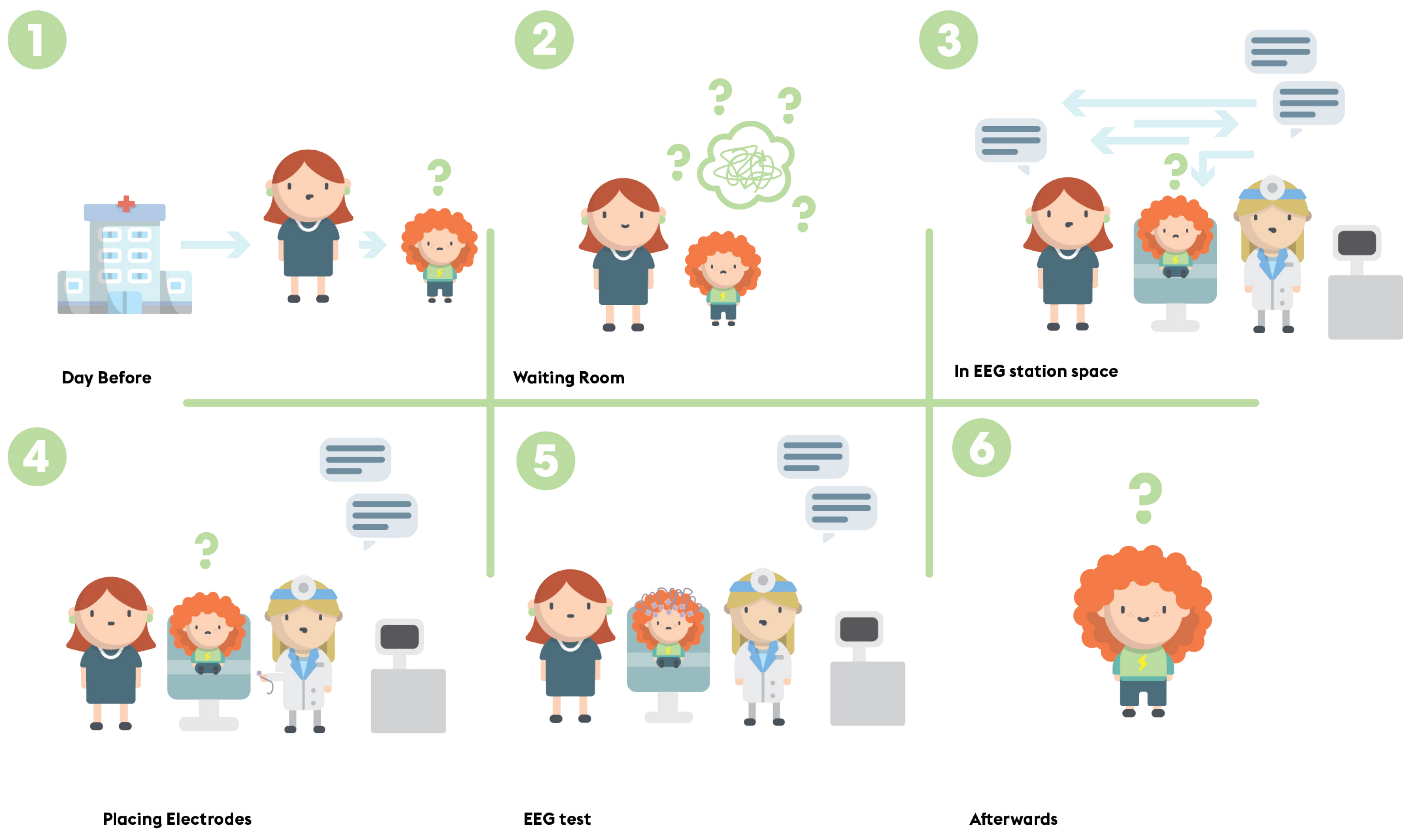


Figure 2.5: (Above) A simplified version of the EEG test procedure

Figure 2.6: (Left) The current EEG room at the Sophia Children's Hospital

Figure 2.7: (Below) The supplies in the EEG room

Children's Experiences in the Hospital

To answer RQ1 and RQ2, literature research was done to better understand children's experiences in hospital settings and their interactions with their parents and healthcare providers. To also focus on the diversity of kids who may visit the CBL (RQ3), literature research was done to learn about how children with different brain developmental levels experience the hospital.

Boredom

Boredom occurs during times of waiting such as in waiting rooms or can be also when the child is not being addressed and the parent and healthcare professional are interacting (Coyne, 2008). Because the hospital can be a sterile space, in terms of color and decorations, it can be an unstimulating space for the child-patients (Coad & Coad, 2008). **Moments of boredom can lead to anxiety as the patient's mind has time wander** (Muskat et al., 2015).

Anxiety

Child-patients are often anxious and apprehensive in hospital settings due to lack of preparation, knowledge, understanding, choice, and power (Coyne 2008; Schalkers et al., 2015; Lerwick, 2016). **The largest fear of children is of the unknown** (Lerwick 2016). In the **unknown and stressful environment of the hospital, children are often passive participants** (Coyne, 2008; Lerwick, 2016). Fear is often dismissed and children have difficulty communicating their needs (Lerwick 2016).

EEG test results are given in a form that is not digestible to children (Gielen, 2019). A co-creation session research study by Gielen (2019), found that **children fill gaps in knowledge with their own wild assumptions** which can cause more anxiety. The co-creation session showed that children thought that the EEG would suck the thoughts out of their head.

But by making these assumptions, it also shows that children are also interested about what is happening in the brain and these are opportunity areas for curiosity and learning.

Reducing Anxiety

To minimize anxiety in hospitals, Lerwick et al. introduces CARE for pediatric patients: Choice, Agenda, Resilience, and Emotional support (2016).

The study states that **Choice helps empower children in an environment where they lack control**, therefore as much choice as possible, even for small decisions, helps reduce anxiety for children.

The next part is **Agenda: knowing what steps will happen next and what is expected helps children feel more control in an unfamiliar situation and less fearful**.

Resilience acknowledges the strength the patient has to help establish a trust-filled relationship with the child (Lerwick et al., 2016).

The last part of the CARE process is Emotional support, being aware of the patient's emotions and comforting appropriately as well as helping them know that everyone is afraid sometimes.

Curiosity

To identify curiosity in the hospital space, it is based on: how children participate in the hospital, how communicative healthcare professionals are with children, how well do children understand what is happening in the hospital, and then focusing on what children understand about the EEG.

Child Participation

Children often have difficulty participating in hospital spaces. **Children are accustomed to not participating in conversations in the hospital and taking a passive role** (Coyne, 2008; Lerwick, 2016).

Coyne's study (2008), indicated parents and hospital staff usually directly communicate with one another and this can cause **children to feel "fear of causing trouble" by asking for questions or explanation**s.

The study further identified that **terminology used is too technical for children to understand** and there is sometimes a lack of time for healthcare professionals to explain procedures and steps properly.

Children's views are not always sought out and they are not consulted on minor decisions, such as bed preferences, which can make a large impact on care and comfort (Coyne, 2006; Lerwick, 2016). By not giving children the space to speak up, it makes it difficult them to do so, especially in an unfamiliar setting such as the hospital.

Even though there are some negative points identified with communication with healthcare providers, Coyne's 2006 study also found **children also have good connections with nurses** who treat them. In Coyne's research, **it was especially seen when children's opinions were sought after from nurses.** Giving children respect and treating them as an adult, empowers them within their own care. Nurse's qualities, such as approachability, kindness, and warmth, gives children comfort in the hospital and children often viewed nurses as a peer group (Coyne 2006). The relationship that children have with nurses can improve their care and allow them to feel comfortable to have conversations and ask questions.

Understanding & Communicating About the Brain

Based on the research from Gielen's 2019 co-design and research study with children, there are key learnings on how to communicate with children about the brain.

This co-design session found that **information to children should be realistic and relate to their current understanding of the brain.** Furthermore, the co-design session found that knowledge of the brain can vary from child to child and information should relate to their current knowledge of the brain. For example, Gielen's co-design session found that because brains are usually depicted as pink, having a blue brain may confuse children.

Abstract information should firstly focus on conveying clarity and this will help children's understanding best. As stated previously, if there is misunderstanding or gaps in knowledge, children fill the gaps with their own imagination.

Children's Understanding of the Brain

Some children see sickness or dreams as tangible objects floating inside of the brain and that the thoughts that are stored in your head can be stored only in one place (Gielen, 2019). Taking these thoughts out would erase them from their own heads (Gielen, 2019). These abstract thoughts are examples of the gaps and jumps children make of knowledge. Therefore clarity is important when communicating with the children.

Inclusivity

The project aims to be inclusive of the different kinds of children that will visit the CBL, such as brain and behavioural developmental disorders. Children with these disorders often are sensitive to many senses, this can be through the sound of machines, how often they are touched by healthcare professionals, or the visuals of the room (Muskat, 2015; Paasch et al., 2012). Also large groups of people can also make the process stressful (Muskat, 2015). With more severe disorders, children have more difficulty understanding what is going on, so **being efficient in treatment and reducing the amount of time of waiting or boredom is key** (Paasch et al., 2012).

Often it is found that inflexibility in treatment makes the experience difficult for parents and patients with behaviour or brain developmental disorders (Muskat, 2015). Flexiblity can be such things bringing toys or electronic devices that will improve care for these patients (Muskat, 2015). **Flexibility in treatment and procedures for individual needs can have a large impact on patient care** (Muskat, 2015; Paasch et al., 2012)

Interactions with Parent

Sometimes patient behaviour is hard to identify as a healthcare provider, especially for patients with lower developmental levels. **Parents are experts in their child's behaviour and know the baseline of the child-patient's mood**, for example how anxious a child is normally (Muskat 2015). Parents help children feel less anxious in hospital settings (Cameron 1996).

But Parents' mood also has a large effect on the child, if parents are anxious, the anxiety can be reflected in the child (Cameron 1996). Though parents are also often aware of this and highly anxious parents also remove themselves from the room if they see that they are affecting the child (Cameron 1996). These factors make the parental interaction important to account.

Curiosity

To answer RQ4, it is necessary to explore and understand what curiosity is.

Difficult to Define

Many different sources use different ways to identify curiosity, for this research's purposes it will focus on **"the desire to understand which you do not know"** (Celeste 2015). One main characteristic can be seen as information seeking, but an important distinction between curiosity and information seeking is that information seeking can be an intrinsic or extrinsic desire and **curiosity is solely an intrinsic value, without any outer goal from learning** (Celeste 2015). This can be related to play, as play is also aimless and without a particular goal other than to play (Gielen, 2009).

A Safe Space

Willis states that sensory information in the brain, such as touch, sound, smell, etc., is regulated by the Reticular Acticiatin System (RAS) and prioritizes this information in particular ways (2019). **If the body feels criticism, embarrassment or fear, then a fight or flight response is triggered, reducing the amount of information intake** (Willis, 2010). Therefore it is important **to create a safe space for curiosity to be evoked**.

Anticipation

By giving clues of information and hints of what is to come, anticipation can help provoke curiosity (Willis, 2010). Thinking about what is to come creates excitement. This can be through visual hints or the way a story is told. Giving a moment of pause to let imagination grow, adds suspense and interest.

Predicition

Predication can be evoked in children **when they have their own knowledge base** and want to learn more about the topic (Willis, 2010). In this way, **they become invested in their own learning**, wanting to predict what will happen next (Willis, 2010)..

The Novel & Unexpected

Triggering curiosity through the RAS can be done through **novel color, movement, or aromatic sensations** (Willis, 2010). Children are curious about new, **unexpected things**, and when this happens **they seek out their own explanation and feel invited to ask questions** (Willis, 2010).

Insights

- **Curiosity and play is without an outer learning goal other than personal motivation to explore**
- **Curiosity requires a safe space**
- **Curiosity can be induced by creating anticipation (e.g. a moment of waiting or some sort of build up)**
- **Prediction help create curiosity, as children become invested in their own learning**
- **To trigger curiosity novel and unexpected color, movement, texture or aromatic sensation can be used**

User Research

Observational research, interviews, and a context mapping booklet were conducted to gain a better understanding of stakeholders experiences.

Interviews & Observations

Goal

To gain a better understanding of the needs of the different direct stakeholders, observational research and interviews were done on the EEG testing at the Sophia's Children Hospital. The focus was on the key moments of boredom, anxiety, and curiosity and also interactions of comfort and reassurance between the child-patient and the parents or lab techinican (RQ1 & RQ2). Children of different brian development levels and their parents were also observed for understanding their challenges (RQ3).

Method

Observations of the entire EEG experience were done. Parents of the patient were called before the EEG appointment to ask if they were willing to participate in this research. The participants were observed during the entire examination. Notes and sketches of posture were used for documentation.

Participants

Four sets of families were observed (n=14). Three child-patients were cognitively 'normal' children and had a 1 hour EEG test. One child-patient had severe brain development issues and was prepared for a 24 hr EEG. Three of the children had two parents present and one had one parent present.

Limitations

There was a limitation of language, for two of the observations a translator was used. For the second two observations, physical posture and tone of voice of the participants were primarily used and questions with the parents after the examination to confirm the interpretation of the emotions of the child-patient. There were difficulties speaking directly to the child and information can be lost in translation.

Due to the situation with COVID-19, there was a limited time that research could be conducted in hospital and only a small sample size of participants were observed. Because there is a limited number of participants, not all of the age groups could be observed thoroughly and differences of needs based on the age groups may be missing. This could be compensated for by testing the design with more of the different age groups.

Context Mapping Booklet

Goal

Because of the COVID-19 pandemic, doing interviews and observations at the hospital had to be stopped. Instead a context mapping booklet was developed to verify the results of the previous observations.

Method

A flyer was sent to patients and parents to see if they were willing to participate in this research. A context mapping booklet was developed based on the research questions for the parent and child to fill out together. After an interview was conducted to talk about the booklet. The flyer and materials for this exercise can be found in Appendix C.

Participants

One parent and child volunteered to do the context mapping booklet and interview.

Limitations

Limitation of language when speaking to the child, but the parent spoke English. There was only one participant due to time limitations, the situation with COVID-19, and because child-patients could not be contacted directly.

Patient Journeys

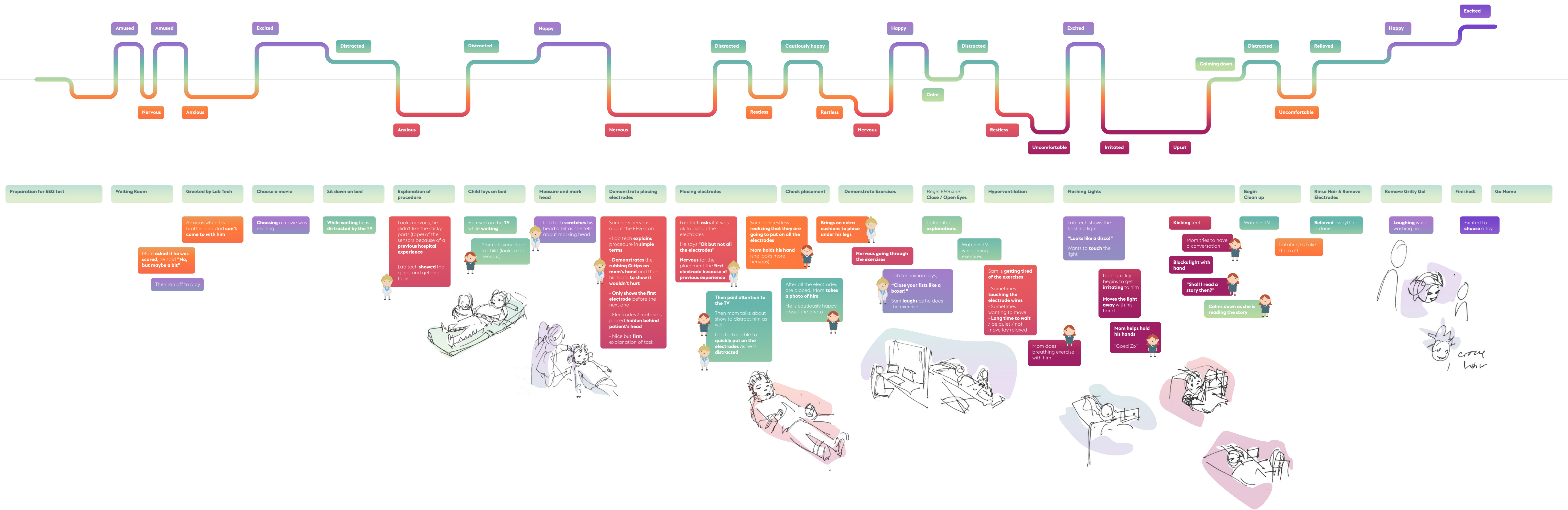


Figure 2.8: Example of one of the patient journeys

From the interviews and observations, four patient journey maps were created detailing the experiences that the child-patient had during the EEG, an example of one of them can be seen in Figure 2.8. All the patient journey maps can be found in Appendix D and names have been changed for anonymity. In addition to the emotions that the patient had and what was happening at that point of the process, sketches that were made during the observation were also included. This helped in identifying the patient's emotions, who was around the patient at the time, and the interactions between the patient, parents, and lab technicians.

After developing the patient journeys, they were compared to see which parts of the process were similar between the different patients, especially regarding boredom, anxiety, and curiosity.

Analysis of User Research

The results of the patient journeys and context mapping booklet were compared to find similarities between the patients.

Moments of Boredom? - Distraction!

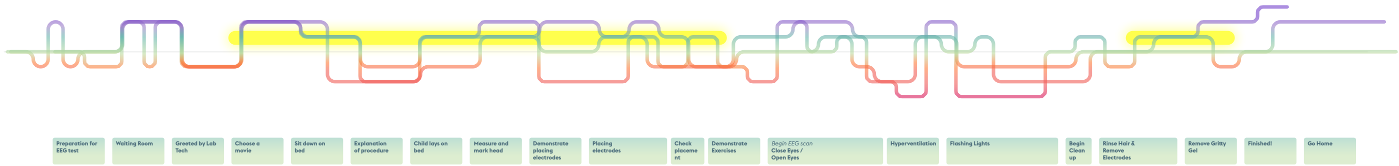


Figure 2.9: Comparing patient journeys for moments of distraction

Boredom

Moments of boredom were not really found during the EEG test, because the first thing the children did was choose a TV show or movie to watch.

So they were always watching the TV while they were waiting for their parents or the EEG lab technician to prepare something. Instead moments of boredom are found to be moments of distraction.

Distraction

If the patient was waiting at any moment there was immediate distraction from boredom. Figure 2.9. identifies these moments and Figure 2.10 shows a sketch of one of those moments of distraction. But if the patient became more anxious, then they were not able to be distracted by the TV and the parent or lab technician comforted them, see Figure 2.11.

There was also distraction from physical uncomfortableness (e.g. the Q-tip rubbing). Sometimes the child patients were distracted from the Q-tip rubbing but over time it got more uncomfortable and they became restless. If they were too uncomfortable or restless then they also needed comfort from their parents or lab technician.

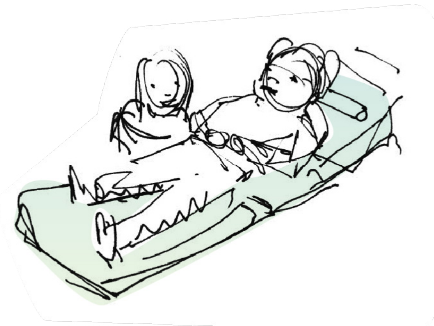


Figure 2.11: Sketch of child watching TV but mother also leans in to comfort him

Figure 2.10: Sketch of child paying attention to the TV during observation

Anxiety

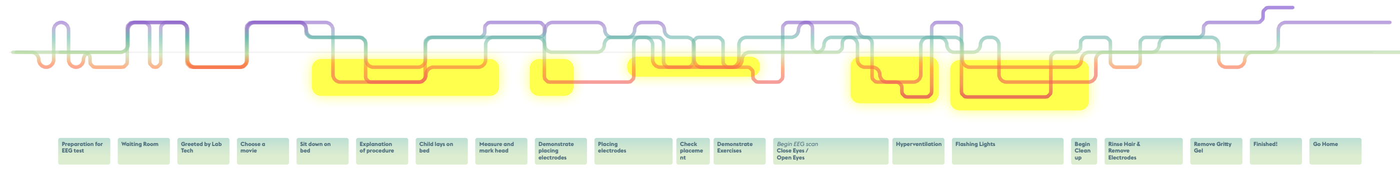


Figure 2.13: Patient journey comparision identifying moments of anxiety

Anxiety was either caused by a few different things in the child patients. First was the anticipation of an unpleasant task. Because the children are laying in a very open position in the center of the room, it could feel especially uncomfortable, see Figure 2.12. Second was from restlessness, from the long time of the task. The third was from physical uncomfortableness such as placing the electrodes, rubbing q-tips for a long time, or some of the exercises, such as the hyperventilation task or flashing lights. These moments are identified in Figure 2.13.

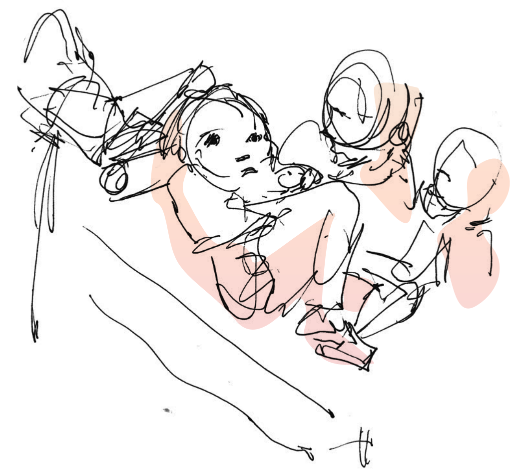


Figure 2.12. Sketch of child nervous during EEG

Curiosity

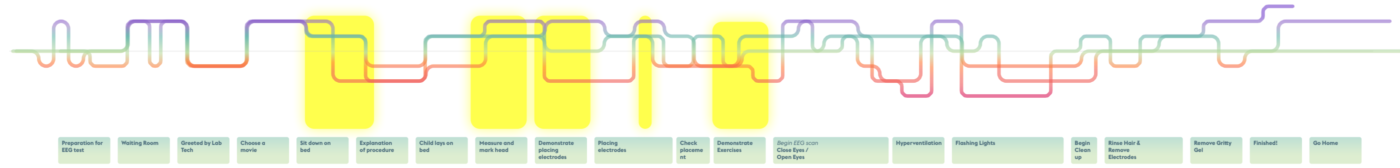


Figure 2.14: Patient journey comparision identifying moments of curiosity

Most of the children were not curious before the exam, more accepting of what was happening. Parents often would find videos to show the child or give an abstract explanation (e.g. "Video of your brain").

Most questions from curiosity occurred during the exam, as each step was taking place, see Figure 2.14. Simple terms are used to describe the process.

Not all children were curious, possibly because of anxiety of being at the hospital. Some children would seem to get more nervous in anticipation, even after explanation of placing the electrodes, but would become relaxed after realizing it was not painful. They expect that it will hurt.

Sometimes if there were too many abstract terms it confused the child and made them more concerned as they didn't know what was going on.

Insights Regarding Interactions with Parents & Lab Techs

These are further insights are regarding the parents and the lab technicians during the EEG experience.

Parents

Parent emotions often affect the child so if they seem nervous, the lab technician also has to manage their emotions as well. Usually they ask questions about epilepsy or the exam (seemingly just making conversation) to the lab technician as they wait.

Some parents are more direct and some parents are more protective about their explanations, but almost all of the explanations were to do with the procedure. Explanation of what the EEG does is limited to "a video of your brain."

Parents get physically closer to the child or hold their hand if the child is nervous, see Figure 2.15a & 2.15b. Children apperciate this, as seen in the results of the context mapping booklet, the child chose to have a couch for his dad to sit on Figure 2.16.

Actions to comfort child:

- Hold hands
- Hold down hands or legs - if the child is too restless
- Sing a song
- Read a book
- Ask questions - sometimes about the TV (another distraction
- Verbally comforting
- Helping the child do the test (such as the flashing lights, using their hand or standing behind the light so the child looks at the light)

Figure 2.15a: Sketch from the observations of a parent leaning closer to their nervous child.

Figure 2.15b: Sketch of parent holding child's hand during EEG observation

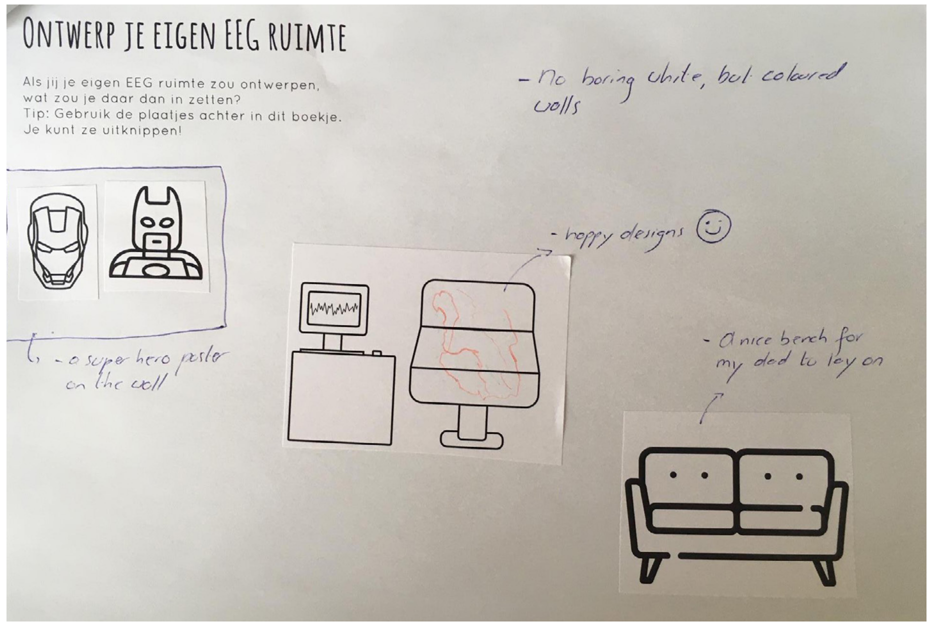


Figure 2.16: Child chooses to have a place for dad to sit in the EEG room.

Figure 2.17: Sketch from observations where a lab technician sings a lullaby to the child as she places the electrodes.

Lab Technician

Lab technicians try to be as prepared as possible with all tools ready for the exam to create minimal waiting for the child.

The electrodes and equipment are all behind the patients head/ pillow on the bed for easy access and working quickly. The table that is next to them was mostly used for storage, not really during the exam. The back of the lab tech's gloves were sometimes used to put the gel on.

Clear, simple, understandable explanations of what is happening is given to the child. There is more of a teacher and child dynamic with straightforward explanations of tasks.

"It will not hurt and we have to do X and X steps."

Explanations are done simply and step by step as the process is occurring.

Demonstrations are used to help the child understand what is happening and to comfort them. For example, rubbing the Q-tip on their own, the parents, and/ or the child's hand to show that it is not painful.

Lab technicians have a "Toolbox" of things to help comfort the child or help with exercises. For example, pillows are brought in if the child is restless or a pinwheel fan helps with the hyperventilation exercise.

Their bedside manner was sweet, kind, and humorous (when appropriate) with the children and parents. Sometimes tickling, making a joke, drawing a smiley face on the hand, or singing a lullaby, see Figure 2.17.

"If you talk too much I'll put an electrode on your chin!"

"Try to be quiet and calm . . . Higher tones help calm the child"

They take their time when needed, such as with explanations, getting extra pillows, or arranging the camera equipment.

"Take your time, don't rush"

They ask permission when possible at the beginning of each step. Sometimes this was not possible due to the cognitive development of the child.

"Can we put on the electrodes?"

Some parents are nervous and ask a lot of questions, its important to keep them calm as this affects the child as well.

Contradictory to the literature research, the lab technicians were very flexible in their treatment with the children - especially those with special needs. They did their best to care for the patients as best as possible, but sometiems patients still get very distressed and the tasks still has to be done.

Main Insights & Analysis of Interactions

The main user insights and interactions are summarized and mapped.

Boredom/Distraction

- Was not seen due to the movie that is playing
- Any moment of boredom is usually distraction

Anxiety

- Most found right before a task: waiting and anticipation of something unpleasant
- If children are too anxious, then a lab technician or parent does something to help them feel better

Curiosity

- Most questions were asked by children during each step of the EEG process
- Sometimes children are confused by abstract explanations which causes anxiety

Moments of Interaction

After going through the different patient journeys and compiling the insights, a map of the interactions between the patient regarding the emotions of boredom, anxiety, and curiosity was created based on the insights previously described. The map of these interactions can be seen in Figure 2.18.

Moments of waiting immediately become distraction for the child because there is a movie playing. If a child becomes restless or is anxious about the procedure, then the lab technician or parent does something to help alleviate the stress.

The moments of waiting are also when children have time to ask a question, usually about what is happening currently. If the explanation is clear, this helps the child be more comfortable, but if they are confused they can become more anxious. Different steps are taken to reduce anxiety and restlessness for the child but sometimes the procedure just has to be done anyways.

Moments of Interaction

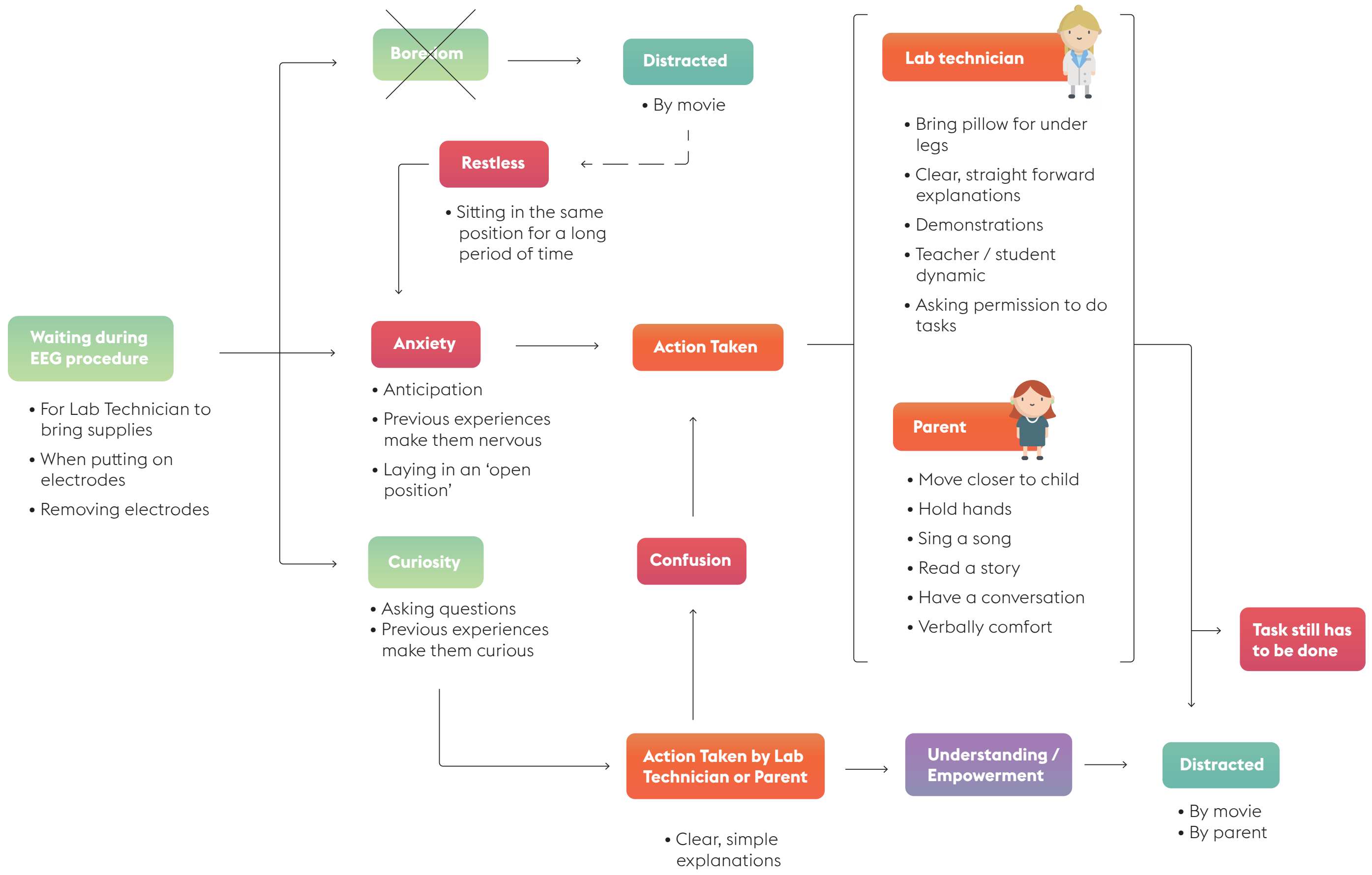


Figure 2.18: The interactions mapped between the child-patient, parents, and lab technician.

Initial List of Requirements

An initial List of Requirements is created to help focus the ideation process by defining the needs of the users, spacial requirements, and procedural requirements. These are based on the insights learned from the literature research, observations, context mapping booklet, and the patient journeys developed.

Concept Requirements

Requirements that the designed concept should fulfill.

The design needs...

1. To be **colorful** and **novel** to the child
2. To be **inviting** to use by the child
3. To help the child-patient **understand** and **learn about the EEG on their own terms**
4. To not **overstimulate** the child to affect the EEG results
5. To create a **safe space** for the child
6. To aid the lab technician in making sure the child is able to **focus on the necessary task**
7. To facilitate the child **sitting comfortably** for **~1 hour**
8. To consider how the **parent** is able to **comfort their child** if they get too anxious
9. To facilitate **choices** when possible to the child
10. To facilitate **clear, simple, understandable explanations** for the child
11. To facilitate **opportunities** for the child to **ask questions**
12. To be age appropriate for children **6-12**

Spacial Requirements

The needs of the space for the child, parent, and lab technician.

The design needs...

1. To consider space for the **parent to be close to their child**
2. To help children feel **comfortable** and **safe**
3. To provide space for the **lab technician** to have **easy access** to their **supplies & tools** (e.g. the electrodes, gel, q-tips, etc.)

Procedural Requirements

The needs of the space for the child, parent, and lab technician.

The design needs...

1. To not get in the way of the lab technician trying to do their tasks
2. To be **relaxing** as even small signals or muscle tension can affect the EEG
3. To be able to be **easily cleaned**
4. To be **adjustable** to tailor to the child's needs and preferences

Design Vision

From the insights complied a design vision is created and opportunity areas highlighted

To enhance **moments of curiosity during** the EEG test to improve the patient experience and **understanding** in a **playful way**

Opportunity & Impact

Because moments of anxiety are when the child is very distressed, a lab technician or parent are needed to comfort a child. Before reaching this anxiety or avoiding this anxiety altogether is a better opportunity area for a design intervention.

The main areas of impact or opportunity are highlighted in Figure 2.19 and in the patient journey Figure 2.20. They correspond to the previous areas identified in the analysis where there are periods of waiting for the child, in between getting supplies or while the lab technician is putting on the electrodes. Usually the child is distracted by the television at this time, but this is a time they could also be exploring and understanding the EEG better.

Areas of Impact

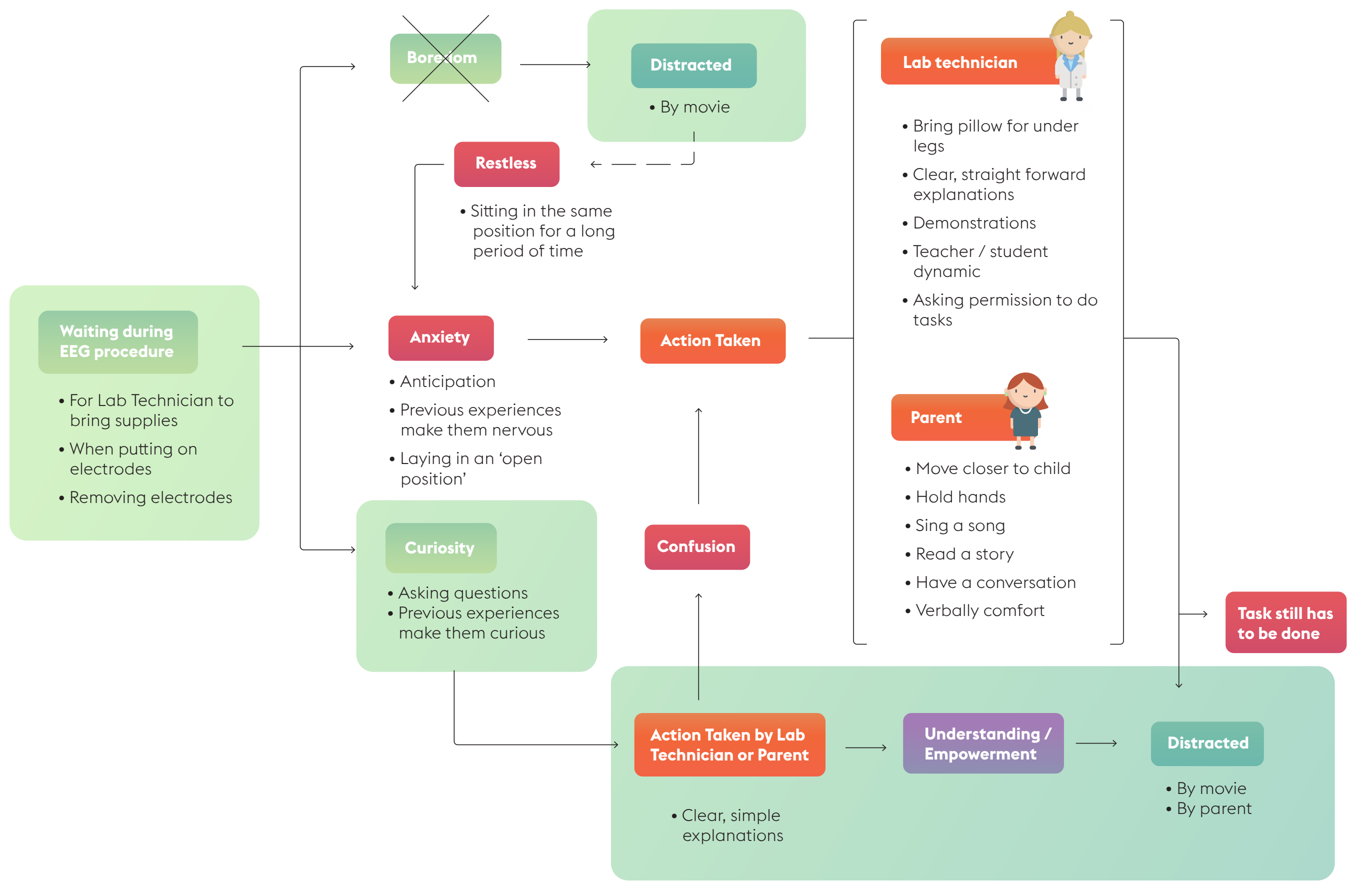


Figure 2.19: Areas of impact and where the design solution can fit

Opportunity Areas

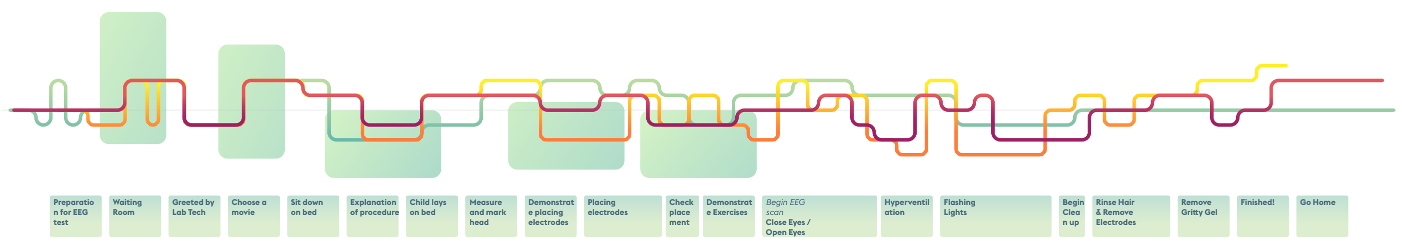
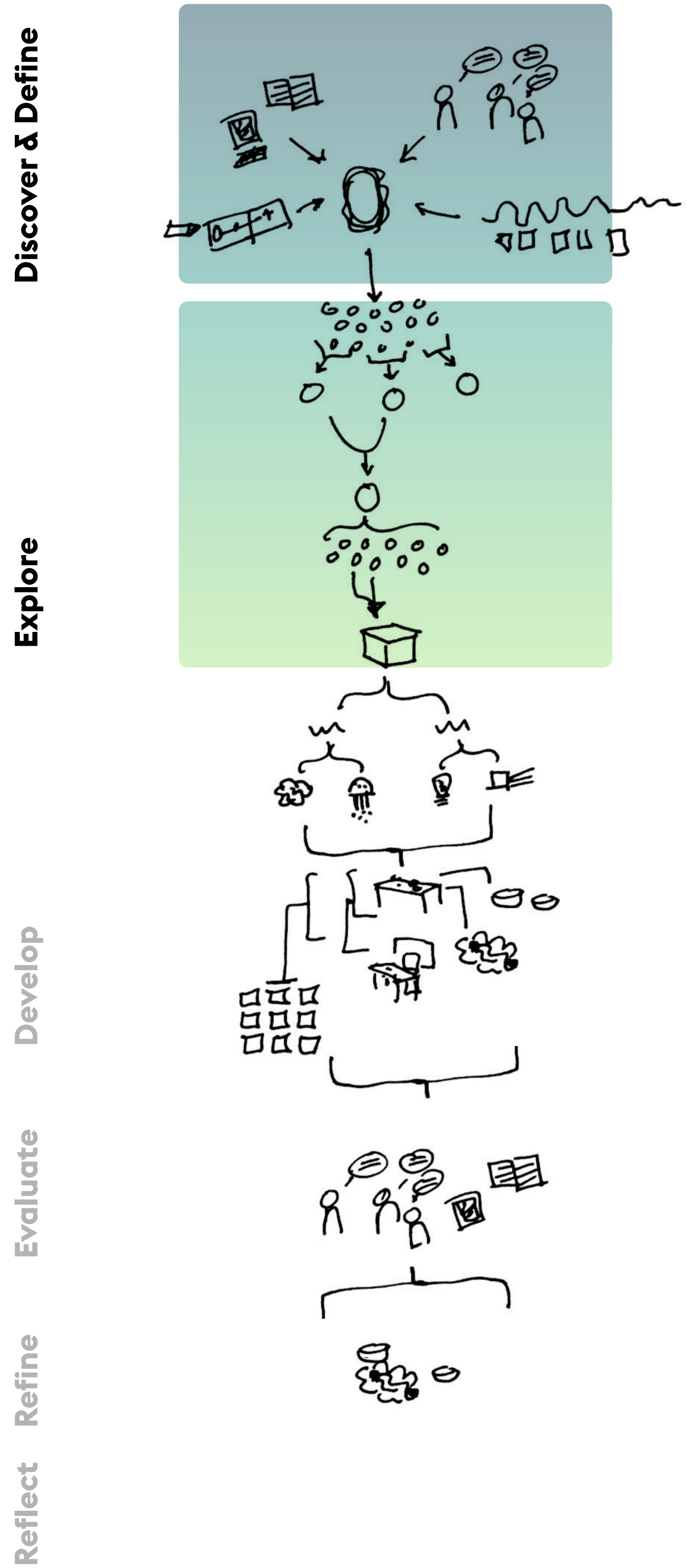


Figure 2.20: Opportunity areas of time identified in the comparision patient journeys

Explore

Ideation Clusters
Impact vs Feasiblity
Feedback
Conclusion on Ideation

Initial ideation was done during the research process and developed further through the insights found and the List of Requirements that was developed. The ideas were clustered and further ideated on. The ideas were compared on their feasibility and impact in the EEG space. To evaluate the design directions, the ideas were shown to a patient and parent, to neurologists, and to lab technicians at different points of the ideation process for feedback. The feedback is compiled at the end of the ideation section.



Ideation

Based on the ideation, the sketches were clustered into three groups: Preparation, Spacial, and Interactivity. While sketching for the Spacial space, there was also a focus on Seating.

Preparation

For preparation, ideas focused on ways to introduce the EEG to the child before coming to the exam, to help them understand the procedure of the EEG and that it won't be painful ahead of time. This is to reduce the 'wandering' in thoughts and while waiting which can increase anxiety for the child.

Questions and topics for discussion are introduced to the child and parent to help open a dialogue about what is happening, because children sometimes have difficulty speaking in a medical setting. There are different storylines of a main character describing their emotions, such as they feel excited, nervous, or scared about certain different activities to help with the dialogue.

The preparation could be through a physical storybook that the children get, with interactive parts such as pop ups or attaching electrodes with velcro, Figure 3.1. Another way is through a digital medium, such as a phone, that could have a different storylines depending on what the child chooses, Figure 3.2.

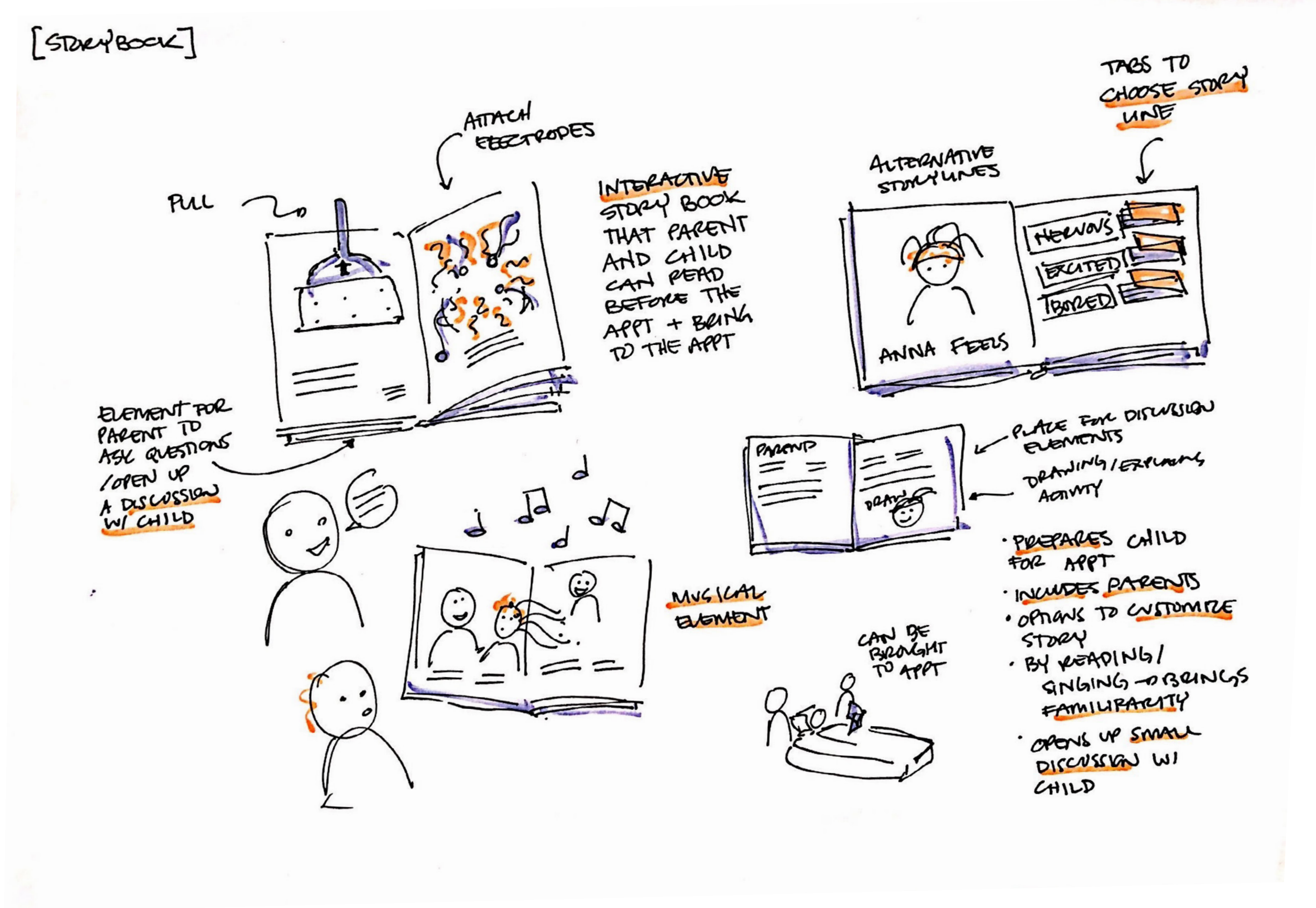


Figure 3.1: Storybook concept

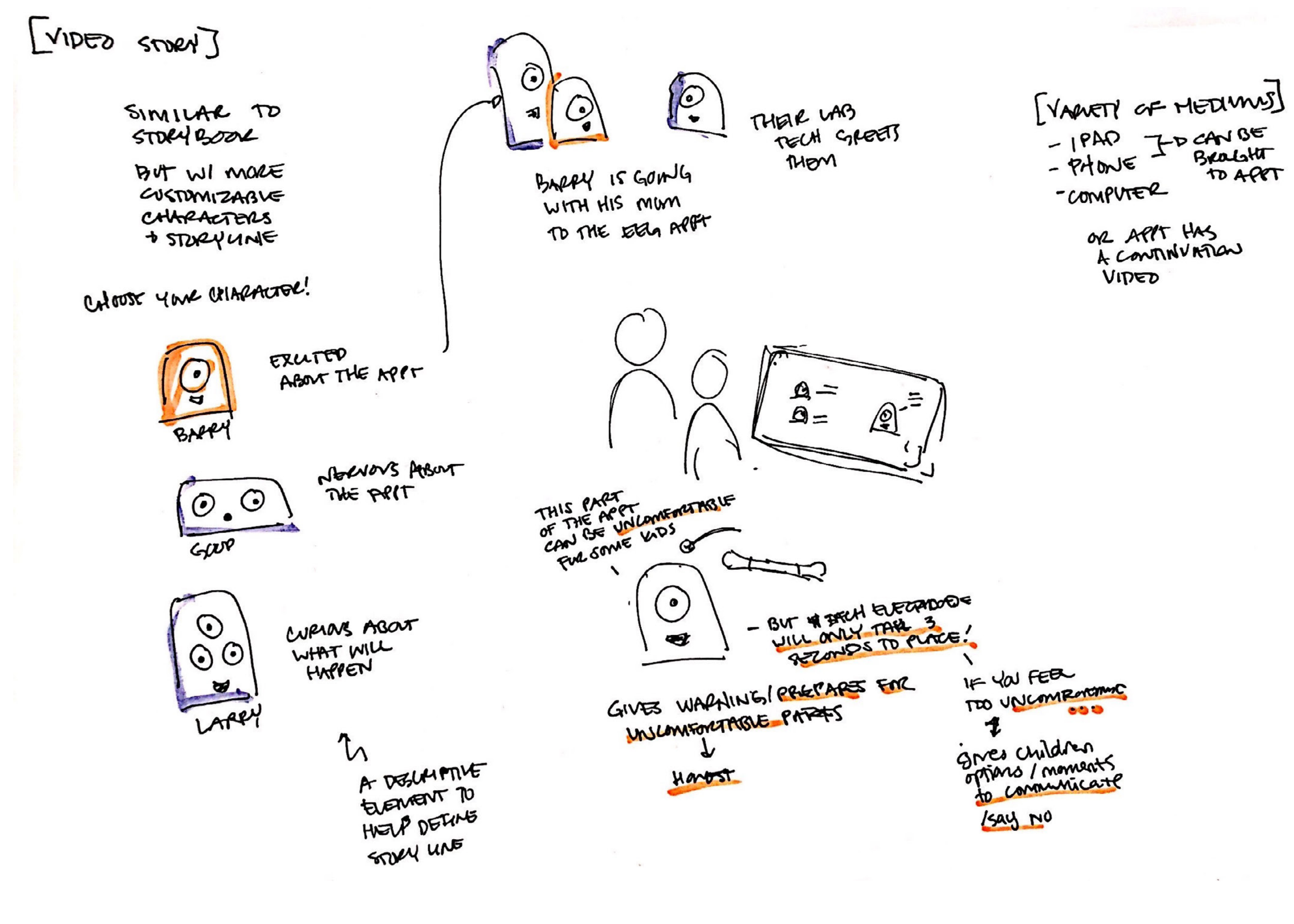


Figure 3.2: Interactive video concept

Spacial

For the space, ideation was done based on the different needs the different stakeholders had for the space.

There is storage for the lab technicians to put the EEG supplies and tools behind the child, as most of the supplies were behind the patient's pillow when they are putting on the electrodes, see Figure 3.3. Other places for storage, such as pillows and the other tools from the 'toolbox' that lab technicians have, are placed around the space.

Because children really like making choices, there could also be options to choose the cover of the sheets before the exam as well, Figure 3.4.

An enclosed space could make the child feel more safe and hide equipment that are scary for children, see Figure 3.5. By having the space be separate from the lab technician, they can feel less watched and more relaxed for the EEG . To make the space fun, there are projected lights that the child can choose from as well.

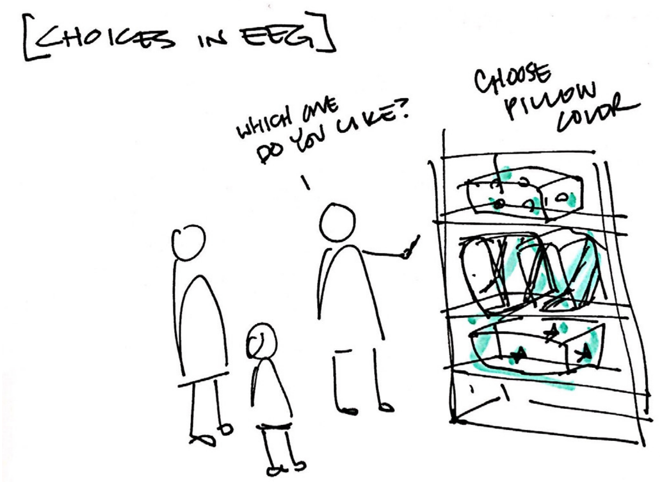


Figure 3.4: Giving choices such as choosing the cover.

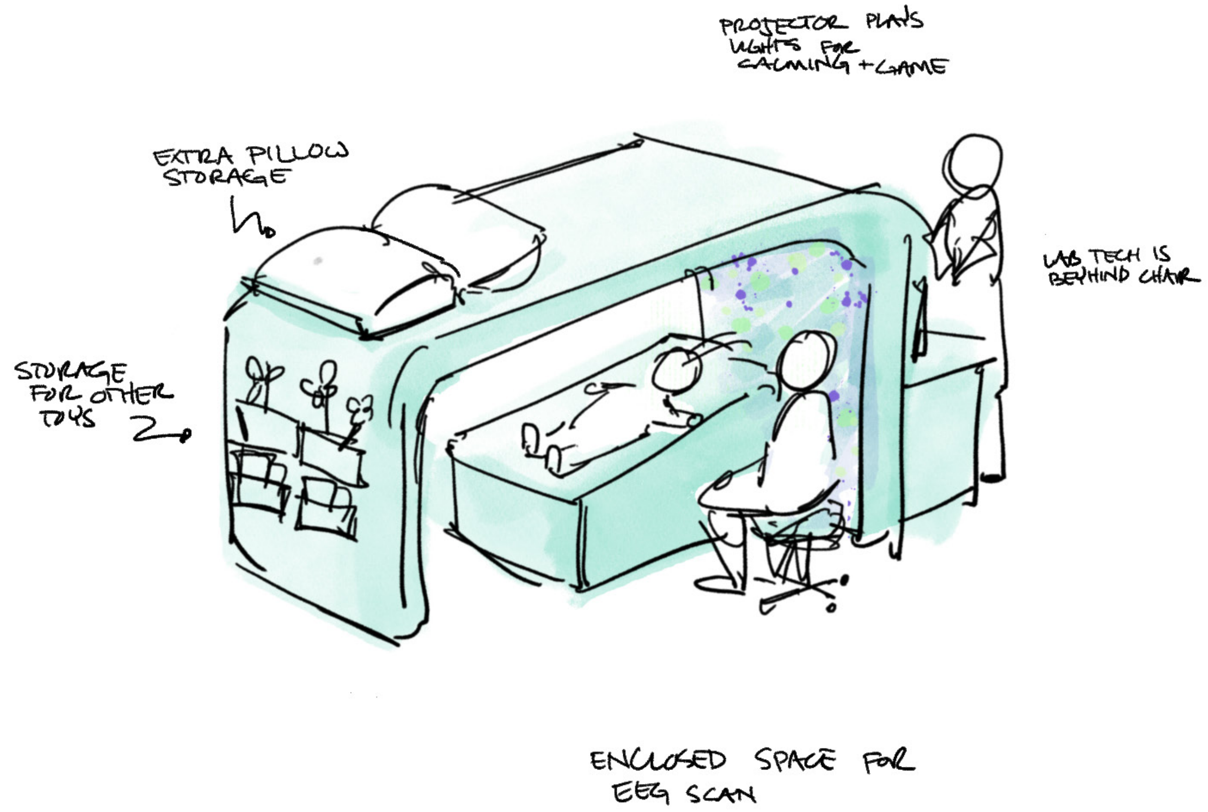


Figure 3.5: Having an enclosed space and storage for supplies

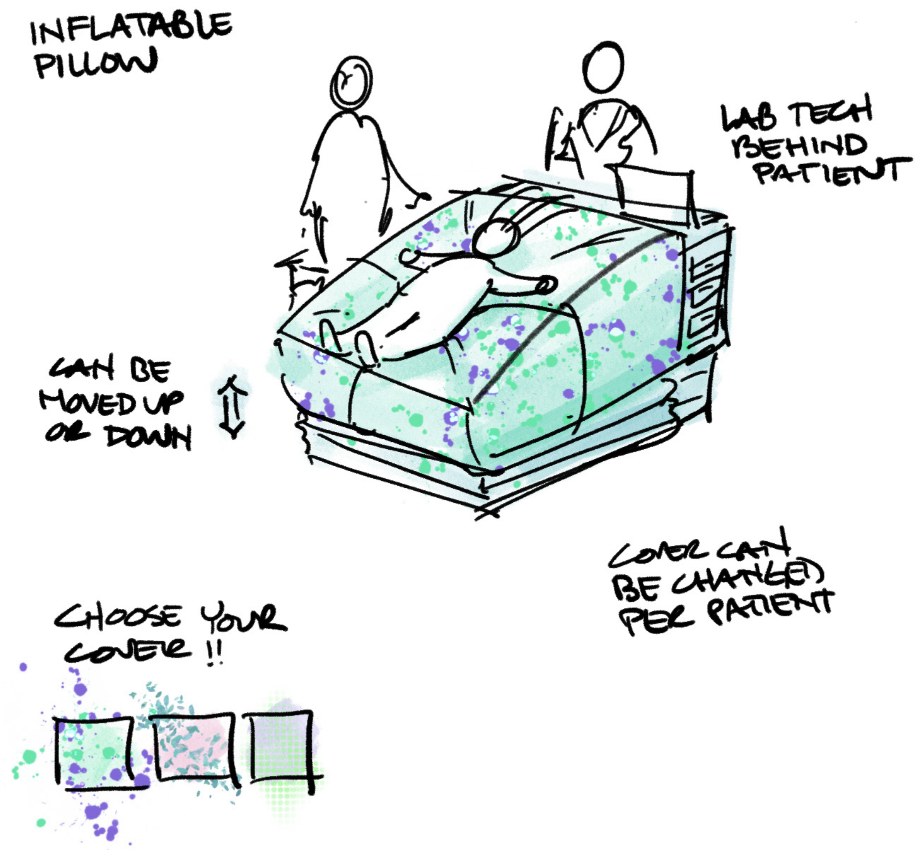


Figure 3.3: Having lab technician supplies behind the patient

Seating

From the spacial ideation, a focus was on the seating, because it seemed particularly uncomfortable for children regarding positioning and they always seemed a bit restless.

Seating was explored from the lying position, how the EEG is done traditionally, and from a sitting position, needed for the eyetracking. The ideation focused on making the seating more fun and exciting for the child so they would like to sit in the chair. The seating would create more comfort for the child and reduce the ominous feeling that is created when sitting in the center of an examination room. This is done by making the space more playful and fun.

Brain sketching was done without limitations, such as having a nest for the chair or a hammock. More realistic ideas were explored as well, such as adjusting traditional hospital beds to make them more fun and comfortable. The overall sketches can be seen in Figure 3.6 and 3.7.

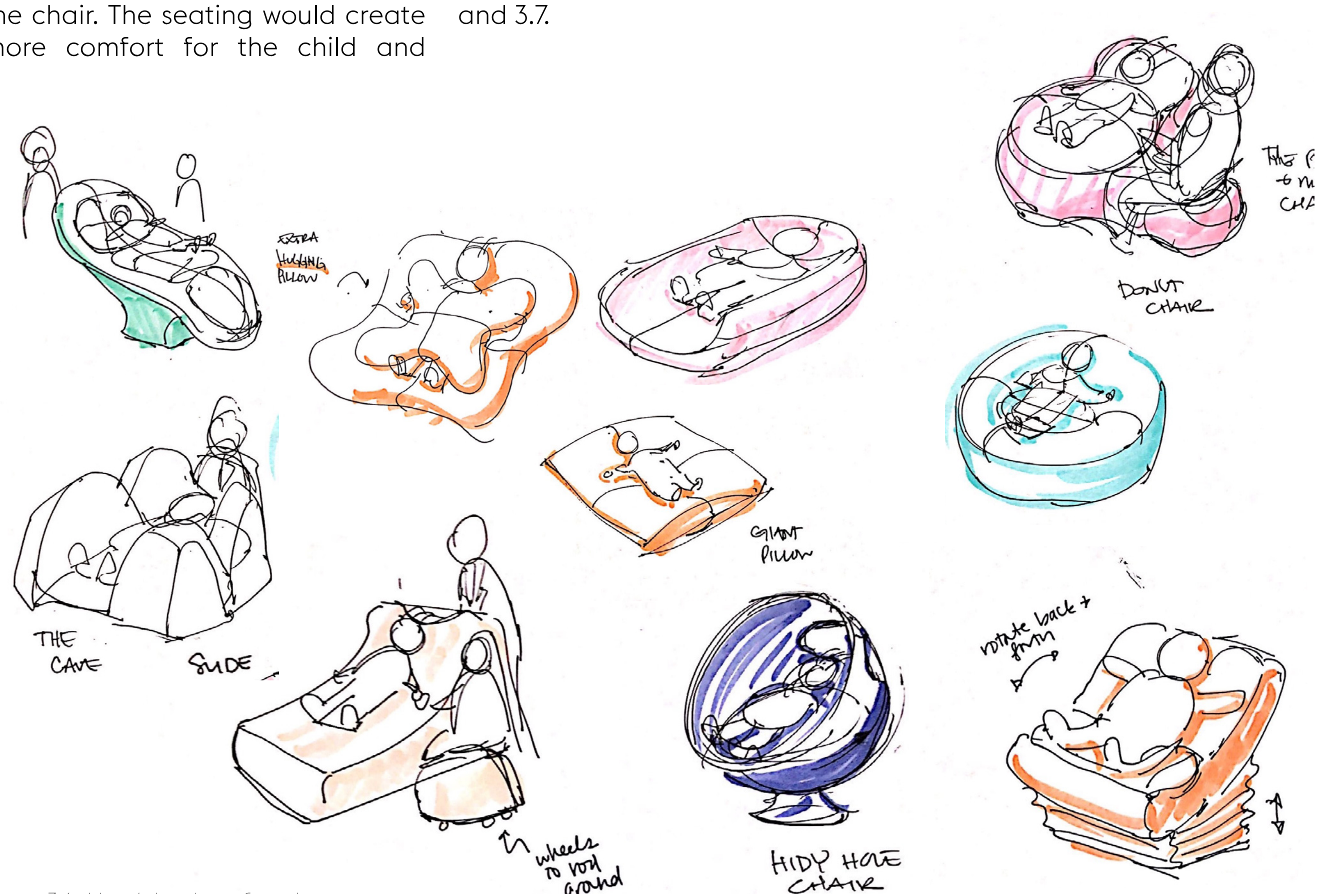


Figure 3.6: Hand sketches of seating

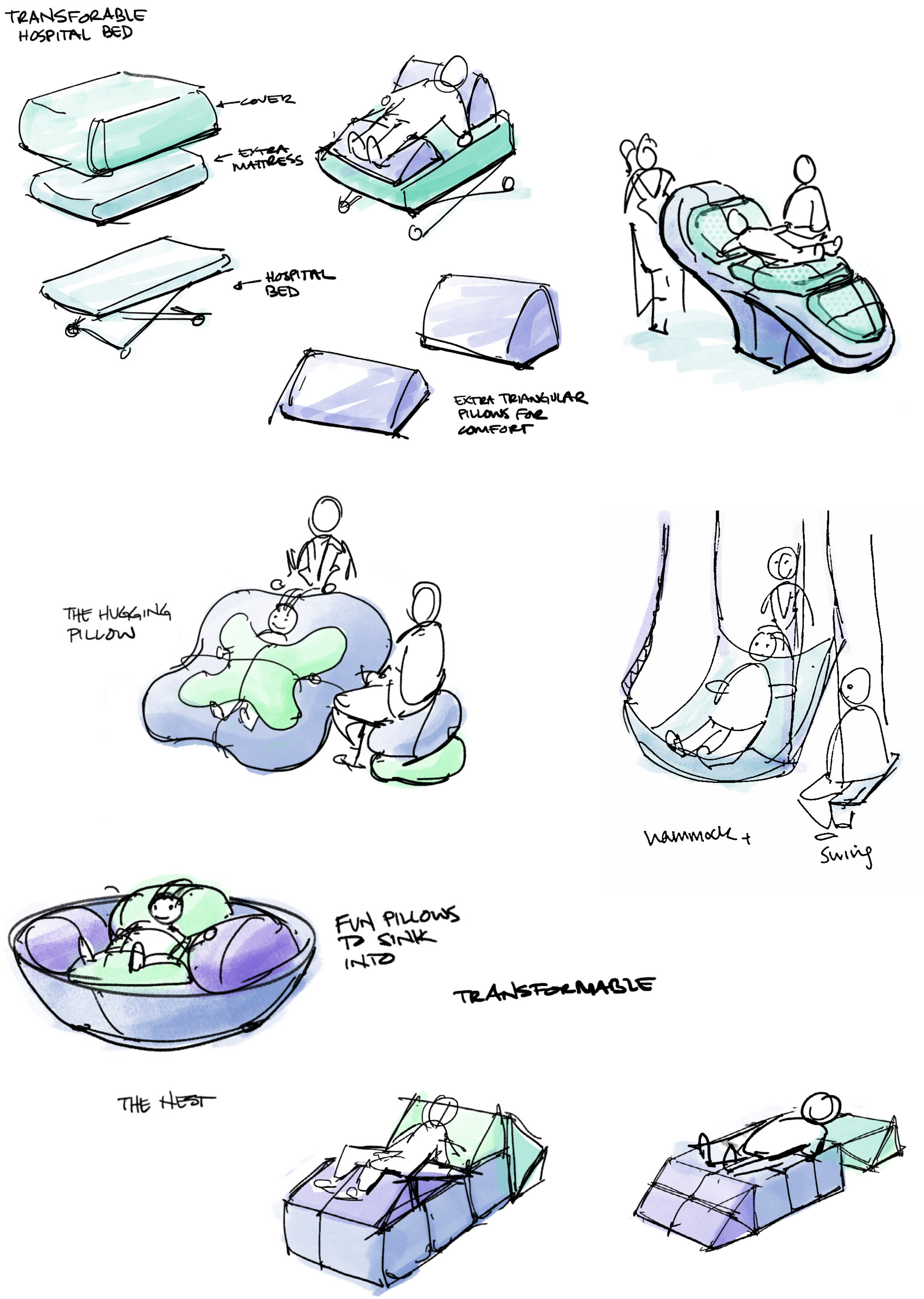


Figure 3.7: Procreate sketches of seating

Interactivity

Interactivity was explored in two ways: focusing more on explaining the procedural side and then also thinkinking about how to explain how the EEG works.

For the procedure, ideas were explored such as having a doll that the child could play with to see how the procedure steps go, Figure 3.9.

There could be an interactive wall, Figure 3.10, to show the different exercises the child would need to do, more tools such as a pinwheel to blow on or a blindfold for the open/close eyes exercise.

For explaining the EEG, there could also be an interactive wall in the waiting room that the child can attach electrodes to, Figure 3.11. The electrodes can be lit up when attached properly, showing the need for all the electrodes to be placed together.

Another concept focuses on explaining more of how the EEG works, Figure 3.12, that it is reading the brain signals and that some deeper brain signals are harder to read than the outer ones. This idea focuses on explaining the EEG, as it is a difficult and abstract concept for children - and even for parents - to understand. This game could be played while the lab technicians are placing the electrodes on the child.

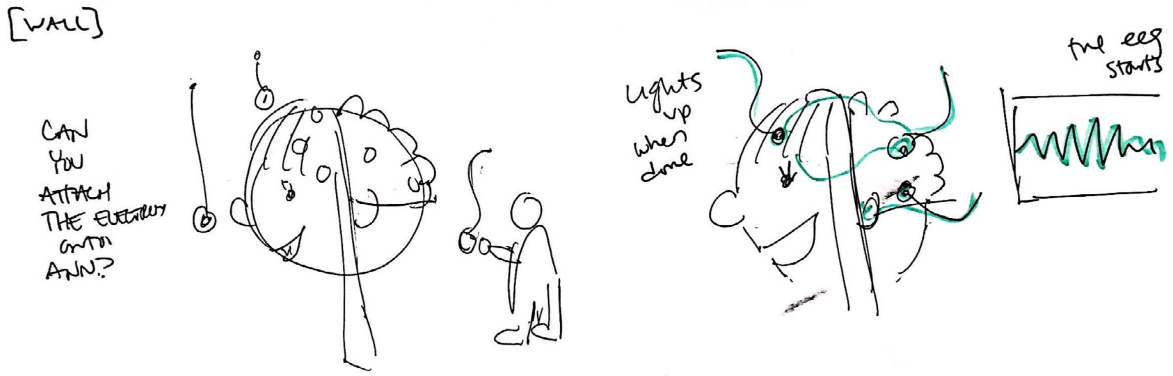


Figure 3.11: Interactive wall to learn about the EEG

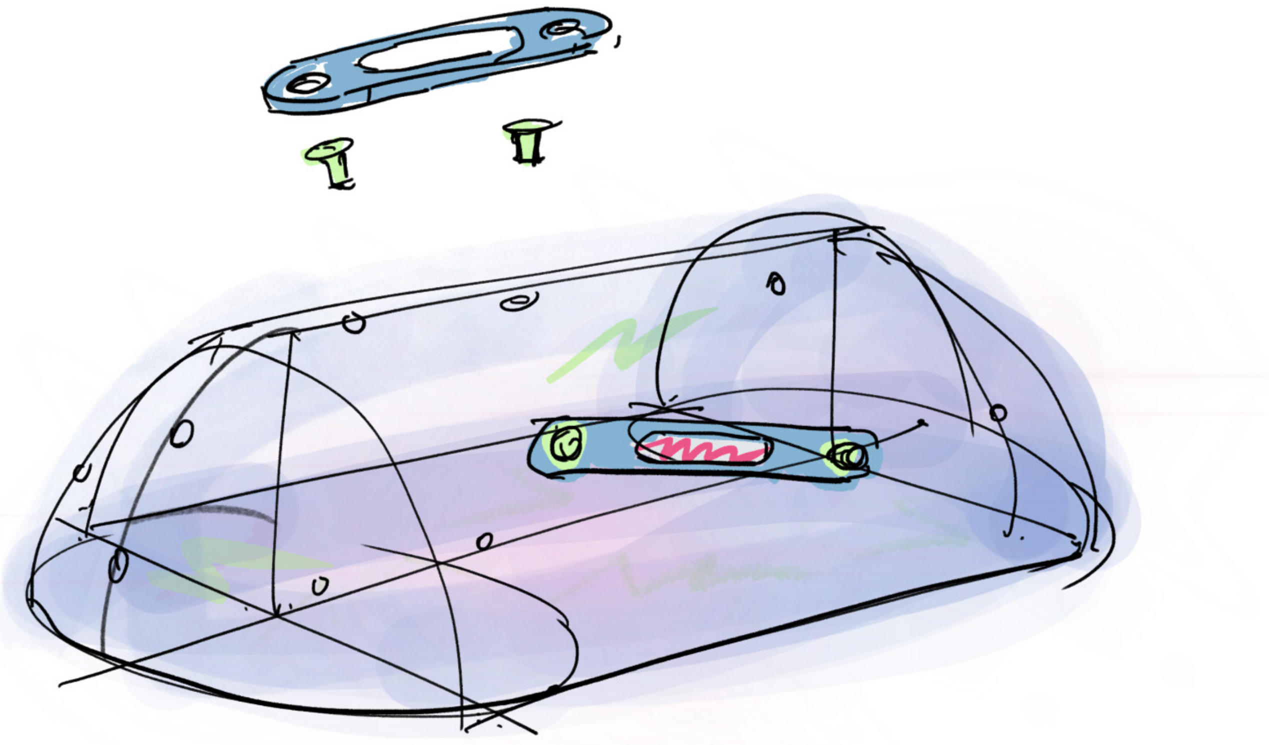


Figure 3.12: Interactive concept where children learn about how the EEG works

Figure 3.9: Using a doll to show the EEG procedure

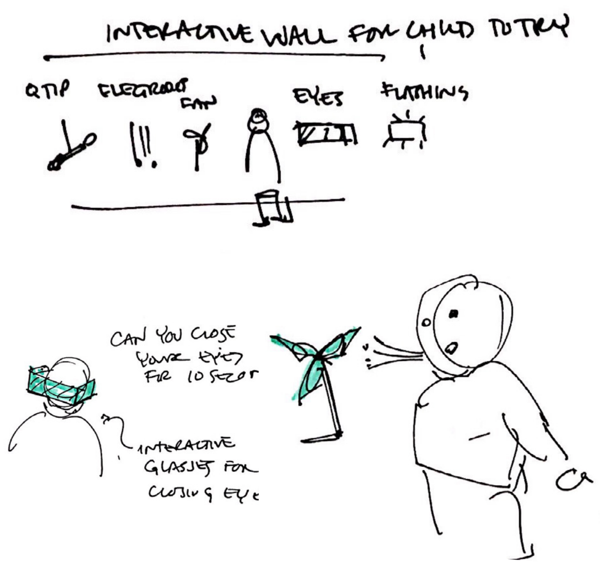


Figure 3.10: Interactive wall to show with the different exercises that have to be done during the EEG, such as hyperventaliation and eyes closed.

Impact vs Feasibility

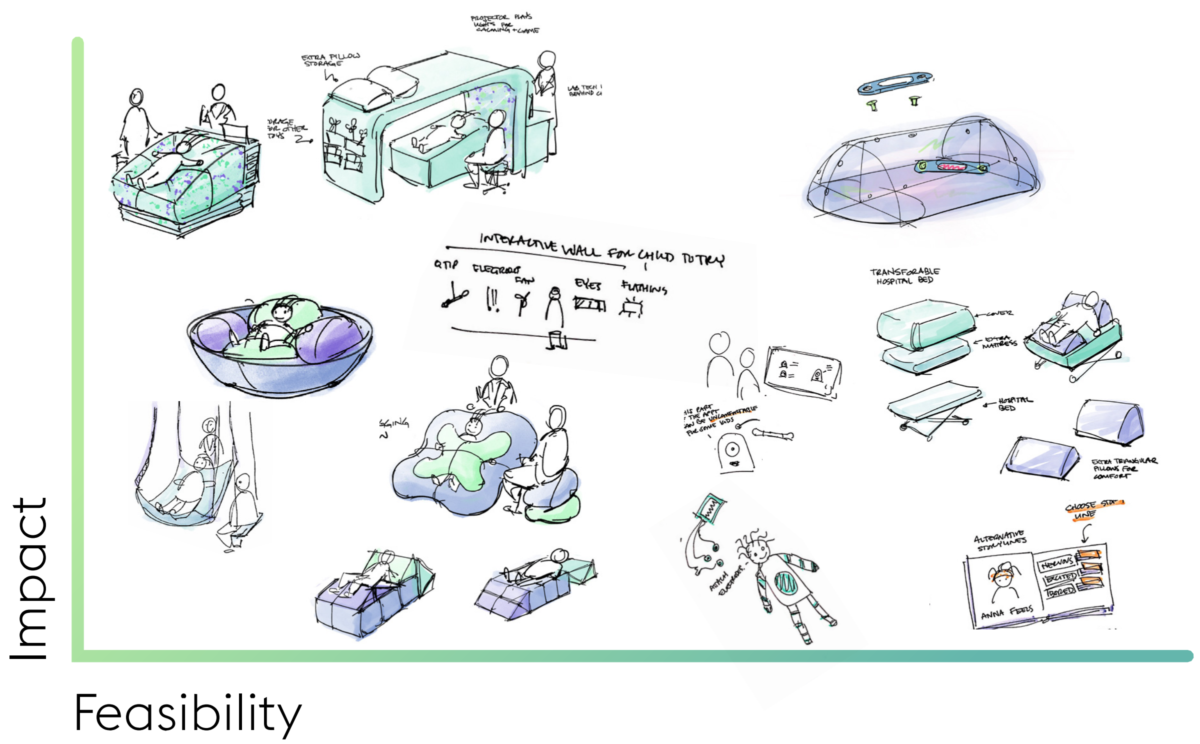


Figure 3.13: Impact vs feasiblity chart

To compare the ideas, an impact vs feasibility chart was created, Figure 3.13, to see which idea is most realistic and can have the highest impact for the children going to the CBL.

The preparation ideas were more feasible, but have less impact because there are already videos that parents can show their children to prepare them for the visit.

The seating ideas could have a higher impact, but it is difficult to design a hospital and also to design one chair for one particular hospital visit, that isn't due to a medical need, seems less feasible. There was also a difficulty at this point of the project, because it hadn't be decided what exercises the children would be doing, so what position that the children needed to be in was unknown.

Feedback on Ideation

Through the ideation process, ideas were presented to: a child-patient and parents who had also been observed at the EEG, a parent of a child who has had EEGs, to a neurologist, and a bigger presentation to some of the lab technicians and neurologists at the hospital for feedback. The feedback has been summarized here in this section, full texts of the feedback can be found in Appendix E.

The parent and child were sent a booklet of the sketches, Figure 3.14, with questions to fill in with their child and an interview afterwards, Figure 3.15. to further understand their feelings regarding the ideas, primarily focusing on the seating. The primary questions were whether the seating could be comfortable for the child for laying for long periods of time and if the design was playful.

There was an online presentation given to the healthcare providers (the lab technicians and neurologists) involved with the EEG regarding the overall ideation. The primary focus of this feedback session was on what difficulties they would anticipate with the designs and whether something would be in the way of their workflow. They were also shown the impact vs feasibility chart to see if they agree with the ranking of the ideas.

Preparation

Neurologist

"It is good to prepare the child for the EEG test, when they are prepared, they feel less nervous about the exam."

Spacial

Parent

"Some children may like having the space enclosed, **but my child prefers to be able to see what is going on because of his previous experiences at the hospital**."

Her child also dislikes closed spaces, because of the MRI which makes him feel claustrophobic. If there was a mirror it would be ideal, because the would be able to see what the lab technicians are doing.

She also said to make the space more cozy and home feeling.

"Because this is not a surgical procedure, I don't know why it has to feel like a hospital with all the white rooms."

"Because the chair in the EEG is also quite ominous, it is in the middle of the room, similar to the surgical room."

Lab technician

"Some children may not like having an enclosed space because it brings up bad feelings."

They would like it if the table had space for their equipment needed for the EEG, a shared space for the EEG and child.

They also liked the lights and projections and thought this would be a good place to give choice to the child.

Neurologist

"The Brain Lab is supposed to be fun."

Seating

Parent

"This seating is an improvement from the standard hospital bed that is for adults (often too big, no confinement so the child feels less secure / safe)."

"It is important for that parents can still easily reach the child for when it needs to be comforted."

Neurologist

The seating may change depending on what exercise the child is doing, such as the eye tracking where the child would be in a seated position.

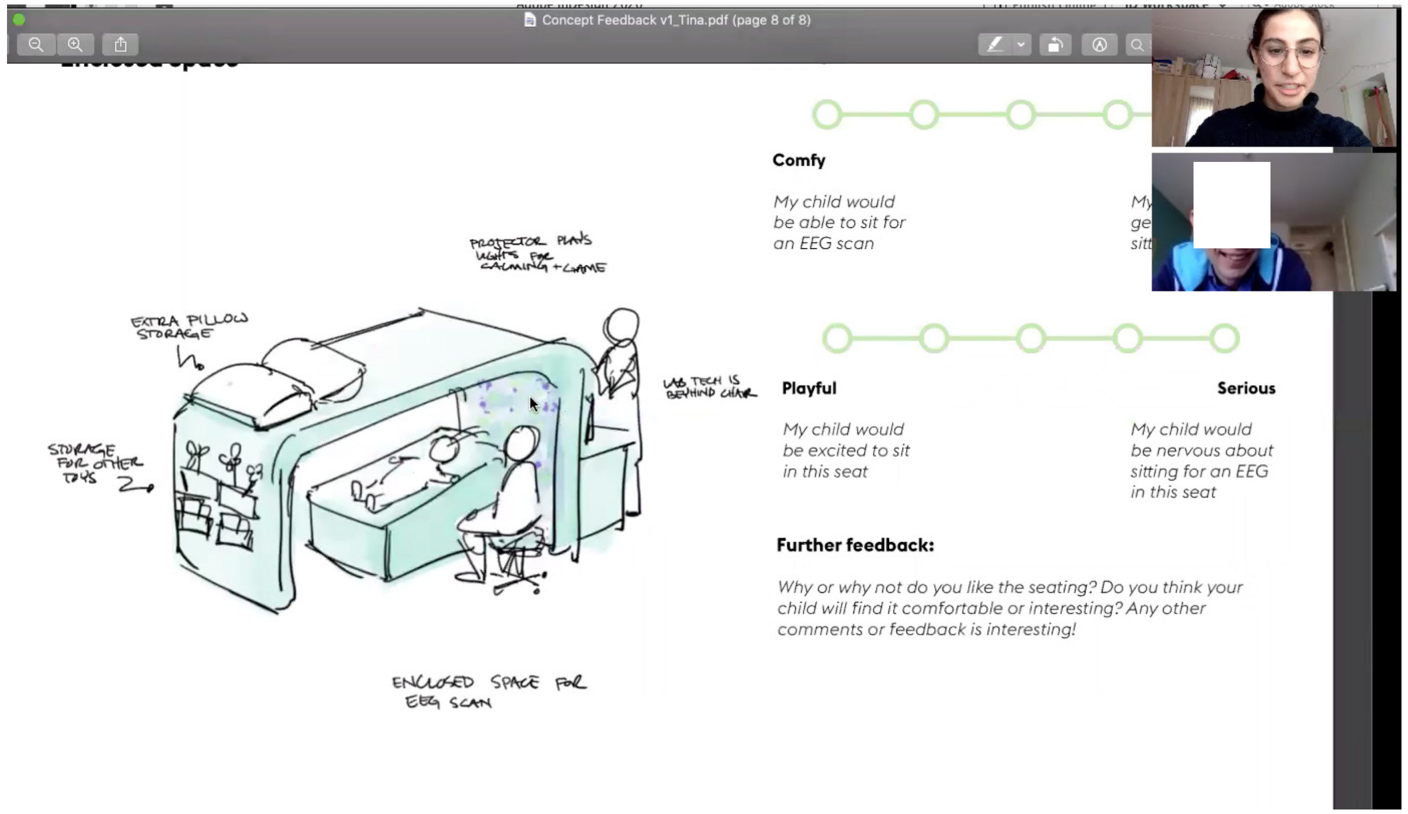


Figure 3.15: Talking to parent about booklet

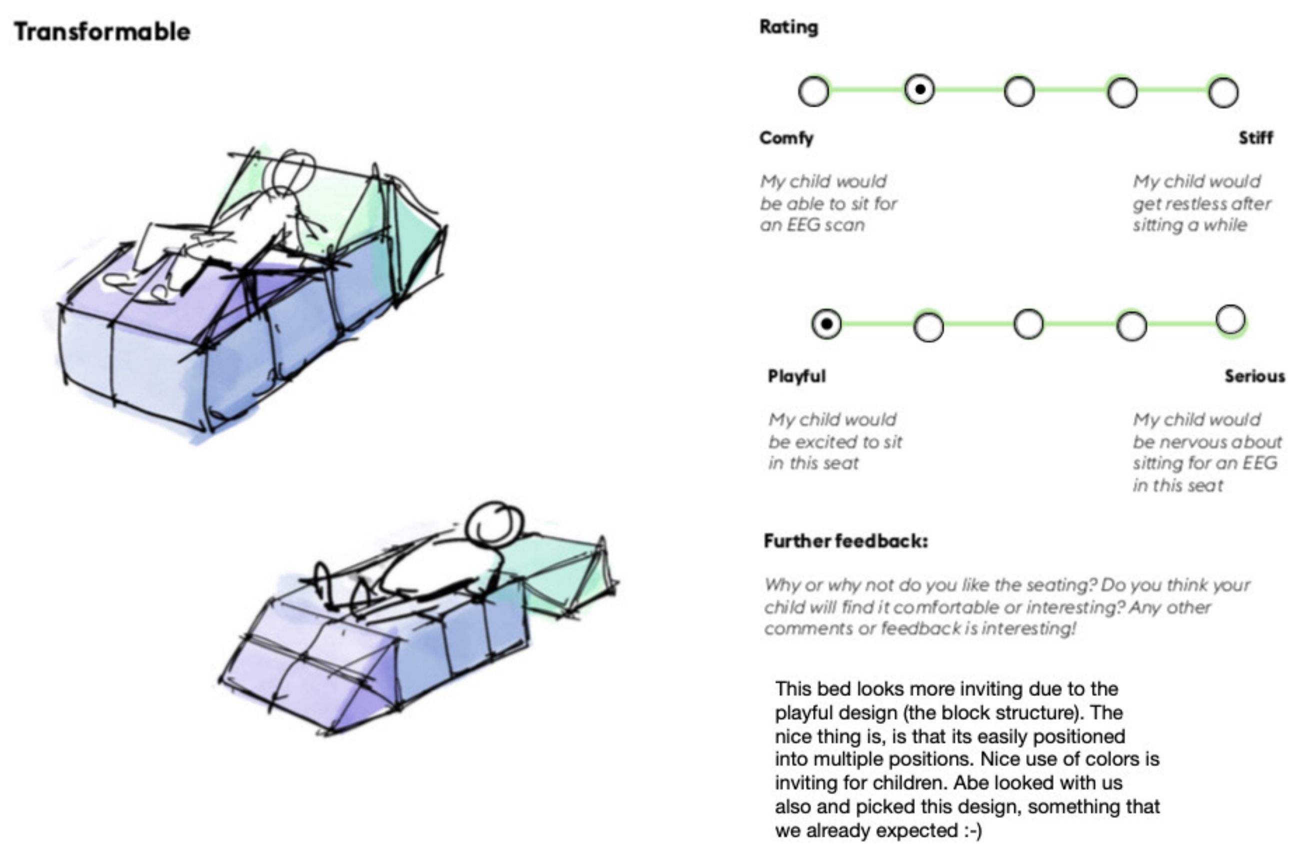


Figure 3.14: Pages of the ideation booklet filled in

Conclusions on Ideation

Preparation

Although there are nice themes to this part of the EEG, this part of the market is already a bit saturated. There are already many videos of the procedure of the EEG that can be found when googled.

Most of the questions occurred during the exam, it seems that it would be better to find a way to invite questions during the exam.

Also because there are other CBL projects, and one is tackling the overall experience and focusing on preparation, overlapping and creating excessive material could overwhelm the child.

Spacial & Seating

Some of the parts of the space, the healthcare providers and parent/child liked, such as having choice included and having space for the 'toolbox'. The enclosed space had mixed feedback, having an enclosed space could have the opposite feeling of safety from children and make them feel claustrophobic, especially ones who have previous experiences at the hospital and with MRI's. Because the experience of the EEG is not painful, actually showing the tools and that it won't hurt is better than hiding the equipment.

The seating is particularly challenging because of the variability in what the exercises will be and what position the child will be for them. Because children have different preferences, there should be a lot of transformability in regards to the seating. There is a high cost and many challenges regarding regulations in the hospital to create a chair. This caused the direction to seem less feasible.

Designing the entire EEG space is difficult and because some of the important factors were not decided yet by the hospital, such as about which equipment and procedure would be done. However the hospital still would like recommendations because of the extensive research being done. Therefore, it is more ideal to make recommendations of a vision about what will be in the space rather than a detailed and concrete plan.

Interactivity

The interactive game, Catch the Brain Signal, Figure 3.16, has the most opportunity because there are limited explanations of the EEG given currently, most of the explanations are regarding the procedure.

Also one comment that stood out was that, "The Brain Lab is supposed to be fun." The CBL is different from a regular EEG as it is a place for research and children and parents are volunteering to aid in the research to create more knowledge regarding the brain. Making the space interactive and look like a fun place to be rather than a hospital room is emphasized.

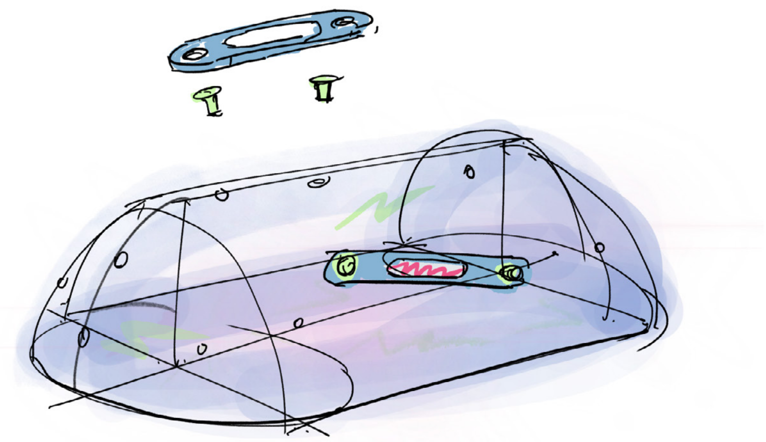


Figure 3.16: Interactive concept

Develop

After deciding the concept direction, several areas were identified where the concept needs to be developed. Each area had further exploration and the conclusion of these decisions are found at the end of the chapter.

Concept Direction
Recaping concept direction & identifying next steps

List of Requirements
Updating the LoR based on the concept direction

Usage & Timing
When and where will the concept be used?

Evaluating the design with experts
Get feedback on the concept's usage and timing to make sure it still fits in the CBL

Technology
How will the design work and how will users interact with it?

Further learnings about the brain
What information and concepts are interesting to convey to children?

Exploring the space
What will the space look like and how does the concept fit into the space?

Game Development
How does the game work?

Exploring the Visualization of the Virtual Elements
How to show the information in a way that will be understandable to children?

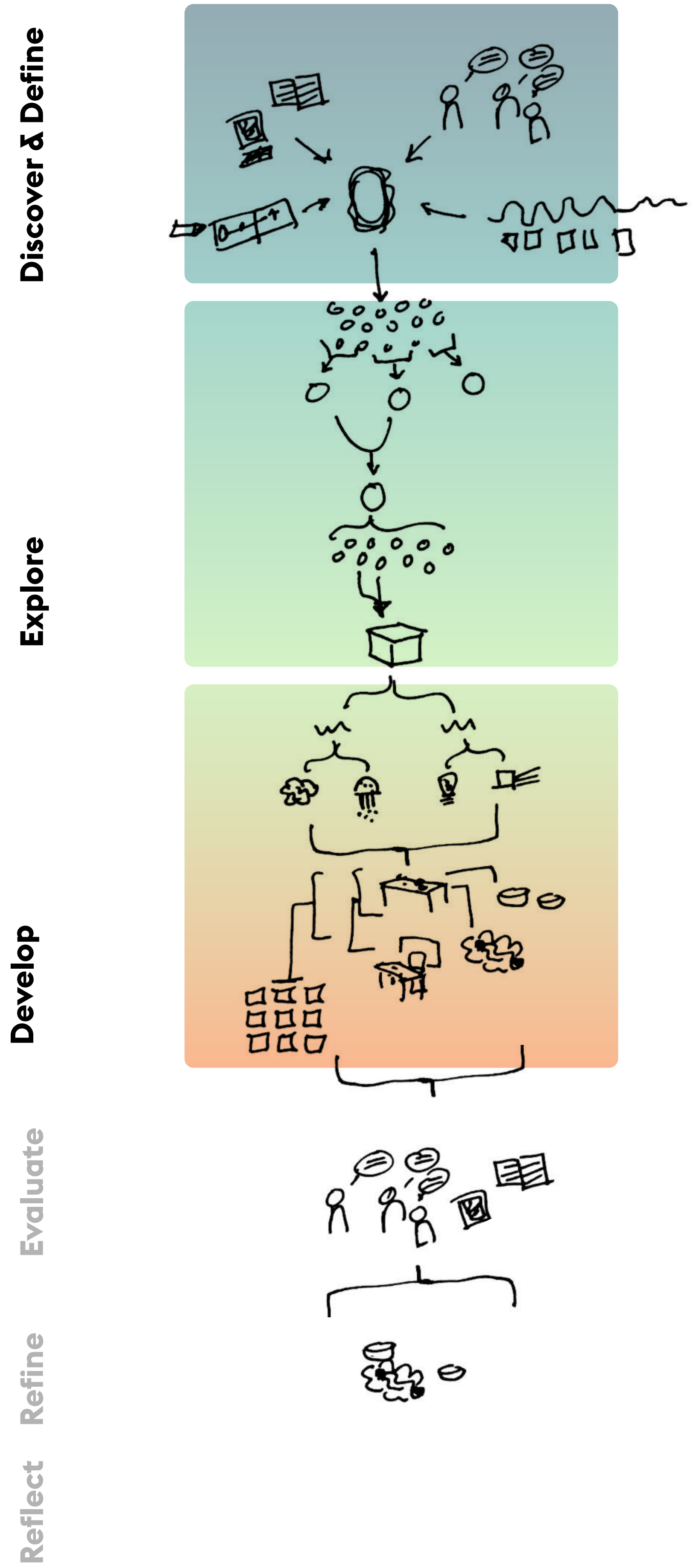
Prototyping Visuals
Creating an interactive prototype that users can test

Game Piece Ideation
What are the physical pieces that users will interact with?

Physical Piece Exploration
Exploring the physical interactive pieces

Prototyping Pieces
Prototyping how the physical pieces look

Testing Physical Pieces with Projected Images
How do all the parts come together?



Concept Direction

Concept Direction

The concept direction chosen is the Catch the Brain Signal, see Figure 4.0. The concept focuses on showing how the EEG works, as this is a part that is being currently explained to children in a limited way, and allowing children to explore on their own what the EEG does.

This concept simulates how the electrical signals are picked up by the EEG and turned into brain waves, some electrical signals are more difficult to read than others because of how deep they are in the brain. It also shows how two electrodes need to be placed to see a brain wave, because EEG electrode readings are all relative.

Goals of the game

- Showing what the EEG does
- Being explorative in nature
- Open up area for children to feel comfortable asking questions
- Being calming
- Not causing anxiety for children about the EEG
- Distract from boredom
- Being age appropriate for the different children visiting the lab
- Not getting in the way of the lab technician

Main Challenges

- Creating a game that is understandable and interesting while also not distracting from the testing task (casual play)
- To not interrupt the lab technician while they do their tasks
- What technology will be used and make sure it won't affect EEG reading
- Balancing information in the game being too medically scientific vs too abstract

Characteristics

Keywords describing the games characterisitics were created to help decision making the development of the game.

- Curiosity / Exploration
- Safety / Cozy
- Control
- Playful
- Tactile

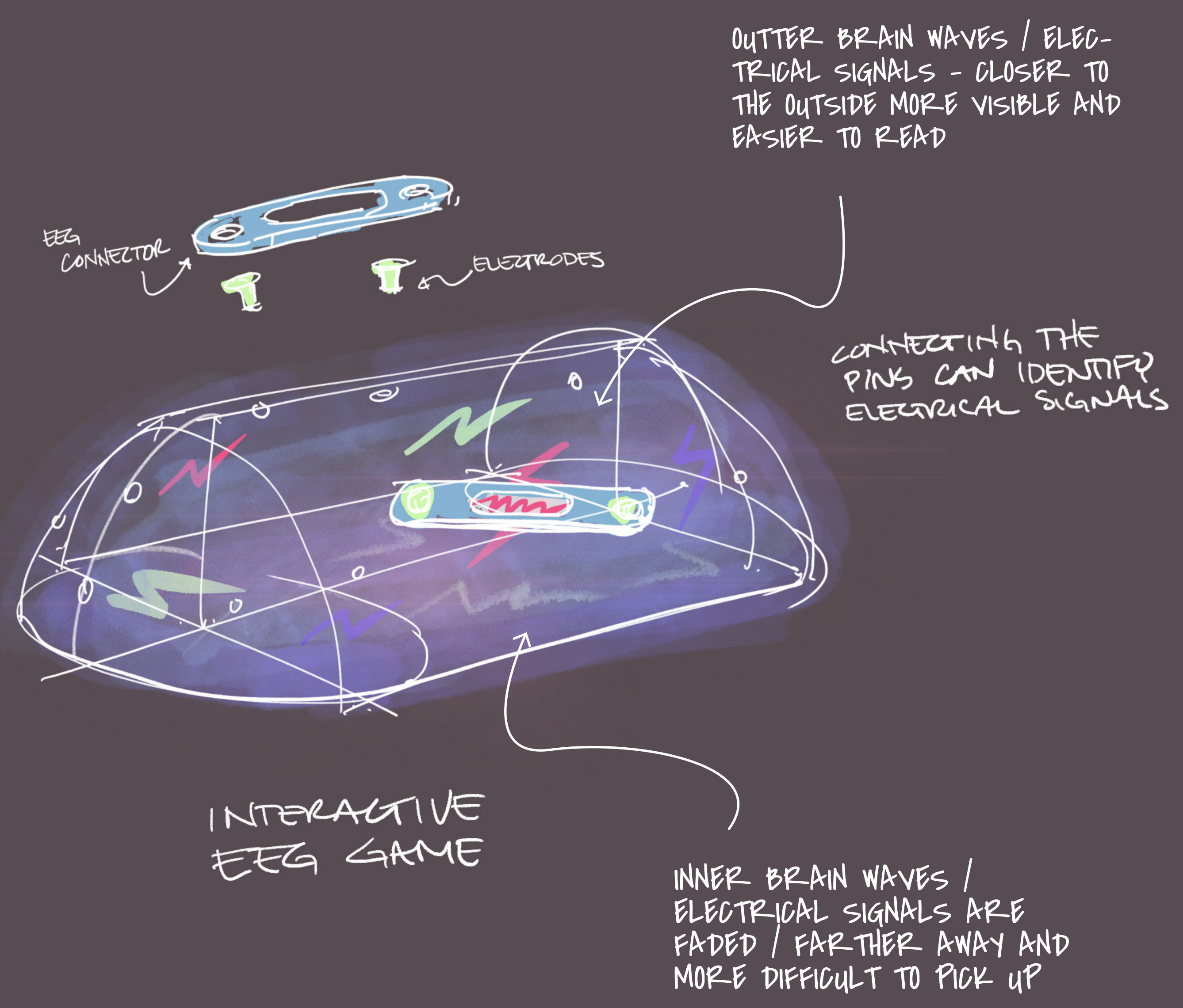


Figure 4.0: Interactive EEG concept direction

List of Requirements

The List of Requirements is updated, focusing on the interactive concept direction, procedural requirements, technical requirements, and on design recommendations for the space. Also by looking back at the research analysis done, more design needs were identified for the final design direction.

Concept Requirements

Requirements that the interactive concept should fulfill.

The design needs...

1. To have **novel elements** for the child
2. To be **inviting** to use by the child
3. There should be **no right or wrong way to play**
4. The design should invite **exploration** & **wandering**
5. To help the child-patient **understand** and **learn about the EEG on their own terms**
6. To facilitate **clear**, **simple explanations** for the child
7. To facilitate explanations that are done **step by step** as the EEG procedure is occuring
8. To integrate a form of **anticipation** to create interest in learning about the EEG
9. To have **elements that build upon one another** to allow the child to **predict** what will happen
10. To help **facilitate opportunities for conversations** about the EEG with the child
11. To facilitate **opportunities** for the child to **ask questions**
12. To facilitate **choices** when possible to the child
13. To **not overstimulate** the child to affect the EEG results
14. To create **a feeling of safety** for the child
15. To give opportunity for **the parent to comfort their child** if they get too anxious
16. To aid the lab technician in making sure the child is able to **focus on the necessary task**
17. To facilitate the child sitting comfortably for about **15 minutes**
18. To be age appropriate for children **6-12**

Spacial Requirements

These are needs for the recommendations of the design space and considerations also for the Lab Technician.

The design needs...

1. To have **a comfortable place for the child to sit**
2. To create a feeling of **comfort and safety** for the child
3. To consider space for the **parent to be close to their child**
4. To allow **easy access to the tools that lab technician** needs
5. To be **adjustable** to tailor to the child's needs and preferences

Procedural Requirements

These requirements are for the procedure of the EEG and what needs to be done in order to have good results from the EEG test.

The design needs...

1. To be **relaxing** as even small signals or muscle tension can affect the EEG
2. To **not get in the way of the lab technician** trying to do their tasks
3. To be able to **stopped** and **started** easily

Technical Requirements

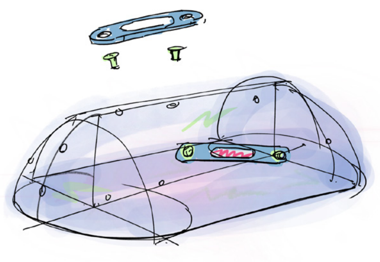
Technical requirements that are needed to make sure that the interactive device does not affect the EEG and works in the EEG space.

The design needs...

1. To not interfere with EEG by having **less than 50 Hz**
2. To **not overstimulate** the child and change the EEG results
3. To be **visible in bright ligh**t (that the lab technician needs to complete the procedure)
4. To be able to be **easily cleaned**
5. To be able to be **durable** enough to not be broken when dropped or thrown

Usage & Timing

Options of when the interactive concept will be used were explored. The interactive game could be played in the waiting room, in between the different steps of the CBL or while the electrodes are being placed on the child's head. The scale and timing of when the interactive game is being used was explored through sketching and low fidelity prototypes.



Layered

The Layered concept uses layers of clear plastic to indicate where the brain wave is in the brain. The ones closer to the surface are easier for the brain signal to be seen on the EEG. The electrodes connect to a screen to display the brain wave, like the electrodes that are connected to a screen show the electrodes.

When/where

This concept would be used while placing the EEG cap.

electrical signal / brain wave

electrode

inner electrical signal / brain wave

electrode cord

brain wave reading

Standing

The Standing concept is a device that is about child size that can be rolled around. The large interactive electrodes can be placed around the device.

When/where

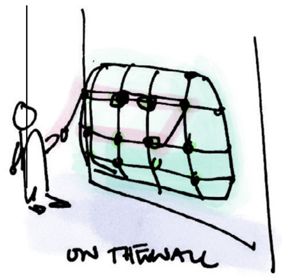
This could be done in the waiting room with other children or while the lab technician is doing a separate task.

brain wave reading

electrode cord

electrical signals

electrode

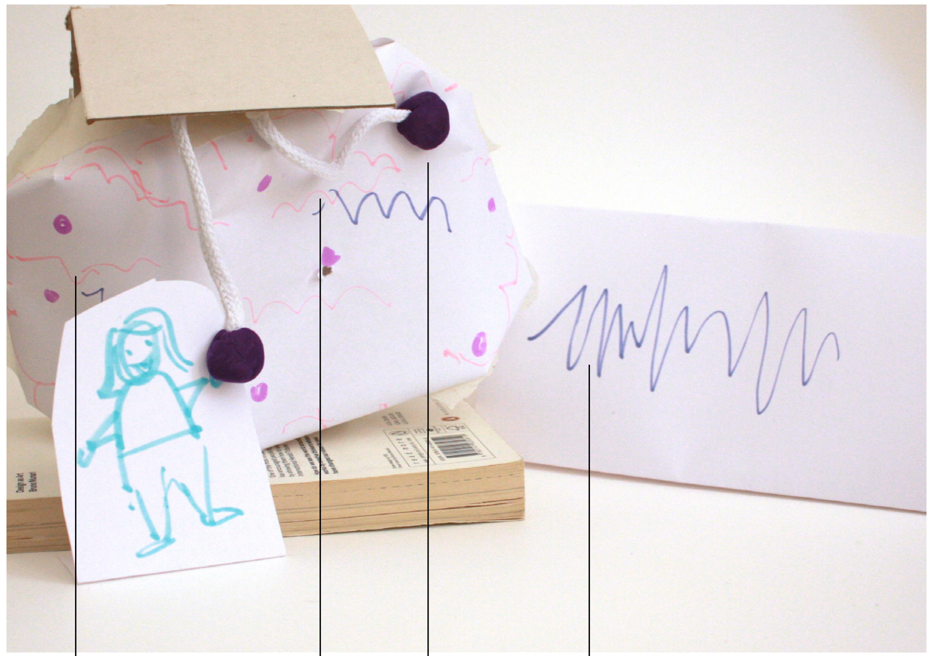


On the wall

A rope is wrapped around each electrode to connect them to catch the brain signal, see the sketch. Or the electrodes could be hanging from the ceiling and connect to the wall, see the prototype. When two electrodes are placed, a projection of the brain wave is shown on the wall.

When/where

The On the Wall concept is in the waiting and can be played with multiple children.

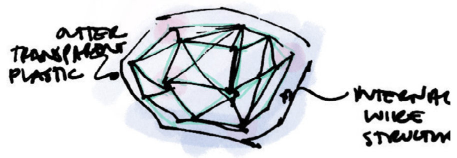


brain waves / electrical signal

electrode cord

electrode

brain wave reading

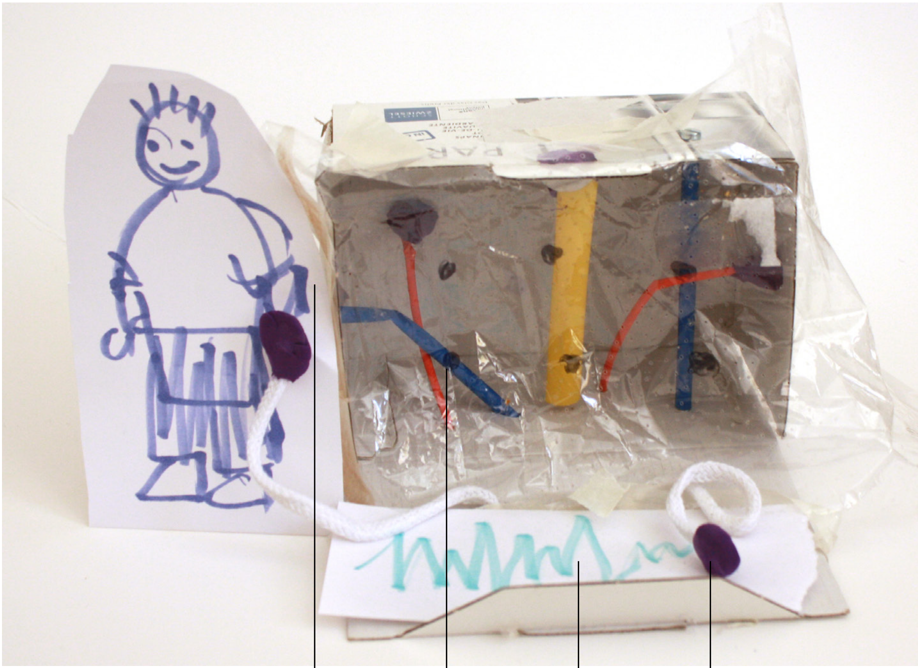


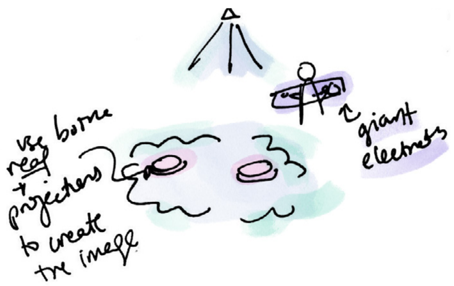
Lighted tubing

The Lighted tubing concept has transparents tubes that would send light waves through randomly to represent the brain signals. The electrodes can be attached to the outside of the device to read a brain signal and the brain waves are shown on the bottom.

When/where

In the waiting room or a smaller version in the CBL.



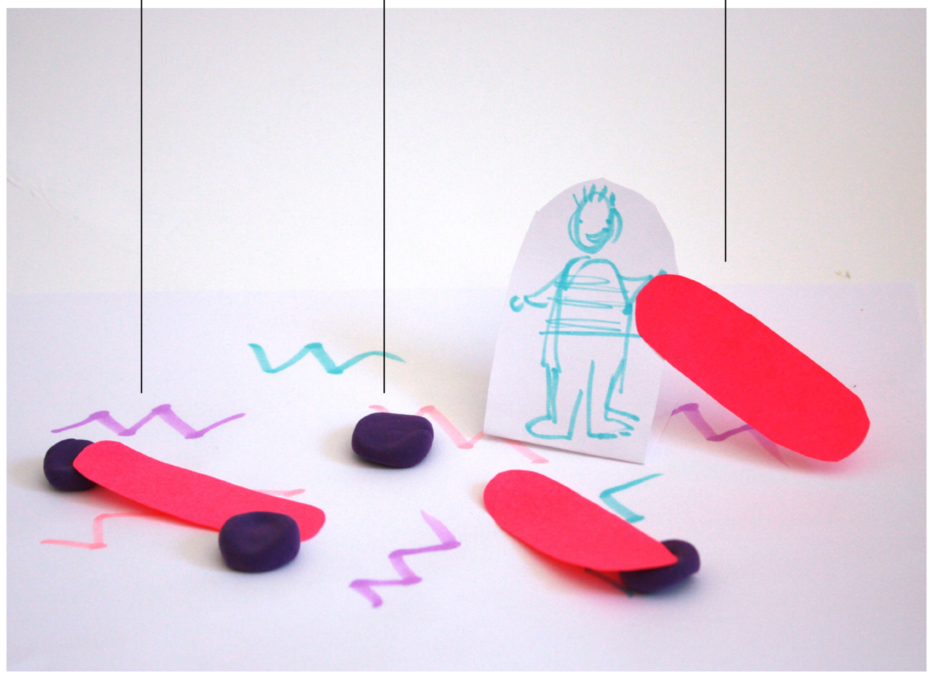


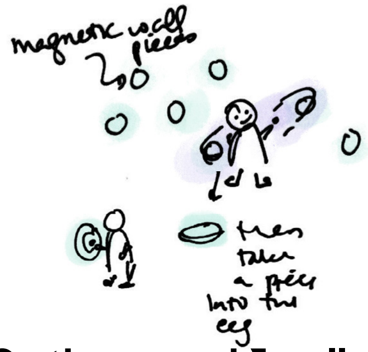
Projection

The projection concept makes use of large scale projections to show the brain and brain electrical signals. Large interactive blocks are used to represent electrodes and cords that connect the electrodes. The projection reacts to the children walking to create more brain waves.

When/where

The concept could be used by multiple children in the waiting room



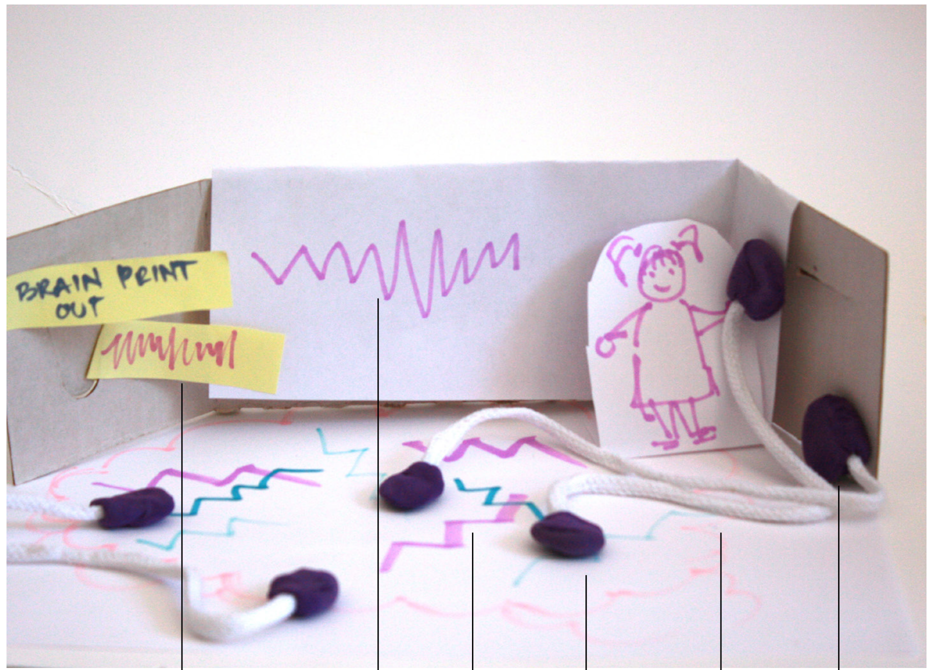


On the ground & wall

Utilizing projections on the ground and magnetic pieces that could be connected to the wall, large electrodes with wires can be connected to catch projected brain waves. The caught brain waves are displayed on the wall. After the brain waves are found in the game, the collected brain waves can be printed out by the child to take home.

When/where

The concept could be used by multiple children in the waiting room



Evaluating Concept Usage & Timing with Experts

The concepts were shown to lab technicians and neurologists for their feedback regarding the best timing of use for the device and also asking how they explain the EEG to children. This was done in an open interview with structured questions. The full notes of the feedback can be found in Appendix F.

“The device could be **used during the procedure**, it would be nice to have **an educational experience about the EEG rather than just watching a movie.”**

The game should not be overly stimulating, as to affect the EEG.

The technology of the game should not have **too much power as to create artifacts** and affect the EEG reading.

“It would also be good **if the interactive game was more integrated into the space** and furniture.”

Conclusion: An interactive table

From the feedback about integrating the design more with the space and furniture, the design is now combined with the table to make the game a part of the EEG procedure, Figure 4.1. The game should be able to be used casually, to be able to be stopped and started easily while not disturbing the game play, so that if the child needed to do something while placing the cap they wouldn’t be irritated. The game should not be competitive and not too stimulating to affect the EEG reading. The technology should also not affect the EEG.

Interactive Table

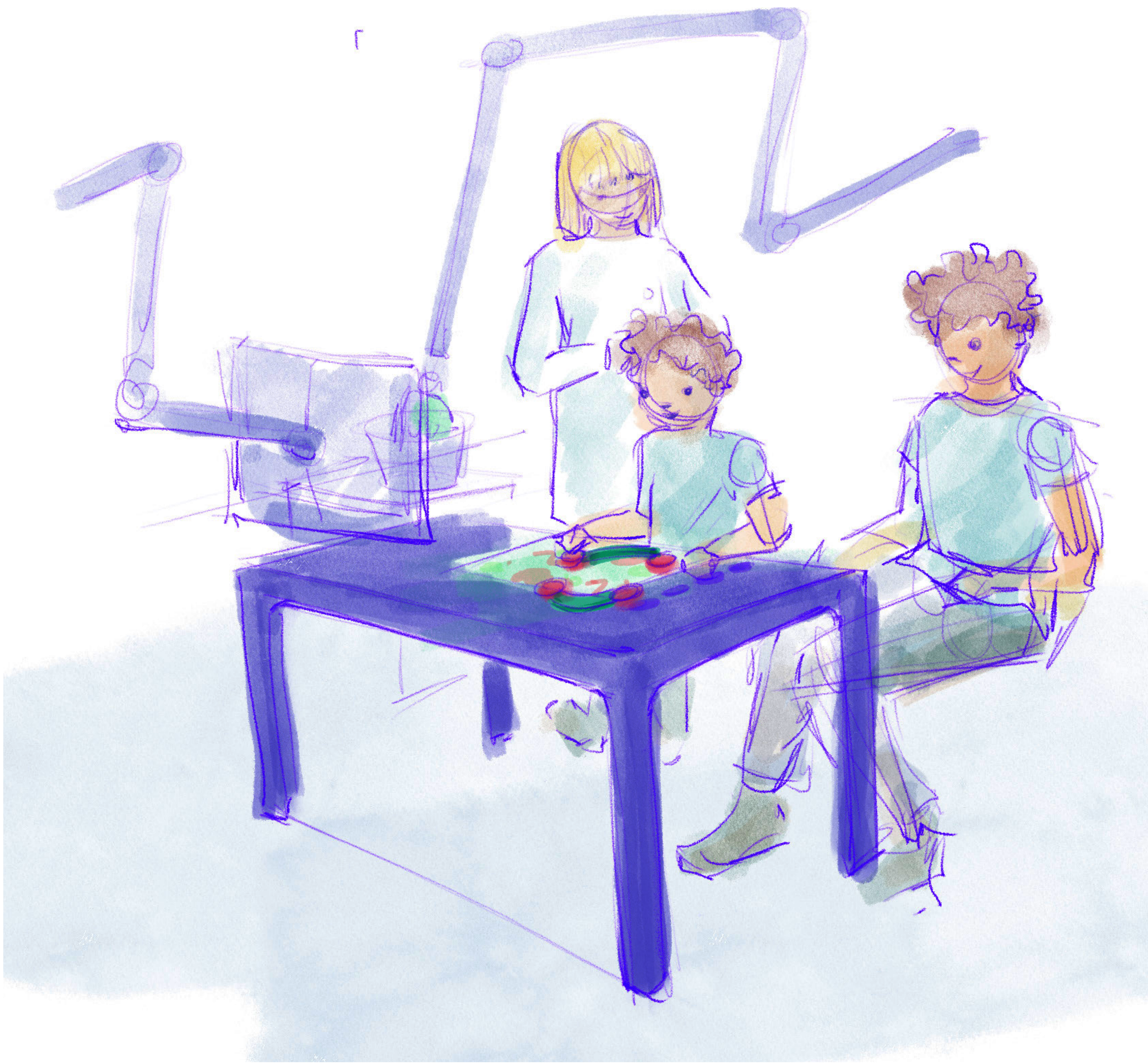


Figure 4.1: Interactive table concept

Technology

Different possibilities for the technologies of the device were explored such as using lights, an interactive screen, and projections. Full descriptions of the explored technologies can be found in Appendix G.

Requirements

The interactive device should be able to be durable enough that a child can play or drop things on it without damaging it. The device should be able to be cleaned easily to hospital standards with areas where dirt or bacteria are limited as much as possible. The visuals should be able to be displayed in daylight, as the lab technician needs light to place the electrodes.

Electronic Artifacts

Electronics with 60 hz can create artifacts on the EEG, affecting the reading (Sazgar & Young, 2019). But during observations, it was seen that electronics such as TVs (120 Hz) and phones (60 Hz) are in the EEG room and do not affect the EEG, because they are placed far enough from the child. The phones are held by the parent sitting next to the child and the TV is placed about 1 meter away from the child's bed.

Figure 4.2: Interactive table technology Samsung Galaxy 8 Interactive table

Interactive Screen

An interactive screen on the table could use touch to detect where pieces are, see Figure 4.2. Interactive screens have better touch sensitivity and faster reaction times in comparison to projectors (Harris-Briggs, 2018). They also have better visibility in light. Durability would vary depending on the kind of screen and could become more expensive to make it durable enough for children in the hospital. The table would also need to be designed with limited seams to reduce bateria being stuck inside.

Figure 4.3: GoTouch Beam

Interactive Projector

Interactive projectors have more variability in visibility and response time compared to interactive screens. However, the surfaces are much easier to clean because it can be a normal table that is used. Also this allows any surface to become the screen, improving durability and transportability (although the projector has to be mounted or placed somewhere as well). There wouldn't be a worry that something could fall and break the screen on the table. Also because the projector is placed on the ceiling, it should not affect the EEG reading.

The interactive projectors can detect either hands or infrared light, Figure 4.3 (Points West, n.d.). The infrared light is interesting because then a smaller toy or device can have this integrated and the projector will be able to tell the difference between the electrode and the child's hand. There is a risk of blocking projections by users' hands or head. There should be consideration for placement of the projector to make sure it can be least affected by being blocked.

Area	Interactive Display	Interactive Projector
Response time	++	+
Visibility	+	-
Durability	-	++
Cleanability	-	++
Transportability	--	+
Affecting EEG	--	+

Figure 4.4: Harris Profile on Technology

Conclusion

A comparison using the Harris profile was used to compare the different types of technologies can be seen in Figure 4.4. Though interactive tables have better visibility and reaction time, the projector has much more important qualities such as having less of a risk of affecting the EEG because it is placed farther away than the interactive table and that the surfaces are easier to clean. The interactive projector would also be easier to transport if changes are made to the Child Brain Lab, as it is smaller and lighter than an interactive table. Therefore an interactive projector is chosen to be used for the final design. There should be considerations for the image being blocked by the user's head or limbs, but the correct position of projector and visuals can avoid this issue.

Further Learnings on the Brain

It was seen that the current understanding of the EEG was not in depth enough to create an interactive and interesting experience for children to understand the brain, therefore further desk research and interviews with neurologists and lab technicians conducted on 'What the EEG does' is done.

What information to show?

The further learnings are based on 'What the EEG does' as this is an aspect that has been identified in the research phase that is left out for children, usually to focus on the procedural aspect of the EEG, as this the information is abstract and sometimes difficult to understand for children. During observations, it was also seen that sometimes the lab technicians show the children the results of the EEG - the squiggly lines of their brain waves.

The interesting aspect about the brain waves, is that it is related to the different activities that a person is doing, and most of the 'interesting activity' - brain activity that the doctor looks at to do a diagnosis - in the brain occurs when a patient has their eyes closed, asleep, or dreaming. By showing that there are many different brain waves when you are asleep, it can help children understand why they have to do the different exercises while having an EEG.

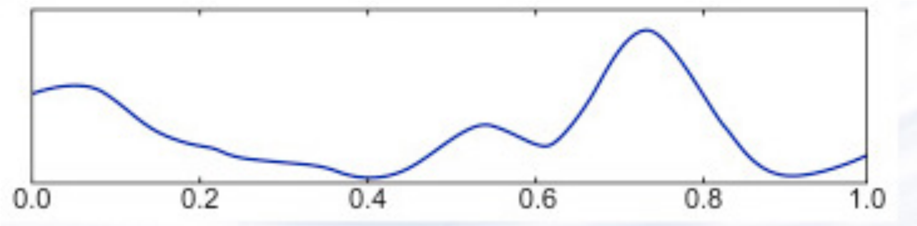
Because most of the children at the CBL frequent the hospital and most likely have had an EEG before, this may have been something they have seen before but not able to understand. Also, because they may also have to do another EEG test in the future, this can help educate the child-patient about their own healthcare, empowering them. This is why it was chosen to include this information in the EEG game, because it can be a building block in the child-patient's understanding of their own healthcare.

Brain Waves

The EEG records electrical activity in the brain and it shows this information in brain waves. The five types of brain waves are Delta, Theta, Alpha, Beta, and Gamma (see Figure 4.5). There are of course variation person to person and depending on age and brain development, but for the purposes of the game, the information has been compiled in a way that can be understood by children.

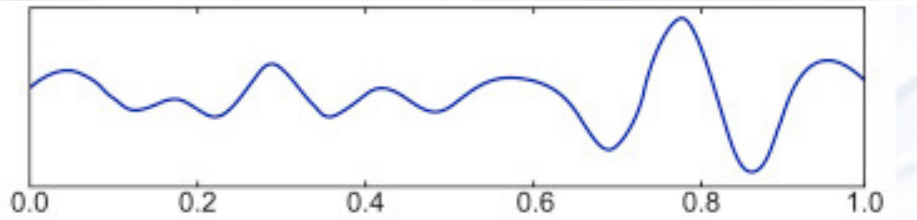
Delta

Delta waves are the slowest waves and they are found often in babies and sometimes in deep sleep (Abhang et al., 2016; Big Think, 2018).



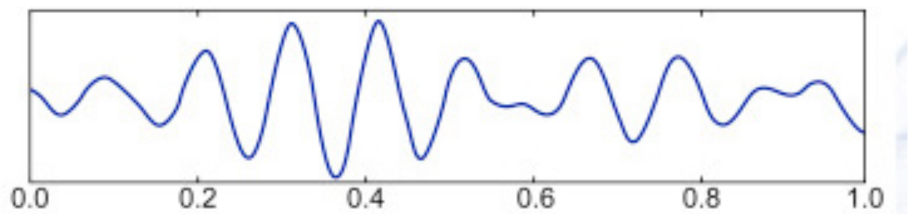
Theta

Theta waves occur when drowsy, asleep, or daydreaming and are involved in restorative sleep (Abhang et al., 2016; Big Think, 2018).



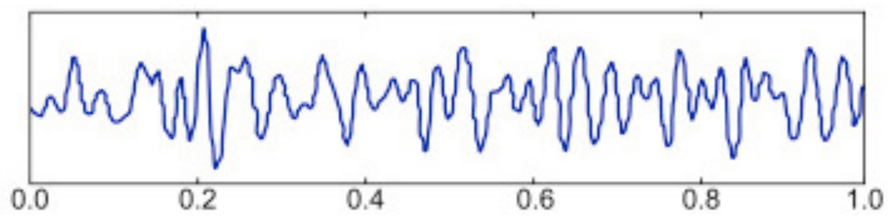
Alpha

Alpha waves are found when calm and eyes are closed, most often in the occipital lobe of the brain - the part that is responsible for sight (Abhang et al., 2016; Big Think, 2018).



Beta

Beta waves occur when awake and active, and are often seen in the frontal lobe, the part of the brain that is responsible for conscious thought and movement (Big Think, 2018). There are different types ranging from when one has focused concentration to high energy and stress (Abhang et al., 2016).



Gamma

Gamma waves are active when a person is in deep focus or in a state of universal love (Abhang et al., 2016). They usually last only only for a second for most people - such as the moment you bite into an apple and have a burst of taste (Big Think, 2018). People who have meditated for over 60,000 hours have been shown to have gamma waves at all times (Big Think, 2018).

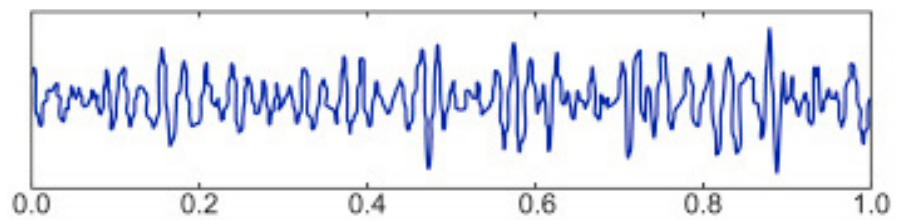


Figure 4.5: From Abhang et al., 2016: The different kinds of brain waves

Exploring the Space

Based on the insights from the research and the needs of the gam the EEG space is also visualize Figure 4.6 & 4.7.

Colored walls with the EEG cap hanging - showing them off rathe than hiding them could make th space more interesting for childre and invite their curiosity.

There is space for the projector t be placed as well as an area to th side for the tray for the EEG game t be placed.

Having space for the parent to s next to the child is very importan this could be through a chair or unified couch. Having a table th can wrap around, integrating th child's space to play the game an the lab technician's supplies make it look more unified and will give less of an ominous feeling of "being looked at".

Storage space for pillows or other tools is also necessary. A rolling tray can hold the lab technicians supplies and adjust for however the patient wants to sit.

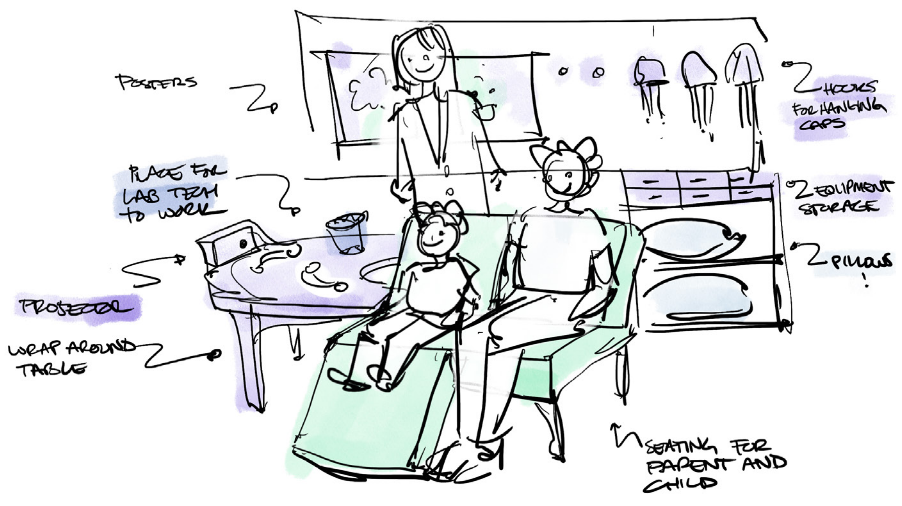


Figure 4.6: A sketch of the EEG space with a couch for the child and parent to sit together on

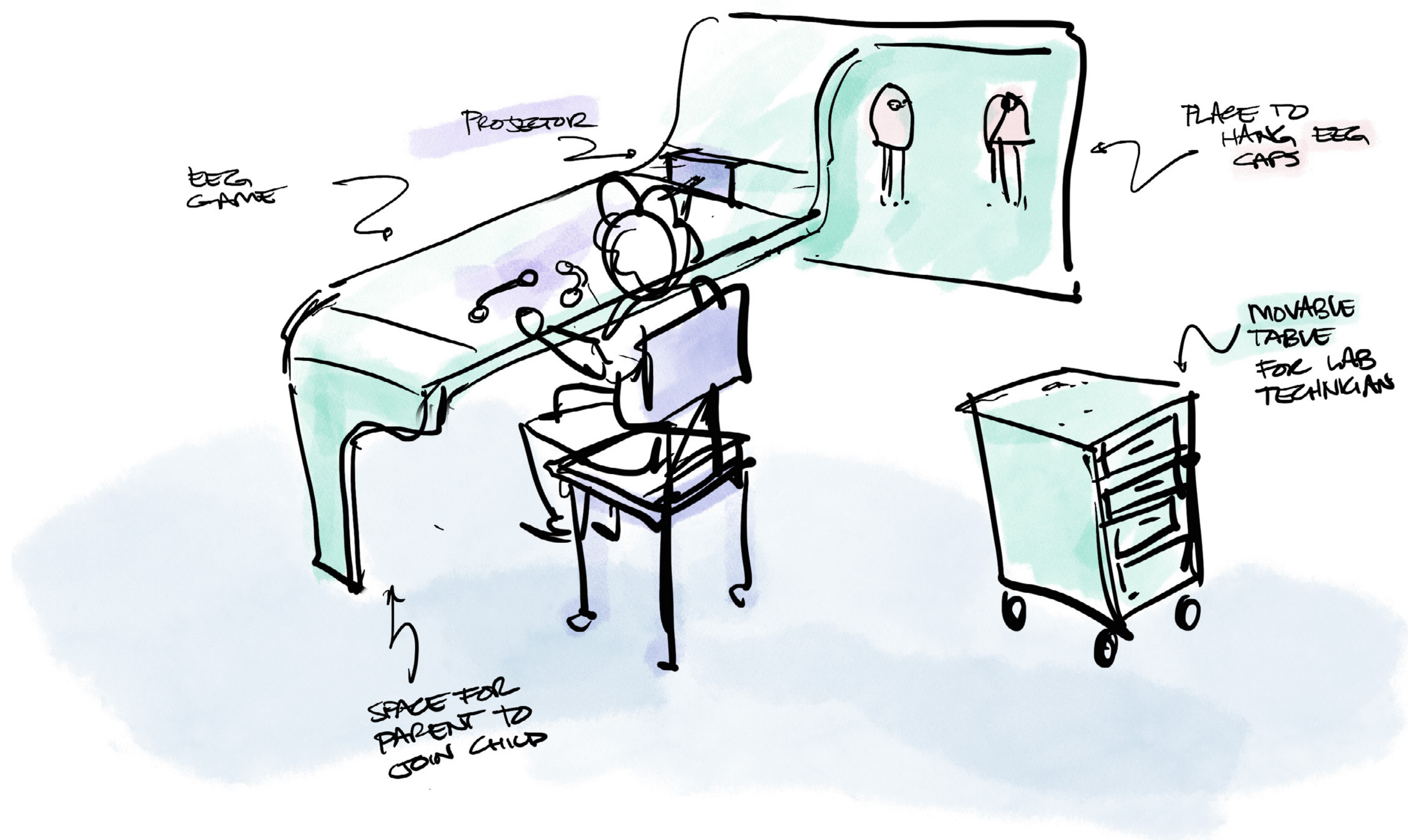


Figure 4.7: A sketch of the EEG space using a table that integrates into the space. A rolling cart is used to hold supplies.

Game Development

After further research into the technical and procedural parts of the game, a more focused goal for the game was developed and aided in the development of the visual and physical aspects of the game. These goals are based on the insights learned during the research phase of the project.

Goal of the Game

Currently most of the questions and conversations are centralized around the procedural part of the EEG and not what it actually does as it is difficult to describe

Control is a need for child patients identified in literature research, interviews with lab technicians, doctors, and parents

Times of waiting increases anxiety for patients

Due to the variability in the appointment, children may have a 15-30 minutes to play the game

Open up conversations and questions in the hospital environment where children often are uncomfortable and 'accepting' of procedures the child who has to then complete other brain tests as well.

For children to explore and learn more about what the EEG does on their own terms. Give a feeling of a safe space and being in control in the hospital setting. Allow them to experiment while playing the game, distracting them from boredom and reducing anxiety from waiting while lab technicians fix the electrode cap and set up the space. To be able to understand how to play quickly and play for a short or long period of time. Be a calming activity that is not overly stimulating or competitive. Help children feel comfortable and open to ask questions.

Curiosity is children learning and exploring on their own terms

For children to feel curious, creating a feeling of safety is necessary

Because it is one of several steps that the children do, the game should not be too stimulating or competitive, as this would affect the EEG results and may overly tire the child who has to then complete other brain tests as well.

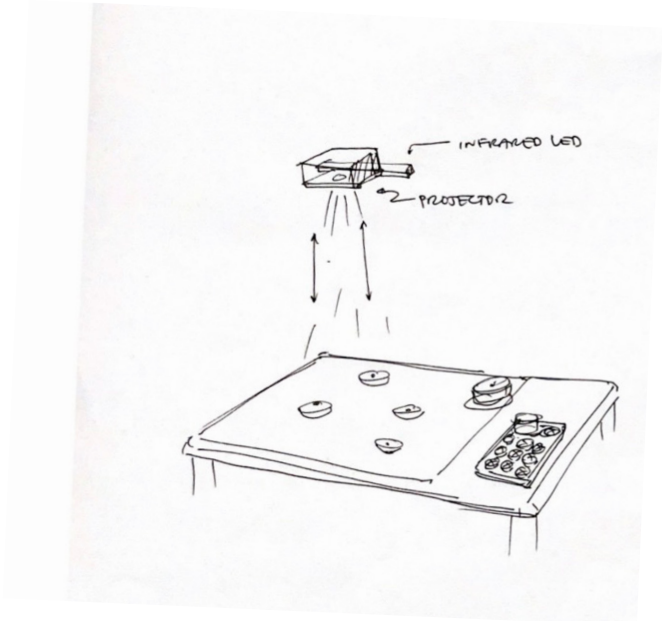


Figure 4.8: A sketch the projector interacting with the physical pieces.

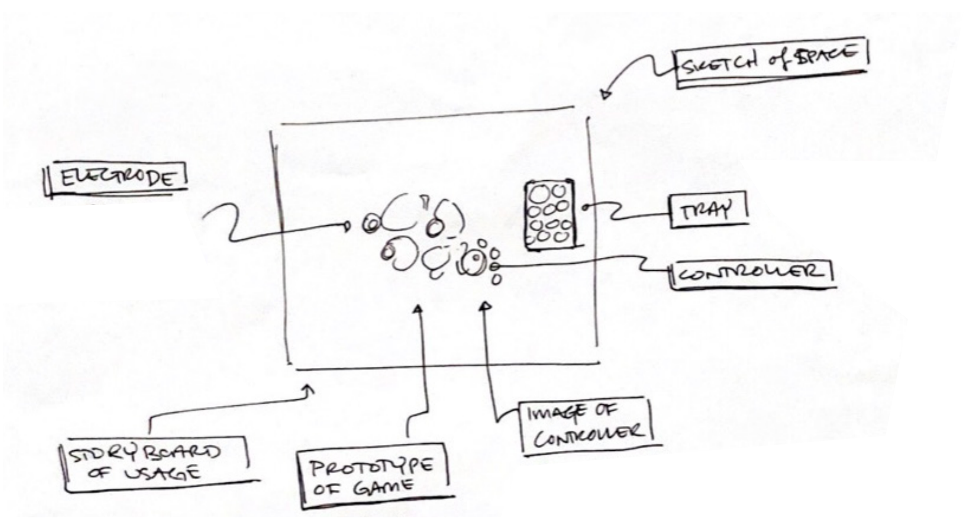


Figure 4.9: The next parts of the game that will be developed

Knowledge Shown in the Game

Information shown in the game is about what the EEG reading shows and what the EEG needs to get a good reading. Electrodes are all relative and more than one is necessary to get a reading. There are different kinds of brain waves when doing different activities, especially when sleeping, dreaming, or eyes are closed.

Irregularities or brain malfunctions were not chosen to be shown in the game. This is due to the timing of the game, possibly only 10 to 15 minutes to play, therefore showing information that may potentially make them upset is not ideal, especially when the child would then have to complete other brain tests as well. Also due to the fact that overly stimulating the child would also affect the EEG results and other brain tests as well. The activity needs to be calming so as to help the child relax for the EEG and the CBL.

How the Game Works

There are two parts to Catch a Brain Wave: virtual images of the brain and brain waves that are displayed on the projector and physical game pieces that interact with the projected brain (see Figure 4.8).

The brain moves in time with how active it is - this depends on what activity is being done. The knob on the left is what is used to change the brain activity. The electrode pieces are used to 'catch the brain waves'. When two electrodes are placed on the brain, they show the brain wave. As more electrode pieces are placed on the brain, they show the brain network. Electrode pieces can also be moved around. The activity knob can be turned when playing, displaying the different brain waves when you do different activities.

Figure 4.9 shows the different parts of the game that need to be developed.

Electrodes

Electrode pieces are used to see a brain wave. With one electrode, the brainwave does not form properly and disappears. When two electrodes are placed, they connect a brain wave and as more electrodes are placed, more brain waves are created - creating a network of brain signals.

Activity Knob

A knob lets the user control the activity being done, relating to the brain waves that appear. The activities are for the five different brain waves, which most of them are when you have your eyes closed or are sleeping.

Tray

A tray is used to hold all the game pieces and to charge them after use. There is an on/off button to make sure the device can be turned off and not interfere with the EEG test. This tray is similar to one lab technicians have to hold their equipment, but is for the children.

Exploring the Visualization of the Virtual Elements

The virtual elements of the game are explored in several different ways through Procreate, Adobe Illustrator, and After Effects, using still imagery and exploring movement through gifs or videos.

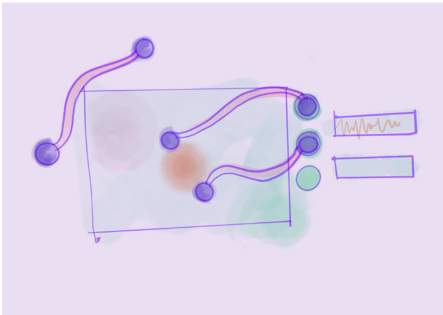
The virtual elements of the game are of the Brain and the Brain waves. Different ways of representing these elements were experimented with. The images of sketches can be found in Appendix H.

The visuals were explored by playing between forms of the brain waves, see Figure 4.10, such as the glowing blobs, paint brush, patterns, electrical signals, neural networks.

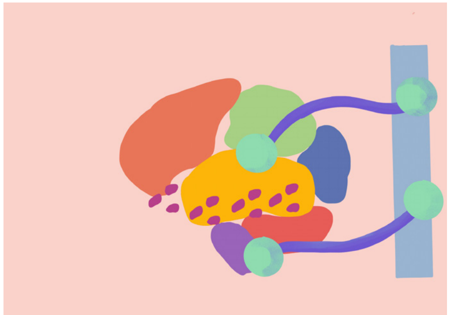
As they were developed further, the visuals became more similar to the brain waves displayed on the EEG scan, see Figure 4.11. This is to help the children relate the imagery they are seeing to the images that are seen on the EEG screen.

Originally light pastel colors were used, but after considering that they will be projected, more a high contrast background and waves were chosen to make sure that it will be visible, see Figure 4.12. Also a knob was designed for changing the different activities that the brain was doing.

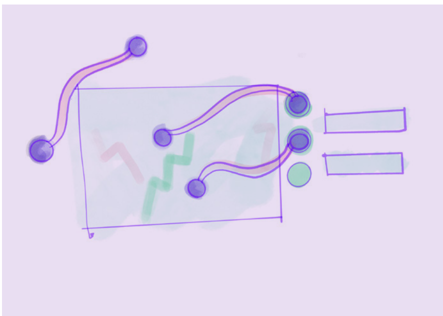
Glowing



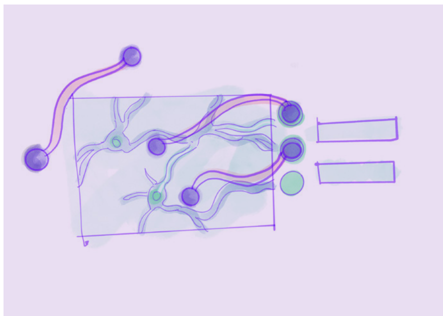
Paint brush strokes



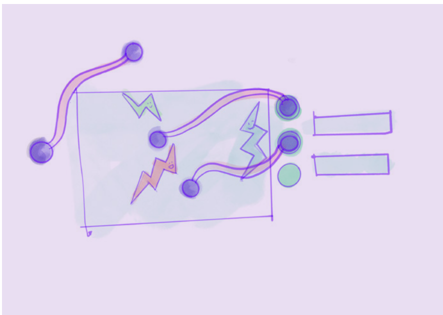
Electrical currents



Neural Network



Lightening bolts



Initial Sketch of Waves

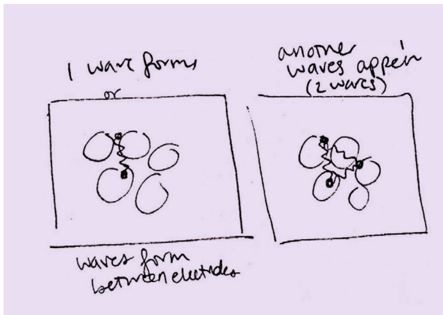


Figure 4.10: Initial experimentation of the visual elements

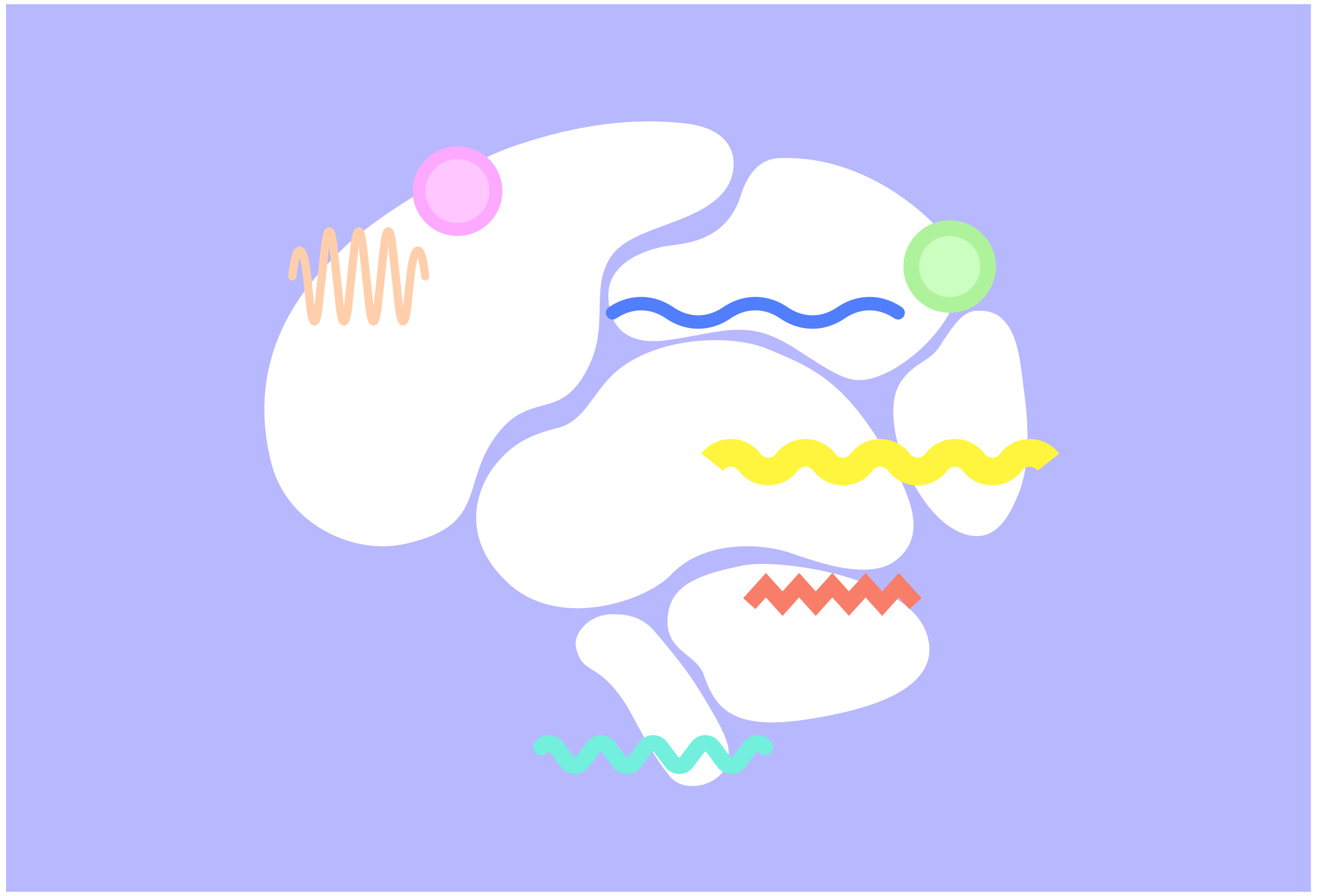


Figure 4.11: Using visuals more similar to waves

Figure 4.12: Changing color of visuals and adding knob

Prototyping the Visualizations

To make an interactive prototype, it was chosen to make it on Adobe XD as it would fast to prototype and easy to share with participants for testing.

Version 1

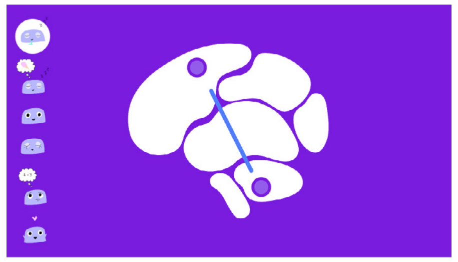
The game is prototyped on Adobe XD and can be seen in Figure 4.13. A side view of the brain is shown with the five main parts of the brain. Because of limitations of the XD program, squiggles or waves could not be created, instead straight lines and bouncing shapes are used for the wave patterns.

First a light blinks to indicate placing the first electrode. The first electrode is placed, but the brain wave is still not created. The line dashes and disappears. Then another electrode light appears and once clicked a bouncing brain wave (line) is created.

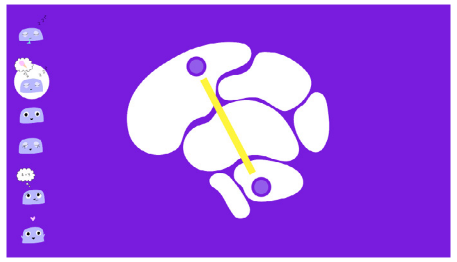
After a panel on the side appears with the different activities. The user can see the different brain waves / bouncing shapes when choosing the different activities.

1. First electrode light blinks

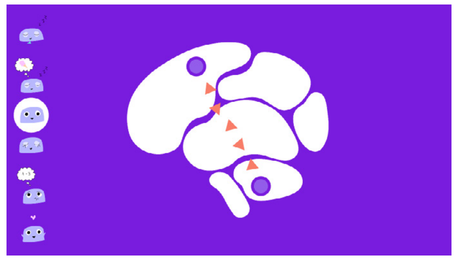
2. Unfinished brain wave dissappears & second electrode light appears



3. Second electrode is placed & delta wave appears. Side activity panel is shown



4. Activity is changed to dreaming & brain wave changes to striaght yellow theta wave



5. Activity is changed to awake and brain wave changes to trianglular beta waves

5. Activity is changed to closed eyes and blue alpha wave ovals appear

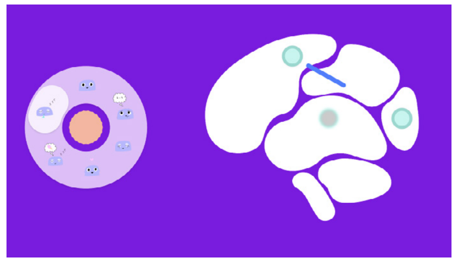
Figure 4.13: The first version of the EEG game

Version 2

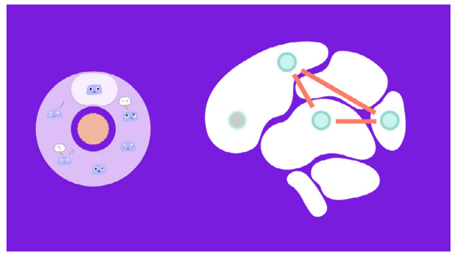
The second version of the game can be seen in Figure 4.14. More electrodes are added to make the game more interesting and interactive.

The second of the game changes the shapes into just lines, as it seemed confusing to have shapes representing the brain waves. The lines better resemble squiggles rather than the shapes.

Also the activity knob is created rather than the panel to make it as close to the envisioned visuals as possible.



More electrodes are able to be played with and the activity knob is added



Beta waves are changed to red lines

Alpha waves are changed to light blue lines

A brain network is able to created to see the brain waves all over the brain

Figure 4.14: The second version of the EEG game

Game piece ideation

To design the physical pieces of the game, moodboards, sketches, and CAD models were created.

The mood boards, some of them are shown in Figure 4.15, related to the keywords defined early in this chapter: Curiosity / Exploration, Safety / Cozy, Control, Playful, and Tactile. They helped define the focus of the game pieces, to see the full moodboards see Appendix I.

Also because the pieces are representing electrodes, electrode caps are shown in Figure 4.16.

The game pieces have an infrared light inside of them that when they are placed onto the projection on the table, the projection will react to them, see Figure 4.17.

Playful **Curious**

Cozy **Tactile**

Figure 4.15: Moodboard for physical game pieces

Figure 4.16: Examples of two EEG caps *Image from NIRX* *Image from NIRX*

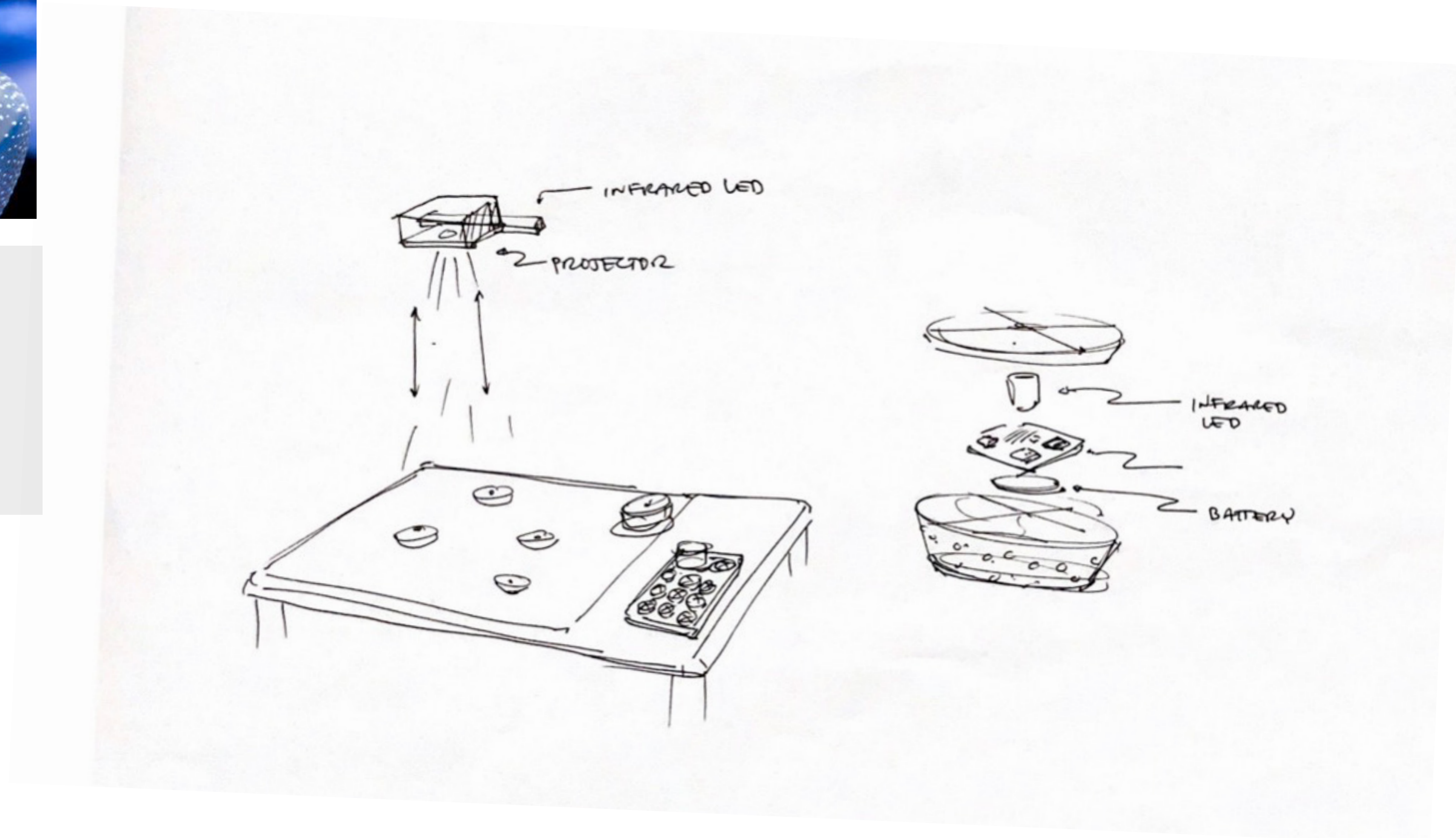


Figure 4.17: Sketch of parts that are necessary to include in the design

Physical Piece Exploration

Electrode

When playing, the electrode piece is used to find the brain waves.

In the virtual model, the electrode pieces had cords to connect them to a base, see Figure 4.18. This was done to resemble the way EEG electrodes are connected to a computer that visualized the brain wave, but in the game play was clumsy because they would block viewing the game and cast shadows.

Individual electrode pieces are designed instead, see Figure 4.19, allow more free movement and exploration while playing.

Also because an EEG cap is being used instead of individual electrodes, cylindrical shapes look more similar and can be better associated as those kind of electrodes electrodes.

The size of the physical pieces are 40 mm based on toy safety standards (CPSC, 2016).

Knob

The activity knob changes what the activity is being done. It needs to look like it can be turned and should look like it goes with the electrode piece. See Figure 4.20

Tray

The tray is used to hold the pieces before use. It represents the child's own EEG set, that they can control. Considerations should also be to make sure all the pieces went together well and are easy to place after playing. The tray should also be easy to clean. The tray exploration with the pieces can be seen in Figure 4.21

The tray has a cord to charge the pieces and an on/off button to make sure it is not charging during the EEG test.

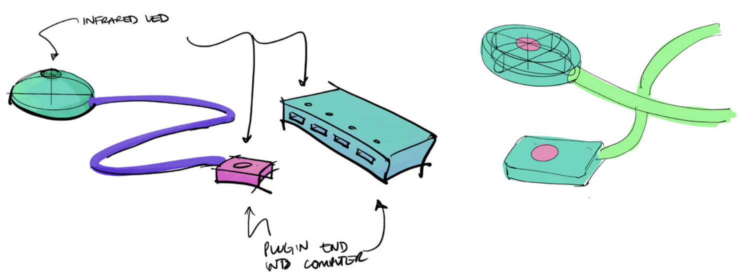


Figure 4.18: Sketch of electrode with cord

Electrodes

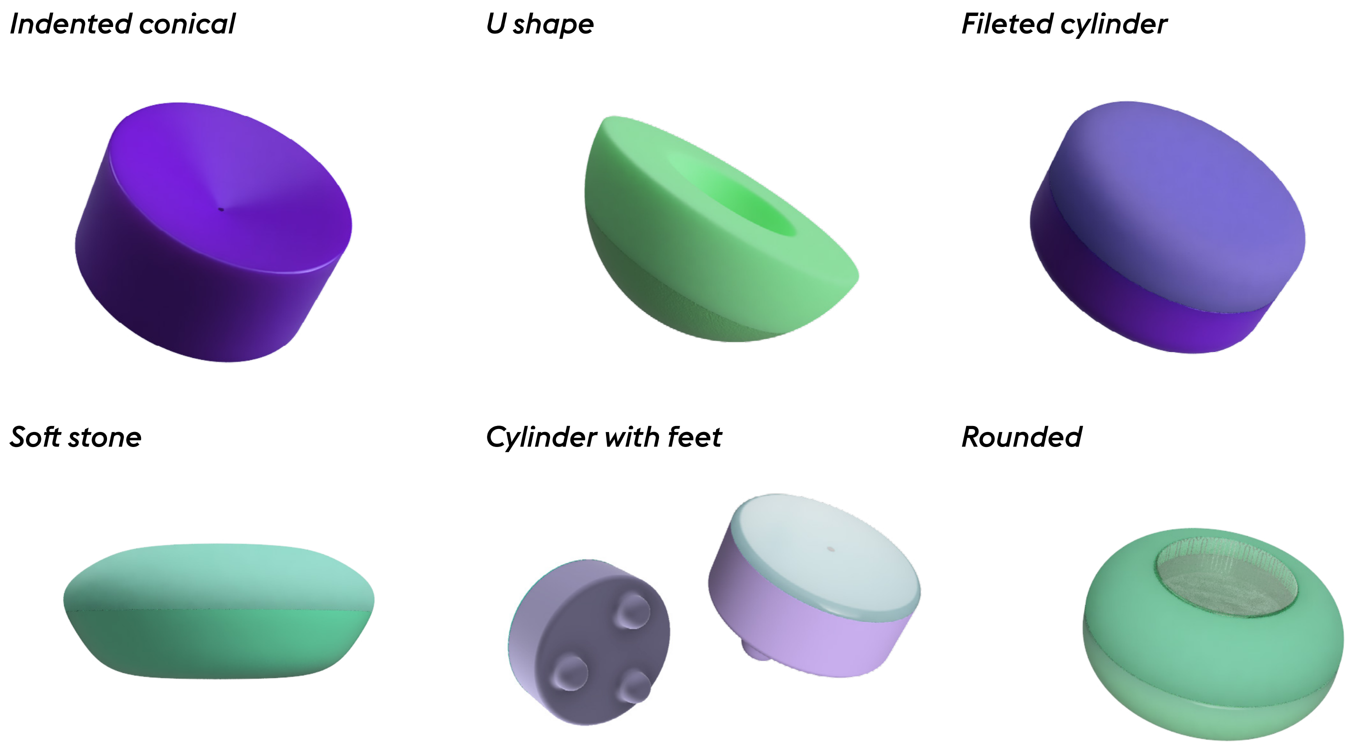


Figure 4.19: Renders of electrode exploration

Knob

Figure 4.20: Render of knob exploration

Tray

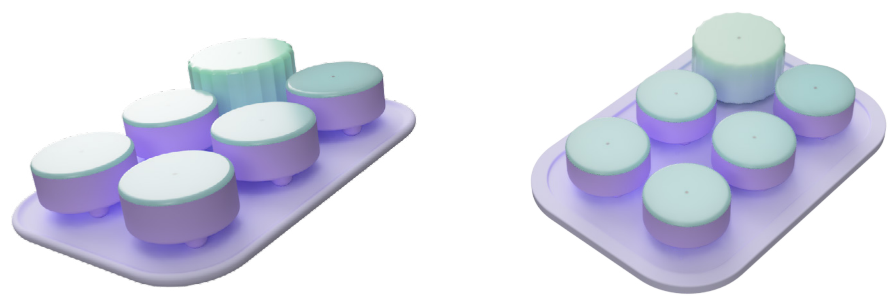


Figure 4.21: Render of tray exploration

Prototyping Physical Pieces

Figure 4.23: All of the 3D prototypes printed

The electrode and knob pieces were 3D printed to see how they would go with the visuals of the projector. Each set of electrodes has five pieces, all of the prototypes can be seen in Figure 4.23.

The visuals were printed out on paper and the electrode pieces were experimented with to see how they would be played with, Figure 4.24 & 4.25.

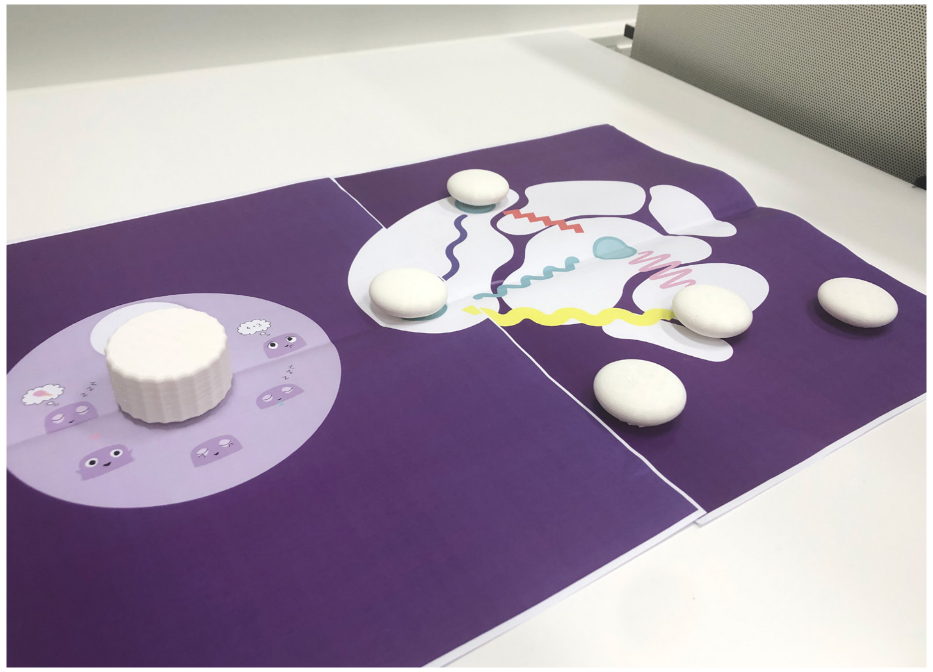


Figure 4.24: Prototypes 3D printed of the stone electrode pieces

Figure 4.25: Prototypes 3D printed of the electrode pieces with feet

Testing Physical Pieces with Projected Images

The set up was tested to see how the objects, the electrode and knob, would look underneath a projector.

Also it was used to see how the colors looked when projected and if they looked how they were envisioned on the computer. When exporting the visuals, the color of the background was darkened to make sure if would visually pop up, see Figure 4.26 for the comparison in color.

The projector was set up so that it was above the user and in front, see Figure 4.27.

Overall the pieces worked very well together. The quality of the envisioned images were able to be seen in the game. Hands that moved the pieces cast shadows but didn't affect the overall viewing of the game, Figure 4.28.

The colors and visuals can still be tweaked to be improved, but the considerations for color ahead of time made a difference in the imaging.

Figure 4.27: Projector testing set up

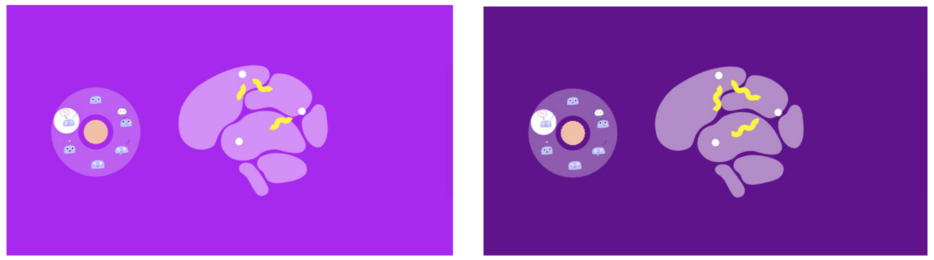


Figure 4.26: Color comparison, left is the virtual colors and right is projector colors

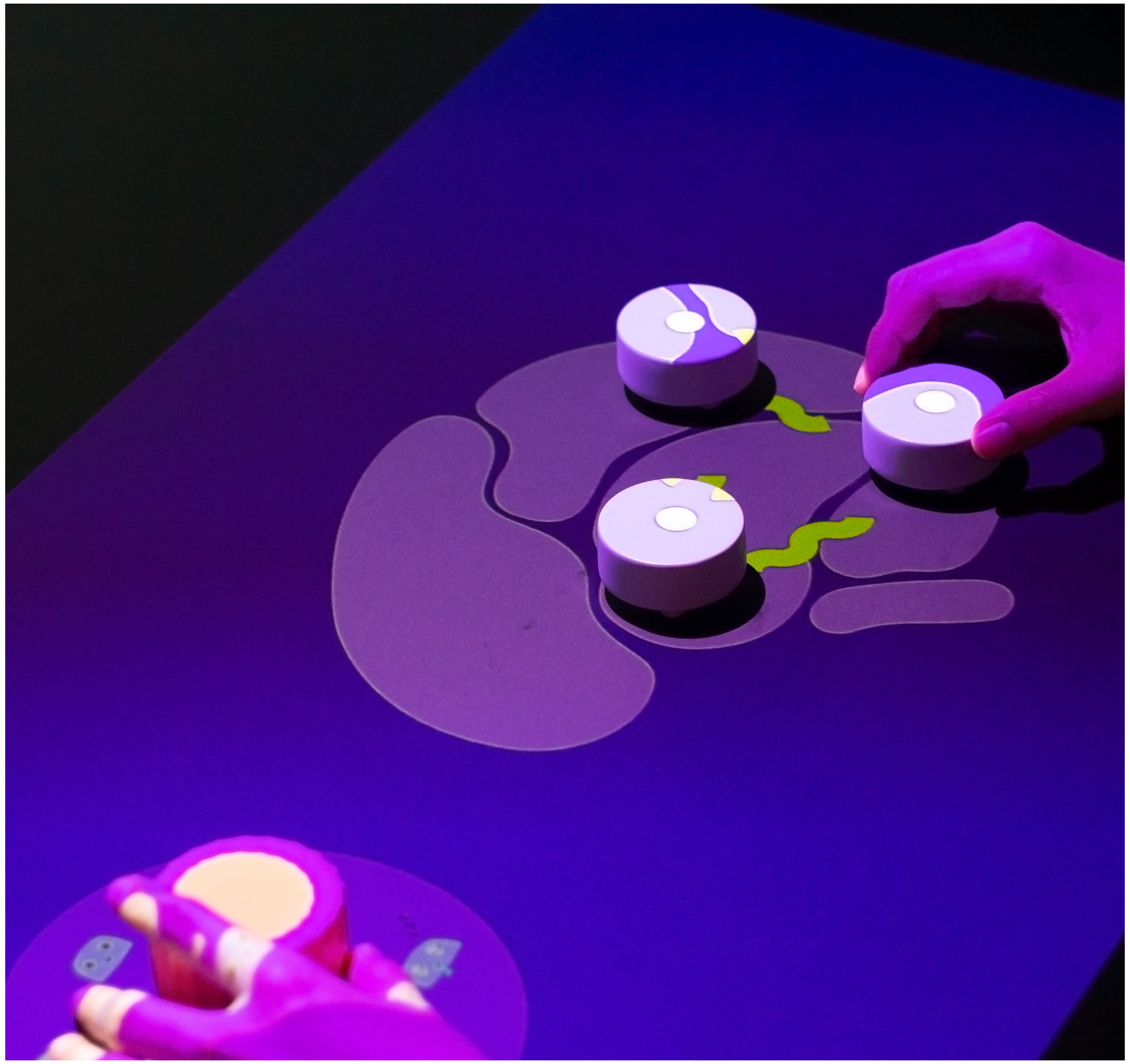
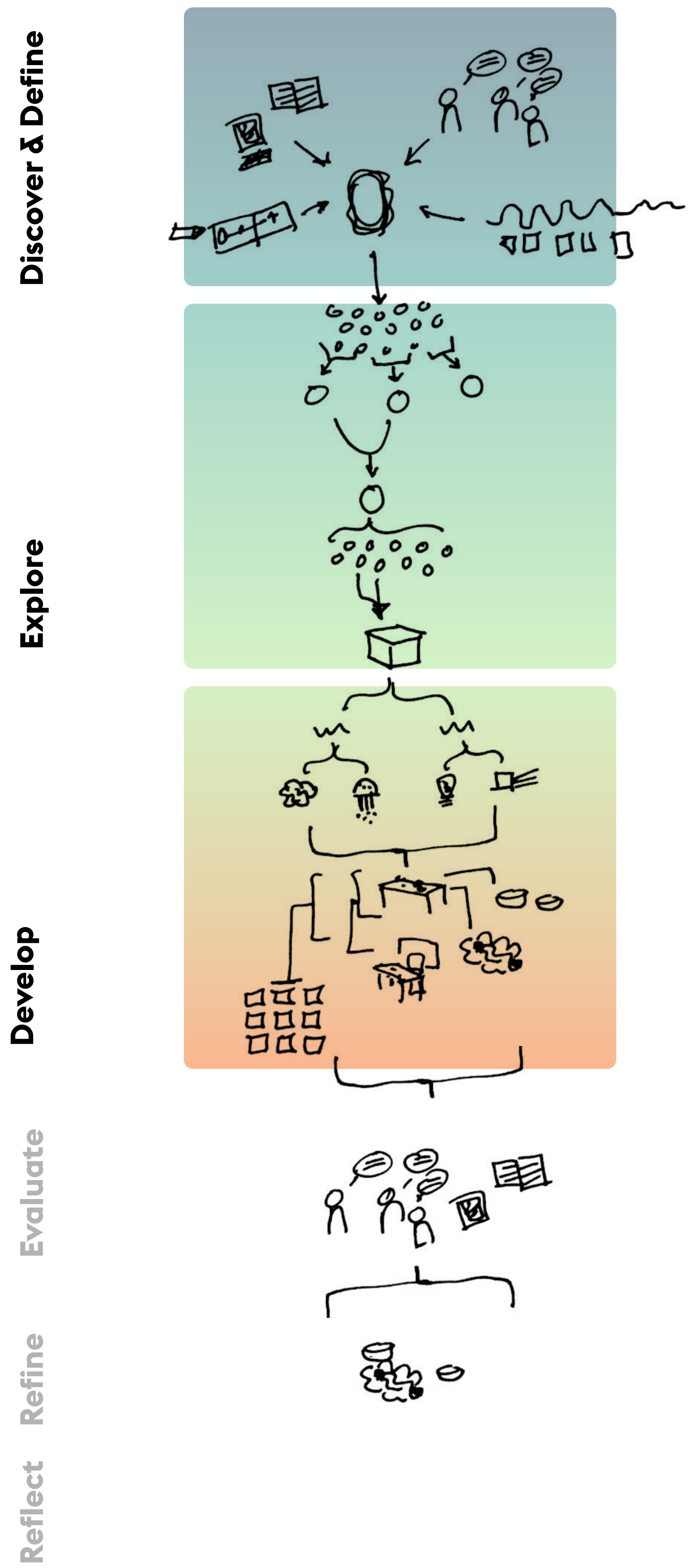


Figure 4.28: Playing with the electrode pieces and the projections

Conclusion of Develop Phase

The decisions of the Develop phase are concluded in this chapter. This is for the entire set up: the space, the physical pieces, the virtual elements, the technology, visualis of the game, and the entire envisioned set up.

The EEG Space
Electrode, Knob & Tray
Technology
Visualization of game
Storyboard of Usage
Envisioned Set Up



The EEG space

Based on the insights from the research and the needs of the game, the EEG space is also visualized in FIgure 5.O.

Posters on the walls with the EEG caps hanging, showing them off rather than hiding them, making the space interesting for children and inviting their curiosity. There is space for the tray for the EEG game to be placed. The projector is hung from the ceiling, slightly in front of the table to reduce the amount of shadow created.

There is space for the parent to sit next to the child. The table is the center of the station, giving less of the ominous feeling of being looked at for the child when they are in the center of the room.

Storage for the lab technician supplies are placed on a rolling cart so they can be moved and adjusted to how the patient would like to sit.

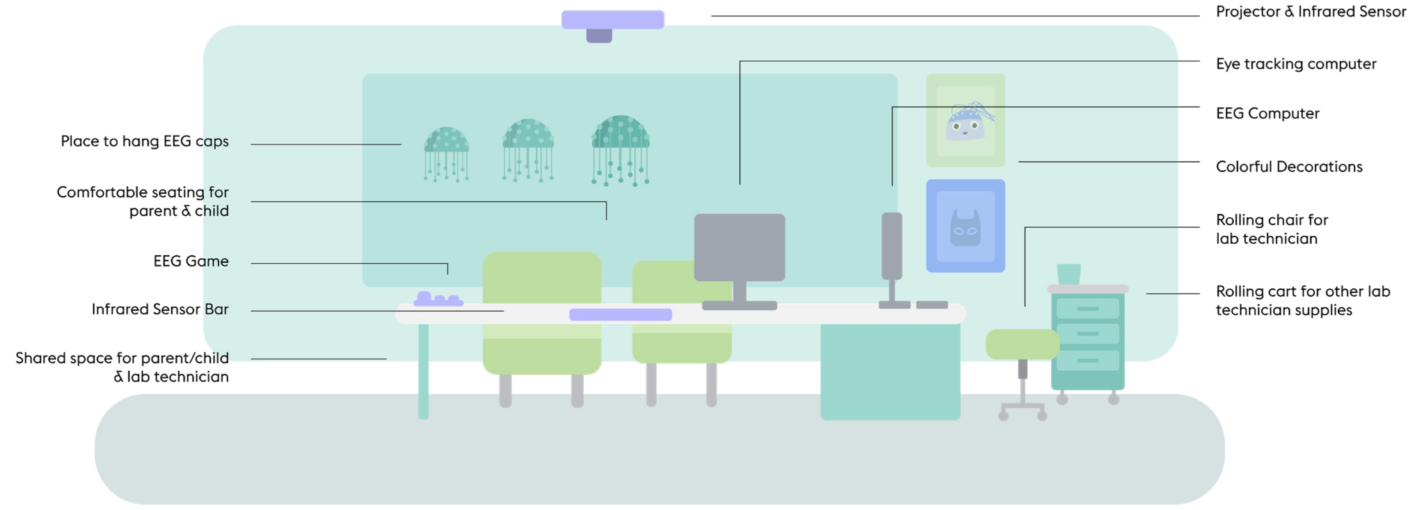


Figure 5.O: The envisioned EEG space

Electrode, Knob & Tray

The entire set of the physical pieces can be seen in Figure 5.1, 5.2, & 5.3.

Electrode

The chosen direction for the electrode pieces are cylindrical with feet on the bottom to show that they can be lifted. Underneath the feet are the charging pads for the charging tray. There are LEDs underneath the physical pieces so that they can light up and glow, indicating to be picked up.

The simple cylindrical shape is similar to the electrodes that are on the EEG caps.

The small feet on the bottom make them more playful and the top is flat, as the indented pieces seemed like a place to put your finger. Although the top of the electrode may be blocked depending on the movement of the user, once placed, the infrared light can be detected and change the game play.

Knob

The chosen direction for the knob is similar cylindrical shape chosen for the electrode, but with indentations to indicate movement. The bottom is also lifted to be similar to the lifted feeling of the electrodes.

Tray

The has simple shapes, a place for the cord and placement for the on/off button.

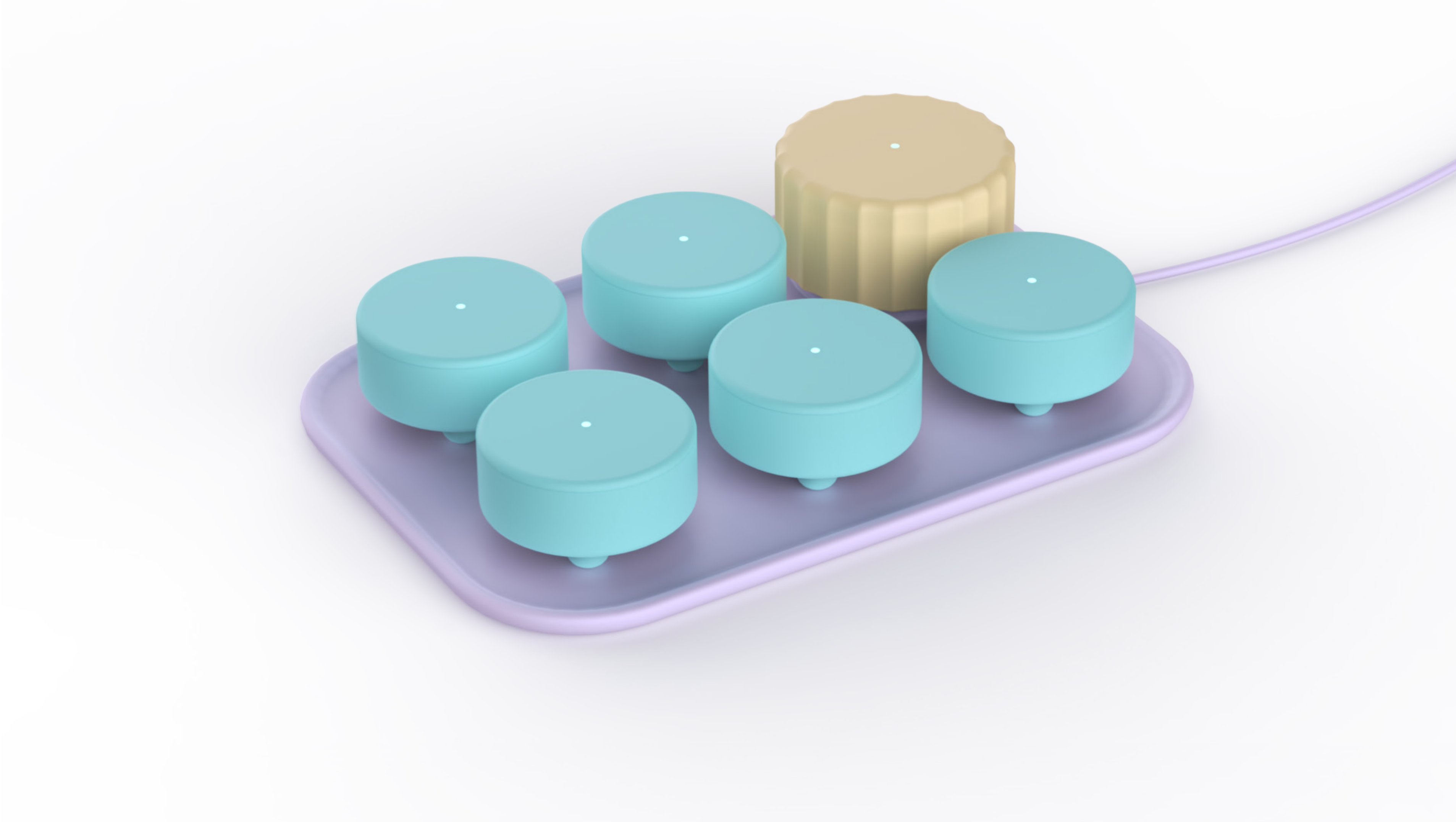


Figure 5.1: The physical pieces: the electrodes, knob, and tray

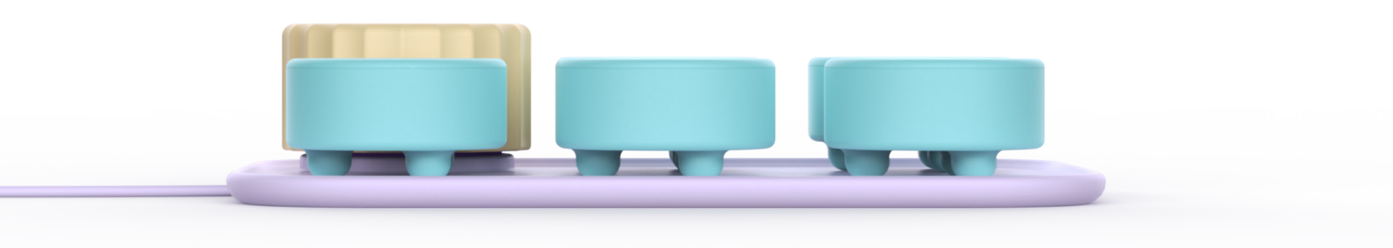


Figure 5.2: The physical pieces: the electrodes, knob, and tray

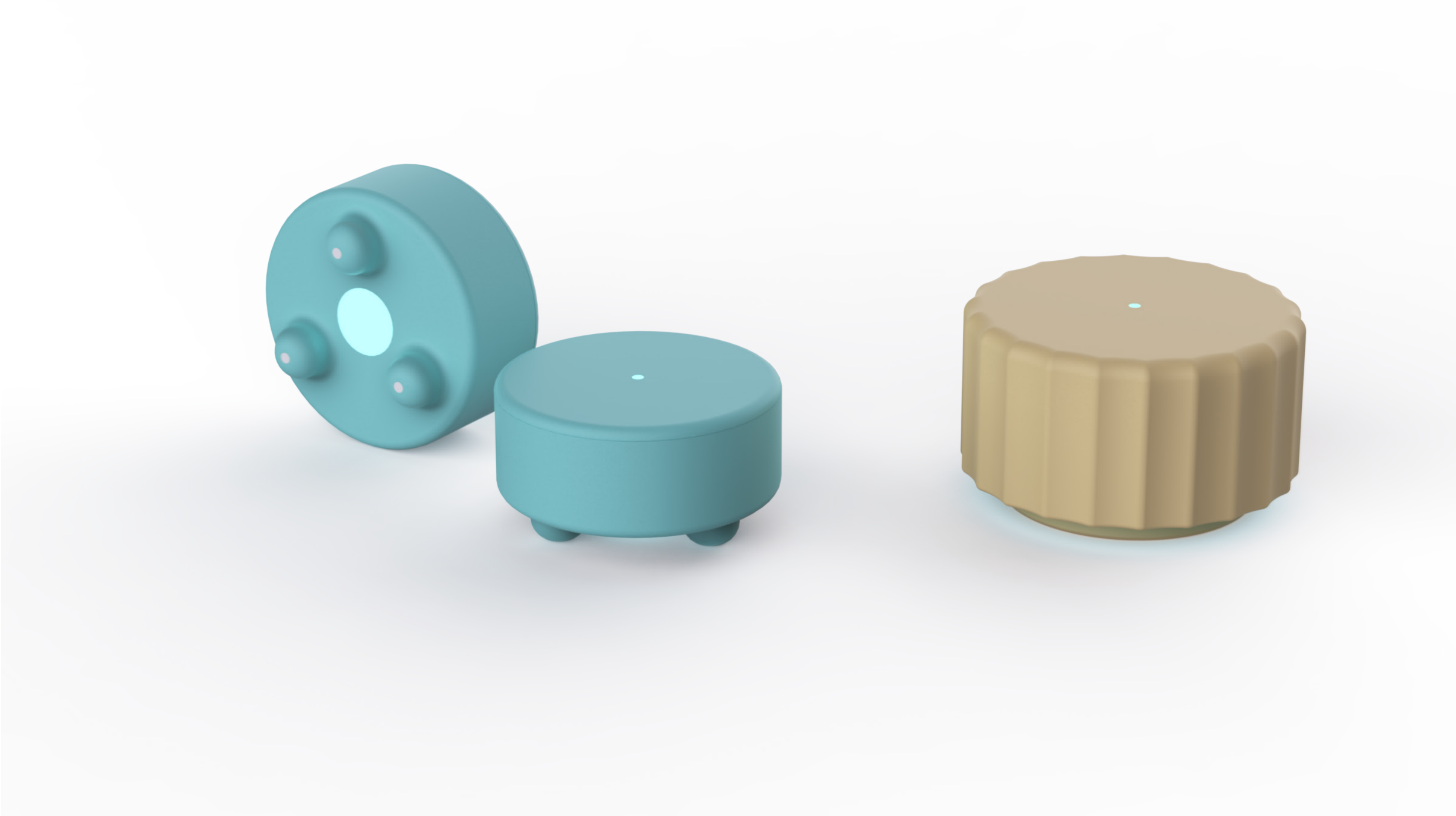


Figure 5.3: The physical pieces: the electrodes & knob

Technology

The Wavy experience utilizes a projector and computer system to visualize images, see Figure 5.4. The sensor next to the projector detects the electrode and knob piece using the infrared light inside the pieces, see Figure 5.5. The sensor bar next to the table helps the sensor know where the physical pieces are in relation to the surface. The infrared light is translated to the computer which reacts to the placement of the pieces to show the brain waves.

Inside the electrode and knob are batteries that are charged through the charging tray. The charging tray has an on/off button on the back to make sure it does not create electrical signals to interfere with EEG.

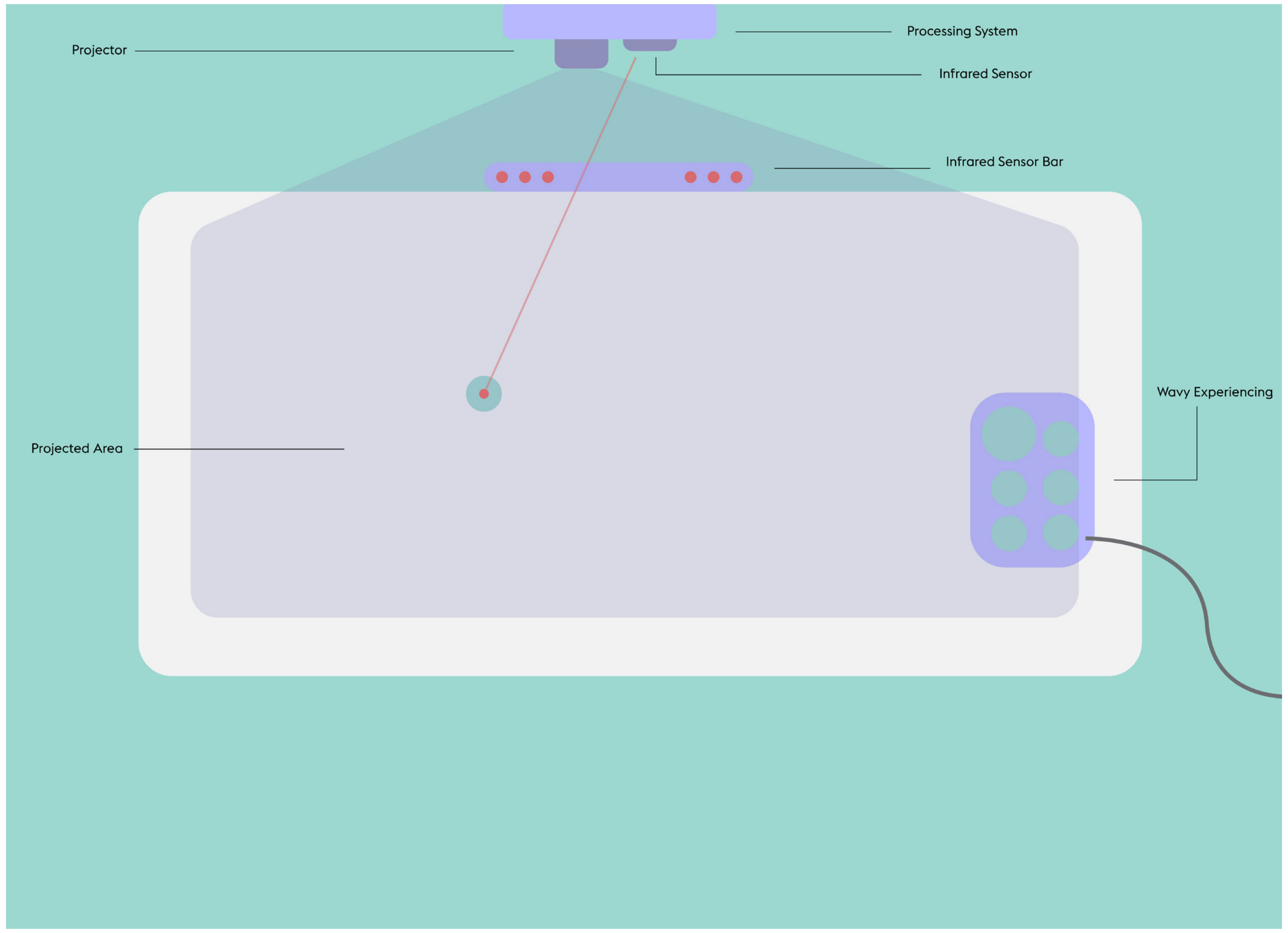


Figure 5.4: How the projector, sensors and infrared light connect with one another.

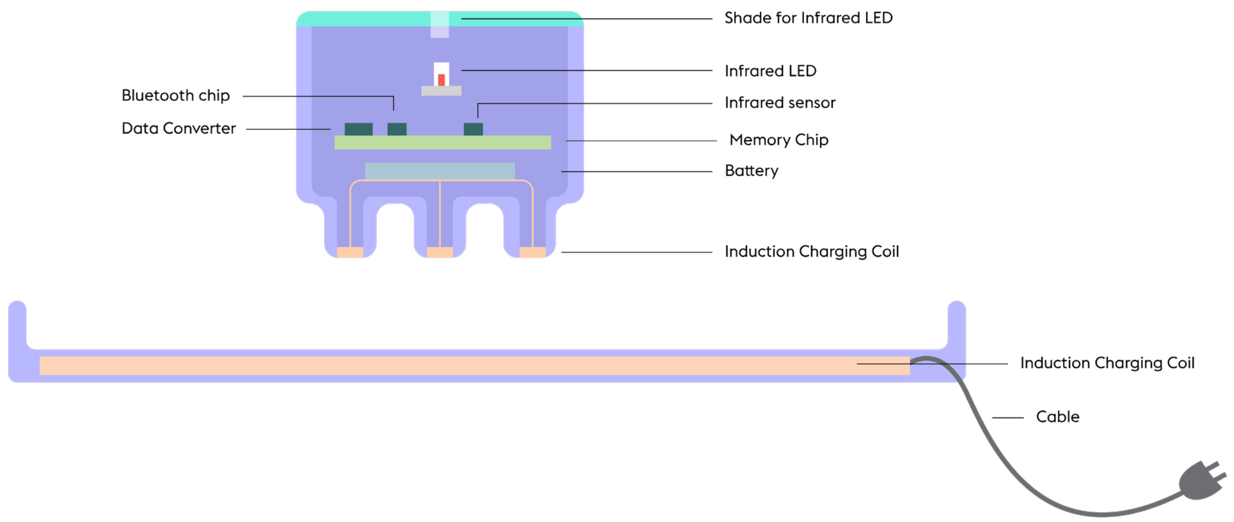


Figure 5.5: The technology inside the electrodes and charging tray

Visualization of Game

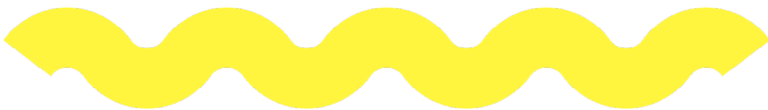
This page shows the final visualizations chosen and their meanings for the different wave patterns, Figure 5.6, and the different activities of the Wavy guy on the activity knob, Figure 5.7. The entire set up is shown in Figure 5.8.

Delta Waves

Deep blue delta waves lazily roll back and forth

Theta Waves

Big, dreamy, yellow Theta waves slothly sway



Alpha Waves

Peppy alpha waves gently bounce around

Beta Waves

Dynamic, zippy beta waves zig-zag quickly up and down

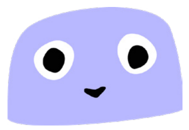
Gamma Waves

Passionate pink gamma waves ooze with happiness before melting away

Figure 5.6: The visuals and explanations of the brain waves based on the reasrch done on what the EEG does

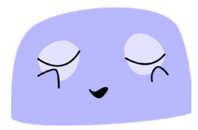
Figure 5.8: The set up of the entire visuals shown

Awake



When awake and alert Wavy has Beta waves

Closed Eyes



Closed eyes & relaxed show Alpha waves in Wavy's brain

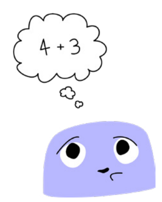
Dreaming

Dreaming is associated with Theta waves

Deep sleep

Deep sleep is associated with Delta waves

Thinking



Thinking has Beta waves, as when awake there are similar brain waves

Love

A burst of love is associated with Gamma waves

Figure 5.7: The Wavy guy and different activities he is doing on the knob. These are based on the learnings about the brain and the EEG.

Storyboard of Usage

The storyboard of the usage can be seen in Figure 5.9. Once the patient and parent arrive at the Child Brain Lab, they will go through a few tests before coming to the EEG station. At the EEG station the lab technician turns on the projector which starts Wavy. The starting video introduces the Wavy character getting an EEG cap. To show usage, the knob and one electrode will light up on the tray and a corresponding color will appear on the projection area. When the first electrode is placed, it shows a partial brain wave. A second electrode lights up to be indicated to be picked up. Once two electrodes are placed, there is a brain wave. After, the activity knob is shown and can be turned to change the activity. When the activity is changed, then the brain wave corresponds and changes. More electrodes glow to be indicated that they can be picked up as well, and as more are placed, a brain network is created. While the lab technician does the tasks they need to do, children can ask questions and have conversations about the EEG.

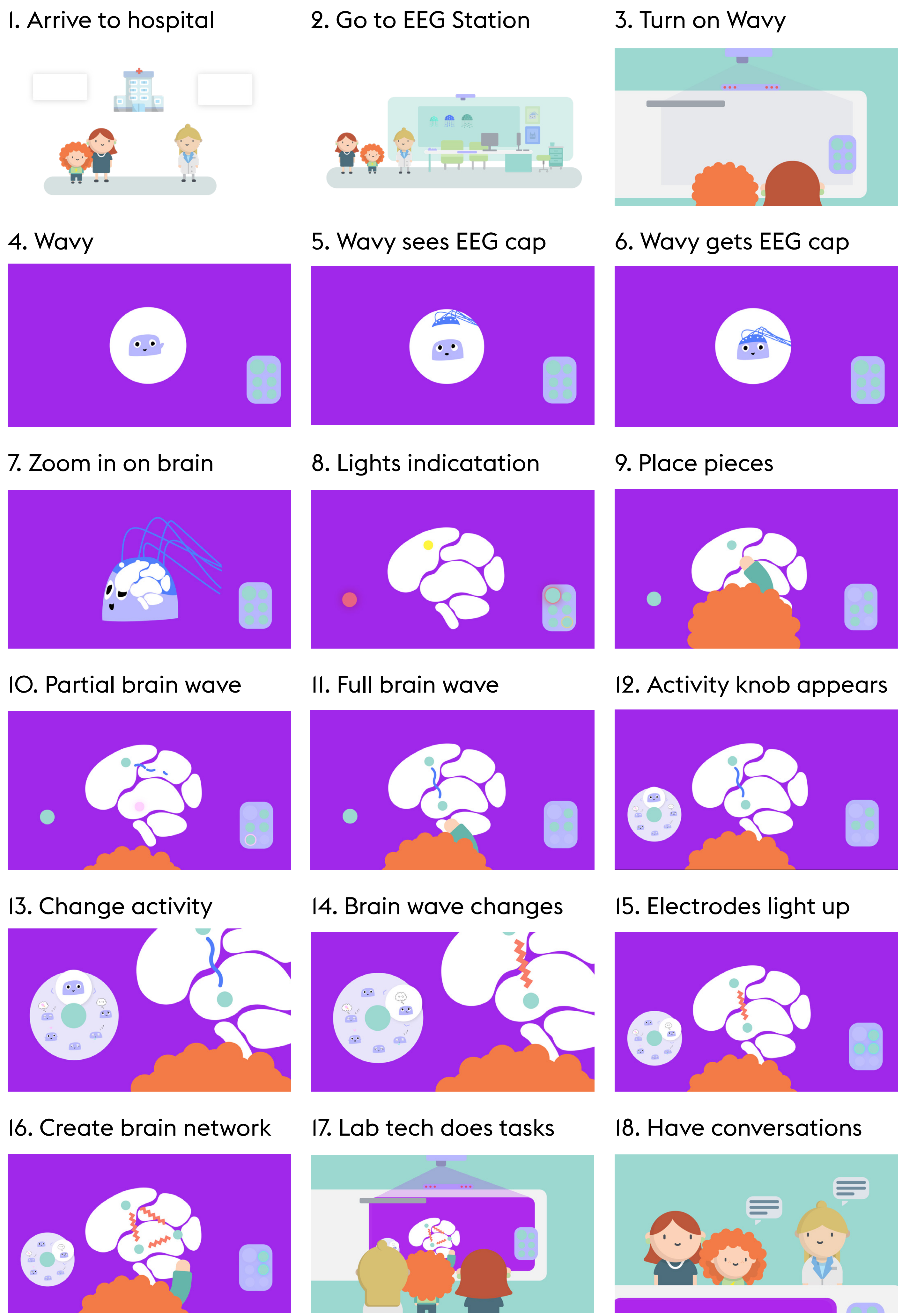


Figure 5.9: Storyboard of usage of the wavy game

Envisioned Set up

The physical pieces and virtual elements can be seen in Figure 5.10 & 5.11.

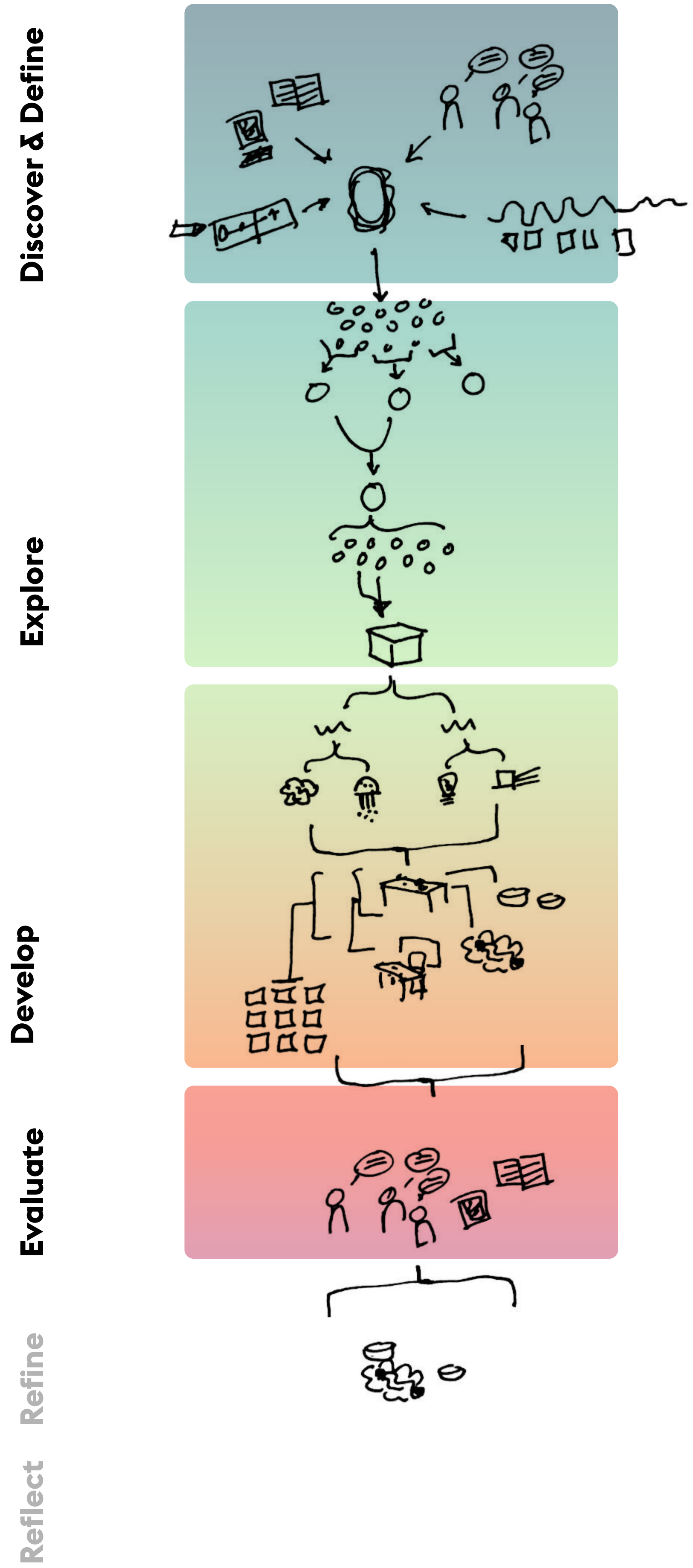
Figure 5.10: Set up of Wavy

Figure 5.11: Wavy being interacted with

Evaluate

To assess the design of the Wavy Game and the design of the EEG space, evaluations are done with experts, the lab technicians and neurologists at the Sophia Children's Hospital (n=5), and child-patients and their parents (n=8). To pilot the prototype, tests were also done with Master's students (n=5) to check for any bugs or limitations before evaluating the design with child-patients and parents.

Evaluation Plan
Evaluation with Experts
Evaluation of Prototype with Students
Refining Based on Previous Evaluations
Evaluation with Child-Patients & Parents



Evaluation Plan

The evaluation plan, objective, and research questions.

The design is first shown to the experts to see if they find the game useful and fit into the EEG Station.

Then the prototype is piloted with students to check how they play the game and if there are any major flaws in the prototype.

The game is tested to see children's interpretations of the game and if children feel comfortable having conversations and asking questions.

Ideally the prototype would be tested during an EEG exam but for ethical considerations, the evaluation of the design was chosen to just play with and to see their interpretations of the game. An EEG test is already difficult and uncomfortable for children, and they should not be subjected to something that may cause them more anxiety.

Objective

To identify if the Wavy Game fits into the workflow of the lab technicians in the CBL and if it creates a safe, comfortable environment for children to explore and learn more about the EEG on their own terms.

Main Research Question

What aspects of Wavy help create a safe, explorative environment for children to learn more about the EEG on their own terms and what can be improved?

Evaluation with Experts

First the designed space and Wavy game is shown to experts to evaluate the design.

Research Objective

The design of the space and the Wavy Game is shown to experts, lab technicians and neurologists at the Sophia Children's hospital to see if it fits into the workflow of the CBL EEG station and if they think it would be a useful tool to help have conversations with children.

Main Research Question

Does the design of the space for the EEG station fit into the workflow of the lab technicians at the CBL?

Would the Wavy Game assist in talking to child-patients about the EEG?

Method

A presentation with parts of the research and ideation were shown to give a background of the reasoning of the design to experts (n=5). Then a description of the space was shown. Afterwards, a walk through was done of usage storyboard, followed by showing the visual effects, and of the demo of the interactive game.

Questions were asked about the different areas of the design and an open dialogue to discuss feedback and possible improvements to the design. The full set up of the evaluation and results with experts can be found in Appendix J.

Participants

A Zoom presentation and interview is done with 3 participants, two neurologists and the head lab technician. In a separate interview, two other lab technicians were interviewed at the Sophia Children's Hospital.

Limitations

The main limitation of the study is as stated earlier, it would be most realistic to do during an EEG and may be difficult to imagine all parts of the design working together. The entire set up should be tested in future studies. The visual shown is also maybe too abstract for non-designers, a more realistic render would aid in participants understanding the design.

Results

Although there was a booklet to fill out by the experts, it was forgotten to be used by the experts and an open discussion was more comfortable for the participants to discuss their opinions.

Initial Reactions

"Something new and different"

The initial reaction to the EEG game was positive and a bit surprised. The game is different from the traditional way of watching TV.

The Space

The lab technicians did not think the shared EEG station space interrupted their workflow.

Workflow

The lab technician said that the measuring of the head and choosing of the cap should occur before the game starts.

"It would be nice if it could be incorporated into the selection of the cap"

"It's better that a game tells them [the children] to close your eyes than a lab technician"

"As long as you have music you have to keep your eyes closed"

The lab technicians wanted the game to be more incorporated into the EEG appointment. This would make the EEG experience more interactive, including music to tell the child how long to keep their eyes closed, as children sometimes do not like being told what to do by a doctor or lab technician.

Playing Independently

"I think it's better if they have to figure out the game for themselves"

"It takes a long time to set up an EEG [would be good if they are distracted]"

Some lab technicians thought it would be ok if there was some challenge in playing the game as this would help distract the child while playing the EEG. This would help children have personal motivation to play the game

Having conversations about the EEG

One lab technician commented that children are conditioned to not ask questions especially in the hospital.

"I like the idea of more ownership and explanation, but there needs to be a moment"

The game would ideally be 'the moment' that children would feel comfortable to ask questions. This was something that needs to be seen during the evaluations with children.

Affecting the EEG Test

The lab technicians were mainly concerned about how much the children would move around during the EEG as this could overstimulate the child. One lab technician stated it would be best if everything was in reaching distance and the child would move around a lot.

Durability

Lab technicians had concerns about durability as the children are likely to throw things around.

"It's ok when the child is throwing around their parent's phone, but not when they are throwing our stuff"

Children do unexpected things with things they are given, so making sure the physical pieces are durable or are not able to be thrown around is important.

Inclusivity with Children

The lab technicians said that children with lower developmental levels could be interested in the lights and sounds, while their parents move the pieces.

Age Appropriateness

There were concerns about what age the game would be appropriate for children - this could be checked in the testing with parents and children. The character may make a certain age group for children younger.

Sound

"Sound is better for little children"

Sound is a very important aspect of the game and should be chosen wisely. It could make the game more novel and interesting, relating to the theme of curiosity discussed in the research. Sound could also aid in creating the different exercises for the children.

Recommendations

- The game pieces should be in hand reaching distance for the children to not overstimulate them or suggest making a lot of movement
- There could possibly be a way to choose the age or level of the game to tailor it for younger vs older children.
- For the eyes closed exercise, it would be nice if the game could play music for how long the children's eyes need to be closed.
- More sounds are necessary to make the game more interactive and fun

Evaluation of Prototype

The interactive Adobe XD prototype is played by students to test how well it functions. Notes and results can be found in Appendix K.

Research Objective

To test the functionality of the interactive game, if there are any problems with buttons or connections, and to see if it is understandable how to use it. The other goal was to see if it sparked curiosity for participants and whether they ask questions about the EEG.

Main Research Question

Are there glitches or difficulties when playing the prototype?

Does the game help start conversations about the EEG?

Method

The interactive game was given to participants, see Figure 6.O, they were told that the game was representing an EEG and a part of the Child Brain Lab, but without verbal instructions of how to play. The participants played through the game as far as they could. Participants were told to feel free to ask if they wanted to.

Participants

Five Master's students participated in the evaluation study.

Limitations

Because these are adult students, they have different capabilities than children. Because some of the students were design students as well, they have knowledge about how user tests are conducted and what questions to ask to help understand what is happening better.

Results

From testing the game, it was found that participants wantedt to take off the electrodes after placing all 5 electrodes. This gave a feeling that the game was 'finished' and that they should stop playing.

There was a lack of introduction to the game, as the game just begins with putting an electrode. More context of what is happening is needed.

All participants asked questions about what the electrodes were and what was happening - which sparked conversations about the EEG.

Recommendations

- To give a more thorough introduction for the game so that the context is understood
- A start over button or go back to remove electrodes, as after placing all the electrodes, the game feels finished

Figure 6.O: A student testing the Adobe XD prototye

Refining Based on Previous Evaluations

Based on the previous evaluations with the experts and students, some updates to the interactive game were done before showing it to child-patients and their parents. These updates can be seen in Figures 6.1.

Introduction to the Game

An introduction to the context of the EEG is given with the character going through similar steps as the child, measuring their head and choosing a cap, to introduce the EEG station steps while playing the Wavy Game.

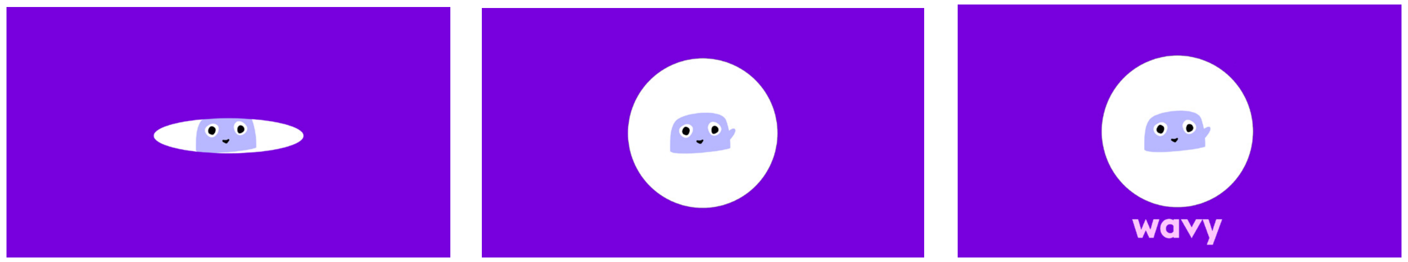
Integrating into EEG Appointment

The experience now is step-by-step, as the child sees Wavy get his head measured, they also get their head measured and choose to move forward in the game.

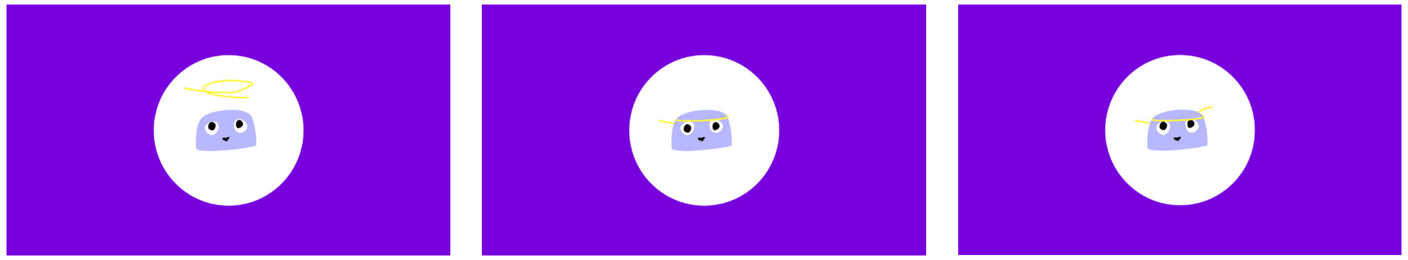
Go Back / Start Over Button

A start over button is added so that the electrodes can be placed again. Due to time limitations with creating the prototype made it difficult to have a button to remove the electrodes one by one, and as in the real game, pieces could be moved around physically it would be less of an issue.

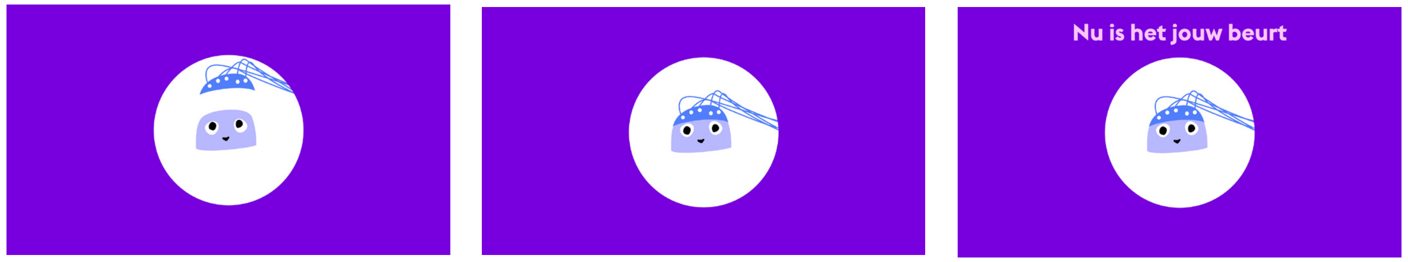
More Introduction to Wavy



Head measuring integrated



Choosing EEG cap added



Adding a Go Back button

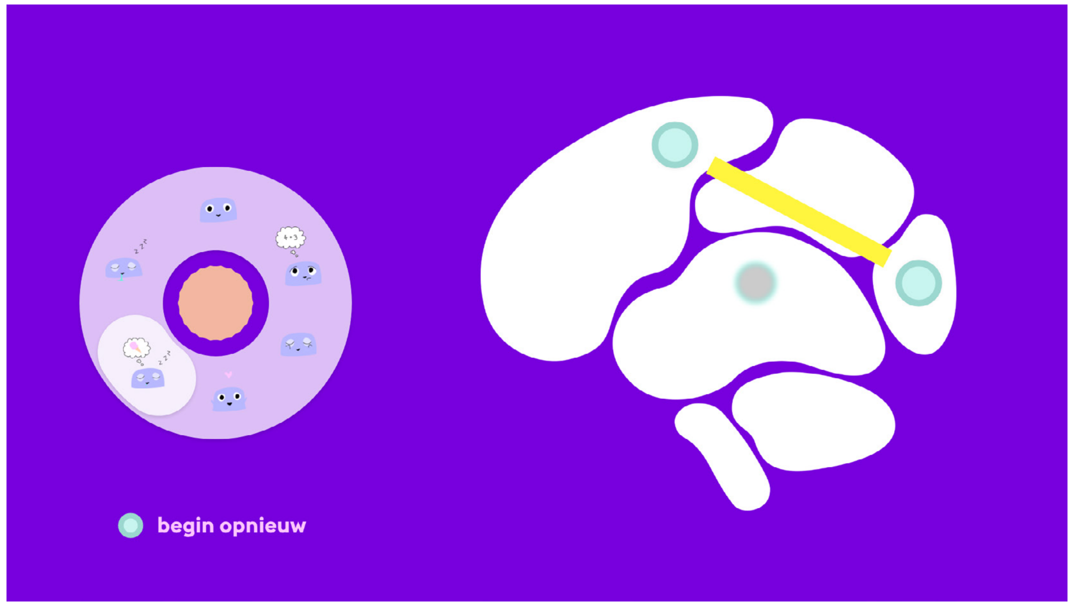


Figure 6.1: The additional steps to the Wavy game

Evaluation with Child-Patients & Parents

To test the final design of the concept, an online interactive prototype that shows some of the functions of the game is used to test with child-patients that have had an EEG test and their parents.

Research Objective

To evaluate the design of the EEG game, Wavy, on whether it creates a safe, explorative environment for children to learn more about the EEG on their own terms. To learn what children interpret from the game, whether the game sparks conversation about the EEG and if it causes anxiety or stress for children.

Main Research Question

What aspects of Wavy help create a safe, explorative environment for children to ask questions and have conversations about the EEG?

Sub Research Questions

Sub research questions were also created to do with the different topics that were explored in this project, such as anxiety and distraction, and with functional and logistical questions about the Wavy game

The full research set up and questions can be found in Appendix L.

Method

User testing is done by creating a prototype that has some of the functions of the game, with the main goal of finding what children interpret from the game and whether it creates a safe space. The interactive Adobe XD game can be played in person or online.

A small introduction is given to the child-patient and parent to give context of the CBL and when the game would be played. Child-patients are asked to start to play the game, but if they need help from their parents or to ask more questions to feel free to do so.

After playing the game, participants are asked interview questions about the game, and then shown the full visualization of the game and room to give a better understanding of what the final design is.

An open discussion (with structured interview questions) is done with participants to ask about how they interpreted the game.

Again-again questions were asked to child participants as this puts less pressure on the child to answer positively (e.g."Would you like to play the game again?").

The full interview results can be found in Appendix M. The interviews are recorded and transcripts are used for notes. The interviews lasted about 30-45 minutes.

Participants

Child-patients (n=3) and their parents (n=5) participated in this study. In one of the interviews, the child was not able to participate, but the parent played the game. One of the tests was done in person at the hospital after an EEG test, but due to COVID-19, three of the tests were done online through Zoom.

The child-patients were ages between 5-10 and were of relatively 'normal' cognitive development.

Limitations

In an ideal scenario, the testing would be done during an EEG exam using a projector and physical pieces but for time considerations and COVID-19 limiting contact with patients, the virtual prototype allows more participants to be able to evaluate the design.

The prototype is created using Adobe XD and was able to be interacted with but was missing some of the visual elements that were envisioned on Adobe After Effects. Mainly the squiggles representing the waves were not able to be replicated and bouncing lines were used instead. There were also no sound effects used in the Adobe XD game and the game is missing the physical pieces which are two elements that make the encompassing interactive experience.

There was a limited number of participants due to the difficulty in recruiting during COVID-19. Although one of the tests was able to be done in person, most of them were done online. Because there are many elements to this game and they have to be envisioned, it may be difficult for children in particular to imagine how the entire game works together.

Also because the children only spoke dutch, the interview questions were directed towards the parent and the parent was asked to translate some of the questions and answers of the children. This causes difficulty finding answers directly from the child and may cause the answers to be biased from the parent's point of view.

Results of Evaluation with Child Patients & Parents

The interviews were analyzed, quotes and interpretations were clustered by the different topics of the interview set up. The individual participant interviews can be found in Appendix M.

Relating the Wavy Game to the EEG Experience

"Remember when they are measuring your head?" - Parent 3

"Yes yes yes" - Child 3

Children who watched the EEG game could understand that it had to do with the EEG, especially relating to the introduction with the head measuring. All parents would mimic the head measuring movement to their child and they could remember their own EEG.

Having Explorative Conversations About the EEG

All child-participants asked questions about the EEG game to their parents and had questions and conversations about the EEG game.

The younger participants (<8 years old) **found the visuals funny and enjoyable, especially the Wavy character**. The younger participants asked about what the Wavy character was doing, such as

"Is he sleeping or awake?".

The older participant (10 years old), talked to her mother about **the different activities that the Wavy character was doing and related this to the brain waves that were appearing**. She was able to understand what was happening, **get a basis of knowledge to predict what was going to happen next**.

Interactions between Parent and Child

The Wavy game was successful in creating interactions between the parent and child during all the evaluations.

The parents would talk about parts of the EEG, especially the part of the head measuring, as this is part of the exam that is memorable to the child.

Even if the child was not able to control the prototype, **they all actively participated in choosing the buttons to press**.

The children asked questions about what the game was showing to their parents, which the parents asked the researcher for more information.

Understanding of What Wavy is Showing

Because of the language barrier when communicating with the children, there was difficulty in judging how well the children understood the EEG game.

The children would ask questions about different parts of the game. The 10 year old participant related the brain waves to the activity that the character was doing. She would change the knob and comment on what color the brain wave patterns was for each activity the character was doing.

Some of the activities that the Wavy character is doing are very similar to one another, sleeping, dreaming, and eyes closed, and causing children to be confused. Because there is no information 'told', parents also looked for confirmation of what is happening.

"Then what happens when I press 4+3 [the thinking activity]? Can you tell me what is happening here?" - Parent 1

Though, **this lack of concrete information helped invite questions** and conversations because participants wanted to understand what was happening. This could be beneficial in creating conversations between patients, parents, and lab technicians. **But also creates confusion:**

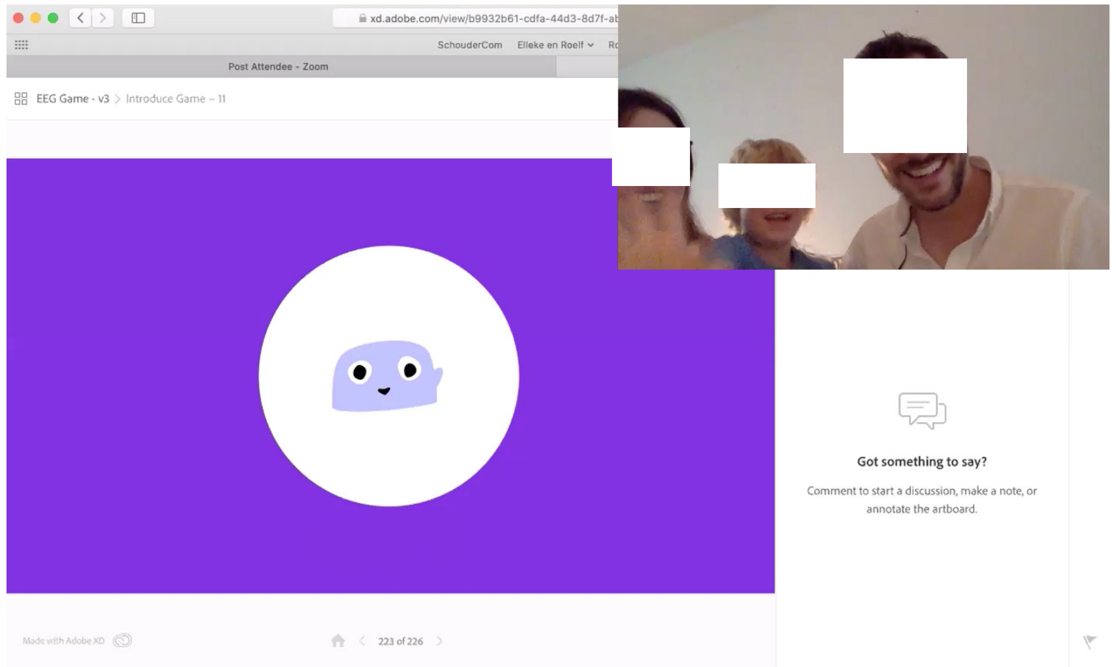


Figure 6.2: During a zoom evaluation, the child enjoying the Wavy character and waving

"Looks very nice, but I don't understand what is happening" - Parent 1

Parent 4 commented that they didn't think that their child would understand the information, although this may have been a bias from the parent's impression, that the EEG is too abstract for children or parents to understand. The child could understand that the brain waves on the prototype were related to ones on the EEG scan. This parent also commented that,

"Having a lab technician, someone who knows what is going on, would be nice to conversations with" - Parent 4

The information is abstract, so much so that parents are unsure of their own knowledge. **They are looking for confirmation from an expert of what is going or to explain what is happening.**

Information that the Wavy Game is showing

The information that was chosen to be shown in the Wavy game was interesting to the children and parents when given verbal explanations, but participants needed more concrete confirmation that what they are interpreting is correct.

"So when there's an explanation, it's very interesting" - Parent 3

I can imagine that if the kid is just given the game and just to figure it out by him/herself what it represents might be very for challenging, - Parent 1

The information shown in the EEG game is interesting but is sometimes difficult to understand with the little use cues.

Step by Step Procedure

The introduction portion of the game helps be one of explanations of the EEG experience as the child is going through the EEG process. Especially for children who have previous negative hospital experiences and where step-by-step explanations help them understand what is going on and feel in control in an uncomfortable setting.

"It is very important for the child to know what to do, because the circumstances are very threatening for the child. If it is explained by a parent or lab technician then it takes away his anxiety/nervousness. You can take away anxiety if you explain everything very well - I think the it [the game introduction] is a great idea" - Parent 3

Calming Effect of Wavy

"I think it will be a calming game, it will calm them [child-patients] instead of making them nervous" - Parent 4

There was this trance or calming effect, where the participants continued to press buttons and watch the effects as the visuals changed. Even if they were saying the game was not very interesting, children and parents still continue to play the game.

Anxiety Caused by the Wavy Game?

The game did not cause anxiety for children playing the game and the Wavy character aided in helping the children feel more comfortable, especially the younger children, see Figure 6.2 When asked about this a parent stated

"I don't see any reason for children to see this as a negative experience." - Parent 1

Understanding How to Play the Wavy Game Prototype

The 5 and 8 year old participants had difficulty playing with the prototype on the computer because they had limited experience using a computer. All children participated in playing and chose which buttons to play even if they were not able to use the computer.

Distraction for Children

Average play time of the EEG game was 8-10 minutes for the participants.

The younger children liked the game and enjoyed playing. But although the children played the game, they all weren't very interested in it. When the 10 year old participant was asked what she thought of the game:

"Boring" - Participant 2

When asked further, she stated that the game was a bit slow and she would like more text or a quiz to play at the end to test her knowledge.

Age Appropriateness

"She finds it a bit boring"

"If there were questions and she had to answer questions"

"And learn about what she is seeing"

-Parent 2

The game was not interesting to older children, in addition to the comments Participant 2 had, parents that also had an older child said that their older children may not find the game as interesting. This could also be due to the fact the physical aspect of the game was missing. Once this participant had physical pieces to play with, she was more interested in playing. The tactile interaction adds to experience and fun of the Wavy game, but also **including age appropriate information is very important.**

Terminology Confusion

For the testing evaluation, the Wavy Game was called a game but it caused confusion with participants.

"It took a bit, because you called it a game, so I thought it was a goal so I thought 'What buttons do I need to push to be successful.' ... 'Am I doing this wrong? What is my assignment? What do I need to achieve?'" - Parent 1

"She thought there would be a real game that she would play" - Parent 2

Terminology is very important and sets expectations for what the users will be doing. This also relates to the previous 'boring' comment that participant 2 said.

Overstimulation

For the virtual prototype, there were not concerns that it would be overstimulating to the child-patient. But there was a calming effect found in the interactive prototype, when one child-participant was shown the physical pieces, she immediately started stacking the pieces, spinning the pieces, and throwing them around, see Figure 6.3.

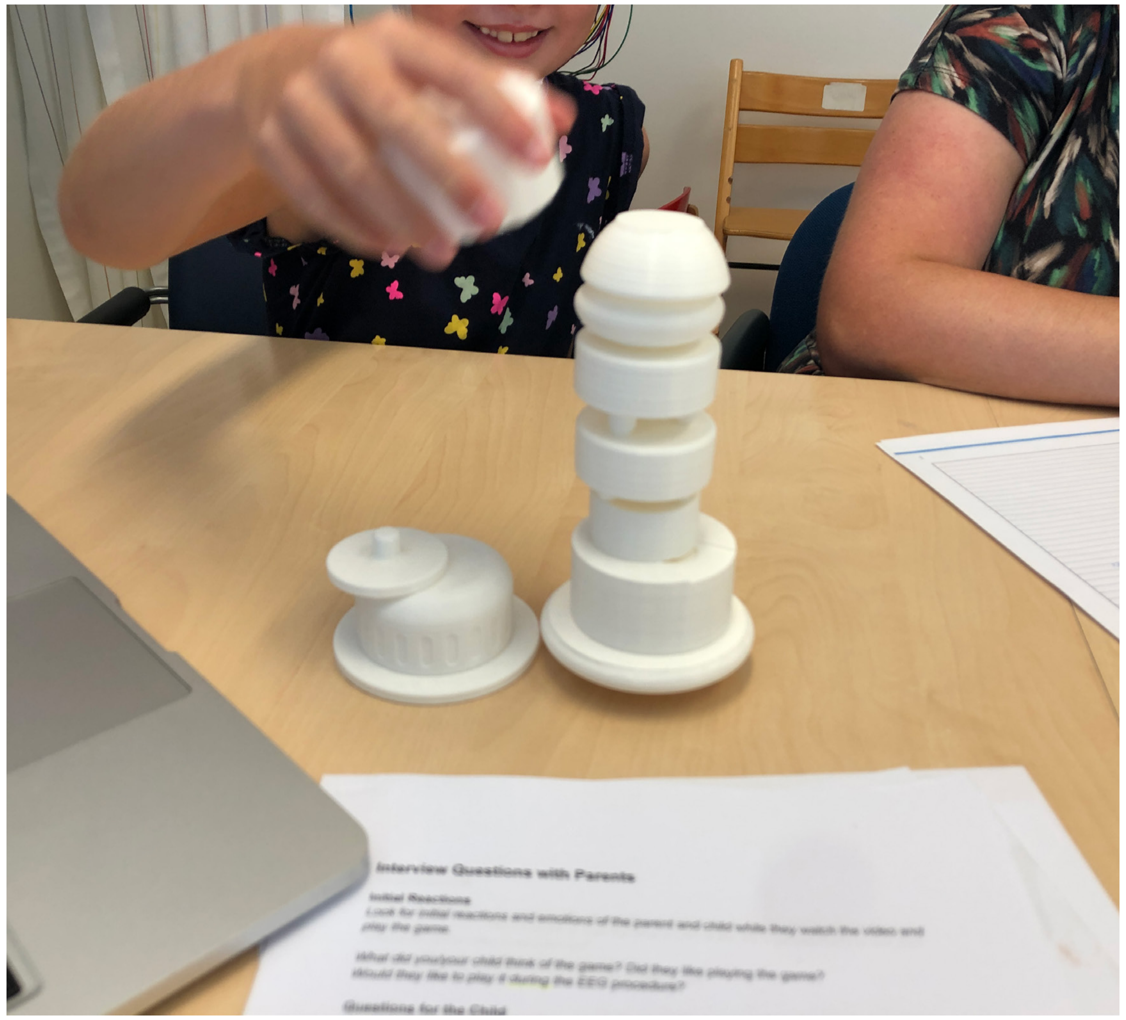


Figure 6.3: Child during evaluation stacking all the electrode pieces into a tower (that was eventually knocked down)

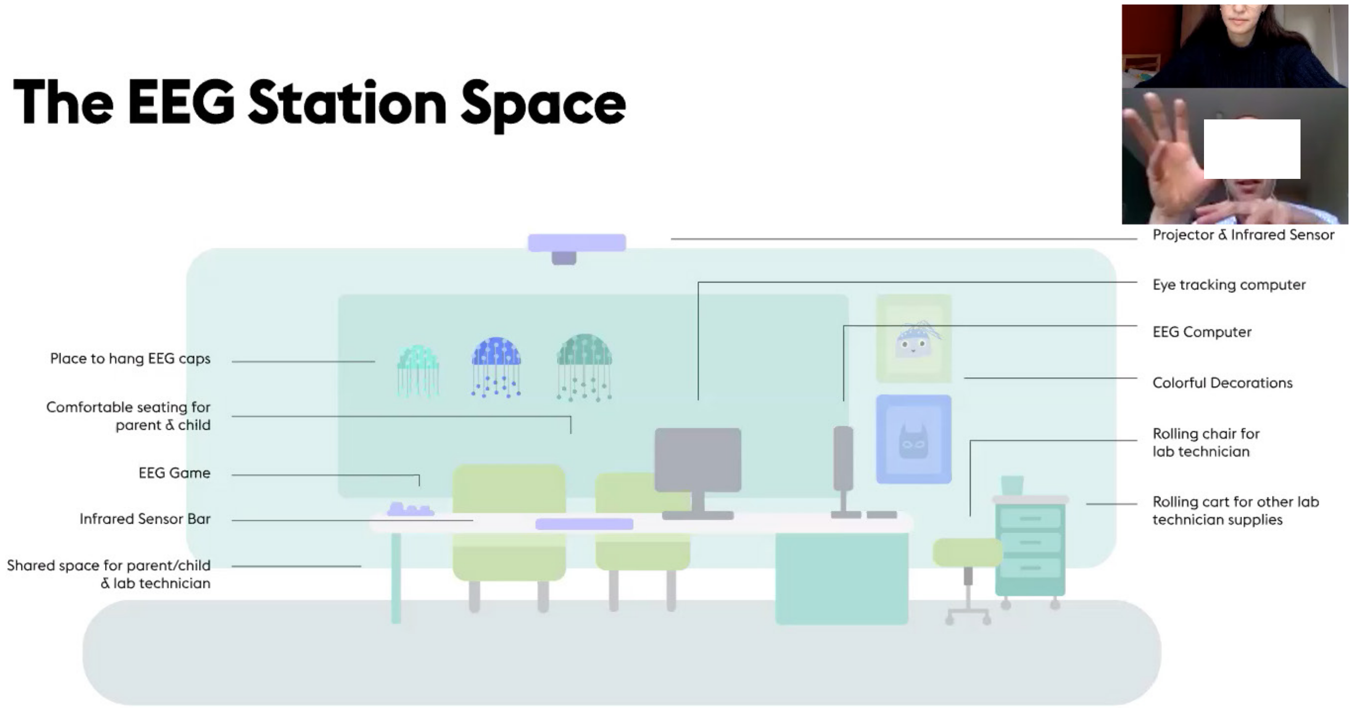


Figure 6.3: Discussing the EEG space with a parent during the evaluation

Stimulating Questions, Conversations, and Interactions

While playing, child-participants asked questions regarding the game and the EEG to their parents and had conversations about the EEG with their parents.

"It would really stimulate him to ask questions of all types" - Parent 3

"He will ask us questions, no doubt about it" - Parent 3

"I think he would be interested in playing with the technician. A communication tool between him and the technician. Of course I can join in a bit, but I think he would be interested in learning about what is going on during the EEG." - Parent 1

Because the game shows what is going on with the EEG, **it gives a moment or space for children to ask questions about the EEG.** They can ask about the different parts of what is being shown, because there is this 'moment' where children are able to ask about what is going on. Also because the game is slow moving, the children are given more time to ask about what is happening.

Regarding the Space

All parents and participants liked the recommendations of the space, that it was a shared space and that it 'celebrated' the EEG more because the EEG caps are shown on the wall, see Figure 6.3.

"I think one thing as well, the design of the room, and that it is very nice that the parent and the child are sitting in the room, at one table, so they are going through this EEG together." -Parent 1

"Maybe the father or mother should put on an EEG cap as well." - Parent 1

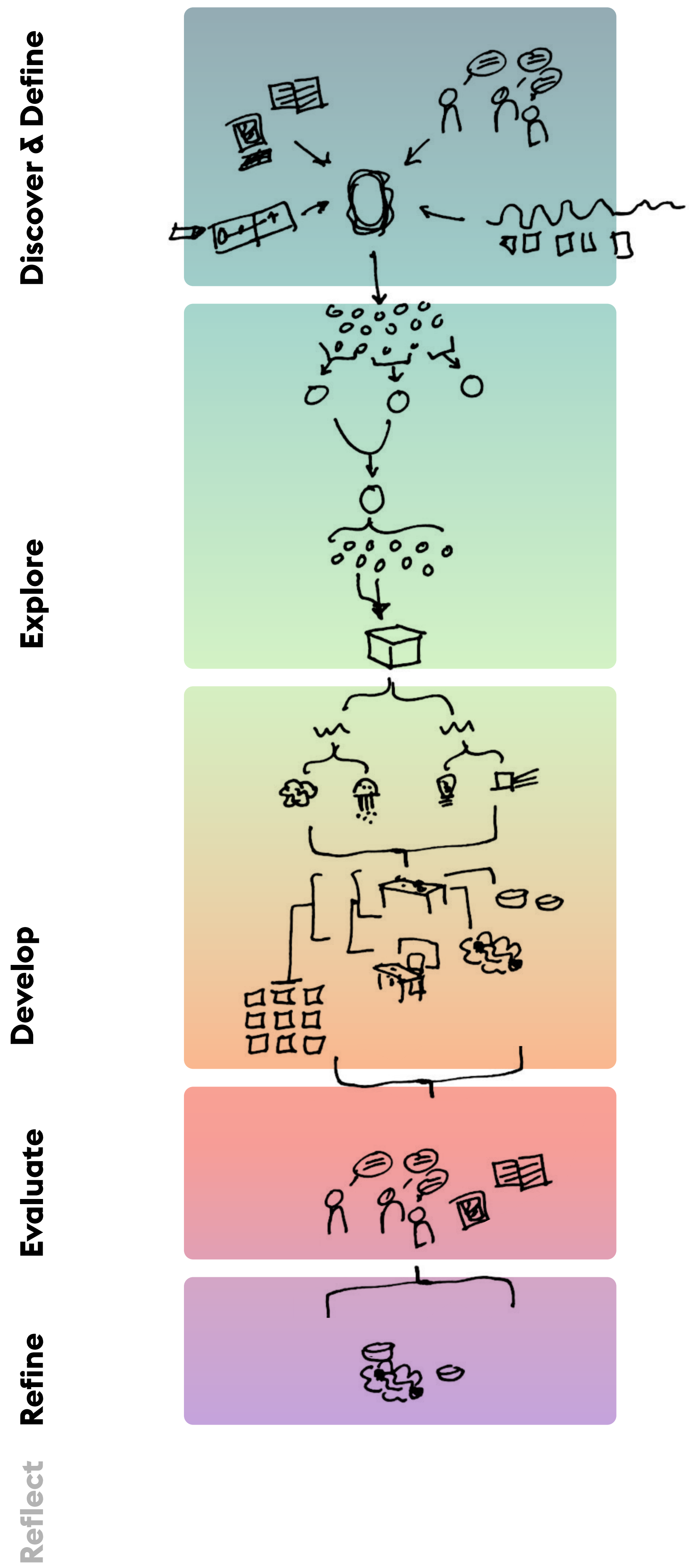
"It's much nicer place than it is now" - Parent 3

The shared space gives a feeling that the patient is not alone and is together with their parents and that they are doing the testing together. **It helps the child feel more safe.**

Refine

The final refinements of the design after the evaluations are in this chapter. The envisioned visuals are created in Adobe After Effects to give a full visual of the final design. The visuals are then tested with a projector and the physical pieces.

Final Screen Flow
Incorporating the Virtual & Physical



Final Screen Flow

The game was recreated with the envisioned graphics in Adobe After Effects to show all of the visuals designed.

After the evaluations, a final refinement to the EEG Design was made and a video showing the final envisioned visuals is created using Adobe After Effects, see Figure 7.0.

Visually, the game is now integrating the brain waves as imagined, with squiggles instead of straight lines, and the animation flows more smoothly, though that can not be seen in still images.

The final screen flow integrates a more step-by-step workflow for the Wavy game so that the child-patient can complete the procedure at the same time as the Wavy character. This is to give more time and explanation to the child, as during the evaluation it was said that repeating explanations is very helpful for children so that they understand what is going to happen.

Therefore, it is designed that after each step, the user turns the knob to continue the video, seen in steps 1, 3, 6, and 7. For example, the Wavy character gets his head measured, then the experience waits for the child to get their head measured, and when the user turns the knob, then the video continues.

More textual instructions are given in the game so that parents can feel more confident explaining to their children and older children can learn more autonomously. Such as in screen 11, where it explains that a second electrode is needed to see a full brain wave.

There are also extra facts inside of the experience, such as in screen 15, as Wavy is played, users can learn new things about the EEG.

Figure 7.0: Final design of the Wavy experience

Incorporating Virtual & Physical

The visuals from the game were incorporated together with the physical pieces to see the entire set up of the design in this and the following pages.

The overall look of the visuals was what was envisioned, see Figure 7.3. The contrast of the colors showed up well and the text was legible.

The individual knob and electrode pieces cast minimal shadows and did not block the visuals from the projector. Because the projector casts images over all of the space, future considerations could be to make more 'space' for the electrode pieces so that the brain image is not projected on the electrode pieces or to somehow incorporate this more into the game.

The text added on the bottom of the knob was seen to be blocked by the hand turning it, see Figure 7.1, but the interesting 'facts' and other information were placed above the knob and were able to be seen, Figure 7.2. Considerations for placement of important information should be above the place for hands.

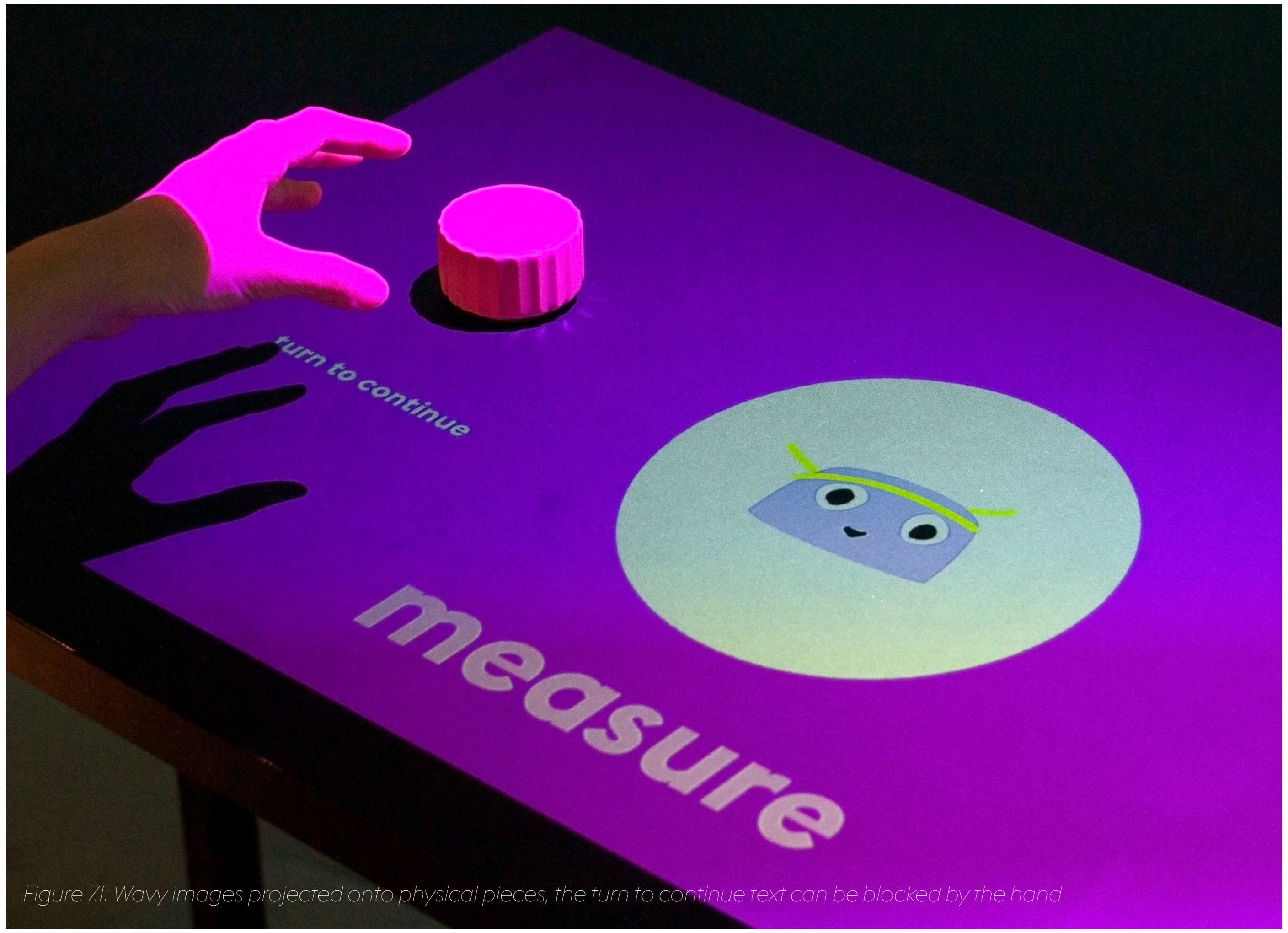


Figure 7.1: Wavy images projected onto physical pieces, the turn to continue text can be blocked by the hand

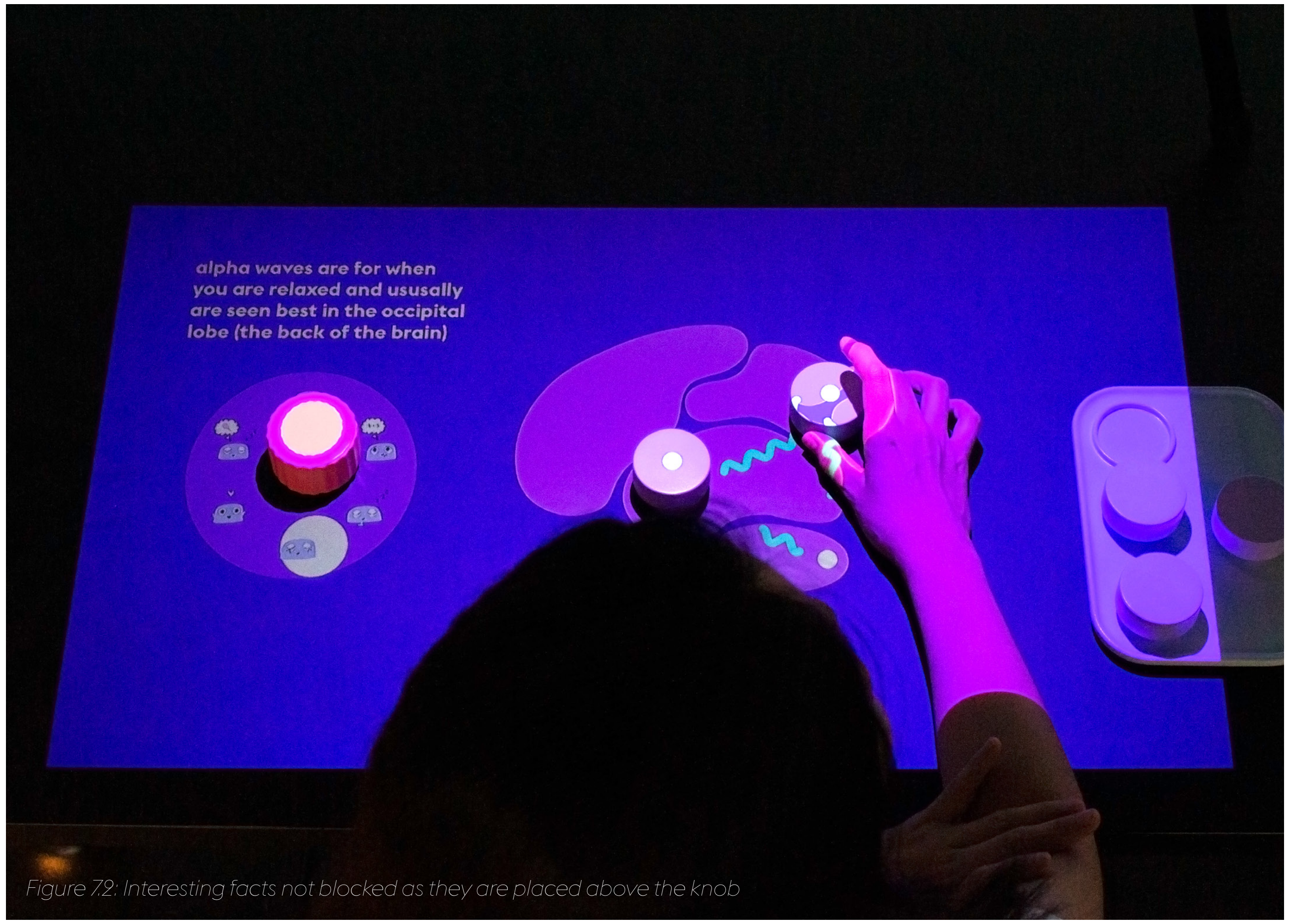


Figure 7.2: Interesting facts not blocked as they are placed above the knob

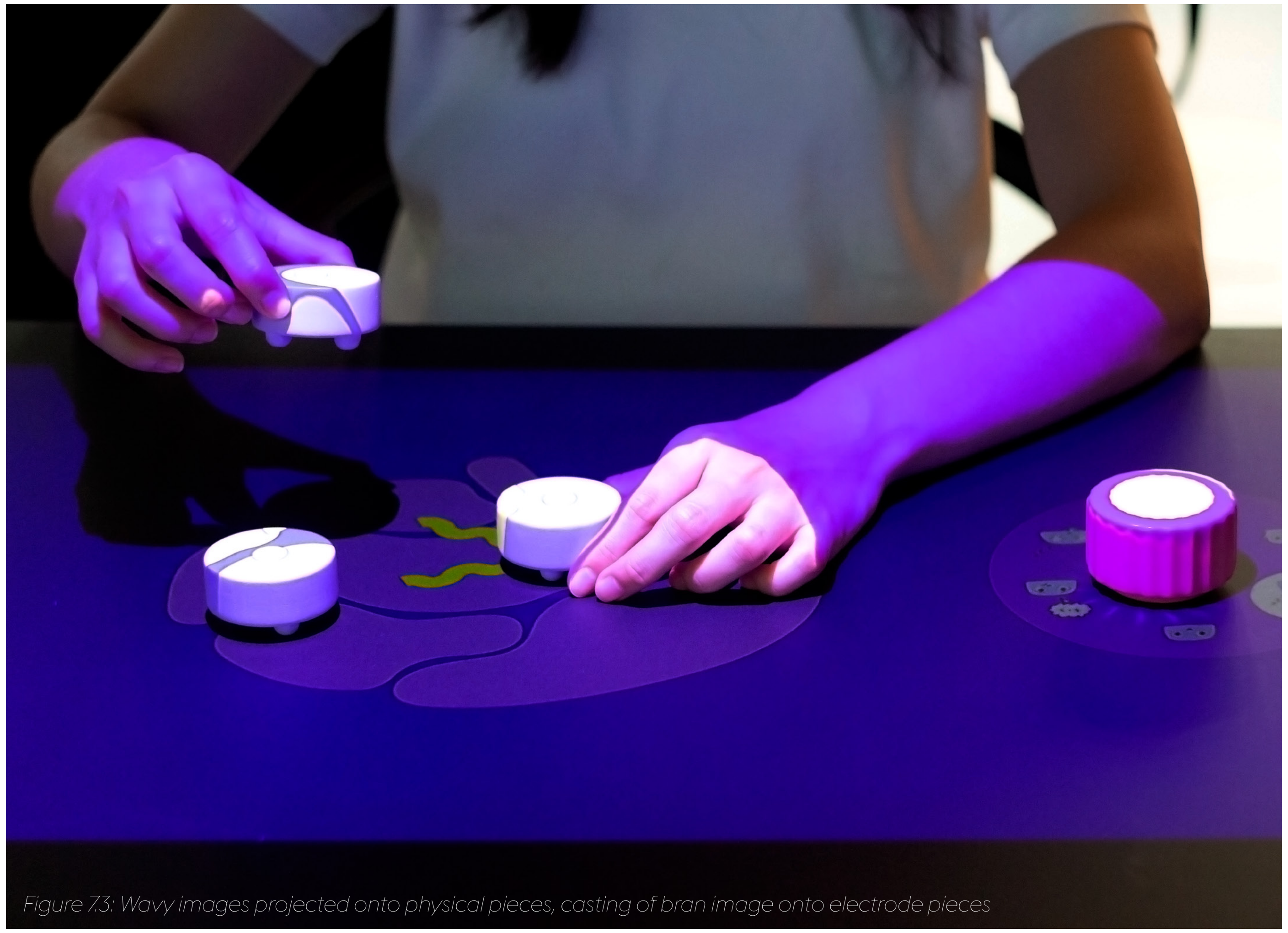


Figure 7.3: Wavy images projected onto physical pieces, casting of bran image onto electrode pieces

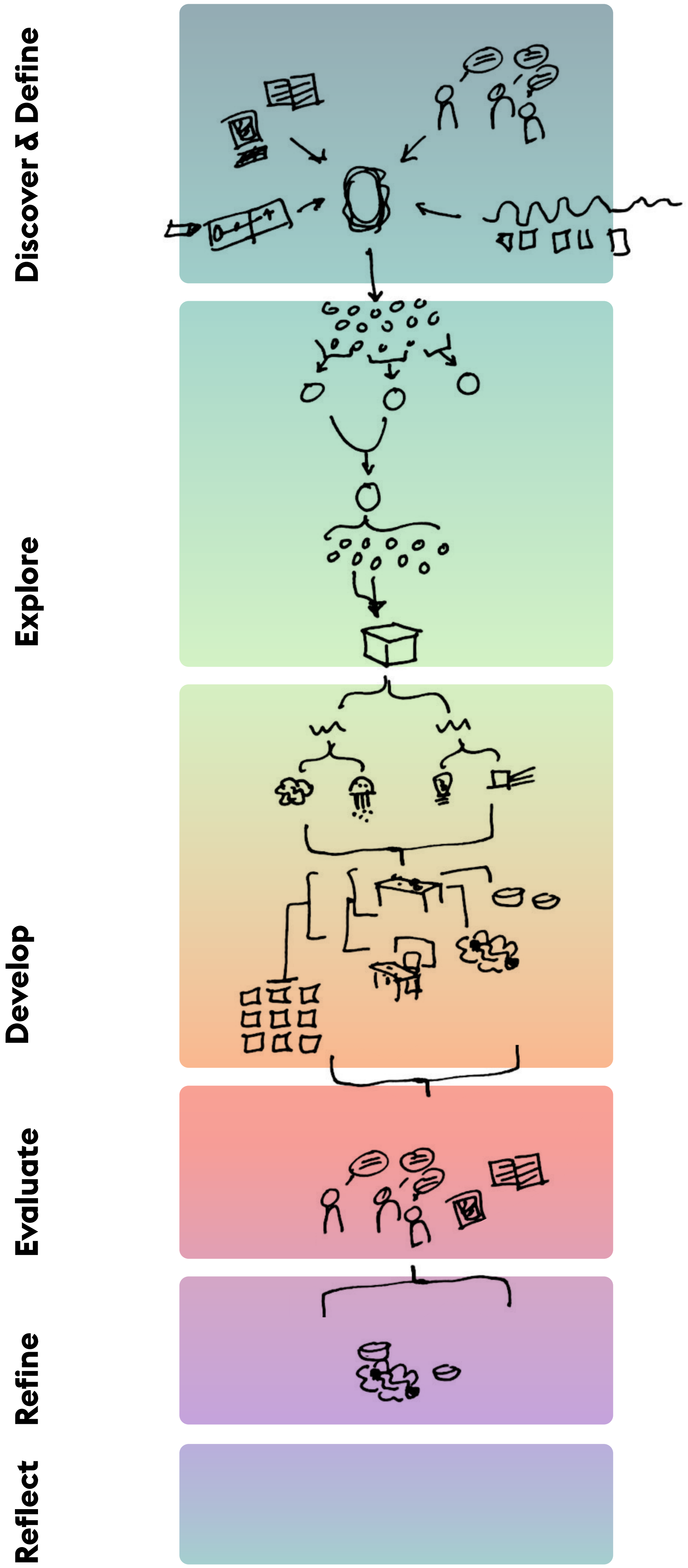
wavy

an interactive experience enhancing curiosity for child-patients to explore the electroencephalogram (EEG)

Recommendations, Discussion, & Reflection

Based on the evaluation and final design recommendations are made. A general discussion is done looking back at the goals of the project. A reflection on the design process is done.

Recommendations
Discussion
Reflection



Recommendations

Discussing the results of the evaluations & the final design and making recommendations for the next steps.

Testing the Design During an EEG

Now that it has been established that the Wavy Game does not show information that creates anxiety or more stress to children, the next step is to test the game during an EEG. Testing should focus on whether children are comfortable playing Wavy while having an EEG cap or electrodes on their head.

For future testing, it is necessary to have the lab technician guide the child and parent through the game, to see if it aids in having conversation about the EEG. This should also be done to see if it impairs or gets in the way of the lab technician in completing the tasks he or she needs to do or if it helps lab technicians explain the EEG to children and their parents.

Clarity in the Wavy Characters Activities

The activities are very similar, sleeping, dreaming, closed eyes, so more clarity on their differences may be necessary to give some sort of confirmation to the user, possibly through text or more identifiable imagery, to help understand what is happening.

Understanding & Information giving

It was seen in the evaluations, that users needed more concrete confirmation that what they are interpreting is correct. This can be verbal by the lab technician or by textual information that is written.

The lab technicians role in the Wavy game is important, they are leading the parent and child through their journey in the CBL.

More information could be shown in text to the child-patient and parent, to help guide them more through understanding what they are being shown while playing the Wavy game, but this should be done gradually. The abstraction of the game leaves room for interpretation and helps invite conversation by the child.

Calming Effect of Wavy

The calming effect of the game is beneficial for the appointment as it will be played during a moment of anxiety for child-patients where they need to become more relaxed.

When testing further the design, heart rate and emotion could be monitored to see if there is a measurable calming effect of the game.

Parents Caution

Parents can be cautious about what they tell their children, it is understandable that this is more so when the child has gone through trauma in the hospital. There were concerns about the more difficult questions that the child would ask.

"So really simple questions but also philosophical questions. He could ask 'Why are we doing this', but he could also ask 'Why is this for me?'"
- Parent 3

Unnecessary stress and anxiety should be avoided for children but avoiding questions may also lead to anxiety. As children can ask questions that are difficult to answer sometimes, lab technicians who lead the EEG appointment are better able to answer these questions.

Future testing should see what questions children ask and if there are ways the game can be adjusted to answer those questions or for the lab technician to be prepared for the questions.

Physical pieces

The electrode pieces need to be tested to see if children identify them as electrodes.

If children have trouble identifying the pieces as electrodes, smaller, more pieces, and more colorful pieces may aid in making them more similar to electrodes.

Adding a cord could also aid in making the pieces more similar to an EEG electrode. This would also help reduce the chance of children throwing or breaking the pieces.

The knob should have rubber added on the bottom to help reduce slippage when turning the knob.

Integrating the Physical and Virtual Elements

As the prototype created was virtual, a more thorough prototype needs to be created that integrates the virtual projected images with the physical pieces and can be played by users.

Technology Development

Although the IR projection technology that is being used in the game is something that is not new and has been integrated in other products, it still needs to be tested and developed to fit into this game.

The technology should also be tested in the EEG space, as they are expected to not affect the EEG but needs to be tested to make sure that the electronics do not create artifacts.

Game Development

The prototype created for the game did not have all the features and visuals that were needed. The game should be developed to include all the visualizations (e.g. the squiggles for the waves). The game should be developed for the projected images to interact with the physical pieces.

Overstimulation

Overstimulation could be found with the physical pieces of the game. Often children don't do what is expected, so giving a bunch of small prototypes, they immediately start making their own world. The lab technicians were very concerned about what would happen to the game pieces and that children would throw them around.

In order to prevent overstimulation, all the physical pieces should be in arm's length. The visuals of the game should also be set up so that children do not overreach, as staying in one place would help reduce stimulation. the electrode pieces could be attached to a cord to prevent children from throwing them around.

Age appropriateness

The age group was very large and during testing it became very apparent the difference between even an 8 year old and 10 year old is very large. The older children want to learn on their own already and would prefer to read independently. Also they would like to demonstrate their knowledge by doing things such as a quiz.

To make the game more suitable for children of different ages, the game should be broken up for children, possibly 6-8, 8-10, and 10-12. It was seen in the evaluation that the prototype was more suitable for children of younger ages and that older children want to learn more on their own terms.

For younger children, it may be more appropriate to have the information said aloud to help them understand it better, this can be through the game or through the parents, as seen in the testing, they enjoy being a part of the experience.

The Wavy game should be adjusted for different age groups, as children get older they can understand more information about the EEG. Information through text is one way to give more autonomy to older children to learn on their own.

Recommendations continued

There should be a way for child-patients to also show their knowledge, ideally not in a quiz as this defeats the purpose of creating a safe space for children to explore and learn on their own. This should also be explored in the future of the project, other ways to give a sense of accomplishment that the child has learned or created something.

Terminology

The word 'game' caused a lot of confusion for the participants and created different expectations of this competitive game, sometimes causing disappointment for participants when they played Wavy. Participants were ready to do some sort of competitive challenging game.

In the future it could be called an 'experience' although this term is also very abstract and maybe difficult for users to understand what exactly Wavy is.

Projection Visualization

Colors were tested in a projection and although the imagery was visible, colors could be more vivid.

Testing should be done with the colors and projector to make them as close as possible to the visualization.

Although the shadows by the object and hand generally did not block the imagery, the text was sometimes blocked by the user's hand when placed underneath the knob. Text and other elements should be placed carefully to avoid being hidden.

The size of the projection image should also be defined for users.

Sound

Sound was missing from the prototype for the user evaluation but created for the video with the envisioned experience. The sounds should be incorporated into the game and tested with users.

The Space

The shared space aids in a feeling of safety for children. Making the space look more like a living room rather than a hospital room, comforts the child and because there is no ominous chair, it reduces this feeling that the child is going into surgery.

The idea that the parent also would put on an EEG cap as well was very funny and could be tested if this helps the child feel more comfortable. During observations, it was seen that many times children felt embarrassed by the EEG electrodes or the net (if they had to wear one). A feeling of togetherness helps children feel supported by their parents and also can bring humor into the hospital setting.

Adding more knowledge

As the base of the game is created, more interesting knowledge should be incorporated to make the game more interesting and explorative. This could be information such as which parts of the brain show more of which brian waves. Or more information on the different brain waves, such as the beta waves, as when you are awake and alert there are mostly beta waves, but this could be expanded and explain more of the different kinds of beta waves.

Discussion

Discussing the final design, looking back at the research questions, the factors for curiosity identified, and CARE goals.

A look back at one of the research questions:

How to provide patients information about the EEG test by utilizing their own curiosity in an understandable and playful way?

The Wavy experience gives a 'moment' for children to feel comfortable to ask questions about the EEG.

Wavy focuses particularly on the CARE goals: Choice, Agenda, and Emotional Support (Lerwick et al., 2016). Giving a game that children can play and control gives more Choice to the child and also gives them a space to lead the conversation. Wavy also introduces step-by-step the procedure, Agenda, so the child-patients have multiple explanations of what is happening, to give them the best opportunity for understanding. By having a moment to ask questions, it allows parents and healthcare providers to also give more Emotional support and comfort to the child.

In a setting that they are not always comfortable or feel welcome to ask questions, Wavy gives a moment for curiosity. To evoke curiosity, the factors were to create a safe space, anticipation, prediction, and novel & unexpected.

In order to invite curiosity, Wavy creates a safe space. The slow moving pace of the game also welcomes discussion, as there is no rushing to do something that will cause you to lose. The Wavy character is friendly and the visuals like the brain waves are given in an abstract way but that can be related to the results.

Anticipation is built in the space that is designed in a playful way different from the normal hospital room and the projector displays the different visuals building interest. The slow moving pace also adds to the anticipation, waiting for what will happen next.

The text instructions allow a basis of knowledge for the child to be built and allow them to predict what will happen next. This was seen already with the 10 year old participant who was relating the brain waves to the activity.

The projection visuals, the physical pieces interacting, and the waves bouncing & changing, all add novel and unexpected factors to the experience.

The Wavy game is a tool for opening up conversation with the child-patient, for them to feel comfortable and safe in asking questions, in a place where children are often 'accepting' of what is happening rather than curious.

Because these children are veterans at the hospital, it is important to have children feel that they have an understanding of their healthcare and to feel empowered. This game is a part of a step for children to feel comfortable asking questions and understanding what is going on around them.

Reflection

A reflection on the design process and end results.

The end result of this project was an interactive system to help children to feel comfortable in a hospital setting to ask questions about the EEG. The interactive experience distracts from the hospital environment to create a space and moment for children to feel able to ask questions.

Throughout the research phase, in literature and observations, it was seen how children are passive participants in the hospital, which is of course not always intentional. But it was seen that the best child-patient is often one that is more accepting of the treatment. The intention of this project is to bring more engagement for the child in the hospital to feel more in control of their own healthcare by having more knowledge.

There were challenges in not being able to directly speak with the children in the process, due to language barriers and COVID-19 reducing the availability of participants. Adults tend to make assumptions about what children think, so it was very difficult to know exactly the children were saying exactly. But through tone of voice and picking up small words that were able to help the researcher's observations.

The project had many explorative phases and it helped create an interesting design. The main challenge was the many parts of the project, the physical pieces, the virtual images, and the space. Exploring all the different elements is difficult when they all affect one another. Prototyping through various mediums, such as different programs and making low and high fidelity prototypes to just get the idea out of the head and to see how everything worked was extremely important. This also slowed down parts of the process, especially having to recreate the visual elements multiple times, but was necessary because one program was not able to do all that was envisioned. The tools should not hinder the design.

Some of the decisions of the CBL were not made at the same time as when a design decision needed to be made such as choosing the concept direction, which was a challenge at times, but it is the job of the designer to account for this decision making process and to make adjustments (because clients also don't know the end result of a project).

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