EMOTION REGULATION THROUGH SOUNDS FOR PEOPLE WITH AUTISM SPECTRUM DISORDER

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Abstract

This study focuses on supporting people with autism spectrum disorder (ASD) to handle their emotions. It happens more than often that people with ASD have difficulty in understanding emotions, and these emotions escalate to a certain point where the person with ASD can have a shutdown (go into isolation) or meltdown (shouting) [1]. This study helps people with ASD to have more insights into their emotions by a tracking application for emotion regulation. The purpose of the application is to make the user feel more at ease to reduce the occurrence of a shutdown and meltdown. The idea of this study is to give feedback about emotions through sounds where the sounds might embody emotion regulation. The embodiment of emotion regulation means that the user can feel their emotions through the sounds. Sounds are being perceived as natural when using the right sounds. The natural aspect can help to perceive the application as non-invasive, such that the application might fit into the daily lives of people with ASD. The sounds relate to emotions, measured by the proxy of a physiological correlate of emotional arousal (PCEA) with continuous heart rate measurements. This technique comes from the Sense-IT project that investigates the emotional regulation for people with borderline personality disorder (BPD) [2]. This study focuses on creating with the PCEA technique a sound feedback Android application that uses emotional arousal to measure an approximation of emotions. The researcher builds the application through iterations of user interviews and user studies. Thus, the study starts with interviews to gain insights into the user needs for such an application. Interviews help to provide insights into the daily struggles with emotions of people with ASD, and the interviews help to incorporate the user into the study. This study focuses on co-designing. In later sessions with the user, the user can provide their ideas for an application. Eventually, the ideas translate into a working prototype where participants test the prototype based on 1) effectiveness of emotion regulation and 2) gaining insights into whether such an application can exist in the daily lives of people with ASD. To gain the rightful insights, I ask myself the following research question:

1. How can sound effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD?

The user interview results show that people with ASD have recognition difficulties of their emotions because of a stimuli overload. Thus, there is a need for people with ASD to support them with their emotion regulation, that might be possible through applications. The user studies/co-design session results show that the people with

ASD think that the sound can 1) react to mimic/simulate the emotions (with emotional arousal) or 2) react as a nudge where the sound is nudging the user to make the listener feel at ease. People with ASD can use the mimic to gain insights into their emotions via emotional arousal, and people with ASD can use the nudge to calm down or energize. User testing with non-autistic people shows that the participants perceive the working prototype as 1) easy to use, 2) personal, and 3) lets the user control how the application reacts. The application shows to work as calming down and energizing. The participants perceive the tracking data of the application as feedback from the combinations of 1) vibrations, 2) colors (of emotional arousal levels), and 3) sounds/music. It is interesting for further studies to investigate how the application would work in the daily lives of people with ASD. It is also interesting to further explore how to calm down/energize people with active/passive emotional arousal levels. To conclude, the embodiment of emotional regulation through sound is partially present in this study. The (non-autistic) participants see the sounds as a tool to handle their emotion regulation, but they do not feel their emotions through the sounds. Therefore, the embodiment by sound might partially exist for relaxation/energizing, but not for feeling emotional arousal.

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Chapter 1 Introduction and Theoretical Background

This chapter will introduce this research with an overview of the theoretical background.

1.1 Autism spectrum disorder

The target user for this study are people with autism spectrum disorder (ASD). It might be a challenge to describe ASD accurately because of all the existing misconceptions in the field. There are misconceptions that people with ASD 1) work too hard, 2) are too engaged, 3) are not thinking enough, 4) are effortless [3]. But the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5) can shed some light on an accurate definition. According to the DSM-5, ASD means having difficulties in social communication and repetitive behavior, including hypersensitivity (over-reactive) or hyposensitivity (under-reactive) to sensory input [3]. This definition goes beyond the subgroups of classical autism, Asperger syndrome (AS), or PPD-NOS. It shows that this definition provides a broader view that ASD involves a complex spectrum of varieties in the behavior of different people. The difficulties with social communications, repetitive behavior, hypersensitivity, and hyposensitivity might cause problems with emotion handling. The following section is about emotion handling problems for people with ASD.

1.2 Emotions and ASD

People with ASD can have some difficulties in handling emotions. People with ASD might poorly manage emotions if they have an overload of stimuli in their environment [1]. The stimuli can be sensory input from the environment. Those stimuli can arise positive or negative emotions for someone. If various stimuli overwhelm a person with ASD, the person can often experience a meltdown (shouting, self-harm, aggression) or shutdown (withdrawal from surroundings) [1]. Both the meltdown and shutdown arise at unhandled emotions, such that those emotions rise to a boiling point where they are no longer maintained. A meltdown example is that a person shouts at anyone when being upset. An example of a shutdown is that a person stays in bed when feeling lost. The upcoming section explains how people deal with their emotions through emotion regulation.

1.3 Emotion regulation

Emotion regulation is a process in which a person is aware and understands emotions and can change parts of the response to the emotions [4]. Thus, emotion regulation means the ability for someone to notice and comprehend emotions and the ability to change reactions to emotions. One example of changing how to react to emotions is that someone can step away from an emotional situation (verbally or physically). If someone cannot handle emotions properly as people with ASD, they

might have emotional dysregulation. An emotional dysregulation means that *"an individual is unable to accept or change different components of the emotion process and experiences such a high level of emotional arousal that it disrupts effective self-management* [4, p. 273]." Because of the co-occurrence of a meltdown or shutdown, people with ASD might have forms of emotional dysregulation. Both the meltdown and shutdown are the manifestations of not being able to self-manage intrapersonal emotions. Prevention of emotional dysregulation is acceptance of emotions and the ability to change emotion responses [4]. For people with ASD, it also works to use techniques to prevent an overload of stimuli that might cause emotional dysregulation. For example, repetitive behavior is typical for people with ASD [3]. Repetitive behavior helps to know upfront what to expect instead of being overwhelmed by new things. The technique of repetitive behavior might prevent a stimuli overload because the stimuli that occur are familiar to the person. Familiar stimuli might prevent occurring negative emotions. Thus, people with ASD use the technique as prevention to reduce emotions from occurring and not as emotional awareness. It might be better for people with ASD to be more aware of emotions before the emotions escalate to a certain point of no return. E-health technology can assist people with emotional awareness, which the upcoming section further explains.

1.4 Existing e-health technology for emotion regulation

Many e-health technologies assist people with emotion regulation. Most of those e-health technologies are on mobile devices. Several e-health technologies use emotion regulation through rating emotions with scales, such as from 0 to 10 [5], but also a 5-point smiley scale [6], and also affect states [7], or even with photos [5]. The e-health technologies can enhance from simple rating scales to daily self-monitoring in which the technologies give reminders for filling in emotions and other notes [8]. But the e-health technologies can be more advanced by including bio-sensing for sensing emotions through biosensors such as heart rate measurement devices. The bio-sensing comes mainly from wearables, such as clothing [9], glasses [10], or bracelets [8]. The bio-sensing can also take place with smartwatches, which the following examples explain further. One example is the Dynamic Balance project, which measures the stress levels elevation through a smartwatch and gives the user (people with ASD) a call about those stress levels [11]. Another example is Sense-IT, in which the user (people with borderline personality disorder) receives a notification on both the smartwatch and smartphone about an increase/decrease of the emotional arousal from measurements of a proxy of the physiological correlate of emotional arousal (PCEA) through heart rate measurements [2]. The e-health technologies lack something in their interaction. The following section explains this missing interaction.

1.5 Embodied Interaction explanation

Current e-health technologies from the previous section show that tracking data informs the user about their emotions through heart rate measurements. The measurements from the tracking data can make the user feel distanced from the (emotional) data [12]. Representation of emotions can be a notation of numbers, graphs, or words that the user does not relate to because the user cannot empathize with that notation of emotions. A notation of emotions does not grasp the actual emotions. It means that the user cannot feel emotions through the data as a blind man would feel the pavement through his cane [12]. This study investigates the possibility of creating a sense of embodiment for informational data by changing the representation of the data. The idea is to incorporate sound as a modality that can react to emotions and does an attempt for users to feel emotions. It means that the sounds are the blind man's stick for people who do not comprehend their emotions. People who might not comprehend their emotions (like someone with ASD) might understand their emotions through sounds. The upcoming section discusses the relationship between sound and emotions.

1.6 Relation between sound and emotions

Sound relates to emotions in multiple ways. First, emotions can associate with sounds like a musical piece that can be dramatic or uplifting, or a voice that can be stressful or enthusiastic [13]. Second, people perceive sounds as fear-inducing when the sound conditions with a negative experience [14]. Conversely, pleasant and natural sounds can counteract the negative emotions such that the listener might even calm down [15]. At last, calming down with sounds is popular with music therapy. Music therapy is a way in which sounds help to evoke positive emotions for the listener by reflecting the current emotions of the user in tonal arrangements, tempos, styles and then changing the sound characteristics to evoke the desired emotion [16]. The upcoming section discusses how emotions can react to sound through technologies.

1.7 Existing technologies that use sound with emotions

Some technologies incorporate sound to regulate emotions. The technologies can have a purpose of 1) bodily responses to music, 2) making music, 3) music therapy, 4) relaxation. First, some technologies incorporate music that reacts to bodily responses from emotions. One example of technology in which the body responds to music is BioMuse. BioMuse is a technology that uses physiological and kinematic sensors to measure physical gesture and emotional changes for a live musical performance [17]. Another example of sounds reacting to bodily sensations and creating sounds is the Dance from the Heart project. Dance from the Heart is a wearable of biosensors on a dancer that collects the heart activity data (that represents emotions) to create a new musical piece [18]. Thus, music can focus on the

body movements and the emotions of a performer. Second, there is also technology that incorporates making music from emotional data with heart rate measurements. An example of making music is Pulse. With Pulse, the environment in the Hirshorn museum changes based on kinetic and audiovisual experiences of biometric data like the heart rate from the visitor [19]. Third, there is also technology that involves music therapy to support the user in regulating their emotions. For music therapy, there is an example of Echolalia. Echolalia is a technique of echoing during music therapy for children with autism spectrum disorder for improving emotions and communication [20]. At last, there is also technology that uses sounds for relaxation. An example of using technology that uses sounds to be relaxing is the Heart Waves project. Heart Waves is a prototype that gives feedback through relaxing sounds, such as water in stressful environments [15]. Another similar project is Unwind. Unwind is a biofeedback interface that uses nature sounds in response to physiological data to induce calmness and evoke positive emotions [21]. The technologies still lack embodied interaction, which is explained in the following section.

1.8 Embodied Interaction with sounds

The technologies mentioned in the previous section all focus on the awareness of the sounds that urge the user to give their attention to the sounds. When paying attention to sounds, the user can make sounds, have therapy, and explicitly listen to the sounds as relaxation. There is no focus from the mentioned technologies on the possibility for the user to feel the emotions through the data. For this study, the focus is to investigate whether the sounds can embody emotion regulation without losing focus from things that happen in everyday life and whether the user can feel emotions through sounds. Thus, the interest is to understand whether the sounds can embody emotion regulation. It means that this study investigates whether the sounds can be present without needing explicit attention. It might cause a non-invasive perception of sounds. Non-invasiveness might help the target user reduce any unwanted stimuli such that the target user still performs their day-to-day activities. Reduction of unwanted stimuli might support people with ASD to better handle their meltdown or shutdown. This study uses emotional arousal as a representation of the emotions of the user. The next section describes emotional arousal.

1.9 Emotional arousal

The measuring of the emotional arousal in this study comes from the Sense-IT application that measures a proxy of the physiological correlate of emotional arousal (PCEA) through heart rate measurements [2]. Emotional arousal helps to measure an approximation of emotions. Emotional arousal stands for the activeness or passiveness of the physiological and mental state of a person [22]. With emotional arousal, it is possible to show whether a user is under-aroused or over-aroused.

Thus, the emotional arousal might show whether the user experiences too many stimuli or too few stimuli in their daily lives.

This study involves the user through co-creation to investigate whether the built prototype matches the user's needs. The subsequent section is about co-creation.

1.10 Co-creation

Previous studies [23], [24] show that there is misjudgment in ASD research because ASD studies do not always involve people with ASD. Therefore, this study involves people with ASD through co-creation. The co-creation means that the target user is part of the design process to meet their needs. For this study, it means that the user is involved in user interviews, co-design sessions, and user testing. The user can give their opinion about the design and development process by giving their opinion, making designs, and testing prototypes. The user involvement intends to prevent a mismatch between the intended use of the application and the actual use. User involvement provides insights into how the target user wants to use the application before it is fully functional.

1.11 Research questions

I ask myself the following questions for this research.

1. How can sound effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD?

    a. How do people with ASD experience emotion regulation, and what is missing in the emotion regulation for people with ASD?
    b. What are the requirements from people with ASD about the emotion regulation sound application?
    c. In which ways can sound give feedback about emotional arousal?
    d. How do users perceive an emotion regulation application that provides sound/music based on their emotional arousal levels?

The following chapters give answers to the research question and sub-questions. The answers to some questions are in several chapters through iterations. Also, sub-sequential chapters might answer in more detail than the previous chapters because of the additional information discovered during the design research process.

First, the next chapter describes the method of this study.

Chapter 2 Method

The method for this study is a combination of user-centered design (UCD) and co-designing.

A user-centered design (UCD) approach is the overall approach of this study and combines the tools/decisions for co-design later described in this chapter. The following figure shows the process of UCD.

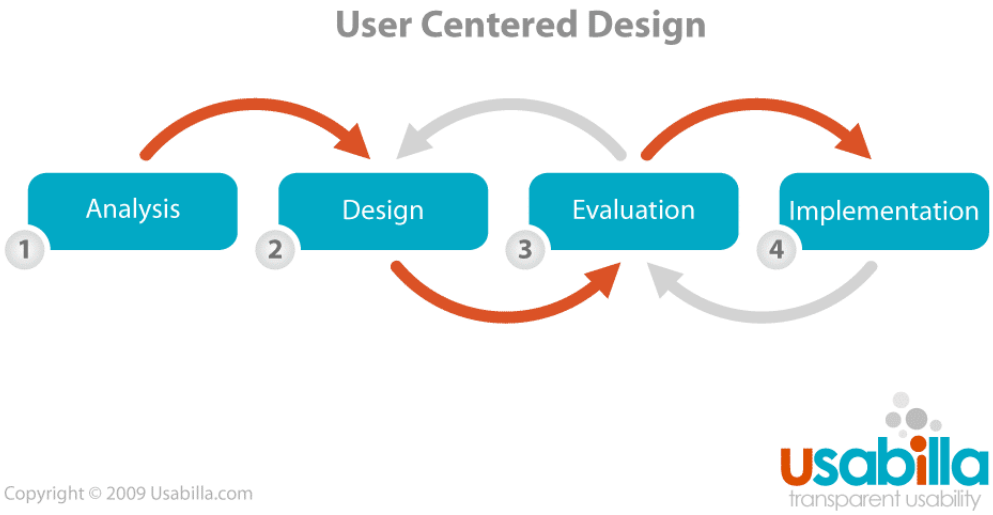


Figure 1 - UCD approach [25]

The UCD approach shows that the design/development process is recurring. Revisits of the design/development process take place from new information. The steps are analysis, design, evaluation, and implementation. There are iterations with user involvement that result in designs, evaluations, and prototypes (implementation). The following text gives a better view of which materials the researcher can use in the different iterations.

Co-designing means that the stakeholders (such as the target user) other than the designers are part of design making by giving them a voice in the early stages of the design process [26]. Co-design adds to studies through crafting, discussing, ideation, or prototyping. An example of crafting is with images, sand, or Kinect [27]. Examples of discussing are assignments before the session, placing cards on a 2D map, map activities on a timeline, filling in a form about the day, drawing or placing smiley stickers in own environment, or weakness/strengths cards [28]. Ideation examples are:

- working with a tangible prototype,
- using a whiteboard,

- redefining the problem,
- solve the problem with concrete objects,
- persona making,
- add functions to physical objects,
- roleplay with a concept or tangible items,
- create scenarios,
- discuss scenarios with cards,
- recreating a situation with Lego,
- placing ideas on the wall which translate to requirements by prioritization,
- create a prototype from tangible material [28].

The examples for prototyping are:

- testing an early prototype,
- working with the prototype in context,
- use a human-controlled prototype (Wizard of Oz) [28].

In each of the examples, researchers involve stakeholders.

Throughout the design processes for this study, the target user has a say with interviews, 2D mapping, sketching, and user testing. For every stage, the ideas translate into requirements and prioritization. The following figure shows the entire design process for this study.

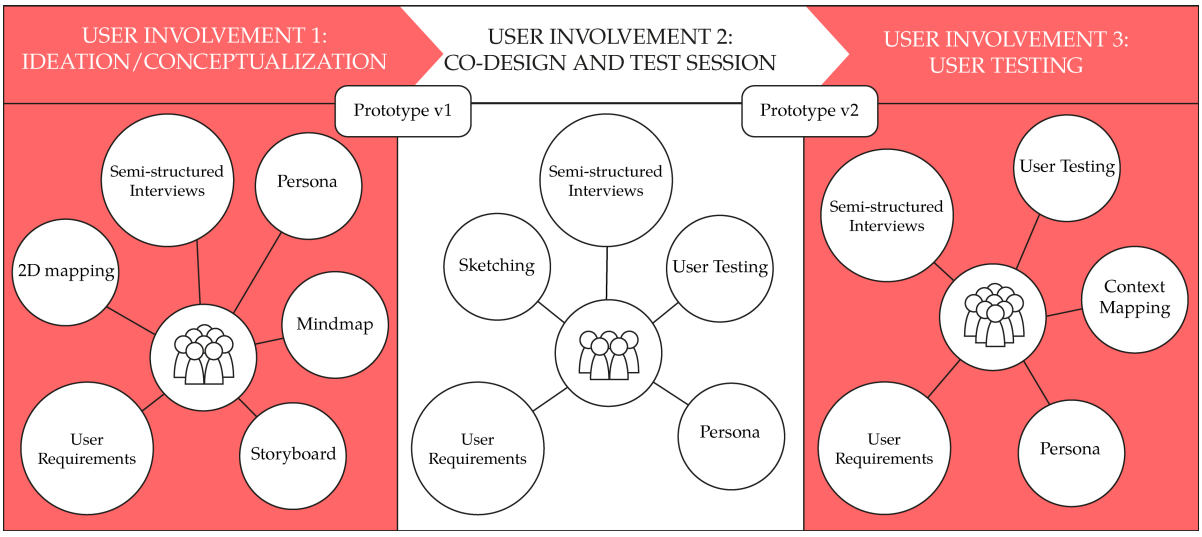


Figure 2 - Design Process figure made by the researcher

Figure 2 shows that the design process comprises 1) ideation/conceptualization, 2) prototyping, 3) testing. Each phase has co-design tools that help to provide insights into the user's needs. The design and development process includes the following co-design tools that are all used during this research:

- **Semi-structured interviews**
  Semi-structured interviews take place at different stages, such that the target user provides insights into their needs by words. A discussion can exist where the researcher provides a particular idea/concept or scenario, and the target user can give their opinions. Semi-structured interviews show that the researcher defines topics beforehand, which are the content of the interviews with the target user [29]. The researcher makes questions from the pre-defined content. The researcher constructs questions with 1) introductory questions, 2) follow-up questions, 3) specifying questions, and 4) direct questions [29]. Thus, the interviews contain pre-defined questions, and the researcher can deviate from the pre-defined questions to gain more insights.

- **Persona**
  A persona describes a typical user for the application [49]. The information for the description comes from the interviews and maybe some fictional information (like a name and picture). The researcher can use the persona during the design and development process to understand what the needs are for the target user.

- **User Requirements**
  User requirements are the requirements that come from the information that the participants provided during the semi-structured interviews. The researcher analyzes answers, remarks, or observations and translates them into requirements. The user requirements show the user needs for the application.

- **2D mapping**
  The researcher creates a map that has two dimensions. For this study, the map is about particular emotions where the dimensions are the intensity of emotions (vertical axis) and quality of emotions (horizontal axis). The target user places cards on this map about their daily activities. It means that the target user links activities to emotions.

- **Storyboard**
  The storyboard is a visualized scenario about the application in daily life [30]. The researcher can create a story about a typical user who uses the application.

- **Mind map**
  The mind map can provide a better view of a particular topic. A mind map has a topic in the middle of a map. Around the middle topic, there are associations with that topic. The information from the participants translates into a mind map, but it can also include information from the literature.

- **Sketching**
  The target user sketches their wishes for an emotion regulation sound application. Restrictions urge the target user to think simply about sketching, such as sketching on a single page and a time limit of 15 minutes for sketching. The target user gives insights (through sketching) into what they find is necessary for the application.

- **Prototyping**
  The prototyping in this research means that information from the interviews with participants translates into a prototype. The participants review the prototype. Feedback from the participants translates into improvements to the prototype. Participants also test the next version of a prototype.

- **Context Mapping**
  Context mapping means that the participant describes the context of the experiences with the application on a timeline [31]. The participants write what happens in their day on a timeline with information about the usages of the application. The context mapping is a self-report in this study.

- **User testing**
  The user testing takes place in multiple steps to gain insights into different versions of the application, such that the research iterates towards an application that is in line with the needs of the target users. The target user tests different versions of the application based on the insights of the different phases.

Participant numbering

The participants receive a number in each user involvement session. The numbering is increasing, and it starts with 1. As an example, PP1, PP2, etc. Some participants take part in more user involvement sessions, where the participant has still the same number.

Participant recruitment

Recruitment of the participants takes place differently for the people with autism spectrum disorder (ASD) and non-autistic people. A change in supervision causes the last user testing to take place with non-autistic people. The researcher recruits the people with ASD through acquaintances that might be familiar with doing ASD research and patient associations about ASD. The researcher recruits non-autistic people by asking acquaintances if they want to take part. Eight people took part in the first user involvement. Five people took part in the second user involvement, from which three participants also took part in the first user involvement. Nine

people took part in the third user involvement. Nineteen people in total took part in the user involvement.

The next chapter states the first user involvement.

Chapter 3 User Involvement 1 - User Interviews

This chapter shows interviews with the target user (people with autism spectrum disorder). The user interviews have the purpose of 1) gaining more insights into the daily lives (of people with ASD) and 2) investigating what the opinions are from people with ASD about an emotion regulation sound application. This chapter tries to answer the following sub-questions: *"How do people with ASD experience emotion regulation, and what is missing in the emotion regulation for people with ASD?"* and *"What are the requirements from people with ASD about the emotion regulation sound application?"*.

The interviews are qualitative, so it was important to gain in-depth answers. Choosing qualitative analysis was also a practical decision because it was difficult to recruit many people with autism spectrum disorder for quantitative analysis. The focus of the interview questions was to understand how people with ASD deal with emotions and whether an emotion regulation sound application can be suitable for them.

The method for the interviews is in section 3.1. Section 3.1 is about how the researcher conducts the interviews and what the researcher asks the participants. The interview results with categorization (thematic coding) are in section 3.2. The conclusion for this chapter is in section 3.3.

3.1 Setup user interviews

The following shows the setup of the user interviews.

3.1.1 Participants

The participants for the interviews are people with autism spectrum disorder (ASD) according to the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5). The participants are 18 years or older. Participants PP1, PP2, PP3, PP4, PP5, PP6, PP7, and PP8 take part in the user interviews.

3.1.2 Purpose

It is crucial to understand whether the ideas for the application are according to the user's needs. Thus, the first stage of the research is about examining the user's needs with the method is semi-structured interviews. The purpose of the interviews is 1) to gain insights into the daily lives (of people with ASD) and 2) to understand whether sound or music can be a coping mechanism in those daily lives. Interviews comprise pre-defined open questions, and it is also possible to ask further through other

questions during the interview. It is even possible to deviate from the pre-defined questions because it is crucial to gain qualitative insights over quantities.

3.1.3 Interviews

Ethics Committee Computer and Information Science (EEMCS) approves the interviews as ethical sound under reference number RP 2020-37. The researcher registers the data collection under the General Data Protection Regulation (GDPR) with reference number WBP19ME0018. Interviews take place with video calling such as Skype because of the social distancing measurements from Covid-19 regulations and will take approximately 30-45 minutes.

Procedures

The researcher asks the user first to read and sign the consent in Qualtrics (see A1). Then, the user answers some demographic questions on the Qualtrics website. The user will then listen to an introduction from the researcher about the emotional model with arousal and valence axis (see Figure 3). The researcher made some clarification changes with colors, retyping, dimension words. Dimension of arousal changed from intense-mild to active-passive for clarification and the valence dimension changed from unpleasant-pleasant to negative-positive for clarification. A person experiences arousal from intense (active) to mild (passive) and describes how awakening, alert or attentive someone is [22]. Thus, intensive arousal means an active state, whereas mild arousal means a passive state. A person experiences valence from unpleasant to pleasant and describes the negativity or positivity of emotions [22].

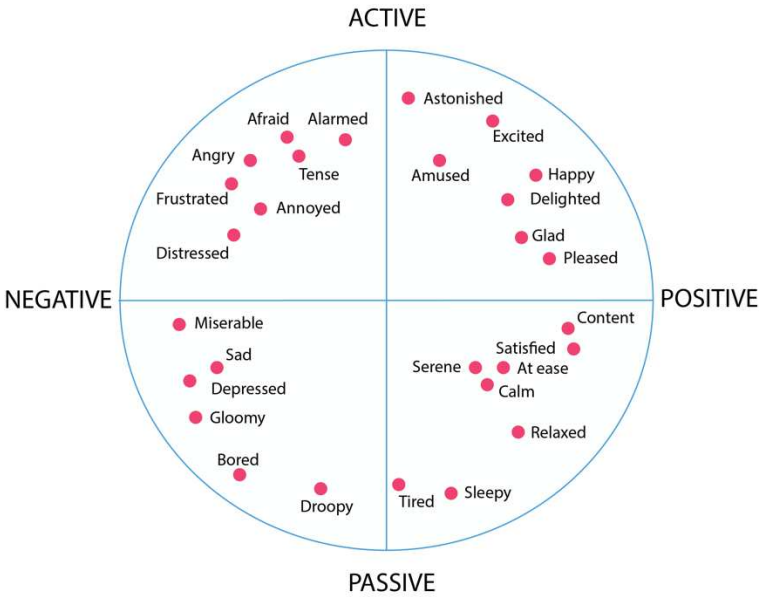


Figure 3 - Emotional model with arousal (active-passive) and valence (negative-positive) axis (Adapted from [32])

After introducing the emotional model, the users place certain daily activities onto the model in the application Mural (https://www.mural.co/). Users place the mentally/physically active activities at the top of the model, the reverse hold for activities that are not or minimal mentally and physically active. The horizontal axis of the Mural card determines whether these emotions are negative or positive. The four quadrants do not restrict the activities, but the activities can be both active/passive and positive/negative. See Figure 4 for an example of activities placed on the card in the application Mural.

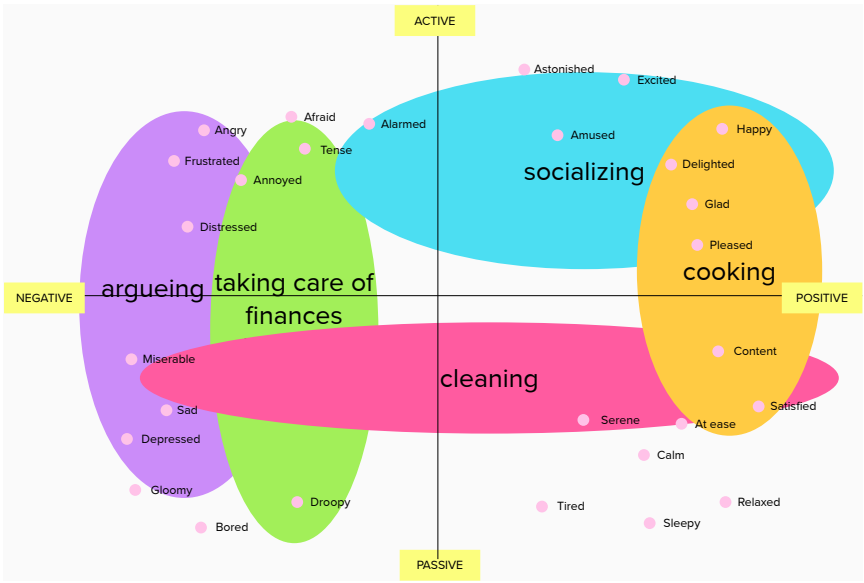


Figure 4 - Example of filled-in activities in Mural

After the participant places some activities on the emotional model, the participant clarifies their filled-in model. Semi-structured interviews are the used method, so the researcher made questions beforehand (see B1A1). However, the researcher can deviate from these questions during the actual interview. The researcher asks some pre-defined questions, such as *"What aspect of the activity elicits those negative emotions?"*, *"Can you describe when the activity elicits both negative/positive or active/passive emotions?"*. The researcher may change the questions based on their judgment during the interview. The researcher will also ask more questions about the emotions of the participants in their daily life. Questions relate to 1) the recognition and expressing emotions, 2) meltdown (screaming), 3) shutdown (isolation), and 4) coping mechanism. After the questions about emotions, the researcher asks questions about sounds and music. These questions are about stressful sounds, noise-canceling, and own preferences. Last, the researcher asks questions about the proposed sound application. The user would describe what features are desirable or avoidable. The user also describes how an emotion regulation sound application would fit into their daily life.

3.1.4 Research materials

The research materials from the user interviews are answers from the participants to the respective interview questions (see B1). The filled-in Mural cards are also research materials from the user interviews.

3.2 Interview Results

The following shows the interview results with demographic information and a thematic coding scheme.

3.2.1 Demographic information

The interviews are with eight people with the diagnosis of autism spectrum disorder. Four participants were male, and four participants were female. The ages of the participants were between 26-73 years old (see Figure 5). All participants had a higher education (2 participants: Bachelor's Degree, 5 participants: Master's Degree, 1 participant: Ph.D.) (see Figure 7). The professions ranged between desk employee, writer, developer, teacher, dive instructor, and student (see Figure 6).

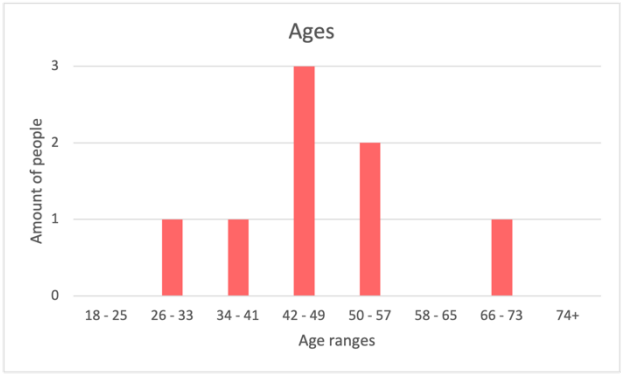


Figure 5 - Age ranges participants interview sessions

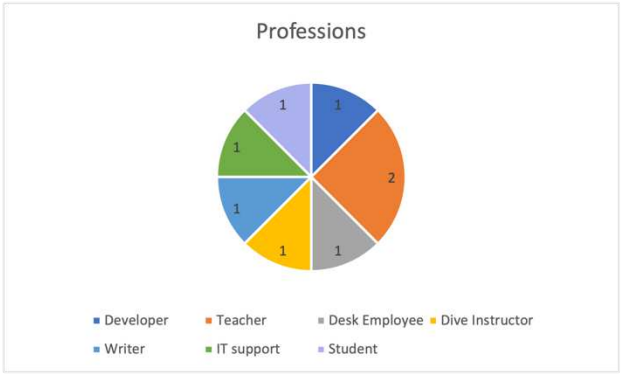


Figure 6 – Profession of participants interview sessions

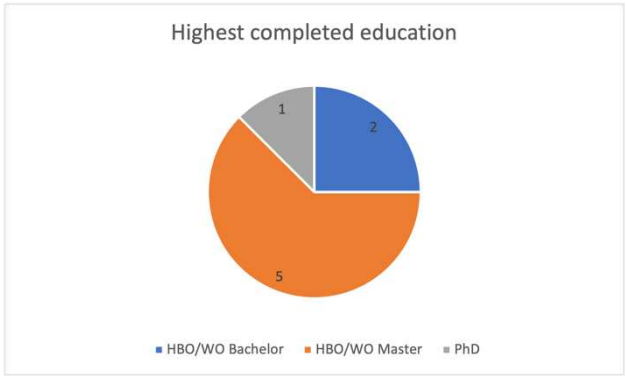


Figure 7 - Highest education participants interview sessions

The demography shows that both females and males are equally present as participants. The age range of 42-49 years old is the average age range of the involved participants. There is diversity in the professions, but the teaching

profession is present more than once. The highest completed education is diverse, but the HBO/WO master is the largest group with 5 participants.

3.2.2 Thematic coding Scheme

The interview data comprises answers to interview questions and the filled-in activities on a map. The researcher analyzes the interview data based on thematic coding. Coding is done with deductive coding, so the researcher defines codes beforehand. The researcher bases the codes on finding answers to the sub-question about the experiences with emotion regulation of people with ASD. The user interviews use the following coding:

1. Emotional Model
2. Activities
3. Positive Emotions
4. Negative Emotions
5. Recognizing Emotions
6. Experiencing Emotions
7. Expressing Emotions
8. Triggers
9. Meltdown
10. Shutdown
11. Coping Mechanism
12. Stressing Sounds
13. Relieving Sounds/Music
14. Noise-canceling
15. Emotional Sounds/Music
16. Activity Sounds
17. Wearable
18. Headphone
19. Functions Sound application
20. Appearance Sound application

The researcher transforms the codes later into categories for themes. Each code has the same level of specificity or importance, so the categorization takes place with a flat coding frame. In the following text are thirteen themes that each comprise codes. Information from each theme translates into requirements. The requirements are first summarized, then concluded with further labeling and prioritizing.

Emotions

The first two themes relate to emotions. The following states the opinions from the participants about 1) recognizing, 2) experiencing emotions, and 3) shutdown/meltdowns (isolation/meltdown).

Theme 3.1 Recognize and Experience Emotions

Five participants (PP2, PP3, PP4, PP6, PP7) did not immediately recognize their emotions. The recognition of the emotions took some time or did not even happen at all.

- The following quote of PP2 supports this: *"Something is happening, but I am not immediately aware of what is going on."*
- Another participant (PP7) also acknowledged the difficulties of recognition by mentioning that recognition is not necessarily the problem, but emotion recognition just takes a little time.

The difficulties with emotions relate not only to recognition.

- A participant (PP4) mentions that emotions are troublesome because the participant does not feel emotions in advance.
- Another participant (PP5) also addressed this with the following quote: "*The inner awareness is hard to communicate because people with autism are only aware of their body sensations until it is too late."*

Patterns:

- PP3 also mentions not recognizing feelings but recognizing patterns. If PP3 recognizes patterns, the participant needs to be alert and act.

Awareness:

- PP5 also even mentions: *"There is a need for people with autism to be aware of their stress."*
- PP6 also mentions having trouble with feeling emotions. PP6 does not know if the feelings are physical or emotional sensations.

Some participants (PP7, PP8) also mention that there is some difficulty in recognizing emotions from others.

- Participant PP8 says to be aware to a certain degree of the emotions of others. But the participant still has some difficulty with recognizing emotions from other people.
- PP7 says that there is not necessarily a difficulty with recognizing the emotions of others, but there is a difficulty in understanding the real intention of others.
- PP1 even mentions that others misunderstand their emotions.
- PP3 also mentions that recognizing emotions from others might depend on being focused. The participant is even better at recognizing emotions from others than the persons themselves when being focused. In these cases, the stimuli level should be at a minimum. However, the participant experiences

difficulties recognizing emotions with too many stimuli and having a bad day because the participant has the disadvantage of first processing stimuli.

Table 1 – Requirement Theme 3.1

# from 3.3.4	Requirement	Description
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.

Theme 3.2 Shutdown vs. Meltdown

The participants from the interview sessions experienced both shutdowns (isolation) and meltdowns (screaming). However, one more participant mentions that a shutdown was more common (PP1, PP3, PP4, PP8) for them than a meltdown (PP3, PP4, PP6).

Shutdown:

- PP1 mentions isolating and telling others: *"I am not available right now, leave me alone."* When people still bother PP1, the situation will mentally worsen for the participant.
- PP3 mentions isolating themselves and not using any social media.
- PP6 also mentions going into isolation after experiencing a massive burnout.
- PP8 also mentions that shutting down is a coping mechanism for them.

Meltdown:

Some participants (PP3, PP4, PP6) also experienced a meltdown.

- An example from PP3 is that this participant has a tension built up that evokes a released warrior in themselves. PP3 is then very irritable to others with: "*Are you not with me? Then you are against me.*" The reactions of PP3 can then be intense where someone who is just the unlucky one receives rubbish, and people would see the participant as a jerk.
- PP4 mentions an example of a meltdown after being approached by strangers and then getting into a panic and then needing to take medicines to calm down.
- PP6 mentions experiencing extreme fatigue but not shouting, which the participant described as an internationalized emotion.

Table 2 – Requirement Theme 3.2

# from 3.3.4	Requirement	Description
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.

Environment Interaction and Perception

The following three themes describe how the participants interact and perceive their (social) environment. The themes state how the participants perceive stimuli and sensory overload. Then there is a description of the social interactions from the participants. At last, participants describe how they cope with everything in their environment.

Theme 3.3 Stimuli/Sensory overload

Five participants can experience sensory overload from excessive stimuli in their environment (PP2, PP3, PP4, PP5, PP6).

- The participants (PP1, PP2, PP4, PP5, PP6, PP7) mention that the stimuli might be 1) scents, 2) talking, 3) sounds, 4) vibrations from sounds, 5) high-pitched sounds, 6) background noise, 7) sudden noises, drilling, 8) tapping, 9) dogs barking, 10) presence of other people, 11) amount of other people nearby, 12) misunderstanding, 13) repetitive movement, 14) flickering fingers, and 15) lights.
- PP4 says that negative emotions do not arise from the individual stimulus, but combined stimuli elicit negative emotions.
- PP3 mentions that the level of stimuli is a queue where the participant needs more capacity to process all stimuli.

An overload of different stimuli can lead some participants (PP1, PP2, PP3, PP4, PP5, PP6, PP7) to negative emotions, such as annoyance, crying, and stress.

- PP2 mentions experiencing extreme crying because of sensory overload.
- PP3 mentions that problems with emotions arise after first processing the stimuli.
- PP5 also clarifies the effect of stimuli overload with the following quote: *"Stress is particularly for people with autism, and it relates to sensory overload."*

Table 3 – Requirement Theme 3.3

# from 3.3.4	Requirement	Description
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.

Theme 3.4 Being Alone/Social Interaction

Social interaction seems to be difficult for people with autism.

- PP3 mentions experiencing social interaction in big groups as challenging. It demands too much energy, and the participant needs time to process all the stimuli from the social interaction. PP3 mentions there might be a need one day after a party to process everything that happened.
- PP4 constantly struggles with always thinking before or during a social interaction about what to say or behave.

The need for being alone is also common for some participants (PP1, PP2, PP4, PP5, PP7).

- The participants (PP1, PP2, PP4, PP5, PP7) are especially alone when they go into isolation.

Some participants (PP5, PP6) even mention that they prefer to be alone in their daily life such that the participants avoid any negative stimuli.

- PP5 mentions avoiding busy areas. There is also a preference to go to an empty restaurant.
- PP6 controls their environment by limiting social gatherings.

Contrary, PP4 might experience social interaction with familiar people as positive. But overall, PP4 mentions that the social interactions are negative in combination with a sensory overload.

Table 4 – Requirement Theme 3.4

# from 3.3.4	Requirement	Description
3.5	Non-invasive	The application provides support for the target user only when the user asks for it to achieve that the user can still perform their day-to-day activities where the application does not play an invasive role in every daily activity.

Theme 3.5 Help/Coping/Techniques

The participants (PP1, PP5, PP7, PP3, PP6, PP4) also mention using techniques to cope with stimuli and their emotions.

- Two participants (PP1, PP4) mention the use of alert plans.
- PP4 also used cleaning schedules and notes on a whiteboard. This participant makes plans with the help of a caretaker. These plans have fixed moments at fixed times. PP4 says: *"When something has a delay, it becomes chaos inside my head."*

Other participants (PP5, PP6, PP7) mention that they structured their life/behavior in a certain way to handle their emotions and stimuli.

- PP3 dives as a coping mechanism to experience water to be quite relaxing.
- PP5 mentions controlling sensory impact by blocking sensory changes or other aspects of the world (such as places or people) and making it more predictable.
- PP6 likes to be prepared to become more settled, like going to events with like-minded people.
- PP7 mentions just going to the bathroom when the participant feels that an outburst is coming up.

Table 5 – Requirement Theme 3.5

# from 3.3.4	Requirement	Description
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.

Using Sound

Using sound from the participants is in the following three themes mentioned. The first theme about music and sounds categorizes into seven subjects to clarify the opinions from the participants about music/sounds. The seven subjects are:

1. music/sound taste
2. nature sounds
3. usage of music/sounds
4. familiar/repetitive music/sounds
5. focused/to the background
6. reflect emotions

7. final application

The participants also mention the feedback form of using sounds. At last, the participants describe headphones/noise-canceling.

Theme 3.6 Music/Sounds

Music/Sound Taste

The taste of music/sound of the different participants are diverse

- PP2 likes to listen to the music of the 70s and 80s.
- PP4 likes to listen to Indie Folk and low tones, not too much noise, and a low voice. This participant prefers a good melody over text.
- PP6 likes to listen to the sound of a bangle (a ring of stiff plastic or metal worn around the wrist as jewelry). New Age, classical and upbeat music are specific types of music for this participant. The participant does not like to listen to heavy music.
- PP7 mentions that their music taste differs between active rock and dance.
- PP8 likes to listen to Wagner/Beethoven or catholic music.

Nature Sounds

Five participants (PP1, PP4, PP5, PP6, PP8) have opinions about nature sounds.

- PP1 mentions that rain or thunderstorms are comforting.
- PP4 sometimes listens to nature sounds, but this participant finds the nature sounds fake because of the mismatch of not being in nature. This participant likes water sounds, but then outside. This participant does not like bird sounds because of the high tones.
- PP5 mentions: *"Some autistic people like animal sounds, but they do not like gardener sounds."*
- PP6 listens to meditation/calming sounds, such as birds.
- PP8 mentions not listening to any nature sounds.

Usage of Music/Sounds

- PP2 mentions that music or any other sounds are not comforting.
- PP4 sometimes listens to music out of boredom. However, the music becomes too much if this participant experiences many stimuli already.
- PP7 mentions using music so now and then to calm down.
- PP8 is not calming from music, but music is more of a distraction.

Familiar/Repetitive Music/Sounds

The following participants mention they prefer music that they already know.

- PP2 mentions only listening to familiar music because the participant knows by then what is coming.

- PP4 also mentions listening to music that is familiar to them. The participant knows what to expect because of the familiarity.
- PP5 mentions: *"Music that is something they know helps for people with autism, such as familiar patterns and rhythms."*
- PP6 and PP7 listen to calm, repetitive music with some variation such that they know what to expect.
- PP7 does not listen to any new music.

Focused/to the Background

There is some disagreement about music in the background or foreground, as in the following statements.

- PP2 mentions being focused only on music while listening to music. Thus, the participant thinks music is not suitable for other activities.
- PP7 thinks that the music should not be a distraction but that it will fade to the background such that the participant does not have to listen to the music.
- PP8 also uses music in the background.

Reflect Emotions

The following participants mention the use of music to reflect their emotions.

- PP1 mentions listening to hard-core/hardstyle music to reflect their emotions as an outlet without getting into any fights.
- PP2 mentions not using the music or sounds in a specific mood. However, this participant has experienced listening to hard rock when feeling angry.
- PP3 mentions that passive negative emotions might fit with dramatic music. However, uplifting music works better for the participant during active/positive emotions. PP3 thinks it is not pleasant to listen to music when the participant is angry, tensed, or frustrated.
- PP5 mentions: *"It depends on the person whether someone likes to listen to angry music when being angry."* This participant sometimes prefers angry sounds but at other times does not. This participant also mentions: *"Highly emotional sounds are useful when you are in a certain mood."*
- PP7 listens to angry music such as hard rock when being angry. The reason is to get out of the angriness.
- PP8 does not have experience with listening to music that represents their mood, such as angry music when being angry. But this participant thinks it would help to divert anger to something else.

Application

- PP1 mentions for the application that music could have a calming function.

Table 6 – Requirement Theme 3.6

# from 3.3.4	Requirement	Description
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.
3.2	Repetitive	The application shall provide sounds with repetition to achieve that the target gets familiarized with the sounds such that they know what they can expect from the sounds.
3.3	Familiar	The application shall provide familiar sounds to the user to achieve that they are more likely to use the application regularly.

Theme 3.7 Feedback from Sounds

Two participants (PP1, PP6) mention that the application could provide sound feedback to inform the user.

- PP1 mentions that the application could provide feedback (with calming music and sounds) to show that the user must pay attention to something. The participant thinks that feedback could be a combination of vibration and repeated reminder sounds. This feedback is a good sign of intervention cited by the participant.
- PP6 mentions that the application could have a verbal thing with a voice that says: *"I have noticed that… please take a breath/Would you like to listen to some music?"* PP6 mentions conceptualizing the application as a reminder when the user is stressing out.

Three participants even mention the requirements for the application.

- According to PP1, the feedback would be personal, and the sound cannot be a load squeak that plays during a conversation.
- PP6 mentions nature sounds could help like waves, rain, birds, tropical rainforest, or white noise like a beach. This participant thinks that the music or sound could fade in or fade out. PP6 also mentions that it might take up to 20 minutes, but any longer is annoying. The application should avoid any beep or high pitch voice stated by this participant. The voice as feedback can (according to the participant) begin soft (such that it will not come as a surprise) with: *"We noticed… "*.
- PP7 likes the idea of adding another product to use at moments of stress, like petting a cat or moving a ball back and forth. Especially the repeating movement is calming, according to this participant. The participant thinks that sounds or vibrations can express the same calming effect.

Table 7 – Requirement Theme 3.7

# from 3.3.4	Requirement	Description
3.8	Feedback by sound	The application shall provide feedback about emotions by sounds to achieve emotional awareness to the user.

Theme 3.8 Noise-canceling/Headphone

Four participants (PP2, PP4, PP6, PP8) prefer silence, and they experience an annoyance towards sounds.

- PP4 even mentions that sounds are a source of stress (such as rattling shopping carts, hedge trimmers, or music).
- PP6 mentions that all sounds might irritate, especially high-pitched sounds (such as washing machines or children screaming).

Some participants (PP2, PP4, PP8) have diverse opinions about the usefulness of noise-canceling.

- PP3 does not have any experience with noise-canceling.
- PP4 mentions using noise-canceling at the need for silence.
- PP8 thinks that music is better than noise-canceling to reduce the noise in a building.

Six participants (PP2, PP5, PP4, PP6, PP7, PP8) also mention their experience with wearing headphones. Wearing headphones seemed to be unpopular for the participants.

- PP2 mentions that headphones do not fit nicely.
- PP4 also mentions that headphones might be a challenge for the application because when to use headphones is situational dependent.
- PP5 even mentions being tactile sensitive, so the participant never wears headphones.
- However, PP6 loves to use headphones when the participant is upset (both inside and outside the house). PP6 listens to sounds of liking.
- PP7 does barely wears headphones.
- PP8 mentions having a negative experience with the heavyweight of headphones.

Four participants also gave some tips for the application.

- PP4 mentions the doorbell should still be audible when using the headphones.

- PP5 also says that the application could both be with music and noise-canceling at first. Later, research shows certain commonalities of best usages.
- PP7 mentions that it is impossible to wear headphones during meetings. In those cases, vibration feedback might come in handy. However, the participant thinks even vibrations might be useless in the meetings because the user cannot act on feedback at that moment.
- PP8 mentions that the headphones should be lightweight and comfortable.

Table 8 – Requirement Theme 3.8

# from 3.3.4	Requirement	Description
3.5	Non-invasive	The application provides support for the target user only when the user asks for it to achieve that the user can still perform their day-to-day activities where the application does not play an invasive role in every daily activity.
3.12	Own headphones	The application shall provide the ability to use the application with a preferred headphone that is comfortable, familiar, and perhaps lightweight, such that the headphone does not hinder the user.

User Ideas for Application

The researcher introduces the idea of an emotion regulation application by sound to the participants.

User opinions

PP8 thinks it is an interesting idea to use an emotion regulation sound application. However, PP8 is indecisive about whether the application works. PP3 also mentions being unsure whether an emotion regulation sound application would fit in their life, but PP3 thinks that the application can help to reduce any tensions. PP2 finds it hard to give an opinion on something undeveloped. However, most participants were enthusiastic about the idea of emotion regulation sound application by sound in their daily lives. The participants' enthusiasm led to mentioning requirements for the emotion regulation sound application. Requirements translate into the following user ideas for the application. The user ideas are in five different themes. The themes are stress level/sign/regulation, wearable/on-to-go, adjustable/personalization, self-learning, be in control.

Theme 3.9 Stress level/Sign/Regulation

Five participants (PP1, PP3, PP4, PP5, PP6) mention that developers should pay attention by giving feedback about the stress level.

- PP5 says: *"Developers should pay some attention that warning feedback might stress out the person with autism even more."*
- PP7 says that the application should not make the user feel more guilty if it is not possible to regulate their emotions.

Two participants (PP4, PP5) also gave some tips about the stress level feedback.

- PP5 mentions that: *"the feedback from the application depends on the things that pick on during the day, i.e., the things that might trigger stressful events."*
- PP4 mentions that the application should display the stress level as a scale instead of specific emotions because emotions in text say little to the participant. The emotional model from the interview helped the participant to realize how emotions link to each other.

Table 9 – Requirement Theme 3.9

# from 3.3.4	Requirement	Description
3.9	Avoid words of emotions	The application shall not provide information about emotions in a text to achieve that the user does not get confused by the words of emotions that they do not understand.
3.11	Simple design	The application shall provide a simple design to establish that the user interface does not evoke unwanted emotions.

Theme 3.10 Wearable/on-the-go

- PP1 mentions that the smartwatch should have a high battery usage because the user does not want to recharge their watch in the middle of the day.
- PP5 mentions that the application can help when the participant is *"out and about traveling."* The participant experiences the rush hour with busy stations as quite stressful, in which the participant cannot do much about the stress. The application might help the participant during these stressful moments.
- PP8 mentions that a wearable (smartwatch) as a product would fit into their life because the participant already wears a smartwatch.

Table 10 – Requirement Theme 3.10

# from 3.3.4	Requirement	Description
3.7	Wearability	The application shall provide the option to use the application anywhere through a smartwatch, smartphone, and headphones to achieve that the user can always work on their emotions.

Theme 3.11 Adjustable/Personalization

- Three participants (PP1, PP5, PP6) mention that the application should be personal and adjustable.
- PP2 mentions that it should be possible to adjust the volume and turn off the application. This participant also thinks that the application should be user-friendly, and there should be an option for not using certain functions.
- PP5 mentions: *"The application could include a button with a warning as a bleeping sound which is quite personal and therefore the application should include the ability to change a setting."*
- PP8 mentions that the application should not be intrusive, and it should be easy to disable the application when you speak to others.

Three participants mentioned the importance of personalization.

- PP3 mentions that the application should be able to customize because "*A particular sound can push people towards their limits, other sounds have the opposite effect."*
- PP5 mentions: *"There are variations on the spectrum, but a universal design is desirable. Customizability is also important for the user and the caretaker. There is even a technical aspect in which the application would give different responses to different people, such as each person has a different heart rate."*
- PP8 mentions that music is personal, so the application should fit these personal needs.

Table 11 – Requirement Theme 3.11

# from 3.3.4	Requirement	Description
3.4	Personalization	The application shall provide the option to be personalized from user preferences to achieve that the application appeals to the user.
3.10	Ability to adjust	The application shall provide options to adjust settings in the application to achieve that the user gets more control over the application.

Theme 3.12 Self-learning

- PP7 mentions that the application should learn from the interaction with the application, like that sometimes a high heart rate is not unhealthy.

Table 12 – Requirement Theme 3.12

# from 3.3.4	Requirement	Description
3.13	Learnability	The application shall provide the ability to learn from the user to achieve that the feedback by sounds tailors the user preferences.

Theme 3.13 Be in Control

- PP2 mentions that being in control is the most important thing for the application.
- PP5 thinks that care homes can use the application to help people regain their autonomy with their music.

Table 13 – Requirement Theme 3.13

# from 3.3.4	Requirement	Description
3.6	In control of own life	The application shall provide feedback through sounds only when the user made that clear in the application to achieve that the user is still in control of their life and the application does not control their lives.

Filled-in Activities

The following figures (Figure 8 **-** Figure 14) show the filled-in activities from the participants. The activities are different for each participant. A first glance at the figures shows the participants place the activities across the arousal/valence dimensions. Each quadrant (negative/positive/passive/active) contains at least one activity. Five participants filled-in activities for different dimensions, other participants (PP6, PP7) could not think of activities for each quadrant. PP2 also finds it hard to think about an activity for the quadrant negative/passive, because the participant might experience negative emotions but cannot relate them to activities. There is also a diversity in the number of activities that each participant filled in. It might be possible that some people with autism spectrum disorder (ASD) struggled with linking activities to emotions because of their emotional difficulties. One participant (PP2) seems to find the exercise difficult at first by mentioning that the words on the model are distracting. However, one participant (PP4) mentions that the arousal/valence model shows great insights into how emotions relate to each other.

An analysis of the activities shows that there is some overlap with the activities of social interaction, taking care of finances, grocery shopping, housekeeping, gaming, cooking, and reading.

The following text shows information about the emotions and activities of the participants during the interviews:

- PP1 has first positive and then negative emotions with gaming. PP1: *"At 8 p.m., I begin with gaming. Then I see the sun is rising and I look at the time. It is 07:30 in the morning and I must be at work around 09:00 am. Thus, I have first positive emotions, but gaming too long raises negative emotions even when gaming is positive."* PP1 mentions that annoying stimuli deal with scents, like being agitated from the scent with cleaning.
- Cooking is for PP2 not fun but something that needs to happen. Participant PP2 sees cooking as negative/active, but not extreme negative/active. PP2 finds volunteer work and taking care of finances positive/active because it is rewarding work for the participant. PP2: *"It gives a fulfillment to help someone else."*
- PP3 has some struggles with social interaction in groups because that requires too much energy, and the participant needs some time afterward for processing. PP2 uses Sudoku and diving as a coping mechanism to calm down and relax. PP2 has also previous experience with addictions (like alcohol, narcotics, or gaming) that can help the participant to relieve some stress.
- Participant PP4 makes a planning, alert plan, and a cleaning schedule at home to create some structure. PP4: *"If something runs out of time, it becomes chaos in my head."* PP4 also has some struggles with social interaction. At the supermarket, the participant tries to find the most effective path to avoid as many people as possible. The negative stimuli during social interaction (like sounds/talking, misunderstanding, scents, or just people) create negative emotions and not necessarily the social interaction itself. PP4 can experience social interaction as positive if it is with familiar people.
- PP6 says to struggle with social gatherings and would like to know upfront what will happen and be prepared such that the participant is more settled. PP6 likes to go to poetry reading because of similar people.
- PP7 has some frustration with eating together because of the interaction with others. A meeting at work can also for PP7 be frustrating if it is taking too long, not efficient, or not effective.
- PP8 does not like cooking or cleaning and experiences those activities therefore as negative. However, PP8 says that there is satisfaction when things are done, as with cleaning or with taking care of finances.

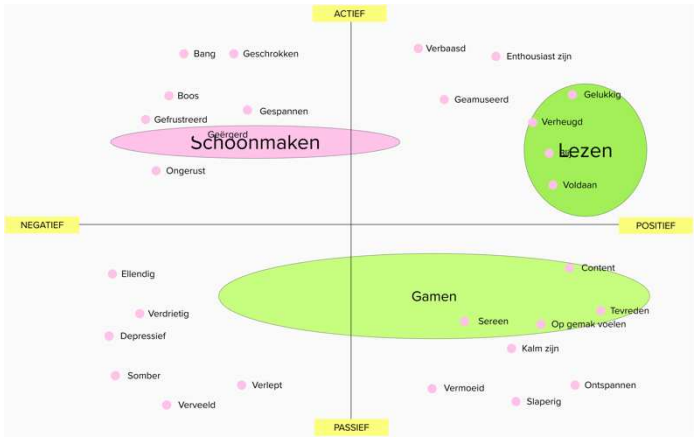


Figure 8 - PP1 Activities

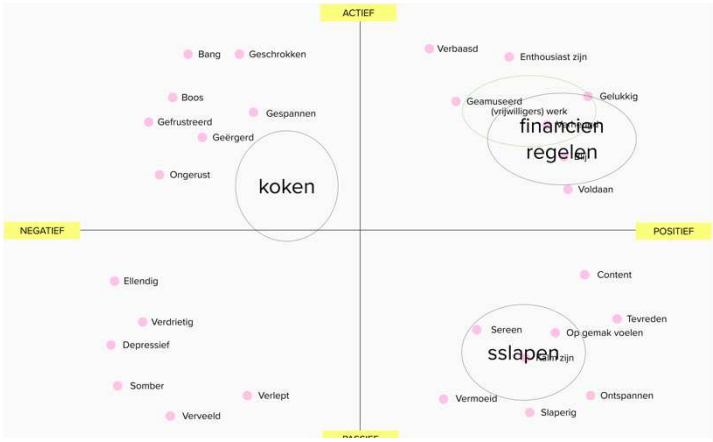


Figure 9 - PP2 Activities

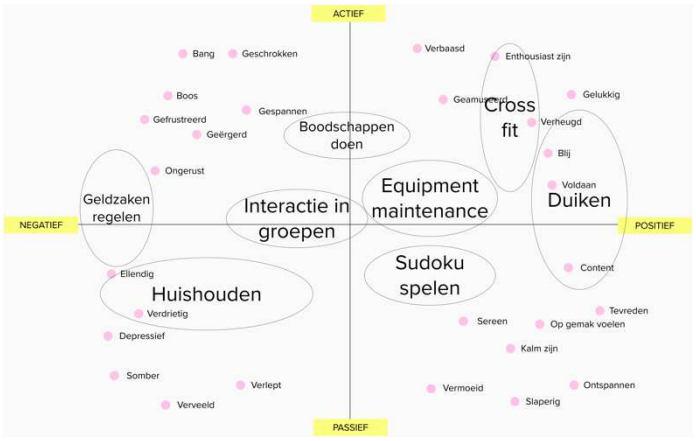


Figure 10 - PP3 Activities

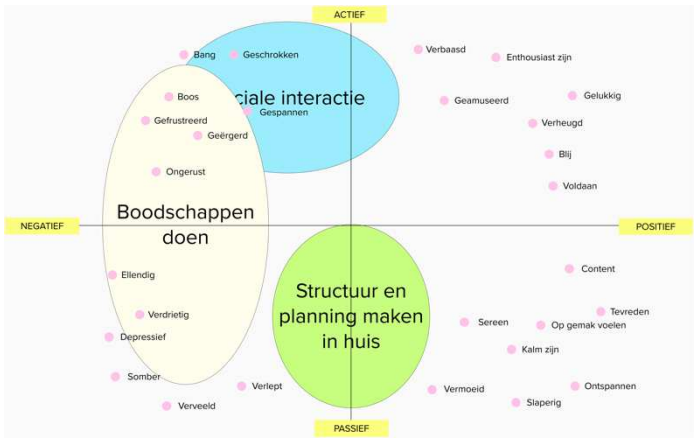


Figure 11 - PP4 Activities

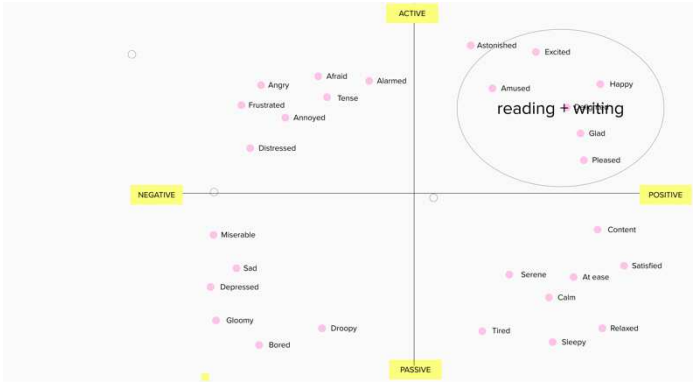


Figure 13 - PP6 Activities

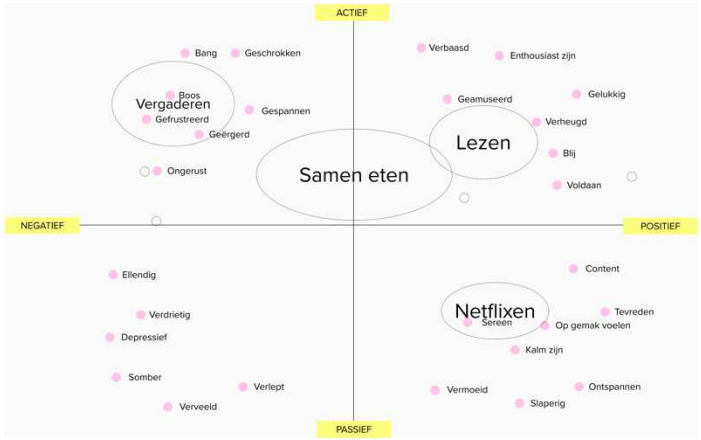


Figure 12 - PP7 Activities

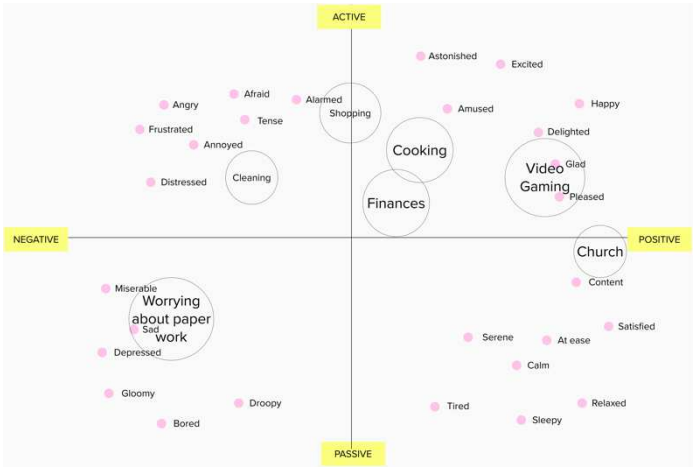


Figure 14 - PP8 Activities

3.3 Conclusion

The information from this chapter translates to the following discussion & conclusion, limitations, persona, requirements, and answers to research questions.

3.3.1 Discussion & Conclusion

The interviews with participants confirm several things from the literature review, but the participants also give new insights. People with ASD acknowledge facing difficulties in their lives with emotions, such as being unable to understand their feelings or at least with some delay. The challenges with emotions originated from too many stimuli in the environment of people with ASD. People with ASD might see anything in their daily lives as a stimulus that might arise negative emotions, like scents, sounds, vibrations, lights, other people, and even expectations from others. When these stimuli all exist at a particular moment in the lives of people with autism spectrum disorder, it can create an over stimulus that causes a meltdown (screaming) or shutdown (isolation).

Therefore, people with autism spectrum disorder have their lives specifically structured to eliminate as many stimuli as possible. The structuring can comprise making plans (schedules or alert plans) or even limiting social gatherings as much as possible.

Related to the emotion regulation sound application, only one participant is familiar with deliberately changing their emotions with music or sounds. However, four participants mention using/used music that represents their current emotions, such as listening to hard-core/hardstyle/hard rock while being angry. The music helps them to release the anger without getting into a fight. Also, three participants listen to nature sounds, such as rain, birds, thunderstorms, or rain forest. But one participant perceives nature sounds as fake because there is a mismatch between what you hear and what you see as someone is usually not in nature when listening to the nature sounds. The participants desire predictability, and therefore they listen to songs that are familiar and repetitive. The opinions diver a bit about whether the music should be in the background or foreground. One participant mentions that the sounds/music should not be invasive, but another participant listens to music and then only focuses on the music. Only one participant has experience with noise-canceling. The participant uses noise-canceling to reduce any noise in the environment. Another participant thinks that music is better than noise-canceling to reduce environmental noise.

The participants think that the application can provide sound feedback about stress levels. The sounds can be a combination of music, sounds, and vibrations. One participant even uses voice feedback. Then the display of the stress level should not be with words of emotions stated by another participant. The participant explains that emotions in text say little to people with ASD.

Three participants dislike wearing headphones because of their weight or tactile sensitivity. The product should be lightweight and comfortable, according to one participant. Two participants see the addition of a wearable as positive in their life. It appeals to one participant that the smartwatch is easy to use during traveling. The application will especially be suitable when traveling in rush hours at busy stations. But another participant mentions that using a smartwatch with headphones is impossible during work meetings.

Five participants mention that the emotion regulation sound application should be easy to use, and the user can adjust some things in the application. It should be a personalized application stated by five participants because people have personal preferences for music and sounds. The participants also mention that the application should eventually learn from the user interaction. It was also crucial for two participants that the user stays in control (of their life).

To conclude, headphones might be inconvenient (due to negative experiences). Therefore, the researcher should pay some attention if the product should still include a headphone. Another conclusion is that there is a real need for personalization because people have different music/sound tastes and diverse heart rates. The music/sounds should be familiar and maybe repetitive for the user. The researcher should also pay some attention to the situations where the user can use the wearable. One participant mentions that the application is convenient during traveling. However, the emotion regulation sound application might be inconvenient at work meetings.

3.3.2 Limitations

One limitation of the user interviews is that the interviews took place online. This might reflect in missed behaviors from the participants. The participants are only visible on a small screen and therefore the researcher might not observe all their body language. Another positive effect of the online interviews is that the user might feel more at ease because they are at their home, where they feel most comfortable. The online limitation might also evoke that the participant must learn how to use unfamiliar tools, such as Mural.

Another limitation is that one participant (PP5) has not filled in the activities on the Mural website because the participant could only use a phone during the interview.

3.3.3 Persona

The information about the demography of the participants translates into a persona. A persona describes the typical user of the application.

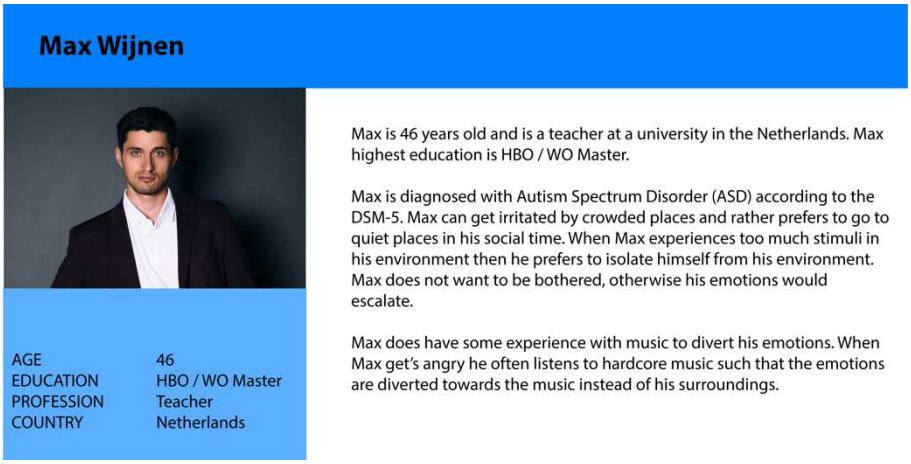


Figure 15 - Persona of a typical user

Figure 15 shows a persona from the demography information of the participants in the interview sessions. The persona comprises a fictional first name and surname with personal details (photo, age, education, profession, and country). Information in the persona comes from the interviews, and the name and picture are fictional. The text in the persona describes the typical user in more detail, which bases on information from the interviews. The following part of this chapter is about the requirements from the interview information.

3.3.4 Requirements

When we look back at the interview data, the conclusion is that the participants mention their interest in an emotion regulation sound application by stating their needs for the application with their preferences. The researcher analyzes the exact preferences from the interview data in the discussion & conclusion. These preferences can translate into the following requirements.

The researcher categorizes the requirements into functions for the emotion regulation sound application (functional) or how the emotion regulation sound application should work (non-functional). This categorization gives input for developing the emotion regulation should application to clarify what is part of developing functions (the functional requirements) or what is part of the design as user experience (the non-functional requirements).

After the categorization, the researcher prioritizes each requirement with the Moscow principle (Must Have, Should Have, Could Have, Would Have) [33]. The

Moscow principle is self-explanatory to show that requirements are a must-have, should have, could have, or would have to implement as a priority of further development from first to last.

The researcher prioritizes requirements based on whether they entail something essential for the target user. In order words, the researcher investigates whether these requirements are about user preferences that are crucial for the application to succeed. The researcher prioritizes these requirements as Must Have. Then, the researcher tries to find the Should Have requirements, which are about the core part/purpose of the application. A core part/purpose is the emotion handling through relaxation by sounds. The researcher prioritizes the remaining requirements as Could Have, which are the ones that do not affect the success of the application and are also not part of the purpose of the application.

Table 14 - Requirements First Iteration

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
3.1	Emotion handling	The application shall provide calming sounds such that the target user does not easily experience extreme emotions or is better at handling the emotions through the sounds.	Non-functional	Must Have	Theme 3.6
3.2	Repetitive	The application shall provide sounds with repetition to achieve that the target gets familiarized with the sounds such that they know what they can expect from the sounds.	Functional	Must Have	Theme 3.6
3.3	Familiar	The application shall provide familiar sounds to the user to achieve that they are more likely to use the application regularly.	Functional	Must Have	Theme 3.6
3.4	Personalization	The application shall provide the option to be personalized from user preferences to achieve that the application appeals to the user.	Functional	Must Have	Theme 3.11
3.5	Non-invasive	The application provides support for the target user only when the	Non-functional	Should Have	Theme 3.8

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
		user asks for it to achieve that the user can still perform their day-to-day activities where the application does not play an invasive role in every daily activity.			
3.6	In control of own life	The application shall provide feedback through sounds only when the user made that clear in the application to achieve that the user is still in control of their life and the application does not control their lives.	Functional	Should Have	Theme 3.13
3.7	Wearability	The application shall provide the option to use the application anywhere through a smartwatch, smartphone, and headphones to achieve that the user can always work on their emotions.	Non-functional	Should Have	Theme 3.10
3.8	Feedback by sound	The application shall provide feedback about emotions by sounds to achieve emotional awareness to the user.	Functional	Should Have	Theme 3.7
3.9	Avoid words of emotions	The application shall not provide information about emotions in a text to achieve that the user does not get confused by the words of emotions that they do not understand.	Non-functional	Should Have	Theme 3.9
3.10	Ability to adjust	The application shall provide options to adjust settings in the application to achieve that the user gets more control over the application.	Functional	Should Have	Theme 3.11
3.11	Simple design	The application shall provide a simple design to establish that the user interface does not evoke unwanted emotions.	Non-functional	Could Have	Theme 3.9

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
3.12	Own headphones	The application shall provide the ability to use the application with a preferred headphone that is comfortable, familiar, and perhaps lightweight, such that the headphone does not hinder the user.	Non-functional	Could Have	Theme 3.8
3.13	Learnability	The application shall provide the ability to learn from the user to achieve that the feedback by sounds tailors the user preferences.	Functional	Could Have	Theme 3.12

3.3.5 Filled-in Activities

A diversity of interests from the participants might explain that the participants have different daily activities. However, it shows that there is some overlap with the activities of social interaction, taking care of finances, grocery shopping, housekeeping, gaming, cooking, and reading. These activities can elicit emotions, but the emotions are diverse for the participant across the arousal/valence dimension (passive/active/positive/negative). Two participants (PP1, PP8) can have both positive and negative emotions with activities. Activities can first be joyful and then arise negative emotions when other obligations suffer from taking too much time in the activity. An activity can also arise negative emotions at first when there is no motivation to do the activity. However, a finished activity is rewarding, and positive emotions arise. Four participants (PP3, PP4, PP6, PP7) have struggled with social interaction because of energy-consuming, stimuli overload, uncertainty, or inefficiency.

3.3.6 Answers to research questions

The results from the interview provide an answer to the following sub-question: *"How do people with ASD experience emotion regulation, and what is missing in the emotion regulation for people with ASD?"*. The results show that people with ASD experience difficulties in emotion regulation by not understanding their emotions. The emotion regulation difficulties can arise through an overload of stimuli for people with ASD. For example, a person with ASD cannot handle a stimuli overload that eventually results in a meltdown (screaming) or shutdown (go into isolation from surroundings). The results also show some experience with emotion regulation from people with ASD by channeling anger towards angry music instead of other people.

Another form of emotion regulation for people with ASD is that they structure their daily lives to reduce the number of stimuli. The interview data show that some people with ASD lack an understanding of emotions and have a delayed awareness of emotions. People with ASD seem to be aware of their emotions when it is already too late. People with ASD currently use emotion regulation to focus only on dealing with emotions by preventing them from happening through structures and dealing with the emotions when it is already escalating with something like listening to music. Thus, people with ASD lack understanding of their emotions and are unaware of them before they escalate. An emotion regulation sound application could help people with ASD to help figure out their emotions before they might escalate. There seems to be already some great interest from people with ASD about an emotion regulation sound application that is also confirmed by the insights into the user preferences for such an application. These preferences translate into requirements, and the following answer to a sub-question discusses those requirements.

The results also show an answer to the following sub-question: *"What are the requirements from people with ASD about the emotion regulation sound application?"*. The previous section mentions the requirements for emotion regulation in more detail that came from the first user involvement with the target user. Requirements state that the application should provide tools for the target user to handle their emotions. The emotions should not be present in words, but the presentation might be in sounds. The sounds can be repetitive and familiar to the target user. Another point from the requirements is that the target user should control the application, which personalization and customization should achieve.

The following shows how the results and requirements can translate into a concept for the emotion regulation sound application.

Chapter 4 Ideation and Conceptualization

The user interviews show that people with autism spectrum disorder (ASD) might need an emotion regulation sound application to make sure that a meltdown or shutdown does not occur that often anymore. This study proposes the solution of a sound modality on mobile and wearable devices for emotion regulation. This chapter discusses the concept of such a sound modality that reacts to changes in the approximation of emotions through emotional arousal. The concept helps to provide a better idea of how to develop the sound modality. This chapter also tries to answer the following sub-question: *"In which ways can sound give feedback about emotional arousal?"*. The next chapter (Chapter 5) discusses how to build such a sound modality as a first test version of the emotion regulation sound application.

Section 4.1 describes the context for the application. This means that there is a description of how this application could play out in the lives of people with ASD. Section 4.2 discusses what the different sounds for the application entail and explains the different characteristics of sound. These characteristics can lay some foundation on how sound can react to changes in emotional arousal. There is a discussion of the exact sound reactions to changes in emotional arousal in section 4.2. Section 4.3 discusses the conclusion of this chapter.

4.1 Context

The following describes the context for the prototype.

Mobile and Wearable Devices
The literature review (from the introduction) and interviews already show promising possibilities of sound as calming feedback for emotion regulation for autistic people on mobile and wearable devices. During this study, a mobile/wearable emotion regulation application will extend by sound. With this purpose, requirement 3.1 Emotion Handling, requirement 3.7 Wearability, and requirement 3.8 Feedback by Sounds from Chapter 3 have complied. The researcher creates an application for this project in consolation with the target user (people with autism spectrum disorder). During testing with early versions of the application, the target user gives feedback. The main advantage of an application on mobile/wearable devices is that the application can notify the user anytime and anywhere such that the user can be at ease without being restricted to a certain place and not restricted to certain physical tools, such as paper. Another main advantage of using sound is that this modality might be natural because people are already used to sounds in their natural habitat. It means that requirement 3.5 about non-invasiveness can also comply such that the users use the application in their daily lives without being distracted with unfamiliar

(application) usages. Besides, as described in the literature review and interviews, sounds can help autistic people to handle their escalations of emotions (meltdown/shutdown). It is the idea that the sounds become part of the daily routines of people with ASD, such that the sound embeds into their world. This means that the user can still perform their day-to-day activities without being disturbed by the application, as the application is then part of their day-to-day activities. This also helps to comply with requirement 3.6 about the target user still in control of their life from Chapter 3. The idea is to include a headphone with the application such that it provides a portable option for the user.

Emotion Handling

The current project focuses on a sound application that supports autistic people to prevent them from regularly dealing with a shutdown or meltdown, which is confirmed by requirement 3.1 about emotion handling from Chapter 3. The purpose of the sound application is a coping mechanism in which the user can calm down. It is the idea that relaxation can help people with autism spectrum disorder (ASD) have more insights into their changes in their emotions and then can they be more in control. As described before, people with ASD often experience extreme emotions due to all the stimuli from themselves, others, and the world around them. When people do not handle emotions properly, the emotions are getting more extreme and eventually reach a boiling point in which the person might have outbursts such as screaming (meltdown), or the person might go into isolation from their environment (shutdown). The extreme emotions should decrease for prevention of a meltdown and shutdown. To tackle extreme emotions, it is first important to have insights into the extreme emotions. The sound application can provide the user with information about their emotional changes. Eventually, the goal is to support the user with relaxation through sounds. Sounds from the sound application mean to calm the users down such that their emotions do not boil for too long or their emotions do not even get to a boiling point. The purpose of the calming sounds is to improve the lives of people with ASD. The concept in 4.2 shows the exact sounds that are necessary as calming/relaxation mechanisms (such as nature, ambient sounds, or music that the user enjoys listening to).

Emotional arousal levels

This section discusses the different aspects of the emotional arousal levels. First, there is a description of the background for the emotional arousal levels. Later, the following explains the decision for emotional arousal. At last, the different examples for emotions to each emotional arousal level is in the following.

Arousal and Valence

The application focuses on relaxation, so the application measures emotions to understand whether the user can relax. Research Topics (preliminary research from

the same researcher) show that it is difficult to measure the exact emotion of the user. However, it is possible to place different emotions in a dimensional model (see Chapter 3 and Figure 16). The x-axis shows the positive/negative dimension of the valence, and the y-axis shows the active/passive arousal dimension. Chapter 3 shows that both arousal and valence illustrate emotions. However, there is no technique yet available that can register the valence of emotions through bio-sensing technologies for mobile or smartwatches. Currently, self-report measures the valence in which the person states if emotions are positive or negative [34].

Emotional Arousal

As previously described, self-tracking with mobile technologies cannot measure the valence, but mostly self-reporting measures the valence. To still receive valid results about the user's emotions, we investigate emotional arousal. Emotional arousal shows a simplified view of emotions. By looking into emotional arousal, it is also possible to connect sounds to emotions. The addition of valence could make the sound connections more complex. Thus, the decision is to investigate emotional arousal to gain insights about emotions and provide a simplified connections overview of sound and emotions. Figure 16 illustrates the decision that the focus is now on the arousal axis.

Measuring technique from Sense-IT application

Previous research from Sense-IT [2] even shows it is possible to determine a proxy of a physiological correlate of emotional arousal (PCEA) through heart rate measurements. This emotion regulation sound application will build on top of this technique of using PCEA and then include the sound modality to present these emotional arousal levels. The application is for mobile and wearable devices, where the wearable device (watch) registers heart rate via emotional arousal that is measured by PCEA. The emotional arousal levels can be high where the person is physiological and mentally active (over-aroused), or the emotional arousal levels are low with the person physiological and mentally passive (under-aroused). During over-aroused and under-aroused, the user experiences negative or positive emotions (see Figure 16). The Sense-IT technique measures the over-aroused and under-aroused. At first, Sense-IT measures the baseline of the heart rate from the user [2]. Then, Sense-IT classifies every heart rate measurement under the baseline as under-aroused and Sense-IT classifies every heart rate measurement above the baseline as over-aroused [2]. The Sense-IT technique uses the following formula [35] for this classification:

Equation 1 - Formula to measure emotional arousal levels [35]

$$average\ heart\ rate + \big((standard\ deviation * sensitivity) * x\big) < emotional\ arousal\ level < average\ heart\ rate + ((standard\ deviation * sensitivity) * (x + 1))$$

The x stands for the scale for matching the heart rate measurement to the emotional arousal level [35]. Sensitivity stands for the sensitivity of the system with a lower or higher range of the emotional arousal level [35]. The average heart rate, standard deviation, and sensitivity are for each user different and means that the ranges of emotional arousal levels can differ for each user. Thus, different users can be in the same emotional arousal with different ranges. The ranges of the emotional arousal levels depend on the individual values for the average heart rate, standard deviation, and sensitivity from the baseline measurements.

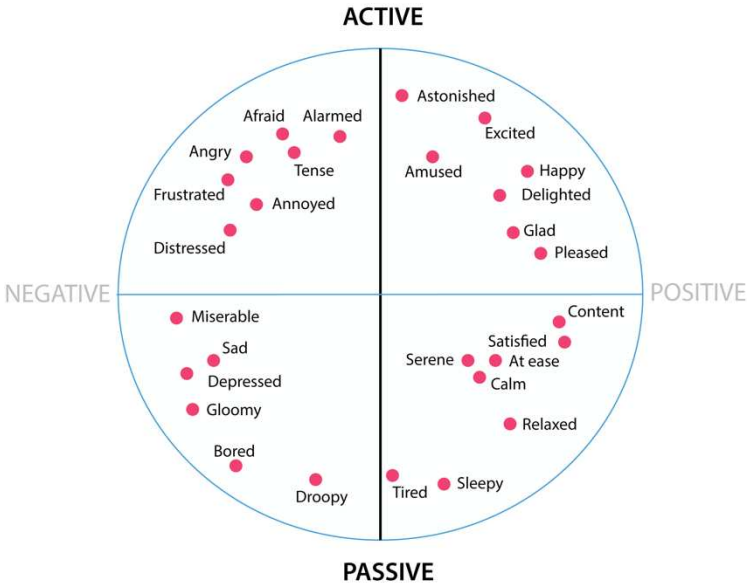


Figure 16 - Emotional arousal levels [32]

Emotion Examples for Emotional Arousal Levels

Table 15 shows an example of emotions for each emotional arousal level from Boukens [36]. The development does not consider the calmest level (0) because the user does not need to relax as the user is already at ease at level 0. For this research, the emotional arousal states under- and over-arousal through six levels (from -3 to +3 without 0). These six levels contribute to the representation of emotions without the word of a particular emotion to comply with requirement 3.9 (from Chapter 3) about avoiding the emotion words.

Table 15 - Example of different levels

-3	-2	-1	0	+1	+2	+3
Depressed or Tired	Gloomy	Sad	Calm	Distressed	Annoyed	Angry or Hyper

Scenario

There are responses with suitable sounds from the application based on the emotional arousal levels. The user can listen to these sounds when possibly wearing

a headphone (from requirement 3.12 about own headphones in 0). When the user wants to relive some negative emotions, the application can do so. The moments can even exist when the user is going out and about (to comply with requirement 3.7 about wearability in 0).

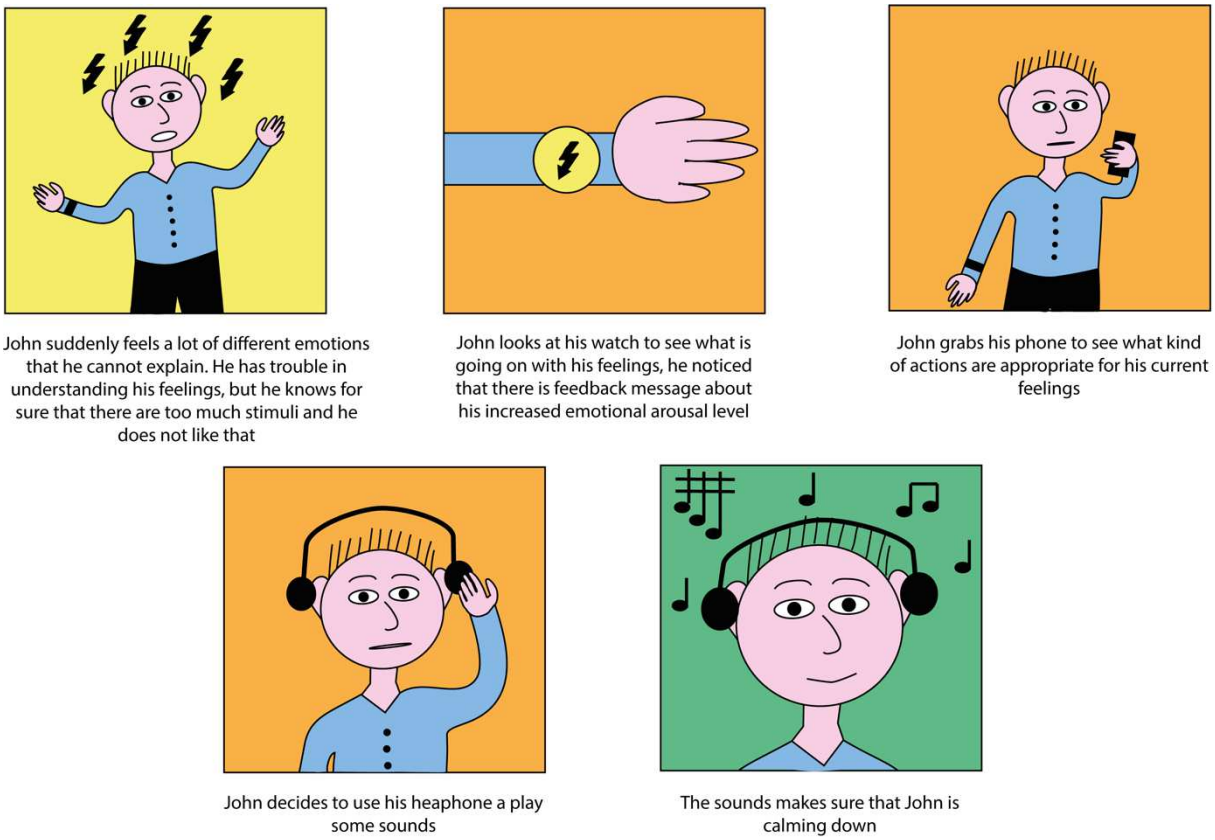


Figure 17 - Concept in storyboard

Figure 17 shows the concept as a storyboard to better understand how the application can play a part in the daily lives of people with autism. This storyboard includes a story (scenario) with a fictive persona of an autistic person called John. Different interviews that were held earlier (described in 0) are the basis for the story in the storyboard. The story includes the following information from the interviews: the participants mention dealing with different stimuli which provoke different emotions and can make the participants feel overwhelmed or even pressured. The researcher takes the information from the interviews of people dealing with a lot of emotions and incorporates that into the storyboard in Figure 17 with the following story and persona: the illustrated story starts with that of an autistic person (called John) who suddenly does not feel at ease. John does not know what is happening because he has trouble recognizing his emotions. The smartwatch of John shows in a subtly (unrecognizable to others) that he is over-aroused. John examines his smartphone to see what kind of coping technique he can perform. John listens to

some nice sounds, he grabs his headphone and is slowly calming down by listening to some nice familiar sounds.

4.2 Concept

The following describes the sounds for the emotion regulation application designed for people with autism spectrum disorder (ASD). First, there is a description of the different sound options. Second, there is a description of sound characteristics. At last, there is a description of different sound reactions. It is interesting, for the application, whether the sound modality is a good representation of the emotional arousal levels. Besides sound representing emotional arousal, there is also an interest in the effect of the sound modality on emotional arousal.

4.2.1 Sound Options

There is a description of sounds for the emotion regulation application. The mentioned sounds come from the results of user interviews in Chapter 3 and a literature review about calming sounds.

Nature

Listening to nature sounds seems to be a common calming mechanism for the target user. The interviews show that nature sounds, such as rain, thunderstorms, birds, meditation, water, are comforting for three participants. A study [37] even confirms that nature sounds (such as forest sounds) induced physiological and psychological relaxation, lowered heart rate, and increased feelings of comfort, relaxation, and improved mood states compared to city sounds. Thus, the application considers nature sounds (such as sounds of animals and weather [38]).

ASMR

Autonomous Sensory Meridian Response (ASMR) is a type of tingling, static-like sensation that is triggered by special audiovisual stimulation. This sensation makes the user feel more at ease. For this study, we focus solely on the audio part of ASMR. Another research [39] also shows that ASMR sounds calm down users. One participant also mentions listening to ASMR, such as white noise. The ASMR sounds are typical sounds that must propose to be relaxing. Examples of these sounds are soft voice [40], crackling [40], whispering [41], hair combing [41], food texture and eating sounds [42], typing [43], turning pages [43], scratching [43], tapping [43]. The application can include ASMR sounds.

Meditation

People might often use meditation as relaxation, and Metra-based meditation is a technique where sound, word, or phrase (mantra) narrate aloud or silently [44]. Another study showed that certain sounds (i.e., brain waves, heartbeat, nature, piano

melodies) are beneficial for being mindful and relaxed during meditation [45]. The same study [45] also shows that silence helps with meditating. One participant mentions listening to mindfulness sounds as relaxation. Thus, the application can also include sounds, mantras, or silence.

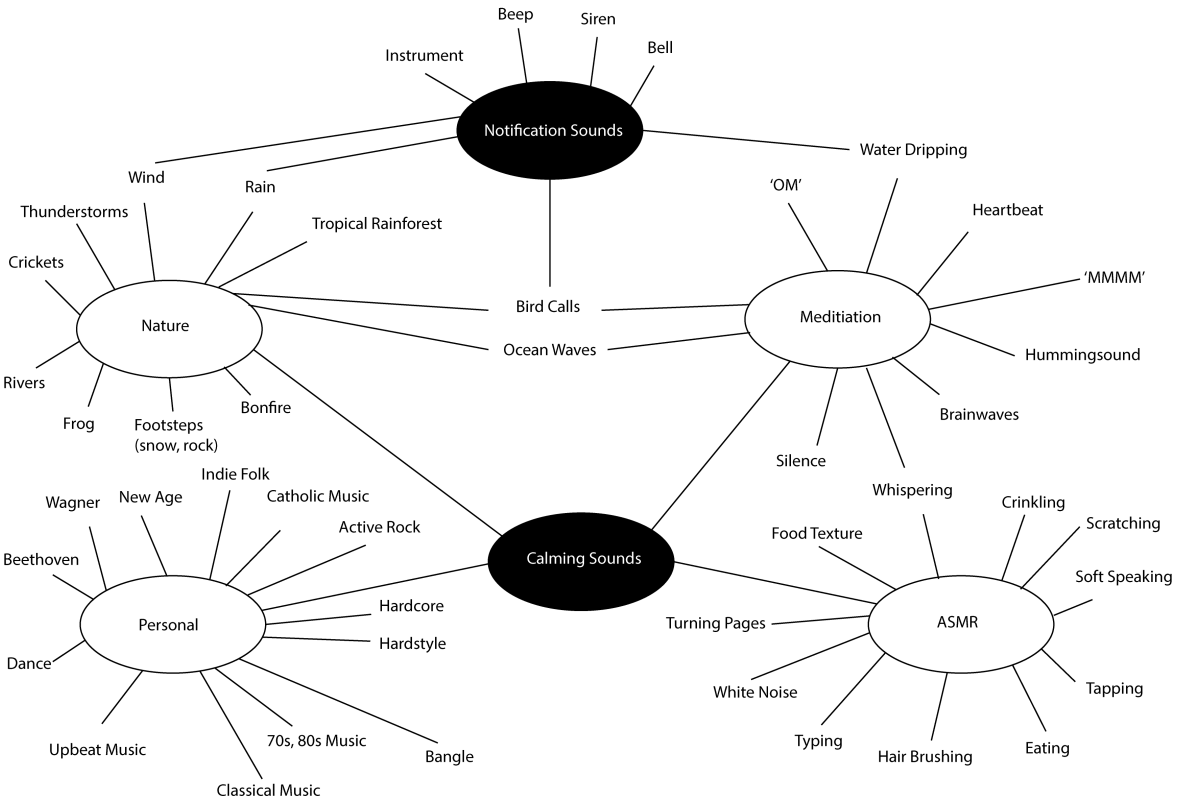


Figure 18 - Mind Map from Literature and Interviews

In the Appendix (see C1) is a table that describes both calming sounds from both the interviews and literature. Both the calming sound options (personal, nature, ASMR, meditation) and notification sounds translate into a Mind Map in Figure 18.
Figure 18 shows the different sound options for the application. These sound options come from literature and interviews. The four different categories for calming sounds are nature, meditation, personal, and ASMR. Each category has some examples in the Mind Map. These examples come from both literature and interviews, except the personal sounds. These personal sounds come only from the interviews. The sound examples in the category of personal sounds consist mostly of music that the different participants like to listen to. The participants mentioned during the interviews that they like these preferences because of familiarity and repetitive properties. Four participants even use the same intensity of music as their emotional state to redirect their angriness to the music. Different literature [38], [40], [45] generalizes the sound examples of nature, meditation, and AMSR as calming. Next to the calming sounds, there are also notification sounds. Other literature [46]

also generalizes examples of notification sounds. These examples of notification sounds are in the Mind Map (see Figure 18).

4.2.2 Sound Characteristics

Different aspects (such as pace, volume, rhythm, pitch) can characterize each sound. There is a focus on the sound characteristics for the application because of realizable reasons but also because of the user's needs from user interviews and different literature like Music Therapy. Music Therapy shows with the iso-principle that through tonal arrangements, tempos, styles, beats can reflect how someone is feeling and reflect their heart rate in which the sound characteristics then gradually alter to affect the desired mood state [16]. According to Seibert [16], if you are connecting with someone on an emotional and physical level, the person is more than likely to relax and have a lowered heart rate. The following sound characteristics can lay some foundation on how the sound might react to changes in emotional arousal.

Volume

A finding from the interviews was that one participant uses noise-canceling, and another person mentions thinking that music is better than noise-canceling. This means that there is a user's need to reduce the sounds in the environment. This can also work with volume, as a higher volume makes the user solely focus on the sounds. The interview results confirm this because one participant mentions solely focusing on the music when listening to it. When the volume gets lower or even goes to silence, the user can focus on themselves by being mindful and literature [45] also mentions that silence can contribute to relaxation for people.

Beats (Pace)

Beats are another characteristic of sound. One of the design requirements from the preliminary investigation by the same researcher for the course Research Topics mentions the importance of beats from Music Therapy. The field of Music Therapy discusses that music can help in therapy. When the beats of the sound level with the heartbeat, it means that the sound meets someone where they are physiologically and then the sound gradually decreases in beats to lower the heart rate. For example, an angry person can only listen to angry music at first. The interviews also confirm this as four participants mention listening to hardstyle when they were angry. These participants mentioned that the use of high-intensity sound when having a high-intensity emotion helped to channel their emotions towards the sounds instead of their surroundings, such as other people. Another example of using beats is during a run when you listen to faster beats and eventually would run faster.

Category
If we only look at the volume and beats as the sound characteristics, then we might miss something. For example, the application might play a certain bird call in higher or lower beats/volume for the different intensities of emotions. This can cause the same bird call that is adjusted with different beats, but then the audio reduces its quality and is perceivable as unnatural. Therefore, we look at another characteristic of sound that can create changes that are still meaningful and not reduce its quality, which is the characteristic of the category (genre). The category characteristic can combine with the volume and beats (pace). It means that when the intensity of the arousal changes, there is an intensity change in the sound by a different sound record of the same sound option. For example, when the emotional arousal level is increasing, the sound of a bird is changing to a sound of a different bird call with a higher pitch.

4.2.3 Sound Reactions
In the following, there is a description of how the sound can react in the application to changes in emotional arousal. Sounds can play in the background that can create an ambiance for the user. The user can therefore still perform certain activities in their daily life by using sounds. It makes the sounds perceivable as non-invasive and natural for the user. The sounds differ from regular sounds because of their changes based on the emotional arousal level.

As discussed in the concept, this research uses six emotional arousal levels. These emotional arousal levels show the different intensities of being under or over-aroused.

The following explains the sound reactions mimic/stimulate, nudge, alert personal, and filter. The inspiration for the sound reactions comes from Music Therapy, where the sounds try to level the current mood of the listener and then alter the sound to improve the user's mood positively. For each sound reaction, there is an example in a table. The sound reactions refer to the sound options in 4.2.1. Mainly, the sound reactions refer to the sound options of nature and meditation. It is difficult to represent different connecting emotional arousal levels with ASMR. Therefore, the ASMR sound option is not in the tables.

Mimic/Simulate
The mimic (or simulation) means that sounds simulate emotional arousal. Thus, a high heart rate is a high intensity of a certain sound characteristic. For example, the pace or beats increase when there is an increase in the emotional arousal level of the user. Therefore, the sound increases or decreases in the same way as the heart rate, where the audio represents the heart rate. Thus, a person who feels down or is angry hears sounds that appeal to them at that moment through the same intensity.

In the following table, there are some examples of sounds that represent the same intensity of each emotional arousal level. The sounds can change with pitch, category, speed, or rhythm. A chosen sound characteristic of either high or low intensity simulates highly intense or less intense emotional arousal (measured by fast or slow heart rate). Table 16 states different bird calls that have a slower or higher tempo compared to each other [47], [48]. Brainwaves can differ in six frequencies [49] to represent the emotional arousal levels. The researcher categorizes different nature sounds (ocean waves, rain) by the intensity of each emotional arousal level. The heart rate of a healthy person is between 60-100 bpm [50]. By exercise, the heart rate can go up to 150-200 bpm [50]. The researcher divides the ideal heart rates from 60 to 200 bpm equally for each subsequent emotional arousal level. These heartbeat sounds are preset and do not relate to the actual heart rate of someone when listening and reaching any of the emotional arousal levels.

Table 16 - Mimic Sound Reaction

	Emotional arousal level -3	Emotional arousal level -2	Emotional arousal level -1	Emotional arousal level +1	Emotional arousal level +2	Emotional arousal level +3
Birds	White-throated sparrow [47]	Song sparrow [47]	Pine warbler [47]	House finch [47]	Canada warbler [47]	Marsh Wrens [48]
Brainwaves [49]	Infra low	Delta waves	Theta waves	Alpha waves	Beta waves	Gamma waves
Ocean Waves	Running water from the crane	Water Stream	Waterfall	Water at shore	Ordinary waves	Stormy Waves
Rain	Drops from crane	Little Rain	Rain	Rainforest	Hurricane	Thunderstorms
Heartbeat sounds (preset) [50]	< 75 bpm	75-100 bpm	100-125 bpm	125-150 bpm	150 -175 bpm	175-200 bpm

Nudge

The nudge means that the increase/decrease is a little lower or a little higher than the heart rate. For example, the sound is increasing when the user deals with low emotional arousal levels, or the sound decreases with high emotional arousal levels. The purpose is to see whether sounds can nudge the behavior of the user. It is possible to notify and/or improve the behavior of the user by nudging. Sounds might nudge the user to be aware of some changes. The nudge can also indirectly

induce positive behavior. For example, when the user is under aroused and listening to sounds with higher frequency or higher beats per minute, the sounds might unconsciously nudge the user, and their heart rate might indirectly increase. This can also happen when the user is angry but gets to listen to a calmer sound. The same can happen when the user is over-aroused, and the sounds present with a lower frequency of beats per minute. In that case, the sounds might indirectly nudge the user might indirectly to lower their heart rate.

Thus, the sounds are a little higher or a little lower in intensity in comparison with the heart rate such that the sound might nudge the user, and their behavior is indirectly affected such that the user might increase their heart rate with faster sounds when they have a low heart rate.

The following table shows the same examples as with mimic. The sounds are a bit shifted in comparison with the mimic examples, such that the user hears sounds that are lower or higher in intensity. -3 and +3 sounds from the mimic sound reaction are not present anymore. The sounds of -2 and +2 from mimic sound reactions are present with the -3 and +3 nudge sound reaction. -1 and +1 mimic sounds are present in nudge with -2 and +2. For the nudge sound reaction of -1, the mimic sound reaction of +1 is present. For the nudge sound reaction of +1, the mimic sound reaction of -1 is present. The purpose is to nudge the heart rate towards the calmest level, which is 0.

Table 17 - Nudge Sound Reaction

	Emotional arousal level -3	Emotional arousal level -2	Emotional arousal level -1	Emotional arousal level +1	Emotional arousal level +2	Emotional arousal level +3
Birds	Song sparrow [47]	Pine warbler [47]	House finch [47]	Pine warbler [47]	House finch [47]	Canada warbler [47]
Brainwaves [49]	Delta waves	Theta waves	Alpha waves	Theta waves	Alpha waves	Beta waves
Ocean Waves	Water Stream	Waterfall	Water at shore	Waterfall	Water at shore	Ordinary waves
Rain	Little Rain	Rain	Rainforest	Rain	Rainforest	Hurricane
Heartbeat sounds (preset) [50]	75-100 bpm	100-125 bpm	125-150 bpm	100-125 bpm	125-150 bpm	150 -175 bpm

Alert

The calming sounds can also be present as a notification. This helps the user to be aware of their emotional arousal level such that they can better handle their emotional arousal changes. A study [51] mentions that notifications are a way to make users easily aware of new information in their daily lives. Another study [46] mentions that notifications can present with the sounds of a beep, siren, bell, birds, rain, water, wind, or instrument based on the priority that the notification has.

The sounds in the application can also work as notification sounds. This means that a notification sound accompanies an increase or decrease in emotional arousal. Notification sounds are common with the use of mobile devices. For example, notification sounds appear when new information is available on social media or when there is a phone call. The sounds can even be personal, thus different sounds for different applications or even for different people that are calling. The alert sounds are mainly event-based. This means that when an event appears (social media message or phone call) that a particular sound is playing. The sounds can play occasionally. Some sounds only play when using the application. These sounds are called in-app sounds. For example, when the user is playing a game on the smartphone, the specific sounds of that game only play when using the game application. Both the event-based and in-app sounds inform the user about what is going on. Research [52] shows that sounds are even mediating human-object interactions where the sounds can be functional to the use of the application, and they contribute to the overall appreciation of the application. Examples of the notification sounds from another research [46] prioritize with:

- high priority: beep, siren, and bell
- medium priority: birds, rain, water, wind
- low priority: musical instruments integrated into the background.

For the alerts, the beep, bell, and bird sounds are in the following table, with each a different execution. The researcher has determined the executions such that the sounds are testable during user testing, or the user can come up with other ideas. Alert sounds are present for a few seconds, such that the sound immediately notifies the user that something is happening. The first execution is to have the sound played the time that it appears from emotional arousal level -3 to +3, thus the sound plays once at emotional arousal level -3 and 6 times at emotional arousal level +3. The user is then immediately aware of their current emotional arousal level. Another execution is to only play the notification sound at extreme levels, such as at -3 or +3. This helps as a reminder for the user to take immediate action, such as stepping out of a highly emotional situation and doing some relaxation exercises. There is also execution for the user to make their preferences of how the alert should react to every emotional arousal level. The reason to include this option is the information

from interviews about the need from the users to have the emotion regulation sound application personalized.

Table 18 - Alert Sound Reaction

Emotional arousal level	Beep/Bell/Bird		
-3	Played 1 time	Played 1 time	personalized
-2	Played 2 times		
-1	Played 3 times		
+1	Played 4 times		
+2	Played 5 times		
+3	Played 6 times	Played 2 times	

Personal

The participants also mentioned during the interviews that there is a real need for the application to be personalized. For example, there was a diverse music taste from the participants (from hardcore, Indie Folk, 70s music, dance music to Wagner). This means that the application cannot offer a one-fits-for-all solution because every music or sound taste is personal. Thus, the sound options should also include personalized music/sounds.

Besides specific music, the participants also mention using music as an outlet for calming down. Four participants used music as their outlet where the music symbolizes their emotional state. For example, listening to hard rock/hardstyle music when being angry helped four participants to divert their angriness towards the music. This diversion results into that the participant not expressing angriness towards their surroundings, such as other people. Thus, it is also important for the application to consider sounds/music that symbolizes the current emotional state of the user.

The personal sounds can also change with a filter. This filter is a sound decrease or increase in response to an increase or decrease in the emotional arousal level. This filter is suitable for the volume or speed characteristic. The sounds can simulate heart

rate with the same increase/decrease in volume/speed. The user can change the exact increase/decrease, or the user uses pre-defined options. In the table below are percentages divided in each emotional arousal level by the researcher. These percentages are volume/speed percentages where the sound is still present and does not lose its quality. The user testing shows insights into the exact percentages that are suitable for the user.

Another filter is to only play some sounds/music when the user is in their extreme emotional arousal levels. For example, when the emotional arousal level is -3, the user is under-aroused, and the user might feel depressed. At this level, the user can listen to depressing songs from sadcore. Sadcore is a music genre that is made by and for depressed people and a slow downbeat defines the music [53]. At level +3 the user is over-aroused, and the option is to listen to hardcore. The reason for both the sadcore and hardcore is that the interviews show that an angry person might listen to hardcore to channel their angriness towards the music. Sadcore is a counterpart of hardcore in this study, but the user can eventually personalize these options in the emotion regulation sound application. Another preference for personal sounds from the interview is upbeat music, so this study uses also upbeat music and then with a counterpart of slow music. ASMR sounds have the counterpart of silence, thus the ASMR sounds decrease gradually in volume with low emotional arousal levels. Section 4.2.1 states that silence can work as a meditation, thus it might also help when someone is under aroused.

Table 19 - Filter Sound Reaction

Emotional arousal level	Every Sound			Sadcore/ Hardcore/ Hardstyle	Slow Music/ Upbeat Music	Silence/ASMR (Tapping/ Whispering/ Crinkling)
-3	Volume: 40%	Speed: 40%	Personalized volume percentages	Sadcore	Slow Music	Silence/ Volume: 0%
-2	Volume: 52%	Speed: 56%				Volume: 20%
-1	Volume: 64%	Speed: 72%				Volume: 40%
+1	Volume: 76%	Speed: 88%				Volume: 50%
+2	Volume: 88%	Speed: 104%				Volume 80%

Emotional arousal level	Every Sound			Sadcore/ Hardcore/ Hardstyle	Slow Music/ Upbeat Music	Silence/ASMR (Tapping/ Whispering/ Crinkling)
+3	Volume: 100%	Speed: 120%		Hardcore/ Hardstyle	Upbeat Music	Volume: 100%

4.3 Conclusion

The information from this chapter translates to the following discussion & conclusion, and answers to research questions.

4.3.1 Discussion & Conclusion

This chapter describes the concept of the application that is created from the user interviews and literature. The application is an emotion regulation application that is built on mobile and wearable devices. The emotion regulation application focuses on the emotion regulation of people with autism spectrum disorder using sound. Mobile and wearable devices make sure that the user can use the application anywhere. The user can still do their day-to-day activities and have sounds played in the background wherever they want.

The emotion regulation mechanism of the application focuses on providing tools to the target user to better handle extreme emotions that arise with the shutdown (isolation) or meltdown (screaming). Sounds of the application provide information about the emotional arousal of the user, such that they are better aware of them. The sounds also provide ideally the possibility for the user to cope with their emotions and hopefully prevent any extreme emotions such that a shutdown or meltdown will not occur that often anymore.

The application identifies the emotions with a proxy of a physiological correlate of emotional arousal (PCEA) that is measured through heart rate measurements. Thus, emotional arousal determines the emotions of the user. For this project, the researcher divides the emotional arousal into six arousal levels (from -3 to +3 without 0) that are based on earlier research from Sense-IT. Where the negative levels stand for high emotional arousal (over-aroused) and the positive levels stand for low emotional arousal (under-aroused).

The user might wear a headphone and the user can listen to sounds that represent the emotional arousal levels. The user can then relive some negative emotions by listening to suitable sounds. A person with ASD might get overwhelmed by all the stimuli in their environment. In these cases, the person has some elevation in their

emotional arousal that is recorded by the smartwatch. The person gets the notification by their smartwatch that something is going on, then the person can look at their phone to figure out what is going on and which strategy could help them feel more at ease. The person can decide to listen to some familiar sounds and cope with their feelings. Sounds only play by the action of the user to make sure that the sounds do not invade the daily life of the user.

The application can use sounds of nature or meditation. Each of the sound options has the benefits of coping with emotions, which both the user interviews and literature confirm. The sound might change on certain sound characteristics, such as volume, beats (pace), and category (genre). The volume and beats might increase or decrease for each emotional arousal level. Each emotional arousal level can also change the sound in the same genre based on certain sound characteristics (pace, volume, rhythm, pitch). Sound can react in four ways (mimic, nudge, alert, personal) to changes for each emotional arousal level. The mimic sound reaction is a simulation where the sound imitates the same intensity as the emotional arousal level. The sound is then an exact representation of the emotional arousal that is measured by PCEA. Nudge is the sound reaction where sounds are a little higher or a little lower than the actual emotional arousal level to nudge the user towards the calmest arousal emotional level (0). The user then listens to the sounds that might be a bit more cheerful than their current emotional state. The alert means that a single alert sound notifies the user. These alert sounds notify the user of their emotional arousal level and when the emotional arousal would get to extreme levels (such as +3 or -3). The application could also contain personal sounds that are based on the literature review and interviews. These sounds react differently in intensity to changes in the emotional arousal level.

To conclude, it is the idea that the application provides information to the user by sound about their emotional arousal, such that sounds embody emotion regulation. The emotion regulation sound application also serves as a coping mechanism for the user to prevent a meltdown or shutdown from happening that often. Sounds are based on the changes in the emotional arousal level of the user that is measured by a proxy of a physiological correlate of emotional arousal (PCEA) from heart rates. The sounds can be about nature, meditation, or ASMR. The sound can change by volume, beats, or within category (genre). The exact sound reaction can be a simulation (mimic), nudge, alert, or a personal sound.

4.3.2 Answers to research questions

This chapter does an attempt to answer the following sub-question: "*In which ways can sound give feedback about emotional arousal?"*. The ideation and conceptualization show that the combination of sound and emotional arousal can derive feedback

ideas. One feedback idea is to present emotional arousal through sounds. This helps the user to gain insights into their emotional arousal such that the user can better grasp their emotional arousal changes before escalation. Another feedback idea is that sounds can affect emotional arousal. For example, the sounds can help the user to cope with their feelings. This can help the target user to deal with their emotional arousal changes more easily before they escalate to a meltdown (screaming) or shutdown (isolation). Both feedback ideas focus on nature and meditation sounds. The sounds might change with volume, beats, or within category (genre). The sound change can be a simulation (mimic), nudge, alert, or personal sound.

The next chapter shows how the feedback ideas translate into a web-based prototype.

Chapter 5 Prototype 1.0 (Web-based)

This chapter describes the web-based prototype for the co-design sessions. The chapter explains the development and design choices with the web-based prototype. In the chapter also several screens of the web-based prototype are visible to give better insights into the built prototype. The chapter explains every screen of the web-based prototype. This chapter also tries to answer the following sub-question: *"In which ways can sound give feedback about emotional arousal?"*.

5.1 Design choices

The web-based prototype is an emotion regulation sound application that is built with HTML/CSS and JavaScript. Thus, an HTML page shows in the web browser a mobile and smartphone design that the user can navigate through. Web-based means that the user is not wearing heart rate measuring devices. A simulation of heart rate data is part of the web-based prototype. The web-based prototype is called Soundrate, which is the words sound and heart rate combined. The logo shows the letters SR which stand for SoundRate.

In Figure 20 - Figure 23 are some screens visible. The user is already in distress when using the emotion regulation sound application and therefore both the layout and functions are simplistic which also comes from requirement 3.11 from Chapter 3. The black/grey/white layout with pink accents makes sure that too many colors do not create any annoyances for the user (see Figure 20-Figure 23). The web-based prototype is completely in English because both English and Dutch-speaking people can take part in the testing phases.

5.2 Design requirements

The web-based prototype is based on the user's needs from the interviews, but the web-based prototype is also based on the following design requirements (DR) that came from a preliminary investigation by the same researcher for the course Research Topics. Each of the following design requirements states whether and how these requirements are in the current web-based prototype.

DR1: Include physical and cognitive parts of emotions

For DR1, it was important to include both the physical and the cognitive parts of emotions. By using the physiological correlate of emotional arousal (PCEA) it is possible to determine the emotional arousal of the user. Emotional arousal explains the emotions from depression to angriness that are both physical and cognitive. In the current web-based prototype, the measuring of emotional arousal is simulated. The representation of the emotional arousal is visible with dots in the six levels from -3 to +3 (see Figure 23). The user can view all the levels with the exact levels from 0

being highlighted such that the user knows at which level they are and how far it is towards the calmest level (0).

DR2: Consider aspects of D4EB

For DR2, it was important to consider Designing for Embodied Being in the World (D4EB) [12]. It means that the application design focuses on making an application that can exist in the daily lives of the user with the purpose that the user can still perform their day-to-day activities. D4EB is possible by focusing on the social context with such an application and focusing on the way the user acts on sensory stimuli (sensorimotor coupling). If both the social context and sensorimotor coupling apply, then the emotion regulation sound application embeds in the lives of the user.

The web-based prototype considers that constant signaling happens through the smartwatch. Messages on the smartwatch of the user are only understandable by the user, so the user can still use the smartwatch around other people. The emotion regulation sound application on the phone and starting sounds can only start when the user has given a command. Thus, the emotion regulation sound application does not disturb the relation to others. The emotion regulation sound application creates a new social context that is quite individualistic. The user can isolate themselves from others with the use of headphones and listening to the sounds on the emotion regulation sound application. There is a new social context between the user and their device and the world around them using the emotion regulation sound application.

Relaxation of the user through sounds achieves the sensorimotor coupling in the emotion regulation sound application. The user hears the sounds as a sensory stimulus. The user acts on the sensory stimulus by getting into a relaxed state (motor action).

DR3: Consider abstract representation

DR3 states it is important to consider abstract visualization of data. Representing the data of the levels in dots (see Figure 23) instead of numbers of the heart rate data in the web-based prototype achieves the abstract visualization of data.

DR4: Consider pleasant, neutral sounds and sounds from nature

For DR4, it is important to consider pleasant, neutral sounds and sounds from nature such that sounds do not invoke more intense emotional responses. For the web-based prototype, there are sounds of nature and meditation that are pleasing/neutral. There are also personal sounds in the web-based prototype such that the user can listen to sounds that would fit their taste and are pleasing to them.

DR5: Consider aspects of music therapy

The DR5 deals with considering the aspects of music therapy. Music therapy means that the therapy focuses on making people feel better through music [16]. The web-based prototype includes the iso-principle from music therapy, so the sounds and music level with the emotional state of the user. With the nudge sound reaction in the web-based prototype, there is an attempt to present more pleasant sounds to the user such that their extreme emotional arousal levels are decreasing or increasing towards the calmest level (0).

DR6: Consider non-invasive sound

DR6 states that the sound/music should not have a dominant character and that the user should be able to perform their day-to-day activities. Requirement 3.5 also confirmed this design requirement in the user interviews (0). Non-invasiveness with the current web-based prototype is achievable by the usage of the emotion regulation sound application. The users can decide when to use the emotion regulation sound application. The user wears the watch all the time, but this might not be invasive because a watch is a common accessory for many. An emotion regulation sound application might be invasive if the user views it that way, but the emotion regulation sound application itself is not invasive as in how it would play sounds if the user did not give that command.

5.3 Explanation screens web-based prototype

The web-based prototype is further explained below.

5.3.1 Sketch of the web-based prototype from researcher

The web-based prototype is first sketched (see Figure 19) and then developed into HTML/CSS and JavaScript (that is described in the remaining parts of this chapter). The sketch shows that the web-based prototype comprises selecting sounds (at the top and the left). This selection is from how the sounds react (at the top) and which sound is being played (at the left). An overview of the sounds is visible in the middle of the screen. The user can play the sound. Sounds, emotional arousal level, and an option to play/pause the song are visible on the smartwatch. The sketches translate into a web-based prototype that is described in the next part of the chapter. The next part of this chapter shows also a more in-depth explanation of the different elements of the web-based prototype.

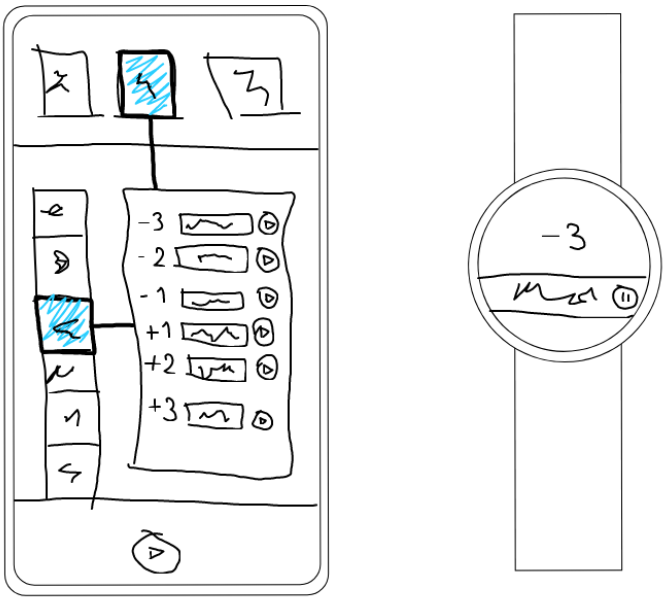


Figure 19 - Sketch web-based prototype (researcher)

5.3.2 Info text

Figure 20 shows that if the user hovers above the info icon, a pop window appears with an explanation that the user can select above the sound reaction and at the left the type of sound.

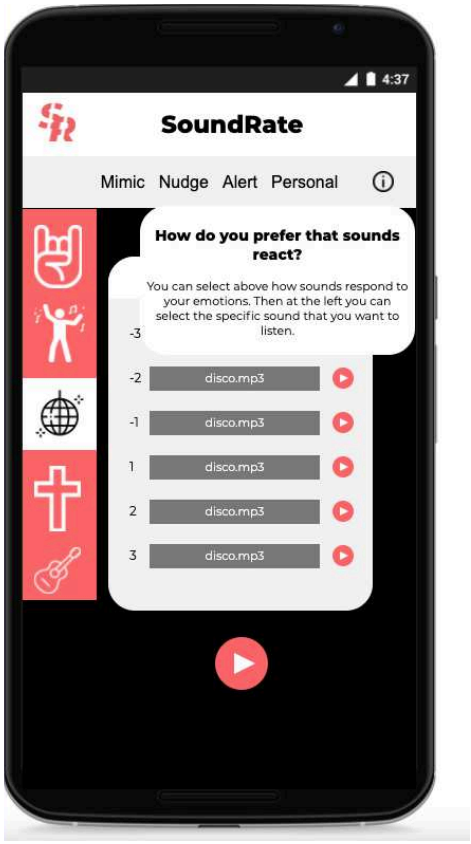


Figure 20 - Info text

5.3.3 Sound reactions

Figure 21 shows the selection of a sound reaction (mimic, nudge, alert, or personal). The web-based prototype provides the user with the four sound reactions, mimic, nudge, alert, and personal, that respond to the emotional arousal level of the user. Mimic is the simulation where the sound has the same intensity as the emotional arousal. Nudge represents the sound reaction, where sounds that are an intensity lower or higher nudge the user to the ideal emotional arousal level. The alert means the alert sounds at the highest or lowest emotional arousal level play to warn the user that their emotional arousal level is too high or too low. Sounds that are used for the web-based prototype do not differ because of technical issues for each emotional arousal level such as playing multiple times alert as discussed in Chapter 4. The researcher decides to only include the alert sounds at the highest (+3) and lowest (-3) emotional arousal level to gain insights into whether the alert sounds would succeed according to the user's needs and in later versions of the emotion regulation sound application it is further explored to include differences in the sound for each emotional arousal levels. The personal sound reaction means that the user can listen to personalized songs that came from the interviews. These personal sounds have a characteristic change for each emotional arousal level. Thus, the decision is to not represent the personal sounds as having a sadcore sound at -3 and hardstyle sound at +3 as discussed in Chapter 4. The reason that the web-based prototype does not include the sadcore/hardstyle is that it is first investigated whether the personal sounds mentioned during the user interviews are suitable for the emotion regulation sound application according to the user, in later versions of the emotion regulation sound application the specific changes are explorable based on the user's needs. These personal sounds are in the same simulation manner, where the intensity of the sound levels with the intensity of the emotional arousal level. The reason for this is to first investigate in the user test whether the user prefers the option mimic or nudge and then one of these becomes part of the emotion regulation sound application. The option for the user to personalize any of the sound reactions is not part of the current web-based prototype because of time constraints. Design sessions gather the user's needs for personalization.

Figure 21 - Sound Reaction selection

5.3.4 Sound options

When the user clicks on one of the sound reactions, a vertical bar pops up with the different sounds that the user can select for each sound reaction (see Figure 22). The categories for the type of sounds are nature, meditation, and personal sounds from the literature reviews and interviews. Every category in the web-based prototype has multiple sounds that the user can listen to. When the user clicks one sound, the web-based prototype redirects them to the info page, as seen in Figure 22. On each info page are the sounds placed for the different emotional arousal levels. The user can play and pause the sounds on this info page.

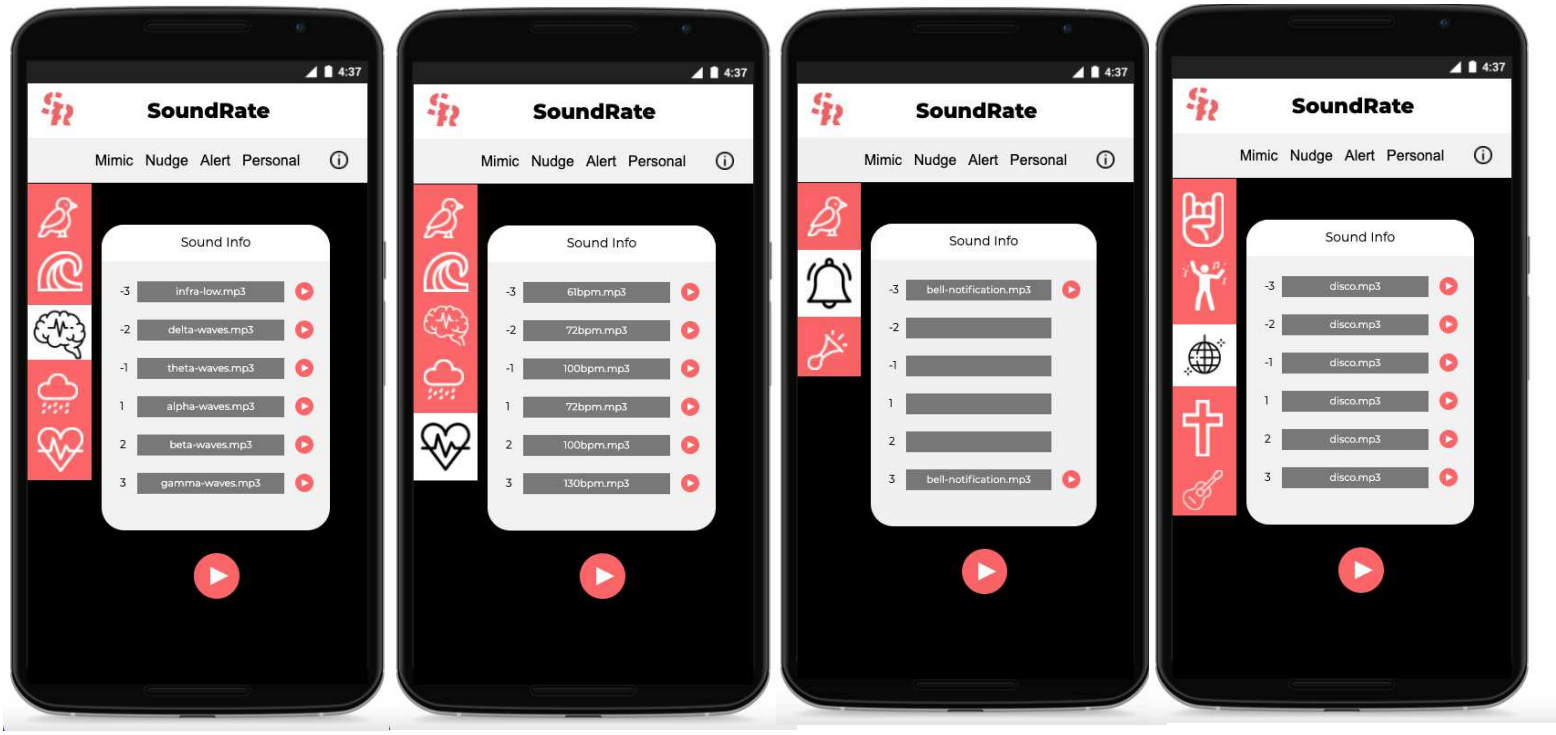


Figure 22 - Selection of Sound Type

5.3.5 Detail pages

If the user clicks on the play button on the info page, the web-based prototype goes to the detail page of each sound. Figure 23 shows some examples of these detail pages. The detail page is viewable on the smartphone as a smartwatch. On the detail page, the user can pause and play the sound on both the smartphone and smartwatch. The user sees the different emotional arousal levels in dots that become white. They are first grey such that the scale is visible upfront. The web-based prototype goes through each emotional level and the sound changes accordingly. The detail page comprises a picture and color. These pictures and colors are different for each sound to create a more customized overview of the different sounds. The user can return to the home screen by clicking to triangle at the top left corner.

Figure 23 - Detail Pages of Sounds on web-based prototype

The next chapter discusses how the target user tests this web-based prototype.

5.4 Conclusion

The information from this chapter translates to the discussion & conclusion, and answers to research questions.

5.4.1 Discussion & Conclusion

The concept from Chapter 4 translates into the above web-based prototype. The web-based prototype description clarifies that the web-based prototype has a neutral design to avoid any annoyances for the user. Both English and Dutch people can take part in the next round of user involvement, thus the web-based prototype is in English. The design requirements from the Research Topics course are in the web-based prototype. The design requirements are about 1) including a cognitive and physical part of emotions (DR1), 2) use Designing for Embodied Being in the World (DR2), 3) use an abstract representation of emotions (DR3), 4) use pleasant, neutral, nature sounds (DR4), 5) include principles of Music Therapy (DR5), 6) make sure that the emotion regulation sound application is non-invasive (DR6). Sounds for the web-based prototype can react on the emotional arousal level as sound reactions mimic (simulation), nudge (nudging), alert (sound at extreme levels), or personal (sounds/music from interviews that have a sound characteristic change on each emotional arousal level). The sounds can be nature, meditation, or personal sounds. For every sound, there is a detail page with information about the emotional arousal level represented in dots.

To conclude, the web-based prototype comprises sounds that can react in different manners based on the emotional arousal level. The web-based prototype is based on the concept, user's needs from the interviews, and the design requirements from Research Topics.

5.4.2 Answers to research questions

This chapter tries to answer the following sub-question: *"In which ways can sound give feedback about emotional arousal?"*. The previous chapter also tried to answer this sub-question. The difference between this chapter and the previous chapter is that this chapter goes into more detail on how sound reacts to emotions and eventually tries to change emotions by designing and developing the concept into a web-based prototype. Thus, the answer from Chapter 4 also holds for this chapter. The answer from the previous chapter was that feedback ideas were that sound represents emotions, but sound also affects emotions. This chapter also gives the same answer but also includes the feedback idea of using the ability for the user to choose how the sound reacts to the different emotions. Thus, the user can decide how the sound should react. The user decides on whether the sound should present the emotions

with mimic, affect the emotions with nudge, give an alert on extreme emotions with alerts, or change on the emotions with personal sounds.

The next chapter shows how the target user tests the web-based prototype in a user study and whether the target user provides new insights through co-design.

Chapter 6 User Involvement 2 - Co-Design and User Test

This chapter describes the second user involvement. The chapter also attempts to answer the following sub-question: *"What are the requirements from people with ASD about the emotion regulation sound application?"*. The user involvement with the target user takes place in design and test sessions. During the design and test session, the researcher asks the user some questions. These questions are qualitative and semi-structured. For more in-depth insights into the user's needs, the researcher can deviate from the questions. The sessions comprise a part of co-design and a part of the user test. Participants translate firstly their ideas for an emotion regulation sound application to a design (co-design), and then they test a web-based prototype (user test). For co-design, the goal is to gain insights about which sound or music is suitable for which emotional arousal level from the perspectives of the participants, such that the further development choices satisfy their opinions and needs. Another goal for the co-design part is to allow the participant to express their needs for an emotion regulation sound application design through a sketch. The goal of the user test is to gain insights into what would work best for a sound option for people with autism spectrum disorder (ASD). Participants can give their opinions on the current web-based prototype, on the difference between mimic and nudge (the different sound reactions), and on the difference between the nature sounds, alert sounds, and personal sounds.

6.1 Setup co-design and test sessions

The following shows the setup for the co-design and test sessions.

6.1.1 Participants

The participants for the interviews are people with autism spectrum disorder (ASD) according to the Diagnostic of Statistical Manual of Mental Disorders, 5th Edition (DSM-5). The participants are 18 years or older. Participants from the first user involvement (user interviews) might also take part in the co-design and test session. Participants PP1, PP2, PP3, PP9, PP10 take part in the co-design and test sessions.

6.1.2 Purpose

For the web-based prototype, the researcher investigates how the user would react whether the sounds simulate the emotional arousal level (heart rate) or the sounds act as a nudge where the sounds are a little higher or a little slower than the heart rate. The heart rate in the web-based prototype is a simulation and has no relation to the emotions of the participants. The assumption is that the target user prefers either the sound reaction mimic or the sound reaction nudge. During the design and test sessions, the researcher investigates whether the participants prefer the sound

reaction mimic or the sound reaction nudge. Next to the mimic and nudge are also alert and personal sounds as sound reactions. The researcher gathers the opinions from the target user about all the sound reactions to a generated heart rate.

6.1.3 Design and Test Sessions

The first insights of users' needs in the user interviews translate to a web-based prototype (see Chapter 5). During the design and test sessions, the target user tests this web-based prototype. As described in the literature review, it is important to involve the users in the research because a finding from the literature review shows that rarely people with autism spectrum disorder are involved in research about autism spectrum disorder. Therefore, the target user is involved in the research by giving input for a user interface by sketching. So, the session includes both a design and test part. Another reason for including sketching by users is that it gives input for requirement 3.4 about personalization. Ideally, the tested web-based prototype should include personalization, but this was not possible due to time constraints. Now it is possible to gain insights into the user's needs about personalization by letting them make their sketch.

The user first sketches some screens for an emotion regulation sound application and then the user tests a web-based prototype. The design and test session comprises the tasks that the user performs a sketch and test a web-based prototype. Between these tasks, the researcher asks some open questions (see B2). The questions are based on the requirements from Chapter 3. So, the researcher asks what the target users think about certain subjects that are related to the requirements and whether they think it is in the current web-based prototype and/or should be in the emotion regulation sound application. These questions are semi-structured and pre-defined, but it is possible to deviate from the questions such that it is possible to gain more in-depth insights.

Set-up

The Ethics Committee Computer and Information Science (EEMCS) approves the design and test sessions as ethical sound under reference number RP 2020-37. The researcher registers the data collection under the General Data Protection Regulation (GDPR) with reference number WBP19ME0018. Video calling (Google Meet) is used to conduct the design and test sessions. Google Meet is GDPR proof. The video calling takes place because of the Covid-19 measurements, but it also makes it more accessible for the target user to join. The sessions take approximately 60 minutes.

Procedures

Qualtrics

The researcher asks the participant to read the information brochure in Qualtrics that was also sent by mail before the session (see A2). The user is then also able to sign the consent form in Qualtrics. In Qualtrics are also some basic questions. For example, what are your gender, age, and education? These questions give insights into the demographic of the participants.

Calming Sounds and Emotional Model

The researcher asks some questions about the usages of calming music and sounds. Then the researcher explains the 6 different emotional arousal levels.

Mimic vs. Nudge

After the explanation of the emotions, the researcher explains sounds can react as mimic (simulates emotions) or nudge (pushing emotions to lower/higher level). The researcher asks the participant what they think of these sound reactions and whether they think that there should be another sound reaction added.

Mapping Sounds to Emotions

Then, the researcher asks the participant to map sounds on emotional arousal levels. The participant listens to examples of how sound might change in category (genre) and beats pace for nature, meditation, and personal sounds. There is no volume change during testing because of some technical issues that the change for the different emotional arousal was not present. All the examples are a simulation (mimic) of emotional arousal levels. The first example is sound with birds, where the sound changes with a different type of bird with a faster or slower bird call. The next example is about a drum where the speed changes for the same audio file. Each level has a higher or lower heart rate in the last example. After listening to these examples, the researcher asks the participant to map sounds on emotional arousal levels.

Sketching User Interface

Then, the researcher asks the participant to sketch something about a user interface that they think should be part of the emotion regulation sound application on the website https://sketch.io/sketchpad/. There are no restrictions for the participant in what they want to be included in the emotion regulation sound application. The only restriction is to think as simply as possible. To achieve this, each participant uses a background of a smartphone and smartwatch where they can draw one. So, the sketch restricts to a single page for the smartphone and smartwatch. Each participant restricts to a limit of 15 minutes on the timer they see during sketching. The timer helps each participant to keep track of not thinking too complex and the visibility of the timer helps the users to be aware of how much time they still have. The

researcher asks after sketching some questions about the choices that the participant made.

User Test

The researcher then asks the participant to perform some tasks with the following web-based prototype that was explained in the previous chapter (see Figure 24). It is up to the participant how the sound should react through mimic, nudge, alert or personal. The participant can also decide which sound to play (e.g., nature sounds, meditation sounds, or personal sounds). The researcher explains to the participant to select sounds by clicking a sound reaction at the top, at the left a sound, and then on the play button at the bottom to start a sound. Then, the researcher asks the participant to navigate through the web-based prototype and select sounds for each sound reaction.

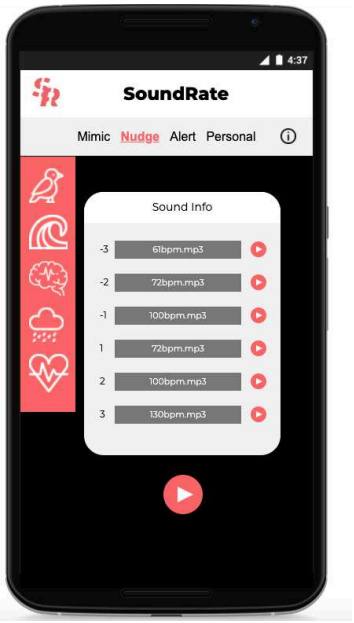


Figure 24 – Web-based prototype

The participant goes to the web-based prototype on https://codepen.io/. This website provides a full-page view. The participants listen to each sound reaction and decide for each sound reaction to which sounds they want to listen. The researcher asks the participant afterward what they think about the web-based prototype.

General Questions

After the user test, the researcher asks some general questions that the participant did not answer, through a semi-structured method. See B2 for the questions. It is also

possible to deviate from these questions to gain a more in-depth understanding of what the user's needs are for the emotion regulation sound application. The questions are based on the requirements from Chapter 3. The requirements translate into questions to investigate whether the current web-based prototype includes those requirements according to the user. The requirements are about emotion handling (Req. 3.1), repetition (Req. 3.2), familiarity (Req. 3.3), personalization (Req. 3.4), non-invasive (Req. 3.5), in control of own life (Req. 3.6), wearability (Req. 3.7), feedback by sound (Req. 3.8), avoid words of emotions (Req. 3.9), ability to adjust (Req. 3.10), simple design (Req. 3.11), own headphone (Req. 3.11), and learnability (Req. 3.13). There is an attempt to include all these requirements, but the researcher did not ask some of them because of the technical issues that the web-based prototype did not include some requirements, such as learnability and own headphones. The participant can also give some other ideas or tips for the emotion regulation sound application.

6.1.4 Research materials

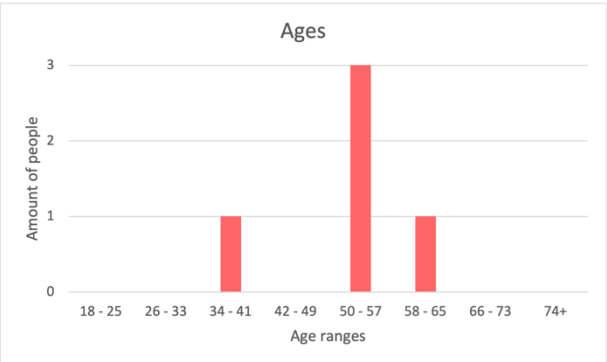
The research from the co-design and test sessions are answers to the interview questions and sketches of the participants.

6.2 Co-Design and User Test Results

The following shows the co-design and user test results with demographic information and thematic coding scheme.

6.2.1 Demographic information

Five people with the diagnosis of autism spectrum disorder took part in the design and test sessions. 4 participants were male, 1 participant was female. The ages of the participants were between 34-65 years old (see Figure 25). All participants had a higher education (1 participant: Community College, 2 participants: Bachelor's Degree, 2 participants: Master's Degree). The professions ranged with 3 developers, 1 IT support, and 1 Dive instructor (see Figure 26).



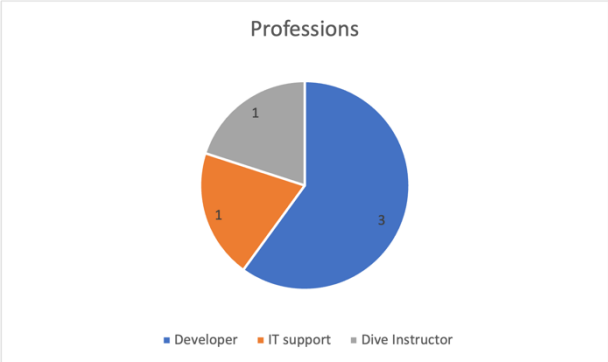


Figure 25 - Age ranges participants co-design and user testing

Figure 26 - Profession of participants co-design and user testing

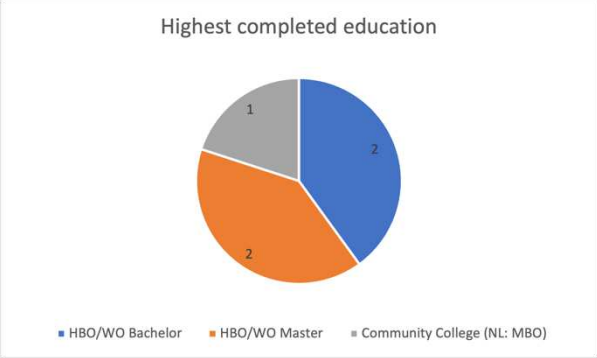


Figure 27 - Highest completed education participants co-design and user testing

The demographic information shows that more males than females took part. The age range of 50-57 years old is the average age range of the involved participants. Three participants had the profession of a developer. Another participant had also a technical profession of IT support. The highest completed education is for both the HBO/WO bachelor and HBO/WO master equally the highest groups.

6.2.2 Thematic coding Scheme

The results of the design and test sessions comprise answers to questions and sketches for an emotion regulation sound application design. The following are first the answers to the questionnaire analyzed and after that the different sketches.

Questionnaires

The researcher analyzes the results from the questions based on thematic coding. The researcher defines the following codes beforehand (deductive coding) to answer the sub-question about what the requirements are for the emotion regulation sound application from people with ASD.

1. Simulate/Mimic
2. Nudge
3. Calming sounds/Music
4. Design
5. Mapping

The researcher made themes from the codes, with each code from the same level of specificity or importance (flat coding frame). Each theme's information translates into requirements. The section below has summaries in each theme section of these requirements. The conclusion states the further labeling and prioritizing of the requirements.

Theme 6.1 Improvements for Emotion Regulation Sound Application

- PP2 mentions having doubts about whether the web-based prototype could work. PP2 gave the example of using a paper by a family member with one side an angry face and the other side a happy face with experiencing extreme emotions. This example is according to PP2, the same thing that the emotion regulation sound application wants to achieve. PP2 thinks that the analog version might even be better.

PP3, PP9, and PP10 think that the web-based prototype can improve and should not only focus on sounds.

- PP3 mentions that the other choices should not be immersive, as people with autism spectrum disorder have difficulty with making choices.

The advice can be an addition according to PP3, PP9, and PP10.

- PP3 mentions it is useful to receive some advice about what you are doing because sometimes you are stuck in a certain pattern, then the emotion regulation sound application can provide some advice about finding some rest and stopping what you are doing or stopping with social media now. PP3 mentions it might be interesting if the user can determine their advice.
- According to PP3, an option for advice can be actions or instructions about what can help to calm down.
- PP9 also mentions that the alert plan with different pans, as the different emotional arousal levels might be useful. Thus, the advice can come from the alert plan and sound might be an option as advice.
- PP9 also mentions that walking outdoors or breathing exercises after a long run might fit as advice.
- PP9 thinks that the advice can present with a text balloon or icon with: *"You are apparently in +3, then it is wise to do this or that, so… for example, to go outside."*
- PP10 mentions that the emotion regulation sound application is nice when you are out of control and can start a sound or receive some advice about singing because singing helps PP10 to cheer up.

PP9 and PP10 also think that the user should be able to choose a mode such as mimic or nudge.

- PP9 mentions another mode could be meditation exercises.
- PP10 mentions that it is important to provide the modes such that the user is in control of choosing the sounds. PP3 confirms this by saying that the user should be able to determine whether they want a mirror (mimic) or go down on the scale (nudge).
- PP10 mentions that the modes should be in a settings screen. PP10 mentions that the emotion regulation sound application should register everything, but the user should execute the actions.

Register:

- PP9 mentions that the emotion regulation sound application can register whether a certain exercise is helping by measuring a decrease or increase in the heart rate. According to PP9, the emotion regulation sound application can then give another advice that helps to relax.
- PP9 also mentions that the emotion regulation sound application should register extreme cases where the emotional arousal level of the user jumps to a level with skipping several levels in a short period.
- PP9 also mentions that the emotion regulation sound application should provide some advice on these extreme cases.

Design:

- PP2 also mentions that it is important that the User Interface contains as few as possible elements because people with autism spectrum disorder do not want to experience too many stimuli.
- PP9 mentions that the emotion regulation sound application should be visually appealing and should contain more functionalities with more information, such that: *"I can learn more about myself constantly*. "

Functionality:

- PP9 mentions that the emotion regulation sound application might work best if it is always on and only notify with functional messages when something is going on. The messages should not be intrusive, but meaningful, according to PP9. For example, every day or every week advertisements or tips that you do not need are intrusive according to PP9. PP9 mentions it is important to think about the meaning of the tip and the frequency.

Table 20 – Requirement Theme 6.1

# from 6.3.4	Requirement	Description
6.1	Meaningful messages	The emotion regulation sound application shall provide meaningful messages to achieve that the user benefits from the messages.
6.2	Minimalistic design	The emotion regulation sound application shall provide a minimalistic design to achieve that the target user is not overwhelmed.
6.7	Not too many advice options	The emotion regulation sound application shall provide not too many advice options to achieve that it is not complex, and the user is not overwhelmed.
6.8	Select the sound reaction	The emotion regulation sound application shall provide the user with the ability to select their preferred sound reaction to changes in the emotional arousal level to achieve that the user has to ability to customize parts of the emotion regulation sound application.
6.9	Visual appealing	The emotion regulation sound application shall provide a visually appealing design to achieve that the target user wants to use the emotion regulation sound application more than once.
6.10	Personal data	The emotion regulation sound application shall provide the option for the user to include personal data such as advice, sounds, or sound reactions to achieve that the user has more control over how the emotion regulation sound application acts.
6.11	Non-intrusive messages	The emotion regulation sound application shall provide non-intrusive messages to achieve that all messages do not overwhelm the user.
6.16	More and personal advice via mode selection	The emotion regulation sound application shall provide more advice options for the user when their emotions are intensive to achieve that user can choose what they want to do.

Theme 6.2 Mimic vs. Nudge

Mimic and Nudge:

- PP3, PP9, and PP10 think that there is no preference for simulation (mimic) or nudge and that it is especially context-based.
- PP1 thinks that the preference lies in the goal that you have for using the emotion regulation sound application. PP1 thinks the nudge might work better with a stressed person who goes into a situation such that the emotion regulation sound application can advise on what can help you calm down and

that you also get calm down. On contrary, PP1 thinks the mimic is nice when you hear a change in between with something that you are doing, then it would work like a notification that notifies you about a change that can present with a heartbeat.

- PP2 thinks the nudge might work better because PP2 perceives it as calmer. PP2 says that the nudge helps with influencing to get calmer through the calmer sounds. Participant PP2 also thinks that it is not a clear-cut situation in which sound reaction can work best because PP2 also had some experience with calming down when being angry by listening to angry music.
- PP3 mentions that nudge is better to decrease the emotional arousal level, but mimic is nice to have a mirror in front of you.
- PP9 mentions that sometimes there is a need to acknowledge your feelings (mimic) and sometimes there is a need to cheer you up (nudge). PP9 mentions that the mimic helps the user to be aware of their emotions and the nudge stimulates the user to calm down. Nudge is reacting to how you feel, and mimic is more signaling according to PP9.
- PP10 also mentions that mimic might be best to simulate the same mood. But PP10 also mentions that nudge might work better to have insights into your emotions and calm down.

Mimic:

- PP1, PP3, and PP10 think that the mimic also has some disadvantages of staying in the same emotional state that makes you wallow in pity and eventually lose yourself.
- PP1 thinks that if you are a little sad it is fine, but something happy is desirable if the sadness is for a long time. PP1 mentions if you are severely depressed, then there is a desire to go as fast as possible to the calmest level.
- Both PP1 and PP10 think that for example angriness and sadness would not disappear if you stayed listening to angry or sad music for too long.
- PP3 also mentions that it might be nicer to listen to happy/upbeat songs when being angry or agitated because happy/upbeat songs have a positive effect on people such that they can help people to overcome negative emotions according to PP3.

Nudge:

- PP1 thinks that sound reaction like the nudge can be an addition to listening to music. For example, the music can deduce in volume and the nudge would be present with something like a heartbeat.
- PP9 also mentions that the word nudge is not intuitive. PP9 knew it means through explanation from the researcher, but PP9 thinks that someone else would not understand the word.

Table 21 – Requirement Theme 6.2

# from 6.3.4	Requirement	Description
6.12	Understandable words	The emotion regulation sound application shall provide the text that is intuitive and understandable to achieve that the user immediately knows what it means.
6.17	Sound reaction based on context	The emotion regulation sound application shall provide the sound reaction that is based on the context (wanting to calm down, have more insights into the emotions, or being in a meeting) to achieve that the user can better handle their emotions.

Theme 6.3 Recognizing Patterns

Patterns:

- PP1 and PP9 think it would be nice if the emotion regulation sound application recognizes patterns. PP1 thinks a pattern could be when the user is going from 0 to 100, so the user is at one moment calm and at the other moment experiences a lot of stress.
- PP9 also mentions that sound can be based on patterns if the user suddenly jumps to a different level and skips several levels. If that happens often and repetitively according to PP9, then it is possible to analyze the data and is there a follow-up for each level.

Notes:

- PP1 mentions that the user might view back the patterns in time, then the emotion regulation sound application would serve as a diary with:" Hey, *what happened then?"* Then you have, according to PP1, also more insights into what you were doing and if you felt that way. PP1 mentions the following example: at half-past five, you always experience stress, but then noticed that it comes from cooking dinner.
- PP9 also mentions that the emotion regulation sound application can improve with a log that the user can look back to what was going on in the past for the heart rate measurements, and patterns in the emotional arousal levels from the emotion regulation sound application. PP9 mentions this data can present in a time frame, such as with a graph.
- PP9 mentions that you can see in the emotion regulation sound application things like: *"from 3:00 pm to 4:00 pm I felt that, and I was doing this."* PP9 mentions that the user might add certain icons about how he/she is feeling.

- PP9 also mentions the addition of information about what everything means and notes with: *"What I was feeling in my stomach of emotions."*
- PP9 also mentions that the user can add notes on every level about how he/she is feeling, such that it is easier retrievable when talking to someone like a therapist about what the user was feeling and why at that specific moment.

Table 22 – Requirement Theme 6.3

# from 6.3.4	Requirement	Description
6.13	Include notes and a diary	The emotion regulation sound application shall provide the option to include notes and a diary in the emotion regulation sound application to achieve that the user can provide more information about the changes in the emotional arousal levels.
6.18	Recognize patterns	The emotion regulation sound application shall provide the ability to recognize patterns in the emotions of the user to achieve that the emotion regulation sound application can give tailored advice to patterns that happen often.

Theme 6.4 Alert Sounds

PP3, PP9, and PP10 mention that the alert is a good sound reaction to prevent the user from receiving extreme emotions.

- PP9 mentions it is important to help the participant timely prevent the increasing of emotions with an alert message that can be personal.
- PP9 thinks that the alert might be useful for themself because: *"It helps me to be aware and know what is going on. I have to do something with it."*

Current form:

- PP2 thinks that the alert in the current form has no added value, because when you start a sound, then you hear nothing unless you are in extreme emotions. PP2 says: *"Why am I pressing it if I don't hear anything?"*
- PP9 mentions that in the current form, the user must think a lot because the sounds of -3 and +3 are the same so the user cannot know if their emotions are passive or active. PP9 mentions that the user does not want to think a lot when they have intense emotions, because in these extreme cases, the user has an emotional blockage according to PP9.

Vibrations:

- PP9 thinks that in these cases, a vibration from the smartwatch might be suitable that divers in intensity. PP9 mentions the vibrations should not be a lot because that is stress-inducing.

Mimic/Nudge:

- PP9 thinks that the alert can be an addition to the nudge or mimic. For example, if the emotion regulation sound application gives an alert, the user can choose to go to the mode mimic or nudge according to PP9.

Advice:

- PP9 mentions that some advice about actions can be an addition to the alert.

Customize:

- PP1 mentions that the emotion regulation sound application provides an option for the user to decide when the emotion regulation sound application should provide an alert sound, PP1 can imagine that with angriness the alert already plays at -2 or +2 but with sadness, the alert plays only at the extreme levels. PP1 mentions that someone else might want to hear the alert only at the extreme emotions and another person wants to hear the alert with every change.

Music:

- PP1 thinks it might be interesting to have constant music that changes over time according to the emotions of the user. PP1 thinks that the music can play constantly, and you notice that something is changing.
- The alert sounds might be an addition to music according to PP9, such that music plays at that moment according to PP9.

Table 23 – Requirement Theme 6.4

# from 6.3.4	Requirement	Description
6.3	A noticeable sound difference for emotional arousal levels	The emotion regulation sound application shall provide a noticeable sound difference for the different emotional arousal levels to achieve that it is easier for the user to understand the different emotional arousal levels.

Theme 6.5 Image Modalities

- PP2 mentions that there can also be a modality of images. According to PP2, images have also an influence on our moods, such as an image of nice weather, whereas images of rain or thunder have another effect on us.
- PP3 also mentions that images can present the advice for visual people.

Table 24 – Requirement Theme 6.5

# from 6.3.4	Requirement	Description
6.15	Visualize emotional arousal levels	The emotion regulation sound application shall provide an intuitive visualization of the emotional arousal levels to achieve that it is clear for the user if their emotions are active or passive.

Theme 6.6 Representation of Emotions

Awareness:

- PP9 also mentions that the user must still look at their screen to know which emotional arousal level they are at, and that is not immediately clear from the sounds only.

Scale:

- PP1 thinks that the scale of -3 to +3 is clear about the differences between stress and calm, but PP1 is not sure if it should present with -3 to +3. PP1 mentions that the user is only interested in whether they have stress, sadness, etc., and not interested in the number.

PP9 and PP10 think that the representation of the emotional arousal level with the dots can change.

- PP1 thinks that green can be positive, and red can be negative. Participant PP1 also thinks that colors are useful for the smartwatch, which shows a green or red background that is associated with the status. PP1 mentions that the user can then see more information on the phone if they want to know that. The user can then, according to PP1, see what kind of SoundRate they are at and whether this is a positive high or negative low. PP1 refers to the name of the web-based prototype as the current emotional arousal level.
- PP9 thinks that the scale gives too little information and can better change into a horizontal bar that can go both to the left and to the right. Participant PP9 thinks the bar is better because sometimes you are between certain emotional

arousal levels, such as -3 and -2. PP9 thinks the bar has more intense colors to the right and more calm colors to the left.

- PP10 thinks that the left can be more blue or even more green because green is neutral. Then, according to PP10, the right can be redder. PP10 did not know whether left or right should be darker. PP10 mentions that the visualization could be like a thermometer or barometer such that you can view immediately where you are at.

Level 0:

- PP2 mentions that it makes sense to not represent the 0 because PP2 mentions that when being at emotional arousal level 0, you do not need to go to another emotional arousal level.
- PP2 thinks it might be nice to have a joke (like an Easter egg in software) when being at emotional arousal level 0 such that it is fun to use the emotion regulation sound application.
- PP3 and PP10 mention that 0 should be an addition to the emotion regulation sound application. PP3 mentions that 0 is important, such that the user knows what the calmest level is. According to PP10 is 0 important such that the user know where to go back.

Table 25 – Requirement Theme 6.6

# from 6.3.4	Requirement	Description
6.4	Include emotional arousal 0	The emotion regulation sound application shall provide the emotional arousal level 0 to achieve that the user is aware of the calmest level.
6.15	Visualize emotional arousal levels	The emotion regulation sound application shall provide an intuitive visualization of the emotional arousal levels to achieve that it is clear for the user if their emotions are active or passive.

Theme 6.7 Sounds

PP1, PP2, and PP3 think that sounds of nature such as bird sounds can work best.

- PP1, PP3, PP10, and PP9 mention that rain can be an addition.
- PP1 also mentions that thunder, storm, and different wind speeds can be an addition.
- PP2 thinks that water can also work to go into a relaxed mood. PP2 is also positive about waves as sound.

- PP2 thinks that forest sounds might be an addition as well. PP2 thinks that the forest sounds can be about walking through the forest without noise and walking through the forest in spring with birds singing.
- PP9 also thinks that the emotion regulation sound application can use wind and forest sounds can be present.

Map emotions to sounds:

- PP1 thinks that if you relax, you can listen to a slow wind. If you are sad you can listen to heavy rain, and at stress levels, you listen to the thunder and pouring rain.
- PP3 thinks that thunder sounds can be an addition to the active emotions and rippling water sounds fit the passive emotions.
- In passive emotions, the sounds are calm. At the active emotions, the sounds are more intensified according to PP9.
- With wind, you have a light summer breeze at the passive emotions and a heavy storm wind at the active emotions according to PP9.
- With the forest sounds, according to PP9, it is quiet with sometimes sounds of a twig, breeze, and an animal, at the passive emotions with the active emotions you hear passer-by and cycling back and forth.
- PP10 mentions that drizzle sounds can be for passive emotions and pouring rain can be for active emotions.

Meditation sounds:

- PP1 also thinks that heartbeat sounds are suitable to inform the user of their stress level. If the heart rate of the user is high, then it is possible to be conscious when listening to the heartbeat and have a message from the emotion regulation sound application with: *"Is there something going on? Maybe you should take it slow."* according to PP1.
- PP1 also thinks that it is possible to hear the heartbeat during the music.
- PP3 and PP9 are positive about using brain waves as sounds for relaxation.

PP2 thinks suitable sounds should be something that you also hear in your daily life.

- PP2 thinks that the sounds of cars might also work because PP2 mentions a video example of cars from a bridge that was a great success.
- PP2 also mentions that sounds at movies during thrilling moments or solved mysteries are interesting. The sounds are, according to PP2, intentional and fit with what you are watching.

Map personal sounds:

- PP1 thinks that personal sounds that you can listen to constantly can help if you can adjust them yourself for the emotional arousal levels. But PP1 thinks it might also be difficult for some users to determine the differences in the

emotional arousal levels. PP1 mentions people can think: *"What is the difference between -3 and -2? What do those levels even mean?"*

- PP2 is not sure whether personal sounds can help. PP2 thinks that user can add their sounds, and PP2 thinks people would like that, but PP2 is also not sure what the effect will be.
- PP9 mentions personal sounds help if you can select your music. For example, the user can select which sound fits by how they are feeling according to PP9.
- PP10 thinks that the personal sounds can have a different order in the emotion regulation sound application. For example, the sounds do not change for each emotional arousal level, but the different personal sounds are on each emotional arousal level according to PP10. Certain sounds can have a typical description of the emotional arousal levels, such as a sound is typically a -1, according to PP10.

Personal sounds:

- PP2 also thinks that the music of Mozart or Beethoven can help to divert the emotions of PP2. Also, sad music that is played at funerals can help to divert the emotions of PP2. When being angry, PP2 likes to listen to ACDC.
- PP3 mentions listening to upbeat songs when feeling down and relaxing ambient songs when feeling agitated. PP3 also listens to Imagine Dragons, Fitz and the Tantrums with Handclap, Mark Ronson with Uptown Funk. Participant PP3 dislikes house.
- PP9 listens to melancholic music when being emotional and to Santana, Pink Floyd, when being happy. Participant PP9 also mentions enjoying listening to folk and church sounds. PP9 also likes Vangelis and Engima, and mainly relaxing synthesizer sounds. PP9 does not like hard rock or hardcore because it is monotonous and aggressive according to PP9. PP9 does not like repetitive sounds such as playing with keys or birds on the alarm clock.

Table 26 – Requirement Theme 6.7

# from 6.3.4	Requirement	Description
6.10	Personal data	The emotion regulation sound application shall provide the option for the user to include personal data such as advice, sounds, or sound reactions to achieve that the user has more control over how the emotion regulation sound application acts.

Theme 6.8 Personalization

- PP1 thinks it might be a nice addition to include classification from the user where the user decides what is normal or calm. The user can then, according to PP1, decide on their own what can work best for them. For example, PP1 mentions that something might relax them but might not relax others or someone else can touch deeply by something that does not affect PP1.

Table 27 – Requirement Theme 6.8

# from 6.3.4	Requirement	Description
6.10	Personal data	The emotion regulation sound application shall provide the option for the user to include personal data such as advice, sounds, or sound reactions to achieve that the user has more control over how the emotion regulation sound application acts.

Theme 6.9 Presets of Sounds

- PP1 thinks that the emotion regulation sound application can provide a grab bag of suitable sounds that would point out when someone has stress.
- PP2 also mentions that there can be an option for the user to download a template from a server. PP2 mentions that this template offers an alternative to personal choices, that the user can select some personal choices and the emotion regulation sound application also offers some other ideas.
- PP3 mentions it might be interesting if the user can customize their emotion regulation sound application in which the user can choose their sounds.

Table 28 – Requirement Theme 6.9

# from 6.3.4	Requirement	Description
6.19	Preselection of sounds	The emotion regulation sound application shall provide a preselection of sounds to achieve that the user can choose something that might fit them.

Theme 6.10 Delayed Awareness

- PP2 mentions that there is a delay in the awareness of emotions. Participant PP2 mentions that sometimes it can go faster than other times. PP2 also mentions that this delay also happens when having a sound in the background. PP2 mentions the example of being in the supermarket and hearing Santa Claus music that you first did not notice, but later you have an annoyance with the music.

Table 29 – Requirement Theme 6.10

# from 6.3.4	Requirement	Description
6.5	Track emotional and physical feelings	The emotion regulation sound application shall provide the ability to track the emotional and physical feelings of the user to achieve that the user gets more insights into their emotions.

Theme 6.11 Approachable

- PP1 mentions the sounds show the stress but should not invoke stress, then the purpose of the emotion regulation sound application is not achievable. PP3 thinks that the emotion regulation sound application does not work for everyone, because someone else can see sound as a bad trigger.
- PP2 is not sure whether the user can use the emotion regulation sound application when being fully angry.
- PP2 thinks that when the sounds would immediately play when being angry, the user might throw the phone out of the window. Participant PP2 thinks that the emotion regulation sound application might even be contrapositive in those cases. PP2 also thinks that the user might perceive the sound as invasive, PP2 compared the emotion regulation sound application with immediately seeing an advertisement on a news website at first arrival.
- PP3 thinks that sometimes the sound can help, but the sound might even trigger emotions again in the extreme levels.
- PP9 also mentions that you cannot think clearly when you have extreme emotions, people then have an emotional blockage according to PP9.
- PP9 also mentions that the sounds cannot play (constantly) when interacting in social gatherings. PP9 also mentions that it might be hard to follow up on every piece of advice when being around people. For example, you cannot walk away from someone when you still must work with them. The emotion regulation sound application can, according to PP9, not solve every situation

for you, because the message cannot be to walk away when you are in a meeting and the emotion regulation sound application does not know that.

Table 30 – Requirement Theme 6.11

# from 6.3.4	Requirement	Description
6.14	Be cautious with approaching extreme emotions	The emotion regulation sound application shall provide the ability to be cautious when the user is at their extreme emotional arousal levels to achieve that the user can still get help but does not receive an extra trigger.
6.17	Sound reaction based on context	The emotion regulation sound application shall provide the sound reaction that is based on the context (wanting to calm down, have more insights into the emotions, or being in a meeting) to achieve that the user can better handle their emotions.

Theme 6.12 Usages

- PP1 would recommend this web-based prototype if it is fully functional to someone with autism spectrum disorder, especially during a conversation about recognizing emotions.
- PP1 mentions recommending to others that the emotion regulation sound application can track how you are feeling emotionally and physically.
- PP2 is not sure whether this web-based prototype can be successful. PP2 thinks the idea is nice but mentions: *"I will wait and see if it happens."* Thus, PP2 does not think that they will use the emotion regulation sound application and there is a big question mark whether PP2 would recommend the emotion regulation sound application to other people with ASD.
- PP3 thinks they cannot use the emotion regulation sound application in their daily life because PP3 does not have any electronic device with them during their work as a diver. Besides, PP3 normally would reflect on their day when they are at home. PP3 thinks that the emotion regulation sound application might be useful to see what happened during the day. PP3 thinks that the web-based prototype has potential, but PP3 does not know how others would react.
- Participant PP9 is not sure whether they will use the emotion regulation sound application in their daily life because PP9 thinks it is hard to use the emotion regulation sound application every day and that usage will be even less over a longer time. When PP9 is feeling good, the necessity of using the emotion regulation sound application ends. PP9 thinks that when you need

the emotion regulation sound application, the emotion regulation sound application is not on. PP9 thinks they would recommend the emotion regulation sound application to someone with autism spectrum disorder, such that they can focus on relaxation in which they deal with things they can handle.

- PP10 thinks that the emotion regulation sound application is not suitable for their daily life because PP10 does not use any applications. PP10 thinks their child would use the emotion regulation sound application. But in that case, the emotion regulation sound application should contain personal music.

Table 31 – Requirement Theme 6.12

# from 6.3.4	Requirement	Description
6.5	Track emotional and physical feelings	The emotion regulation sound application shall provide the ability to track the emotional and physical feelings of the user to achieve that the user gets more insights into their emotions.
6.6	Reduce stimuli in the environment	The emotion regulation sound application shall provide the ability the reduce stimuli in the environment by relaxation to achieve that the things happening in the user's environment do not overwhelm them.

Sketches from participants

The participants made the following sketches for a user interface for an emotion regulation sound application. The participants did sketches before seeing the web-based prototype. Three participants did not draw something on the smartwatch because there was for them a technical issue of not being able to import the drawing template or they did not know what they should draw on a smartwatch. The participants explain the sketches with the following texts.

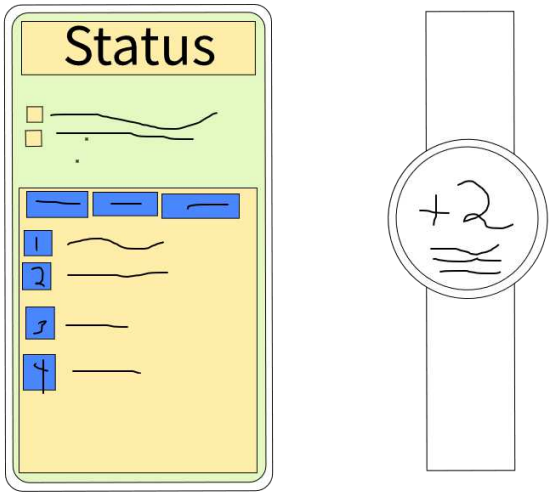


Figure 28 - Sketch PP1

PP1 mentions that the emotion regulation sound application should contain first a status bar at the top with the current emotional arousal with information about whether you have stress or are calm. Beneath that, is: *"Emotional status is x."*, which summarizes the status. So, on top of the page is the information about what is going on with you. Then, the emotion regulation sound application states: *"The stress level is this much."* Beneath that, there is an overview with tabs with settings. At that level, you can hear these sounds. At the emotional arousal level -3, you have these sounds, and with +3, you have those sounds. The user wants to view the watch quickly, so there is not much information on the watch. On the watch, there is only a +3 and what it means, such as stress or irritation. On the watch, there is not much information and can be also just a color, so green stands for +1. If the user wants to know more, the user can find more on their phone. PP1 mentions also that the user can feel the vibration as a notification if the user is angry. The emotion regulation sound application needs to be simple and to the point, according to PP1.

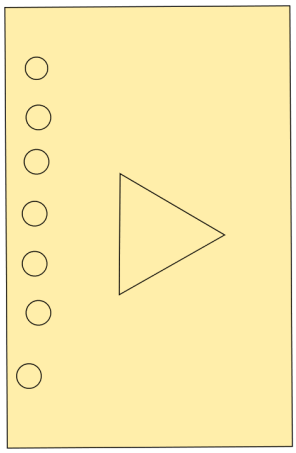


Figure 29 - Sketch PP2

PP2 sketches 7 radio buttons where the user can show how they are feeling. During the discussion afterward, PP2 mentions that slides are better than radio buttons, such that the user can easily slide with their thumb. There is also a play button on the page. PP2 mentions that the user can add how they are feeling and listen to the sound. So, the play button is on in the middle of the page. Participant PP2 also doubted whether there should be a slide for volume, but PP2 thinks that might not be efficient when someone is intensely angry. PP2 mentions that when being angry, the user does not feel like stepping up things. PP2 also mentions that people with autism spectrum disorder want as few stimuli as possible, so the User Interface should contain as little as possible.

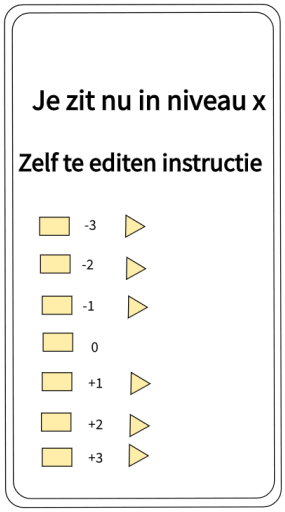


Figure 30 - Sketch PP3

According to PP3, there are 7 emotional arousal levels, so with the calmest level (0) to make sure the user is aware of this calmest level. The user can add their customized instruction according to PP3. Then can the user select play. PP3 does not sketch the smartwatch because PP3 does not have an idea due to not wearing a smartwatch. PP3 mentions that the user can see the emotional arousal level as a notification in the emotion regulation sound application. Then, there is a triangle where the sounds are behind and that can play.

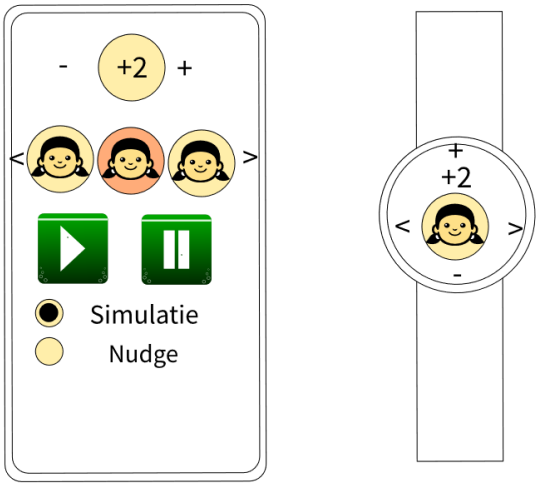


Figure 31 - Sketch PP9

PP9 sketches that the user can first select the type of sound and their mood. The user can navigate through the sounds. The representation for the emotion is with an icon. PP9 mentions that there might be another face for anger, etc. Then there is a play and pause button. Then, there is a mode indicator in which the user can select simulation or nudge. PP9 mentions that a third option might be desirable where everything can turn off (so that you can select yourself how the sounds should react). At the

smartwatch, the user can choose and navigate through types of sounds. When tapping at the icon on the smartwatch, the sound can go on and off. PP9 mentions that a play and pause button on the smartwatch is not possible because of the limited space.

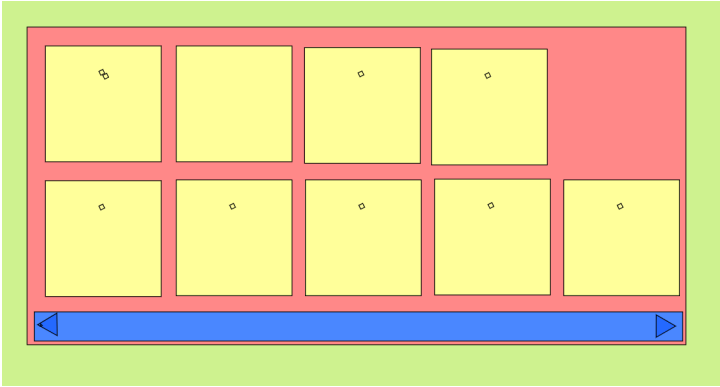


Figure 32 - Sketch PP10

PP10 sketches a vertical phone. There are different sounds. The user can select the sounds and swipe left or right.

6.3 Conclusion

The information of this chapter translates to the following sections about discussion & conclusion, limitations, persona, requirements, sketches from participants, and answers to research questions.

6.3.1 Discussion & Conclusion

Three participants mention improvements for the web-based prototype by focusing on more advice from the emotion regulation sound application than only sounds. The researcher should pay some attention that these extra advice options are not complex as a participant mentions that people with autism spectrum disorder have difficulty in making choices. The extra advice can come from an alert that the user made beforehand with their therapist. Some examples of the advice are walking outside, breathing exercises, singing, finding rest, meditation exercises, looking at images. However, the participants recommend the personal advice for each user. One disadvantage, according to a participant, might be that the advice cannot have a follow-up in every situation because other people are around you (like in a meeting). However, the advice can be based on what you were doing and when you are stuck in a certain pattern that the emotion regulation sound application might register according to three participants. A participant thinks that the emotion regulation

sound application can present the advice with a text balloon or icon. Two participants mentioned that the user can select the advice through a mode with the possibility of also selecting the sound reaction.

Two participants mentioned that the sound reactions can best react based on recognizing patterns of changes in the emotional arousal levels, as a jump from one emotional arousal level to another. The participants compared the sound reaction mimic and nudge. There is no preference for the mimic or nudge from the participants. The participants want to choose the sound reaction that would fit the situation. Mimic is best used when the user wants to be aware of their feelings. For example, mimic makes them look at themselves in a mirror. There might be a disadvantage for the mimic sound reaction according to two participants because the user might be too long in the same emotional arousal state and eventually lose themselves in their sorrow. One participant has other doubts about the emotion regulation sound application being used in the extreme emotional arousal levels, such as with angriness. The participants mentioned that in those cases they find it hard to think clearly, and the emotion regulation sound application might even evoke more stress. The participant expects the sound reaction nudge to cheer the user up a bit and help the user cope with their feelings. A participant even mentions that the nudge can be an addition to music that is already playing. The music decreases in volume and the user can hear another notification sound. The alert sounds can even be a combination with the other sound reactions according to one participant, such that the emotion regulation sound application provides an alert where the alert can present as a mimic or nudge sound. Three participants think that the alert is a good way of preventing the user from going into extreme emotions by informing the user about their emotional arousal levels. Another participant mentions that the alert can also be vibrations on the smartwatch. But another participant mentions that the current form of only alert at -3 and +3 can best change such that there is a difference in sound present in the different emotional arousal levels. It is noticeable that the current form of alert sounds does not show what the current emotional arousal level is. The user must still look at the screen. Two participants mentioned that on the screen certain notes and a diary can be an addition such that the user can look back in time to what happened and why.

The current emotional arousal level of dots presentation can change according to two participants. A participant mentions that the exclusion of emotional arousal level 0 is logical, but the participant thinks it might be interesting to present the user at that level something fun, like a joke. Another participant also mentions that including emotional arousal level 0 is necessary because the user then knows where to get back to. Three participants also discussed the visualization of the emotional arousal level. A participant thinks that the visualization could be like a thermometer or barometer where the left (passive emotional arousal levels) can have more neutral colors like

blue or green, the right (active emotional arousal levels) can be redder. Another participant also mentions that the current emotional level presentation can change into a horizontal bar with more intense colors to the right (active emotional arousal levels) and more calm colors to the left (passive emotional arousal levels). Another participant also mentions that green can be for the active emotional arousal levels and red for the passive emotional arousal levels and this can be, according to the participant, a background on the smartwatch. It was also interesting that a participant referred to the emotional arousal level as SoundRate, which is the current name of the web-based prototype.

There were several suggestions from the participants for the suitable sounds in the emotion regulation sound application. One thing that was often mentioned is the use of nature sounds (e.g., birds, water, forest sounds, rain, thunder, storm, wind). Other sounds that were also mentioned were heartbeat, brain waves, cars. At last, the personal sounds can improve with more personal sounds, but the participants mention they should select these personal sounds for the emotional arousal levels (e.g., Mozart, Beethoven, ACDC, funeral songs, upbeat, ambient, Mark Ronson, Fitz and the Tantrums, Imagine Dragons, Vangelis, Enigma). A participant mentions it might be interesting to have a different personal sound for each emotional arousal level instead of the same personal sound changed for each emotional arousal level. Three participants even mention that the emotion regulation sound application can provide a preselection of sounds that might fit the emotional arousal levels.

Four participants mention they are unsure whether the emotion regulation sound application would fit into their daily lives because they would normally not use applications and smartwatches much in their daily lives. However, four participants think that the idea for the emotion regulation sound application is nice, and when the web-based prototype is fully functional that they would recommend the emotion regulation sound application to someone with ASD. A participant mentions that the tracking of how someone is emotional and physical feeling is beneficial. Another participant mentions that the emotion regulation sound application can help people with ASD cope with their feelings and prevent them from having too many stimuli.

Thus, the design and test sessions conclude the following things. First, the assumption about a preference for sound reaction mimic or sound reaction nudge is not applicable for the target user. The target user needs more options as advice than only the sounds. This might be interesting for future research, as the current study focuses on including a sound modality. It is another conclusion that there are improvements in the web-based prototype to fit the user's needs, such as personalizing the selection of sounds and improving the visualization of the emotional arousal levels by colors and a thermometer. Finally, another conclusion is that there is still some interest from the target user if the web-based prototype is fully

functioning about the tracking and coping with feelings of the emotion regulation sound application.

6.3.2 Limitations

One limitation of the co-design and test sessions is that the sessions took place online. This might prevent the researcher from fully observing the behaviors of the participants. The online component might also put the participants in the position that they must learn how the use some tools (Google Meet, Sketch.io) that might not be familiar to the user. Another limitation for the co-design and test sessions is that the heart rate measurements are a simulation and do not have any relation to the heart rate of the participants. This might influence how the participants experience the web-based prototype to some extent that they might feel distant from the data that is present about emotions.

6.3.3 Persona

The demographic information of the participants transforms into a persona, which describes the typical user of the emotion regulation sound application.

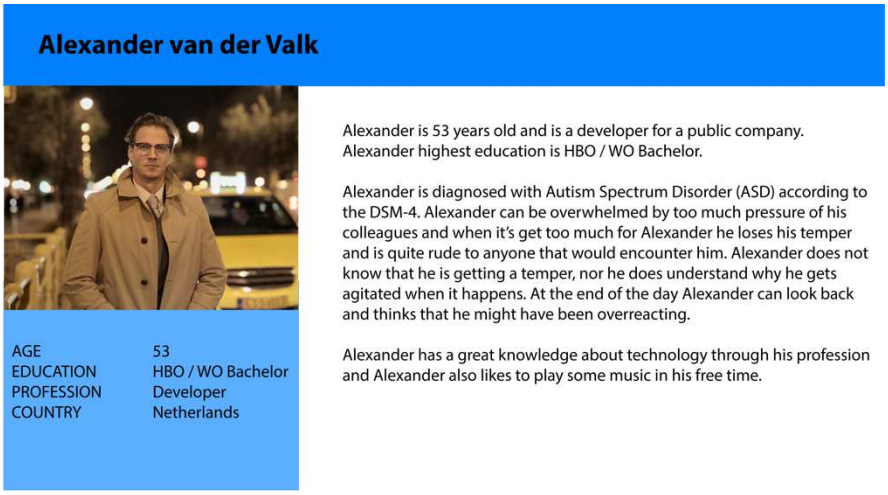


Figure 33 – Persona of a typical user

Figure 33 shows the persona from the demographic information of the co-design and user study. The persona comprises fictional information, such as name and picture. But the other information, such as age, education, the profession is from the interviews. The text in the persona comprises information that comes from the interviews.

6.3.4 Requirements

The data from the design and test session shows the user's needs for the emotion regulation sound application. The researcher analyzes these needs and translates them into the following requirements.

The researcher categorizes the requirements into a functional requirement (what the emotion regulation sound application should do) and a non-functional requirement (how the emotion regulation sound application works). After the categorization, the researcher prioritizes the requirements with Moscow. The prioritization depends on whether it is achievable for development to include this requirement into the emotion regulation sound application or is it is more than likely to be future work. The achievability of development comes from the task complexity and essentialness for the target user.

Table 32 – Requirements Second Iteration

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
6.1	Meaningful messages	The emotion regulation sound application shall provide meaningful messages to achieve that the user benefits from the messages.	Non-functional	Must	Theme 6.1
6.2	Minimalistic design	The emotion regulation sound application shall provide a minimalistic design to achieve that the target user is not overwhelmed.	Non-functional	Must	Theme 6.1
6.3	A noticeable sound difference for emotional arousal levels	The emotion regulation sound application shall provide a noticeable sound difference for the different emotional arousal levels to achieve that it is easier for the user to understand the different emotional arousal levels.	Functional	Must	Theme 6.4
6.4	Include emotional arousal 0	The emotion regulation sound application shall provide the emotional arousal level 0 to achieve that the user is aware of the calmest level.	Functional	Must	Theme 6.6
6.5	Track emotional and physical feelings	The emotion regulation sound application shall provide the ability to track the emotional and physical feelings of the user to	Functional	Must	Theme 6.10, Theme 6.12

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
		achieve that the user gets more insights into their emotions.			
6.6	Reduce stimuli in the environment	The emotion regulation sound application shall provide the ability the reduce stimuli in the environment by relaxation to achieve that the things happening in the user's environment do not overwhelm them.	Functional	Must	Theme 6.12
6.7	Not too many advice options	The emotion regulation sound application shall provide not too many advice options to achieve that it is not complex, and the user is not overwhelmed.	Non-functional	Should	Theme 6.1
6.8	Select the sound reaction	The emotion regulation sound application shall provide the user with the ability to select their preferred sound reaction to changes in the emotional arousal level to achieve that the user has to ability to customize parts of the emotion regulation sound application.	Functional	Should	Theme 6.1
6.9	Visual appealing	The emotion regulation sound application shall provide a visually appealing design to achieve that the target user wants to use the emotion regulation sound application more than once.	Non-functional	Should	Theme 6.1
6.10	Personal data	The emotion regulation sound application shall provide the option for the user to include personal data such as advice, sounds, or sound reactions to achieve that the user has more control over how the emotion regulation sound application acts.	Functional	Should	Theme 6.1, Theme 6.7, Theme 6.8

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
6.11	Non-intrusive messages	The emotion regulation sound application shall provide non-intrusive messages to achieve that all messages do not overwhelm the user.	Non-functional	Should	Theme 6.1
6.12	Understand-able words	The emotion regulation sound application shall provide the text that is intuitive and understandable to achieve that the user immediately knows what it means.	Non-functional	Should	Theme 6.2
6.13	Include notes and a diary	The emotion regulation sound application shall provide the option to include notes and a diary in the emotion regulation sound application to achieve that the user can provide more information about the changes in the emotional arousal levels.	Functional	Should	Theme 6.3
6.14	Be cautious with approaching extreme emotions	The emotion regulation sound application shall provide the ability to be cautious when the user is at their extreme emotional arousal levels to achieve that the user can still get help but does not receive an extra trigger.	Non-functional	Should	Theme 6.11
6.15	Visualize emotional arousal levels	The emotion regulation sound application shall provide an intuitive visualization of the emotional arousal levels to achieve that it is clear for the user if their emotions are active or passive.	Non-functional	Should	Theme 6.6
6.16	More and personal advice via mode selection	The emotion regulation sound application shall provide more advice options for the user when their emotions are intensive to achieve that user can choose what they want to do.	Functional	Could	Theme 6.1, Theme 6.5

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
6.17	Sound reaction based on context	The emotion regulation sound application shall provide the sound reaction that is based on the context (wanting to calm down, have more insights into the emotions, or being in a meeting) to achieve that the user can better handle their emotions.	Functional	Could	Theme 6.2, Theme 6.11
6.18	Recognize patterns	The emotion regulation sound application shall provide the ability to recognize patterns in the emotions of the user to achieve that the emotion regulation sound application can give tailored advice to patterns that happen often.	Functional	Could	Theme 6.3
6.19	Preselection of sounds	The emotion regulation sound application shall provide a preselection of sounds to achieve that the user can choose something that might fit them.	Functional	Could	Theme 6.9

6.3.5 Sketches from participants

It is noticeable from the sketches and the explanations that the target user needs information about their current emotional arousal level that is prominently visible when the user opens the emotion regulation sound application or as a notification at a home screen of the phone. Another finding from the sketches and explanations is that the user wants more ability to customize the sounds, advice, and sound reaction by themselves through settings. It was also noticeable that the target user thinks that the information on the smartwatch should have a limit. Some findings stood out, but other participants did not mention them as well. One finding was to include sliders about how the user is feeling. Another finding is to include all the sounds on a single page such that the user can navigate through them by swiping. The last outstanding finding was to include icons such that the user can click on a face icon that represents the mood of the user (happy, angry, etc.).

6.3.6 Answers to research questions

This chapter tries to answer the following sub-question: "What are the requirements from people with ASD about the emotion regulation sound application?". Chapter 3 also did an attempt to answer the sub-question. This chapter gives new information to answer the sub-question through iteration, which differs from Chapter 3. The requirements of Chapter 3 translate into a concept (*Chapter 4*) and a web-based prototype (*Chapter 5*). The target user tests the web-based prototype in co-design sessions, which results in new requirements. These new requirements are equivalent to the requirements from Chapter 3 or they can be a completely new requirement.

Table 33 - Requirement's iteration 1

Similar Requirements from Chapter 3	Requirements Chapter 6
Requirement 3.1 - Emotion handling	Requirement 6.5 – Track emotional and physical feelings
Requirement 3.4 – Personalization & Requirement 3.6 – In control of own life	Requirement 6.8 – Select the sound reaction & Requirement 6.10 – Personal data
Requirement 3.9 – Avoid words of emotions	Requirement 6.12 – Understandable words
Requirement 3.10 – Ability to adjust	Requirement 6.17 – Sound reaction based on context
Requirement 3.11 – Simple design	Requirement 6.2 – Minimalistic design
Requirement 3.13 – Learnability	Requirement 6.18 – Recognize patterns

The iteration shows that these requirements are still valid to represent the user's needs, but there are only some small adjustments. One main point that is still coming back at the requirement is that there is still a need to make the emotion regulation sound application personalized. The web-based prototype for the user test with co-design sessions does an attempt but did not fully cover the personalization need of the target user.

One new finding from the user test with co-design is that completely new requirements are about the emotion regulation sound application to provide more modalities than only a sound modality, such as a visual or textual modality. This new finding is out of scope for this study, but it might be interesting for future research. Another new finding from the user test with co-design session is that the sounds representation of the emotional arousal levels and the sounds themselves can improve with 1) including noticeable sound differences for each emotional arousal level (Req. 6.3), 2) including the calmest emotional arousal level 0 to show where the user should get back to (Req. 6.4), 3) including the possibility for the user to decide for the mode of nudge or mimic (Req. 6.16), and 4) including a preselection of sounds

in the emotion regulation sound application (Req. 6.19). One interesting finding is that the first assumption of excluding the calmest level 0 because the user does not need to change their emotional arousal at level 0 does not hold for the user's needs.

To conclude, the main improvements for the next iteration with prototyping are 1) personalized sounds, 2) preselection of sounds, 3) visualized emotional arousal in colors/thermometer, and 3) minimalistic design.

The next chapter shows how the results from the user study with co-design translate into an Android prototype.

Chapter 7 Prototype 2.0 (Android)

This chapter discusses the Android prototype for the third user involvement. The chapter also tries to answer the following question: *"In which ways can sound give feedback about emotional arousal?"*. The Android prototype is based on the findings from the previous iterations with the target user by including personalized/pre-selected sounds, thermometer/colors of emotional arousal, and a minimalistic design. This Android prototype is a working application on a mobile phone and smartwatch.

7.1 Background

This project works towards a working prototype of an emotion regulation sound application by sounds for people with autism spectrum disorder (ASD). User involvements iteratively provide insights in building the Android prototype. The interviews shed light that the target user (people with ASD) has emotion regulation difficulties in their daily lives caused by stimuli overload that needs to be processed. It means that an emotion regulation sound application can be beneficial in the lives of people with ASD. The interviews showed that the target user was enthusiastic about an emotion regulation sound application. The user studies with co-design showed that the target user wants to have authority in an emotion regulation sound application. It also became clear from the user studies with co-design that the target user wants the presentation of the emotional arousal levels through a bar such as a thermometer with colors or smileys. At last, the user studies with co-design showed that the target user wants a simplified layout on the smartwatch.

7.2 Designs for the Android prototype

In Figure 34-Figure 39, the different designs for the Android prototype are visible. This Android prototype builds on top of the code from the Sense-IT project [2]. The color scheme blue for the Android prototype is equivalent to the Sense-IT project, to create an efficient development and comply with a minimalistic design. This Android prototype reuses the technique for measuring emotional arousal levels to link sounds with emotional arousal levels. The target user can add sounds to different arousal levels (see Figure 35). Then the target user can decide if the sound reacts as 1) simulation, 2) nudge, or 3) alert (see Figure 38). Eventually, at the homepage (Figure 34) the target user can start the sounds.

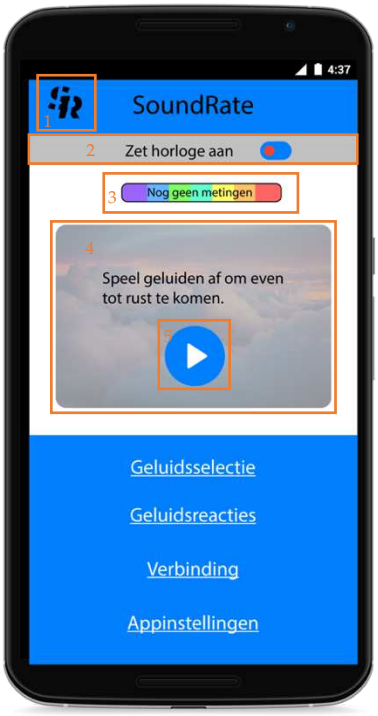


Figure 34 - Homepage design of Android prototype

7.2.1 Homepage

Figure 34 shows the homepage design for the Android prototype. The Android prototype is called SoundRate that is coming from the combination of the words heart rate and sound. There is a logo of SR on the right top corner of the page (see rectangle 1). Beneath the header, there is a bar with the text "set watch on" and a switch (see rectangle 2). A toggle of the switch means a smartwatch connection. At the connection page (third menu item), the user can also see a successful or unsuccessful smartwatch connection. Beneath the connection bar is a bar visible with cold and warm colors that show the positive and negative emotional arousal levels accordingly (see rectangle 3). Thus, purple stands for under aroused, and red stands for over-aroused. This bar is called the emotional arousal meter and is further explained in section 7.2.3. Beneath the emotional arousal meter on the homepage, is an image with the text of play some sounds to relax (see rectangle 4) with a play button (see rectangle 5). The sounds play when the user assigns restrictions on the sound selection and sound reaction. Thus, a warning message is visible if the user clicks on the play button without making sound restrictions. The user can then read that it is necessary to make sound restrictions before playing the sounds.

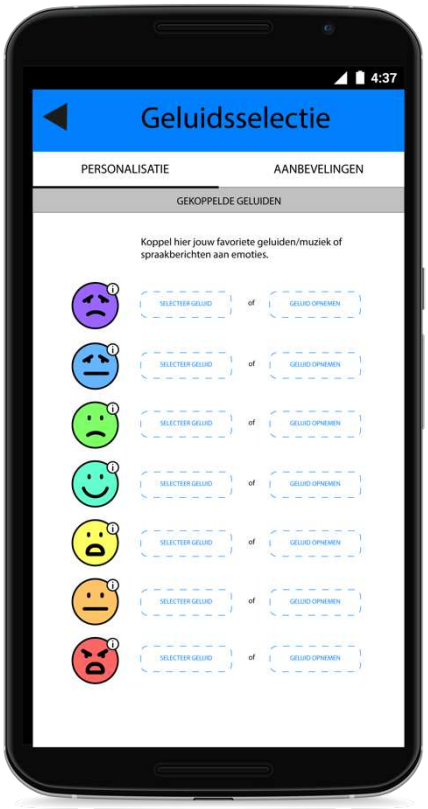


Figure 35 - Sound selection design of Android prototype

7.2.2 Add Sounds

Figure 35 shows the page where the target user can select the sounds for each emotional arousal level. The user selects sounds from their device or records the sounds. The user can decide themselves which sounds can belong to which emotional arousal. For example, the user selects angry or happy sounds by the emotions of overarousal. Recorded sounds can be voice messages. Someone close to the user (a relative) or the user can record voice messages. During intense emotions, the voice messages can calm the user down. The change of sounds that corresponds to a change in the emotional arousal is now with music/sounds from the user instead of a change in sound characteristics with for example volume, beats, or category (genre) as described in Chapter 4. The reason for excluding a sound characteristic change is that the participants during the co-design and test session think the sounds should be personal. The co-design and test sessions show that there is a need from the target user for the sounds to be personal and/or pre-selected. Section 7.2.4 shows the option for pre-selected sounds. The user can select the personal sounds on the page in Figure 35, where the icons present the different emotional arousal levels (that are explained in section Emotional Arousal meter) with icons. The icons might show the user the different intensity of the emotional arousal. This might help the user place sounds that might represent emotional arousal. For example, the user can represent angriness with angry music. The user then selects in 7.2.5 whether the played sounds can represent the emotions (through

a simulation/mimic) or nudges the user towards lower emotional arousal levels (through nudge).

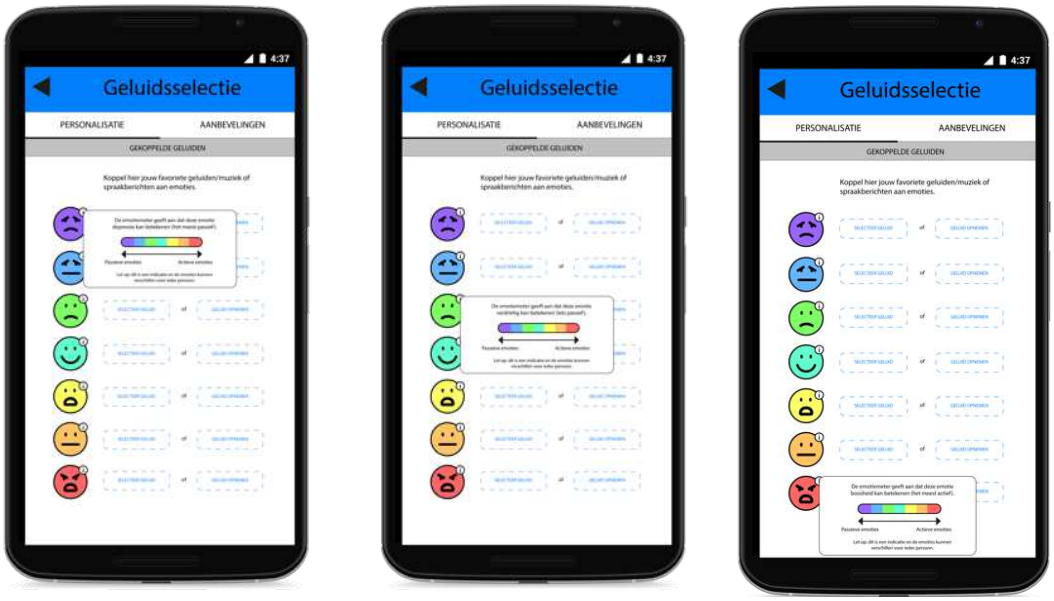


Figure 36 - Explanation of Emotional Arousal Icons

7.2.3 Emotional Arousal meter

Figure 36 shows the description of each emotional arousal level. The user can click on each icon and read the description. User studies with co-design showed that the user wants an emotion presentation descriptively such that the emotional arousal does not relate to a certain number (like -3, -2, -1, +1, +2, +3). The target user thinks that a bar like a thermometer, icons, or smileys can visualize emotions. The Android prototype implements all the advice from the target user about the emotion representation. Thus, an emotional arousal meter shows the different emotional arousal levels. The emotional arousal meter goes from cold colors (under-aroused) to warm colors (over-aroused). The middle of the emotional arousal is the calmest level, which is neutral-colored (green). Clicking on the icons will show the information about the emotional arousal meter. Icons represent different emotions by smileys (such as sad, happy, and angry). The icon description states that the icon represents an emotional arousal level, but it might differ for each person.

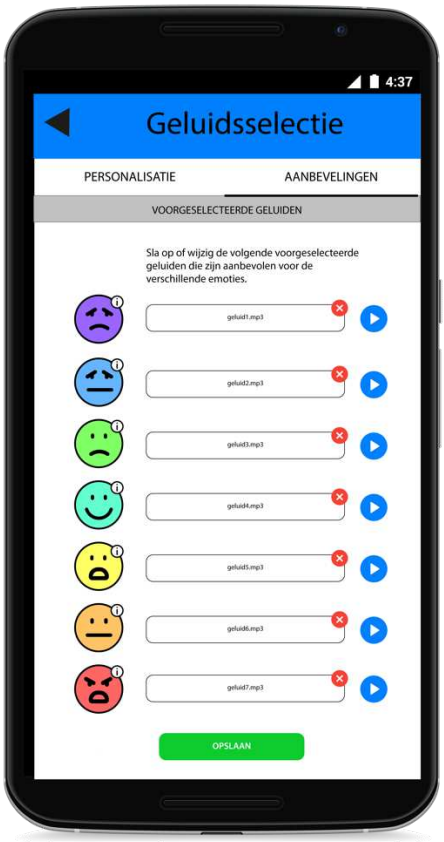


Figure 37 - Recommendations

7.2.4 Recommendations

Figure 37 shows an example of recommendations for different sounds for each emotional arousal level. The recommendations are in the figure named sound1.mp3 or sound2.mp3, etc., and are placeholders for sound recommendations from the application. Complying with requirement 6.19 Preselection of Sounds from Chapter 6 led to the recommendations. The pre-selected sounds might be the sounds that are discussed in the previous chapters about nature and mediation to calm down the user. The layout of the page is also visible on the personalization page when the user has selected a sound for the emotional arousal levels. If the user clicks on the cross at the recommendations, the same layout as the personalization page with selection or record sounds is visible. The user can listen to each sound. The user saves the sound selection by clicking on the green save button.

Figure 38 - Sound reaction

7.2.5 Restrictions

Figure 38 shows the sound reaction options. The user can determine how the sound reacts to the changes in the emotional arousal levels. The sound reaction is first set to the simulation. Simulation means that the sounds react in the manner they are determined through the sound selection on the sound selection page (see section 7.2.2). The user can also decide that the sounds react as a nudge by clicking on that switch. The nudge means the sounds are a little lower or a little higher than the emotional arousal level. It means that there is a condition to rearrange the different sounds for the emotional arousal levels. For example, a sound that was selected for the blue emotional arousal level is present at the purple emotional arousal level that is registered by the smartwatch. At last, the user can decide that the sound can react as an alert. It means that the sounds are only present at certain emotional arousal levels. For example, the user decides to only listen to certain sounds at the extreme emotional arousal levels. The sound restriction does not include the option of personal sounds from Chapter 4 and Chapter 5 anymore because the user can themselves include personal sounds on the sound selection page. All the restrictions (mimic, nudge, alert) show how the sound reacts to changes in the emotional arousal, where the sound feedback forms a reactive role. The sound changes are present when the user clicks on the homepage at the play button (see Figure 34). The user can choose whether the sounds play in the background when performing another

activity, so the sounds can unconsciously change the emotions for the better, or the user listens attentively to the sounds as a mindful exercise for relaxation.

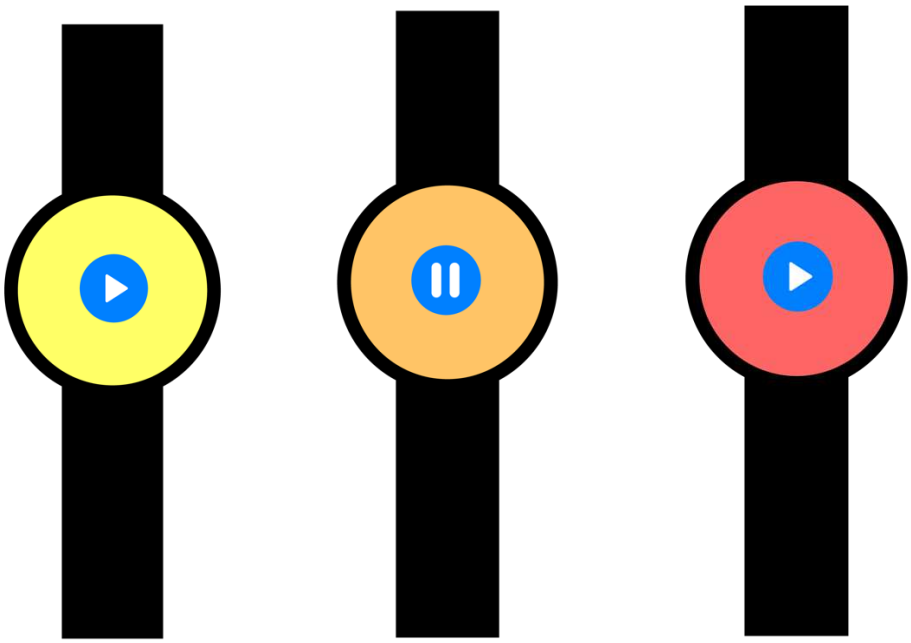


Figure 39 - Smartwatches

7.2.6 Smartwatches

Figure 39 shows the design for the smartwatches. The smartwatches use an implementation of the measuring emotional arousal levels technique from Sense-IT [2]. The design is simplified to satisfy the user's needs. Sketches and explanations of the target user from the user study with co-design in Chapter 6 show that the does not want a complex layout for the smartwatch. The Android prototype helps to minimize the tasks as much as possible for the user on the smartwatch. The smartwatch's background color is the color of the emotional arousal level from the emotional arousal meter. There is also a play/button in the middle of the screen. The user can play sounds from the smartwatch if there are restrictions about sound selection and sound reaction.

7.3 Actual Android prototype

The above screens are further developed into an Android prototype. During development, a certain consensus about the exclusion of play/pause buttons and exclusion of voice recording because of the difficulty of programming and some time constraints that are explained in the following text. Below (Figure 40-Figure 45) are

the different screens from the actual prototype that is built on Android. Figure 46 shows the prototype on a Huawei Watch 2 for a few different emotional arousal levels.

Figure 40 - Homepage Android Prototype

Figure 41 - Soundreaction Page Android Prototype

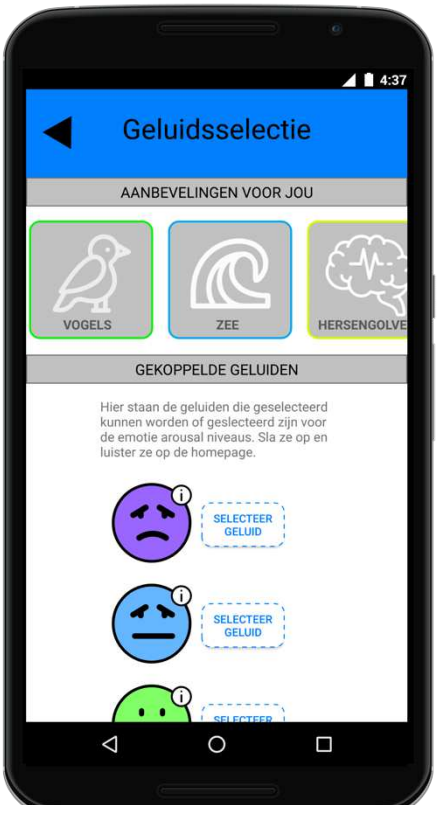


Figure 42 – Sound selection Page (Empty Selection at Top)

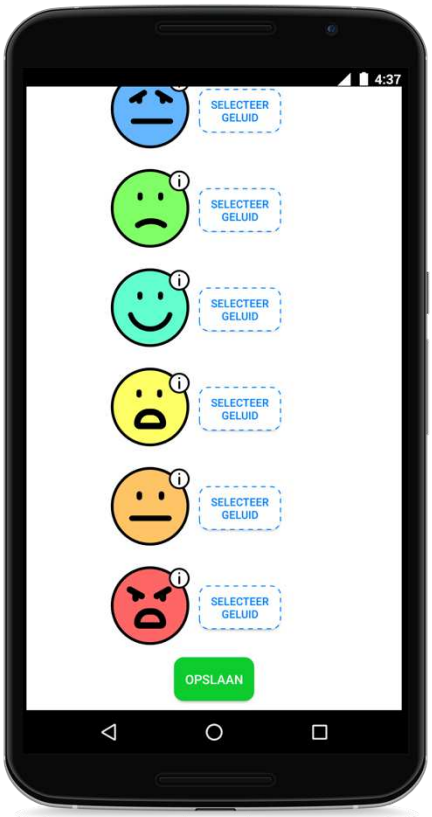


Figure 43 - Sound selection Page (Empty Selection at Bottom)

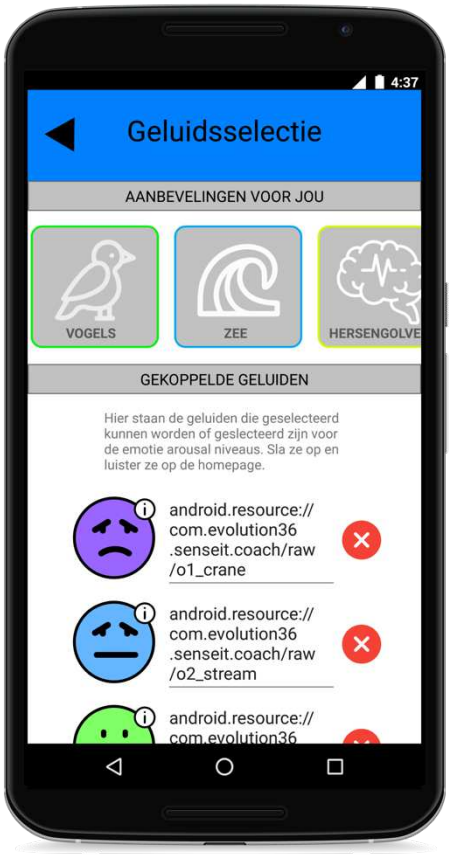


Figure 44 – Sound selection Page (Sea Selection at Top)

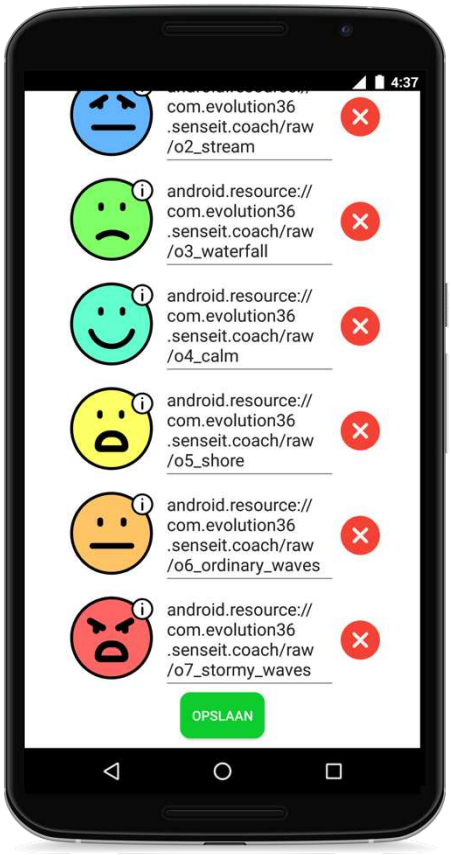


Figure 45 - Sound selection Page (Sea Selection at Bottom)

Figure 46 - Smartwatches with colors purple, blue, green, red

The screens from the Android prototype show some missing things, but there are also some things added to the Android prototype that were not present in the designs.

The things that are left out are: 1) play/pause button at the sound selection page, 2) options to record sounds, 3) the play/pause button at the smartwatch. There is no play/pause button on the sound selection page due to 1) technical issues about being unable to keep track of the sound that is playing, and 2) time constraints. There is no option to record sounds because the 1) development of the current functionalities took longer than expected that made it impossible to develop a recording function, and 2) the recording functionality seemed by longer thought unnecessary for answering what people think about emotion regulation sound application. A play/pause button on the smartwatch is missing due to time constraints.

Things that are added to the Android prototype are: 1) combining the recommendations and sound selections from the phone (personal sounds) into a single page, and 2) the recommendations with icons at the top of the page. The combination of the recommendation and the personal sounds happened because it did not feel right to have two pages that were 99% similar. This might have been confusing for the user; thus, the two pages become one page. Icons from the version of the web-based prototype (in the co-design sessions) are in the recommendations to show the different recommendations sounds. The co-design and test sessions showed that the user liked the icons. The sounds from the mock-up part of the Android prototype as well.

7.4 Conclusion

The information of this chapter translates to the following sections about discussion & conclusions and answers to research questions.

7.3.1 Discussion & Conclusion

The Android prototype includes a presentation of emotional arousal in an emotional arousal meter, which shows the different emotional arousal levels by colors. Yellow, orange, red represent from low to high intensity the over-arousal of a user. Dark green, blue, purple shows under-aroused from low to high intensity. The mint green color stands for the calmest level. In this Android prototype, the user can add sounds to the emotional arousal levels. The user can decide how the sounds react (as simulation, nudge, or alert). With the restrictions settled, the user can play sounds that respond to their emotional arousal.

7.3.2 Answers to research questions

This chapter tries to answer the sub-question: "*In which ways can sound give feedback about emotional arousal?"*. Chapter 4 and Chapter 5 have answered this question. This chapter revisits the question because this project contains iterations so new answers can arise. In Chapter 4, the answers are based on the concept, and in Chapter 5 there is more detail to the answers by including designs of a web-based prototype. The feedback ideas from the previous chapters are 1) to present emotional arousal through sound, 2) sounds affect emotional arousal, and 3) give the user the ability to choose the sounds. These feedback ideas are still valid, but with the addition from the Android prototype of 4) the user gets the ability to link sounds to the emotional arousal themselves.

The next chapter shows how users test the Android prototype.

Chapter 8 User Involvement 3 - User Testing

This chapter discusses the latest user involvement. This user involvement is with non-autistic participants instead of the actual target user to gather more insights into whether the emotion regulation sound application does not cause extra stimuli. After the emotion regulation sound application can work as emotion regulation through sounds, future research can investigate if the emotion regulation by sounds works for the target user (people with autism spectrum disorder). The following text first discusses how user involvement takes place. This user involvement is with user testing and interviews. Second, the chapter discusses the test results. At last, the chapter discusses the conclusion. The chapter tries to answer the following sub-questions: *"What are the requirements from people with ASD about the emotion regulation sound application?" and "How do users perceive an emotion regulation application that provides sound/music based on their emotional arousal levels?"*. It is not possible to gain a complete answer to the first sub-question as people with ASD do not take part in the user testing, but the user testing gives some insights into requirements that might give a partial answer to the sub-question.

8.1 Setup test with Android prototype

The following describes the setup for the test with the Android prototype.

8.1.1 Participants

The participants are not the intended target user. They are 18 years or older and have a description of healthy users. The reason for using healthy users is to investigate whether the emotion regulation by sounds can work without causing extra stimuli that evoke more emotional arousal changes. Future research can later investigate whether the emotion regulation sound application can work for the intended user. The participants who are not on the autism spectrum can still record their emotional arousal through the tracking devices, and those participants can still experience how sound affects their emotional arousal. Participants PP11, PP12, PP13, PP14, PP15, PP16, PP17, PP18, and PP19 take part in the user testing. Two participants lived in the same household. Three participants lived in the same household. Two participants are relatives and visit each other regularly. The researcher schedules the testing and interviews of the relatives close to each other to prevent any bias.

8.1.2 Purpose

The user study provides an answer to the following sub-question with sub-sub-questions:

> *How do users perceive an emotion regulation application that provides sound/music based on their emotional arousal levels?*

- *Perceive users sound as suitable feedback to gain more insights into emotion regulation?*
- *Does sound help the users calm down/energize?*
- *What are the opinions from the users about the sound reaction mimic, nudge, or alert?*

The sub-question shows that the focus of the user test is to gain insight into the overall experience of the user for the Android prototype. This overall experience again divides into the subjects of feedback, gaining insights into emotional arousal, calming, and sound reaction as described by the different sub-sub-questions. Thus, there is interest in whether the sound/music can succeed as feedback. It means that sound/music can be another way of presenting information and notifying the user in comparison with textual messages or vibrations. It is the focus of the research to gain insights into whether sound can be another representation of information and thus the sub-sub question about feedback can help to shed some light on a suitable answer. Another interest is whether the sound/music can give the user more insights into their emotional arousal and/or whether the sound/music provides a calming mechanism. The last interest is to understand whether the sound/music is best to react as mimic (same intensity as emotional arousal), nudge (intensity a little lower/higher as the emotional arousal), alert (sound/music only at certain emotional arousal levels). The different sound reactions come from the previous chapters. Results from the test and design session (Chapter 6) show that participants prefer the availability of different sound reactions. Thus, the user can choose their preferred sound reaction on the Android prototype.

8.1.3 User test

Approval from the Ethics Committee Computer and Information Science (EEMCS) about an ethical sound user study is under reference number RP 2021-227. The researcher registers the data collection under the General Data Protection Regulation (GDPR) with reference number WBP19ME0018. The user study is a type of field research in a natural setting with the use of self-report. Field research means that users test the emotion regulation sound application in the field instead of in a lab. The self-report means that the user reports information during the testing days about their experiences. The following text describes the different aspects of the user test in more detail.

Prepared devices

The devices that are being tested are the Android smartphone (either Nexus 6 or Moto G5) and a smartwatch (Huawei Watch 2). The devices contain the SoundRate application. Each participant has music that they would normally like to listen to on the smartphone.

Instructions and Manual

The researcher instructs the participant before the testing about the use of the Android prototype. The researcher explains the different pages and how to add sounds to the Android prototype from the mobile device. An explanation about how to add sounds from the phone and the recommendations is present for the participant. The participant can ask questions during the testing if something is unclear.

During the testing days, the participants needed more information on paper that they can read at their time. Thus, for half of the participants there is a manual provided with: 1) how to add sounds from the phone, 2) how to add sounds from recommendations, 3) how to add watch face when it disappears, 4) how to use the sound reactions. The first half of the participants only received the explanation orally from the researcher.

Baseline measurement

Before testing, there is a baseline measurement for each participant to measure the emotional arousal levels for each participant. The baseline measurement takes approximately 10 to 15 minutes to measure the heart rate for the participant in which the researcher instructs the participant to sit and do some walking at half of the measurements There is a progress bar on the screen of both the smartphone and smartwatch to show when the baseline measuring is at halfway. The researcher explains the procedure of the test while the participant is sitting. Both the researcher and participant pay attention when the progress bar is halfway. At a halfway progress bar, the participant and researcher walk around the room when the researcher is still explaining the procedure of the test. Sitting and walking might help to measure a heart rate that is more realistic during daily life.

The heart rate measurements translate to the six emotional arousal levels (from -3 to +3). Heart rate measurements that are lower than the baseline measurement are on the passive side of the emotional arousal (-3, -2, -1). The heart rate measurements that are higher than the baseline measurement are on the active emotional arousal side (+1, +2, +3).

Activities

The user test can take 1 to 2 days for the participants, such that each participant can at least perform three measuring/listening moments that fit in their schedule. On these testing days, the participant tests the Android prototype in their environment. The researcher urges the participant to wear the smartphone and smartwatch at moments where the participant might be under-/over-aroused. The Android

prototype offers the possibility to use it during overwhelming moments such that the user can withdraw from their environment/situation. For example, during train traveling that someone with ASD already notices that he/she is receiving a lot of stimuli. In those cases, the user can grab his/her phone and put on the headset to listen to some sounds. Such situations and activities might the participant discuss with the researcher before testing. Activities can exist in the following activities from the user interviews in earlier user involvement with the target user. The participant can also deviate from these activities. The reason for this list of activities is that they can evoke emotional arousal according to people with ASD (see 3.3.5).

- Shopping/Grocery
- Walking in nature
- Reading/Writing
- Gaming
- At work
- Cooking
- Cleaning/Housekeeping
- Meetings
- Eating together
- Watching tv/Netflix
- Taking care of finances
- Sports (e.g., cross fit)
- Making planning's/create structure in daily life

If the participant uses the devices during one or more activities, the participant can decide whether they want to listen to relaxing sounds. The researcher urges the participant to record these encounters and their emotions in the encounters with a context mapping (see Figure 47). A context mapping is a description written by the participant of an experience with context with the use of the Android prototype on a timeline. In the context mapping, the participant can fill at the top the emotion they experienced with a line to the time. The line can continue to go down with a description of the event.

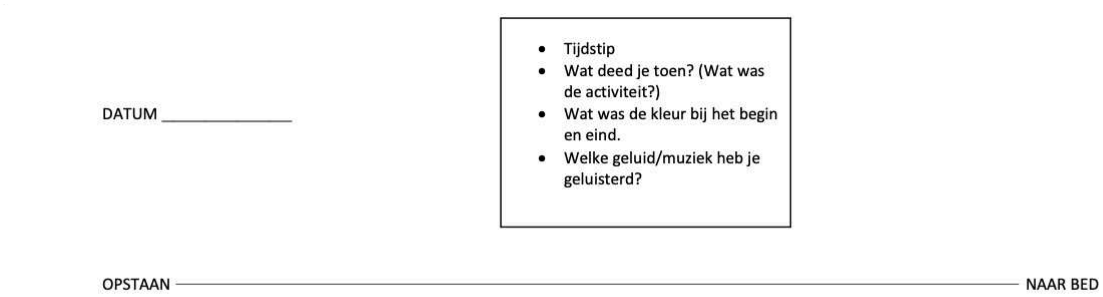


Figure 47 - Timeline Context Mapping

Figure 47 shows a description at the top of the timeline. The researcher added this description halfway through the testing days. Halfway through, the researcher notices that the first half of participants filled in the context mapping differently. To make it more clear for the participants and make the information more consistent, the explanation includes bullet points of the desired context for the context mapping. The bullet points mention:

- Time
- What did you do (What was the activity?)
- What was the color at the beginning and end?
- Which sound/music did you listen to?

8.1.4 Interviews

After the testing days, an interview takes place with the participants. Interviews can take up to 30-60 minutes. The participants read the information brochure and sign the consent form (see A3). The main goal of the interview is to gain insights into the positive and negative experiences of using an emotion regulation sound application.

These interviews are semi-structured, so questions the researcher makes questions beforehand (see B3) but it is possible to deviate from these questions to gain more in-depth answers.

8.1.5 Research materials

The research materials from the user testing are answers to the interview questions, filled-in context mapping (see C2), and data of the emotional arousal fluctuations during the testing data from the SoundRate application (see C3).

8.2 Test results with a working Android prototype

The following shows the test results with a working Android prototype.

8.2.1 Demographic information

Nine (non-autistic) participants took part in the user testing. Seven participants are female, and two participants are male. Ages ranged between 18 and 73 years old (see Figure 48). The highest completed education ranged between high school and master's degree: four participants with HBO/WO master, four participants with Community College (NL: MBO), and one participant with high school (see Figure 50). The professions ranged between manager and desk employee, one participant is with retirement, and one participant is a student (see Figure 49). Seven participants owned a smartwatch.

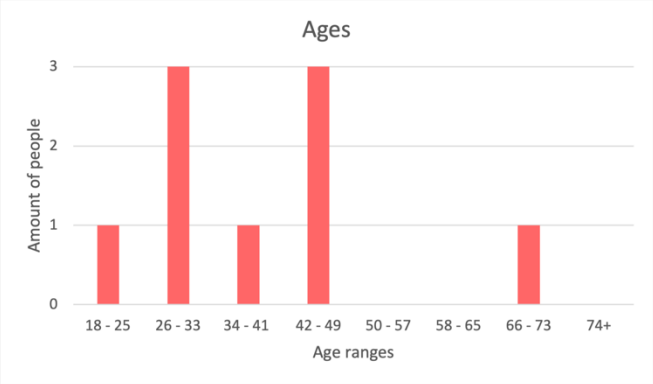


Figure 48 - Age ranges participants user testing

Figure 49 - Profession of participants user testing

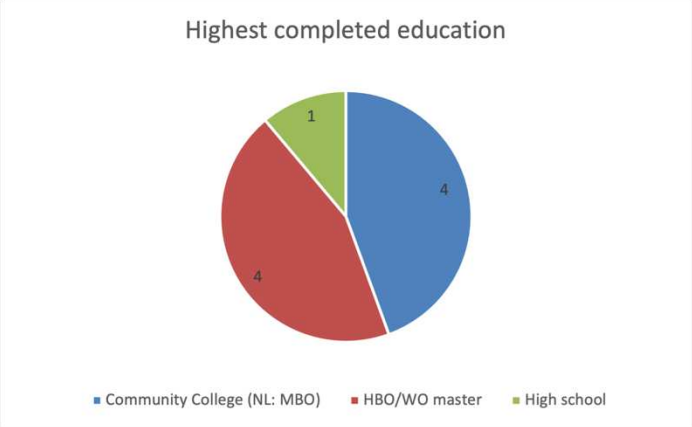


Figure 50 - Highest completed education participants user testing

Demographic information about the participants shows that there are more female participants than male participants. The average age range of involved participants is 34 to 41 years old. The professions of the participants varied but there are two similar professions (front office employee, employee at local authority). Highest completed education also divers with the participants, but two educations (community college and HBO/WO master) are equally the highest groups.

Some participants relate to each other and live in the same household. Two participants and three participants live each in the same household. Two other participants are relatives and visit each other regularly. The researcher schedules the testing and interviews close to each other for the relatives to prevent bias. However,

it shows that during the testing, the relative participants can talk to each other about the testing. The interviews were also close to each other, where a relative was still in the room present when the researcher interviewed the other relative. This happened with three sets of relatives, in total with six participants. The researcher interviewed at a later moment the third relative of a set of relatives.

8.2.2 Thematic coding Scheme

The following shows the thematic coding scheme.

Codes
The researcher analyzes the interview results by thematic coding. It means that 1) the researcher makes codes before the interviews to answer the sub-question about requirements about emotion regulation sound application and the sub-question about the experiences of Android prototype, and 2) the researcher then analyzes the interview answers by looking at commonalities and/or outstanding answers, and 3) the researcher processes those commonalities/outstanding answers into certain themes. The researcher defines the following codes before conducting the interviews.

1. Effect of Sounds
2. Insights into Emotions/Emotional Arousal
3. Handle Emotions/Stimuli
4. Personalization
5. User Control
6. Usability/User Experience
7. Recommendations

Themes

Theme 8.1 Sound vs. Music

Three participants mention a preference for sounds in comparison with music (PP11, PP13 & PP17).

- PP11 liked the sea sounds as the participant likes the sound of the sea and enjoys going to the shore. The sea sounds are calming for PP11. PP11 even did not try the music because the participant had already a lot of experience with listening to music at their work and the participant wanted to try something different: *"Ahh, that's also nice, because you hear music all day long, so that was a wonderful sound to listen to."*
- PP13 mentions the bird sounds especially helped the participant calm down: *"I think that sounds very relaxed or something like that."*
- PP17 preferred the sounds because there was a misunderstanding from the participant on how to work with the music and therefore the music did not work smoothly for the participant. Theme 8.3 Design & Usages explains why the music did not work right for the participant.

One participant (PP17) mentions a strong dislike towards the heartbeat sounds. PP17 immediately stopped the pounding heart sound when hearing it.

- PP17 mentions that the heartbeat remembered the participant too much about their study in healthcare. So maybe the participant negatively associated the pounding heart sound with a person in distress.

Three participants (PP16, PP18 & PP19) have a positive experience with the addition of music in the Android prototype.

- PP16 says: *"I think this is quite interesting. I like it. I listen all day long to music, so I think it is funny that a device can register your emotional arousal at that moment, and then the music is played that would fit that emotional arousal."*
- PP18 says: *"Yes, it is quite nice that you can add your music. I think that it will amplify the effect of calming down."*
- PP19 mentions a desire for using the Android prototype again when it is fully functional because the participant reacts to music and with such an emotion regulation sound application, the participant can calm down.

Table 34 - Requirement Theme 8.1 (a)

# from 8.3.4	Requirement	Description
8.1	Personalized sounds/music	The emotion regulation sound application shall provide the option that the user can select their sounds/music to achieve that the user can select the sounds/music to their taste.

One participant (PP14) experienced the music as overwhelming in the beginning.

- PP14 does not listen to music often in their daily life, thus the participant had to give themselves some time to listen consciously to the music. PP14 also mentions that the text in the music was a distraction and preferred music to be instrumental.

Table 35 - Requirement Theme 8.1 (b)

# from 8.3.4	Requirement	Description
8.7	Instrumental music	The emotion regulation sound application shall provide the addition of a preselection with instrumental music to achieve that music with text does not distract the user.

It became clear from six participants (PP18, PP14, PP15, PP16, PP18 & PP19) that the music/sounds can improve by 1) longer duration, 2) more variety in the music for each emotional arousal level, and 3) ability to listen to a full song.

- PP14 mentions that the music/sounds can improve with a longer duration, because *"I think that people who want to calm down need a longer duration and are not where they want to be (emotionally) in less than two minutes."*
- PP18 mentions that the same song was constantly present. PP18 says: *"You can vary in that by adding more songs."* This participant had a constant emotional arousal level that stayed most of the time at the calmest level (0) during the testing days.
- PP15 also mentions that there can be a preselection from the emotion regulation sound application that shows different songs for each emotional arousal level and the user can choose one of them.
- PP14 mentions something similar: *"I want more music on the same emotional arousal level, such that I don't have to listen to the same song six times."* PP16 also confirmed that by saying: *"Maybe it would be nice to have a playlist for each*

emotional arousal, instead of one song. Now you would constantly listen to the same sound."

- PP15, PP16, PP18 & PP19 do not perceive the change in the music/sound at a change in the emotional arousal level as suitable.
    - PP15 & PP18 mention it was funny that the song stopped and started again with a new song, but both participants think this might not be optimal for the target user.
    - PP15 says: *"Someone who needs it (the sounds/music for calming down) will not appreciate the changes (in the sound/music). If the emotional arousal level is going back and forth, it might be nice to hear the same style of music without it being the same thing all the time where the sound/music starts again all the time. It is weird that you start with some song and then start with another song and then start again with the first song you've heard."*
    - PP18 says: *"If you play the sound, the color decreases. But the music also decreased. I thought I was nicely listening and then suddenly it turned into another color and song. I thought it was funny, but I think it would be nice to listen to the whole song."*
- Both PP16 and PP19 also mention that it was a pity that it was not possible to finish the song.
    - PP19 says: *"It was a bit frustrating that when the color changed, the music also changed. I was relaxing listening to a song and wanted to finish the song. But it went suddenly to another song. It was a sudden change when you were listening to sounds. My preference is that I can finish the whole song."*
    - PP16 says: *"It was unfortunate that when you are listening to a song and then another emotional arousal is reached, and the song starts all over again. In the beginning, you have the intro, maybe you could, I don't if it is possible, but you can start with the chorus for every song."*
    - PP15 also confirms that by saying: *"If you have a song with a story, then you start again. It might be better to begin in the middle and then it will finish afterward. That can help to listen more because otherwise, you won't listen to the first one anymore as you already know. You already have heard that."*
    - PP17 also gave a tip on the music/sound change: *"Maybe you can have the same song but at another level or something. I am not sure if that is possible."*

Table 36 - Requirement Theme 8.1 (c)

# from 8.3.4	Requirement	Description
8.2	Longer duration of the sounds/music	The emotion regulation sound application shall provide the sounds and music with a longer duration to achieve that the same sound or song does not constantly repeat.
8.8	Options of pre-defined sounds for each emotional arousal	The emotion regulation sound application shall provide a pre-defined selection of sounds for each emotional arousal level to achieve that the user can more easily choose a sound that fits the emotional arousal.
8.9	Playlist on each emotional arousal	The emotion regulation sound application shall provide a playlist of sounds for each emotional arousal level to achieve that the user can listen to more sounds with a variety.
8.10	Changes in emotional arousal have a smooth sound/music transition	The emotion regulation sound application shall provide a smooth transition in the sound/music to achieve that the sound/music is not abruptly changed when listening to the sound/music.

Theme 8.2 Calming and/or Feedback

Three participants (PP11, PP16, PP18) mention that the sounds/music does not provide feedback on their own, but it is a combination of the sound, vibration, and color.

- One participant (PP11) uses the Android prototype as a calming mechanism, rather than to receive feedback about emotional arousal. PP11 says: *"The application (Android prototype) can help with the emotion registration (through the watch) and sound. Then you see at the watch to which of both sides (under/overarousal) you are going. You can decrease the emotion by listening to certain music/sounds. The music/sounds have a calming effect, but the sound doesn't give insights. You get the insights by looking at the watch and the sounds are a means to an end."*
- PP16 does not perceive the sound/music solely as feedback but combined with the color. PP16: *"I am a visual person so I will look at the color. The music/sound and color complement each other."*
- Another participant (PP18) mentions that the feedback is a combination of sound and colors. PP18: *"Maybe it is a combination with the colors, where you can still finish the song. But that you can still see which colors change such that you can calm down. Maybe you can have a small beep in the music. For example, I had an*

autistic colleague with Asperges who received one beep at every hour and two beeps at every half hour or something like that. For them it was kind of calming, yeah, I don't know. He liked that. So maybe something like that."

Table 37 - Requirement Theme 8.2 (a)

# from 8.3.4	Requirement	Description
8.11	Provide feedback from a combination of sound, color, and vibration	The emotion regulation sound application shall provide feedback from a combination of colors, vibrations, and sounds to achieve that the user realizes their emotional arousal without the feedback being intrusive.

Six participants (PP11, PP14, PP15, PP17, PP18, PP19) think that the sounds/music are calming/relaxing.

- PP11 does not think to have any problems with their emotions, but listening to sea sounds is experienced as relaxing.
- PP14 relaxes from the sounds after taking the time.
- PP15 saw the color on the watch from yellow to green when listening to bird sounds.
- PP17 thinks that the sounds/music might calm them down, but the participant was already calm when using the emotion regulation sound application.
- PP18 calmed down from the music but thinks it might be a combination of sitting down and turning on the music. PP18: *"It is basically that you are doing multiple things to calm down: you have to grab the phone and put on music. Thus, it contributes to calm down physically."*
- PP19 noticed that their emotional arousal calmed down when starting the music.

Two participants (PP16 & PP17) increased their emotional arousal level when listening to the sounds/music.

- PP16: *"I went actually up with my emotional arousal when listening to music/sounds. The music/sounds might have made me more active, but maybe I might have picked the wrong music/sounds."*
- PP17: *"The sounds/music did not calm me down, but I even can't go to sleep with music on. That might happen with something like piano music. But overall, I became more awake or something from the sounds/music. Something like I want to do things. Something that I also experience with playing volleyball."*

Table 38 - Requirement Theme 8.2 (b)

# from 8.3.4	Requirement	Description
8.3	Pay attention to sounds that are energetic or more relaxing to fit the passive and active emotional arousal levels	The emotion regulation sound application shall provide suggestions for the passive emotional arousal levels to listen to energized music/sounds and for the active emotional arousal levels to listen to relaxing music/sounds to achieve that the user is better nudged towards the calmest emotional arousal level (0).

Two participants (PP11 & PP18) think that the noticeable change in the sounds/music can improve.

- The sound/music immerses in the daily life of PP11, where the participant did not notice the differences in the sounds/music when the emotional arousal level was changing.
- PP18 says: *"I don't know if it is necessary to hear that you are calming down. Because feel that. So, I'm not sure if it is necessary. Maybe it is for someone with autism. So, the person gets a trigger with, hey you're calming down. Or you receive clear signals. For us, this won't be necessary because you already know you are calming down when listening. Maybe for them, it is the problem that you do not feel that."*

Two participants (PP14 & PP15) mention that the environment of the user limits the sound feedback.

- PP14: *"If you are working, you don't want to hear a song immediately. It needs to be a suitable signal that helps you think like wait a minute, I can finish this, but I really need to think about myself. That you are. For example, high in your emotion."*
- PP15: *"The feedback needs to be vibration and not with sound. For example, you are in a classroom or at a desk, you don't want to hear a weird sound. But nobody else notices if you feel a vibration. I will not add a sound to it, then if you walk in the supermarket and you hear a ring, no... It will only work if I decide that I want to turn it on."*

Table 39 - Requirement Theme 2 (c)

# from 8.3.4	Requirement	Description
8.12	Consider the environment of the user	The emotion regulation sound application shall provide feedback with consideration of the environment of the user to achieve that the emotion regulation sound application does not disturb the user.

Five participants (PP11, PP14, PP15 & PP18) prefer to change the vibrations at a change in the emotional arousal level. This feature was already in the Android prototype, but the participants did not discover that but still mentioned the desire during the interview.

- PP11 mentions that the watch was vibrating a lot, so the participant put the watch away, eventually.
- Participant PP14 thinks that the user becomes more aware of the emotional arousal with vibration between two emotional arousal levels, such that the user becomes more aware of the emotional arousal. The user is not always aware of the color on the watch, according to PP14. PP14 also advises different settings for different occasions. PP14: *"You can adjust the settings, if you go to a party, then you can disable it or put it on silence or you can just change to another emotional arousal level. You can have different settings again at work."*
- PP15: *"I had to look at that thing (watch), but you need to have vibration with it actually. So, it helps you to be aware. I think if someone feels such a vibration, then they know they are going too far, and they must calm down. I think that."*
- PP18: *"Maybe I was not aware of all the feedback. At red it will vibrate obvious, but at all the other colors you must look clearly to know the status. I think vibrations would have helped, especially if you look at the purpose of the watch of calming down, that you would better feel and be more aware. So, you know that it can have an effect. Instead of knowing when you are at your highest level. The idea is to prevent instead of getting to your highest level. "*

Table 40 - Requirement Theme 8.2 (d)

# from 8.3.4	Requirement	Description
8.13	Ability to change vibrations to preference	The emotion regulation sound application shall provide the ability for the user to change the vibration at their preferences for the different emotional arousal levels to achieve that the emotion

# from 8.3.4	Requirement	Description
		regulation sound application gives vibrations during convenient moments for the user.

Theme 8.3 Design & Usages

Two participants (PP16 & PP18) mention that the design of the Android prototype can improve.

- PP16: *"The design might be improved because it is now still a bit simplistic... well you know that some apps with design are a bit more, but yeah that is also something, well that is taste. Now it looks like a pilot. But obviously, it is a pilot. But yeah."*
- PP18: *"With the design, it could be fancier. But yeah, that is something that you are used to through all the apps nowadays. With fancy design and such. But for someone with autism, it might not be necessary how the app looks, but that it would work. For example, if you are in your highest emotions then you want to immediately use the app instead of wanting that the app would look nice."*

Table 41 - Requirement Theme 8.3 (a)

# from 8.3.4	Requirement	Description
8.16	Up-to-date design	The emotion regulation sound application shall contain a design that is up to date to the newest trends in application design to achieve that is more appealing.

Three participants (PP12, PP18 & PP19) mention that they would like a fully functional app on the smartwatch.

- PP12: *"Actually, you can need to have the controls on the watch."* The participant wants to have a fully functional app on the watch. PP12: *"I walked at a certain moment upstairs and then I did not have a connection and I thought o I need to have the phone near me. You said that but… I would not carry the phone always with me."*
- PP18: *"The combination of having the phone close to the watch. That is a tricky thing for me. At some point, I was thinking, where is the phone? Also, when I am wearing a dress, you know. You don't have the phone always with you."*
- PP19 has a constant struggle with finding the phone and going to the app. The screen also disappeared on the smartwatch at one time. The participant had also the urge to watch the time at the smartwatch, but there was only a color.

Table 42 - Requirement Theme 8.3 (b)

# from 8.3.4	Requirement	Description
8.20	Standalone application on smartwatch	The emotion regulation sound application shall function as standalone on the smartwatch to achieve that user can use the emotion regulation sound application without the phone in proximity.
8.17	Controls on smartwatch	The emotion regulation sound application shall provide controls on the smartwatch to achieve that the user can control the emotion regulation sound application also from the smartwatch.
8.14	Time on smartwatch	The emotion regulation sound application shall provide the current time on the smartwatch to achieve that the user can also use the smartwatch as a watch.

There are different opinions on the colors for the different emotional arousal levels. There is a side note that most participants only experienced the active emotional arousal levels (yellow, orange, red) including the calmest level (green).

- Seven participants (PP11, PP13, PP14, PP15, PP16, PP17, PP18) mention that the colors and their meaning are clear to them.
    - PP11 says: *"I think green means that you are doing all right. With yellow, you must pay attention, and orange means it is going bad, and red is it terribly wrong."* PP11 did not discover the passive colors (purple, blue, dark green) with the usage, and was not completely sure about the meaning. After an explanation, the participant mentions that is clear.
    - PP13 mentions that the color stayed the same, but this was clear for the participant because the participant mentions that their emotions might not fluctuate a lot. As a side note, the color stayed the same because the participant might not have the watch connected to the phone on the second day, as there was no data present for the participant on the second day of testing. The participant also mentions not knowing all the colors at hand but that it was possible the look that up.
    - For PP14, the colors were clear. PP14: *"I knew that green meant it was good. And if it was another color, I had to check."* The participant mentions to know that one side was red, and the other side was purple. The under/overarousal was clear to the participant. PP14: *"Yes, but that is also visible everywhere, that information you receive on the telephone."*
    - PP15: *"I knew that green was good. Yellow a little bit less and orange again less good. The rest of the colors I did not see. I knew the order, I noticed that of myself. I knew that one side was more active, like with dancing, then you're internally also a little active."*

    - The colors were clear for PP16. PP16: "That yellow, orange, and that red meant agitation was quite clear. I did not experience the minus side, but I think that purple might mean very calm or even depressed."
    - PP17 mentions that the colors were clear. PP17: *"Well, I think green is calm, I don't know why. but it is logical. Darker means more expressions, how do you say that… more outrageous, more active. But I don't know what was on the other side, which colors. I was kind of curious about that. Blacker, purple, or something like that. But those colors did not happen with me."*
    - PP18 finds it clear that there was a down and an upside of the emotional arousal.
    - PP19 mentions the colors were clear about the active and passive sides. The participant did mention that it was only at the start unclear whether the watch worked as it stayed on green. However, later it changed a lot and the color even changed occasionally to red. Thus, the participant later knew that the watch was indeed working.
- The colors seemed for one participant (PP12) not clear.
    - PP12: *"At the end, the watch stayed a lot on the green, I'm not sure what green means. Maybe it would be nice to have the smiley also on the watch or at least some text to indicate what the color means. I was not sure if the application (Android prototype) was working, because it stayed a long time at the green."* As a side note, there was no data for the second day of PP12, so the participant probably wore the watch but did not connect it to the phone. Therefore, the participant got the impression that the app was not working.

Table 43 - Requirement Theme 8.3 (c)

# from 8.3.4	Requirement	Description
8.4	A distinct color at disconnection	The emotion regulation sound application shall provide a distinct color when there is no connection with the watch and phone to achieve that the user can understand that there is no connection.

For three participants (PP16, PP17, PP18) there is some difficulty in recognizing the color for 0 (mint green) and -1 (dark green).

- PP16: *"I find it hard to describe the colors. At some point, I was at the middle color, so I was thinking about what to write down. It is not blue, and it is not green, it is in between. Blue/green, so I write down blue/green. "*
- PP17 noted the middle color as light-blue and gave the tip to switch the color of -1 (dark green) and 0.

- PP18: *"In the beginning, the color is blue or a little bit azure, the one that comes after green. I was first thinking that blue is the basis. Then I thought… wait is green my best color is blue my best color? I find it difficult to see. At some moment the color was green, and I thought wait? But is this then another color as the blue one? Then I saw that it was indeed another color. But they looked similar. " The* participant advised for the green color (of -1) at 0 and towards purple another color, that might be the color that is now visible at 0.

Table 44 - Requirement Theme 8.3 (d)

# from 8.3.4	Requirement	Description
8.5	Switch colors of emotional arousal 0 and -1	The emotion regulation sound application shall provide the colors of emotional arousal 0 with a dark green color and the color of emotional arousal -1 with a mint green color to achieve that the user can better distinguish the calmest level and the levels towards the passive side.

For one participant (PP15), orange was unclear.

- PP15: *"The orange that became a bit... you don't see that clearly, right? Orange was yellow with an orange touch. It was a bit a combination of yellow with an orange glow."*

Table 45 - Requirement Theme 8.3 (e)

# from 8.3.4	Requirement	Description
8.18	Change orange color	The emotion regulation sound application shall provide the orange color for emotional arousal +2 with a different hue to achieve that the color is more distinct from the yellow color at +1.

Two participants mention some difficulties in the usage:

- PP17 mentions that music suddenly stopped and started again. After discussing how the participant added the music, it shows that the PP17 accidentally put the same song on every emotional arousal level. The song also changes if the emotional arousal level changes. The researcher asked whether the participant missed some extra information. PP17 mentions that maybe after longer usage, the participant would understand more clearly how adding music worked. PP17 also mentions that a tutorial could have been a great addition. The participant means that at first usage there are messages

with an explanation about the functions of the emotion regulation sound application that the user can navigate through.

- PP13 also mentions that it was difficult at first, but PP13 also mentions that after learning how to use the Android prototype it was quite easy: *"In the beginning, it was quite a lot of information. Well, if you set it up, then it works. I think with the music it is quite something. You choose birds and if you want something else, then you must change everything. That was quite something. But if you know it, then you know it. The rest is not so difficult anymore."*

Table 46 - Requirement Theme 8.3 (f)

# from 8.3.4	Requirement	Description
8.19	Guide through functions	The emotion regulation sound application shall provide a guide of all the functionalities with the first usage to achieve that the user better understands the emotion regulation sound application.

Four participants (PP13, PP14, PP16, PP18) mention that the Android prototype was easy to use and for some after a learning phase.

- PP13: "*Eventually you think it is quite easy because you know it, but in the beginning, I thought... You must look at how it works. That is with everything obviously, if you understand it, then it is not so hard anymore."*
- PP14: *"I was able to understand the application (Android prototype) and knew how to use it properly. I fully understand how to control the application (Android prototype)."*
- For PP16, some sounds did not work in the Android prototype, but the researcher provided new sounds that worked. PP16: *"Eventually it was easy. Only at the beginning, I thought I was doing something wrong because the sound fragments did not work. Then I thought, oh what a hassle. But eventually, it was not that hard. I did what I had to do, so yeah, it was quite easy."* The participant also thought that connecting with the watch was clear. PP16: *"It took me a bit of time to understand that with the connection and so. But eventually, it was quite easy that it gives a vibration, like 'hey you have a connection'. Then you are ready to go."*
- PP18: *"With adding music that you have to click on save each time, you have to know that. But that is just a one-time thing and then it will be easy."* The participant advised that an interim evaluation can be useful for fully understanding the full Android prototype with all its functionalities (such as making a new measurement). Thus, the participant means that this was to help understand the first usage of the Android prototype, and then the emotion regulation sound application can improve, so at another time the same participant can

again use the emotion regulation sound application. According to the participant, this would help that the user is not overwhelmed with too much information and the emotion regulation sound application can improve in the meantime.

Table 47 - Requirement Theme 8.3 (g)

# from 8.3.4	Requirement	Description
8.15	Save the music selection	The emotion regulation sound application shall provide the option for the user to save the music selection as a recommendation to achieve that the user does not have the select all the sounds from the device after the user selects a recommended sound.

One participant (PP15) mentions that the text on the sound selection page of the path can be smaller and clearer.

- PP15: *"This was such a huge text. It is not clear for me what it says."*

Table 48 – Requirement Theme 8.3 (h)

# from 8.3.4	Requirement	Description
8.6	Readable text of sounds/music	The emotion regulation sound application shall provide text that is not too long and/or ambiguous to achieve that the user understands which sound/song they select.

Theme 8.4 Mimic vs. Nudge

All participants did not change the sound reaction, so it stayed for all participants on the mimic sound reaction. Three participants gave the following explanation.

- PP16 did not try the different sound reactions because the participant was afraid that something would not work anymore. The participant also mentions being very busy with the music, so it was also that the participant forgot to try the different sound reactions.
- PP17: *"O no, I did not try that. I just looked at it, but I did not know how it would work. Maybe it could have helped to be guided through that, step by step, that you must do this and do that. But maybe if I put more time into it, then I might have figured it out."*

- PP18 mentions not using the sound reaction but was thinking about it. The participant thought by choosing a nudge that it would react faster, and the participant thought the app was reacting too fast. The participant also mentions that it could try to use it at only the highest level (with alert), but the participant was already doing that. When the application reached the highest emotional arousal level (+3/red), the participant started the sounds.

Theme 8.5 Context Mapping (self-reporting data) & log data

Context Mapping
C2 shows the filled-in context mapping for each participant.

One observation is the choice of sounds were quite similar for the different participants:

- Six participants (PP11, PP14, PP15, PP16, PP17 & PP19) listened to sea sound and three participants (PP14, PP15 & PP16) listened to sea sounds more than once
- Two participants (PP15 & PP17) listened to bird sounds where PP17 listened to the bird sounds multiple times
- One participant (PP17) listened to rain and brain waves

The researcher filled the phone with the preferred music from the participants. It concludes that the music taste of the participants was quite diverse. The participants listened to Kensington, ABBA, Justin Bieber, Christmas songs, George Michael, Dutch folk music, or carnival music. Music plays for most participants (PP11, PP12, PP13, PP14, PP15, PP16, PP17, PP18) a background role to create some ambiance. The participants also mentioned that the music was used to some extent to steer behavior like being energized for sports (PP13, PP15, PP16, PP17) or having fun at a party with others (PP14, PP15, PP16, PP17). Only two participants (PP16 & PP19) mention having experience with music for calming down.

For the participants, the emotional arousal levels seemed to be mostly on the active side (see Figure 51-Figure 53). The following graphs come from the self-report data in the context mapping. The participants wrote emotional arousal episodes on the context mapping paper that they experienced during the testing days. For the x-axis on the graph, the beginning and end values are not time-restricted, thus the beginning and end values can take place any time and are not the same for the different participants. The graphs show a decrease/increase or constant fluctuations. A participant might experience not one, but multiple different fluctuations as seen in Figure 51-Figure 53. Only two participants noticed the -1 emotional arousal level (PP17 & PP18). There were different fluctuations in the emotional arousal levels:

- Five participants (PP12, PP14, PP15, PP18 & PP19) experienced a decrease in their emotional arousal levels during the testing days. Figure 51 shows the decreases in emotional arousal. The participants report the following decreases of an emotional arousal episode.
    - From +3 to +2 (PP12 & PP19)
    - From +1 to 0 (PP14 & PP15)
    - From +3 to 0 (PP14 & PP18)
    - From 0 to -1 (PP18)
    - From +3 to +1 (PP19)
    - From +2 to +1 (PP19)

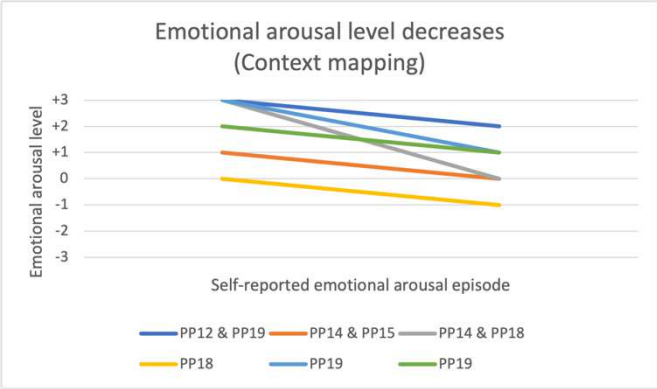


Figure 51 - Decreases Emotional Arousal (Context mapping)

- Five participants (PP12, PP15, PP16 & PP17) experienced an increase in their emotional arousal levels during the testing days. Figure 52 shows the increases in emotional arousal. The participants report the following increases in an emotional arousal episode.
    - From +1 to +2 (PP12 & PP16)
    - From 0 to +1 (PP15 & PP16 & PP17)
    - From 0 to +2 (PP16 & PP17)

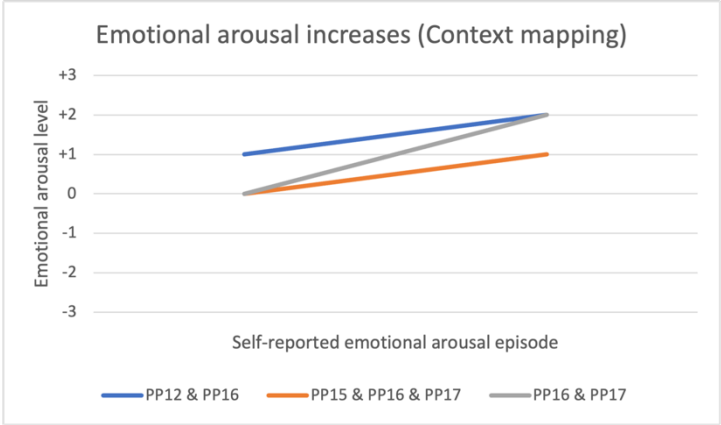


Figure 52 - Increases Emotional Arousal (Context mapping)

- Five participants (PP12, PP13, PP15, PP16 & PP17) mention that the emotional arousal levels stayed the same at some testing moments. Figure 53 shows the arousal levels that stayed the same. The participants report the following constant emotional arousal episode.
    - From +3 to +3 (PP12 & PP18)
    - From +1 to +1 (PP13 & PP15 & PP16)
    - From 0 to 0 (PP15 & PP17)

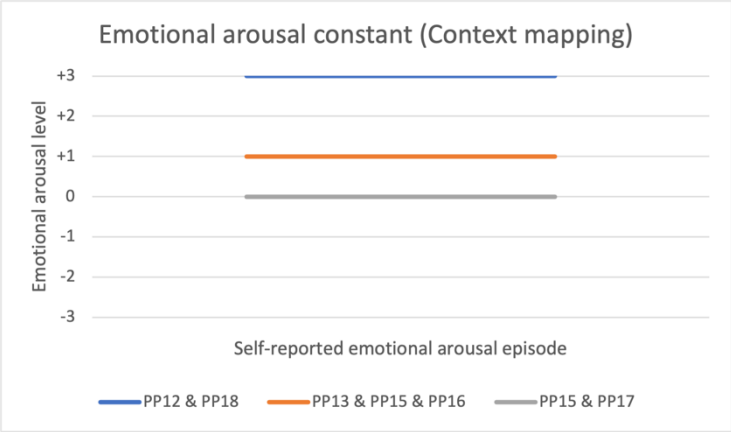


Figure 53 - Constant Emotional Arousal (Context mapping)

Figure 51 - Figure 53 shows that:

- One participant (PP12) has a self-report of experiencing an increase, decrease, and constant emotional arousal episode.
- Four participants self-report experience with only one emotional arousal episode change (PP13, PP14, PP18, PP19).
    - PP13 has a self-report of a constant emotional arousal episode
    - PP14, PP18, PP19 have a self-report of a decrease in an emotional arousal episode
- Two participants (PP16, PP17) have a self-report of both constant and increase of an emotional arousal episode.

Listening to certain sounds/music might cause different fluctuations of emotional arousal (see Table 49). One participant did not record the song name of an artist. Most participants (PP14, PP15, PP17, PP18 & PP19) seem to decrease their emotional arousal level from active emotional arousal by listening to sounds/music. It shows that for two participants (PP16 & PP17) the sounds/music has an increasing effect on their emotional arousal level. PP16 mentions feeling more active when listening to sound/music or that the participant might have picked the wrong songs. PP17 mentions to usually not fall asleep when listing to music but feel more awake when listening to music and have the motivation to do things by listening to music.

Table 49 - Table of Effect from Sounds/Music on Emotional Arousal

Sound/Music	Increase	Decrease	Constant
Bird	PP17	PP15	PP13 + PP16
Sea	PP16 + PP17	PP14 + PP15 + PP19	
Rain	PP17		
Brain		PP17	
Kensington & Armin van Buuren – Heading up high	PP16		
Kensington – Do I ever	PP16		
Justin Bieber	PP17		
Mariah Carey - All I Want for Christmas		PP18	
George Michael - Cowboys & Angels			PP18
George Michael – Last Christmas		PP19	
ABBA – Super Trouper	PP16		

Another observation is that the participants fill in the context mapping differently. The differences are:

- Three participants (PP11, PP12 & PP15) mention the duration of the activity
- Seven participants (PP11, PP14, PP15, PP16, PP17, PP18 & PP19) mention which sounds/music listened to
- Eight participants experienced changes in emotional arousal/color (PP12, PP13, PP14, PP15, PP16, PP17, PP18 & PP19)
- Seven participants (PP11, PP13, PP14, PP16, PP17, PP18 & PP19) mention their activity when using the Android prototype

The differences in the context mapping might show that there might have been some misunderstanding about the exercise and therefore the desired context contents present as bullet points for the last half of the participants. The bullet points are:

- Time
- What did you do? (What was the activity?)
- What was the color at the beginning and end?
- Which sound/music did you listen to?

The last half of participants were more consistent with the content for the context mapping. However, the duration of the activity and the duration of listening to sounds/music were missing. Thus, the explanation with the bullet points might still have missed some clarity. This resulted in the context mapping being difficult to place onto the log data graph for the emotion regulation of the users in the following section.

Log data

The following section presents the graphs of the different fluctuations in the emotional arousal levels. In C3, there are graphs from the participants that are not in this section. The graphs comprise the log data from the SoundRate application that records the fluctuations in the emotional arousal levels for each participant.

The graphs confirm what the participants mentioned in the context mapping that their emotional arousal levels rarely go to the passive side (only three participants, see Figure 59 at 23:13, Figure 60 at 10:48, 10:49, 10:52, 10:55, and Figure 61 between 10:20-12:45, 13:31-18:28. All participants confirm the fluctuations in the graph. One participant even mentions the following (PP16):

"I think I was quickly agitated [ha-ha], so I thought that was funny. I thought it was mostly funny, ... when at first, I did not manage it with the music. I saw the color went yellow, then orange, and then red (see Figure 54 *at 11:31). So, I thought oh. At that moment you think, yes, I am at that moment tearing myself up with why can I make it to work? I thought it was kind of funny that you see that so quickly."*

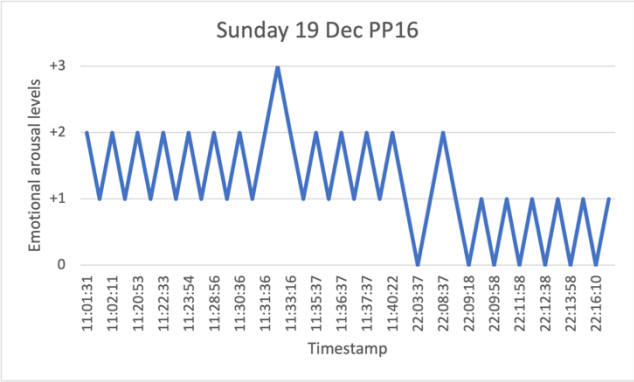


Figure 54 – Log data graph PP16 day 1

The researcher asked all participants about the outliers in the log data graph. The participants could not explain all the outliers, but they gave the following explanations for the outliers that were explainable:

- PP11 mentions that the outliers on the passive side (see Figure 55 around half past 4) might have to be explained by being exhausted from working long hours during the holidays at the chocolate shop.

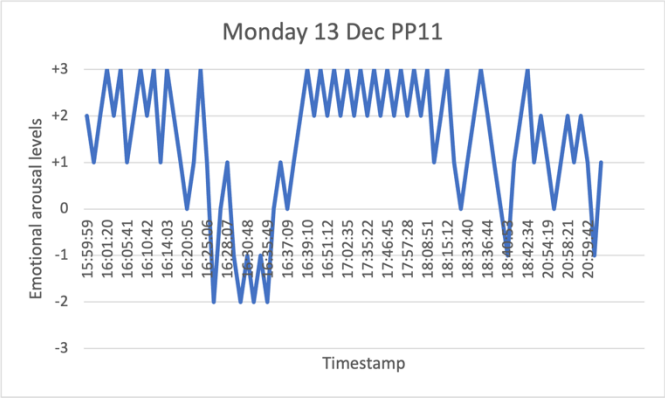


Figure 55 - Log data graph PP11

- PP11, PP12 & PP13 mention that the outliers at the active emotional arousal (see Figure 55 between 16:39 and 17:57, Figure 57 at 12:51, at 19:43 and 19:44, Figure 56 at 12:06) might come from being active, content, and/or energetic after eating something with the lunch and dinner.

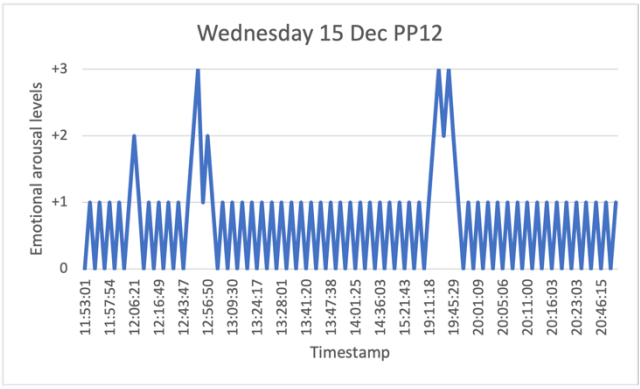


Figure 57 - Log data graph PP12

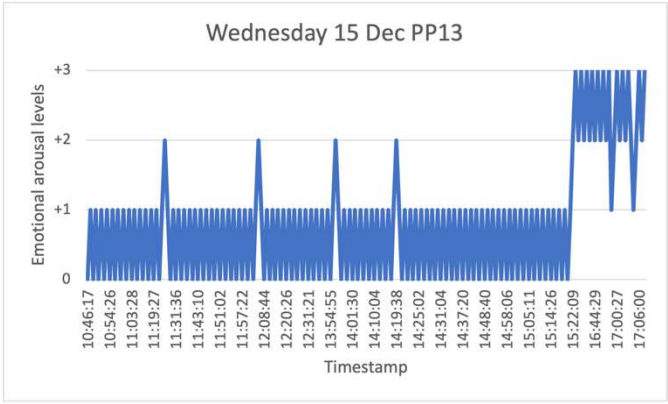


Figure 56 - Log data graph PP13

- PP14 mentions that the outlier at the active emotional arousal might come from something that was frustrating at their regular television series (see Figure 58 at 21:32).

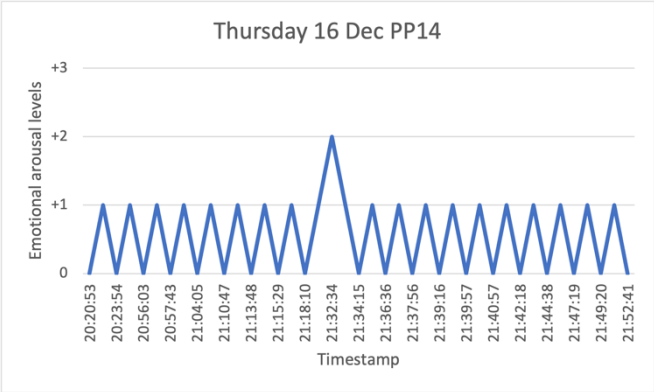


Figure 58 - Log data graph PP14 day 2

- PP15 mentions that the outlier at the active emotional arousal might come from being frustrated that the car broke down (see Figure 59 at 20:47 and 22:14). The outlier on the passive side (see Figure 59 at 23:13) might come from being exhausted from the hassle of fixing the car.

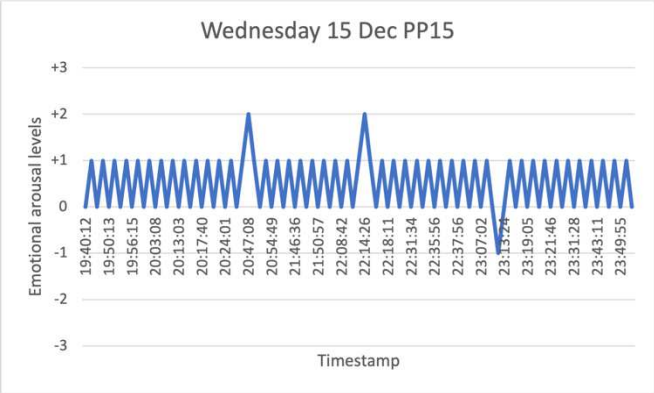


Figure 59 - Log data graph PP15 day 1

- PP16 mentions that an outlier at the active emotional arousal (see Figure 54 at 11:31) might come from being frustrated that the Android prototype did not play the music. *Side note: this was a technical issue with music not playing and this was during the testing fixed by proving other music that worked.*
- PP17 mentions the outliers on the active side might have to do with trying out stuff with the Android prototype and just getting active by it (see Figure 60 at 10:44, 20:54, and 21:00).

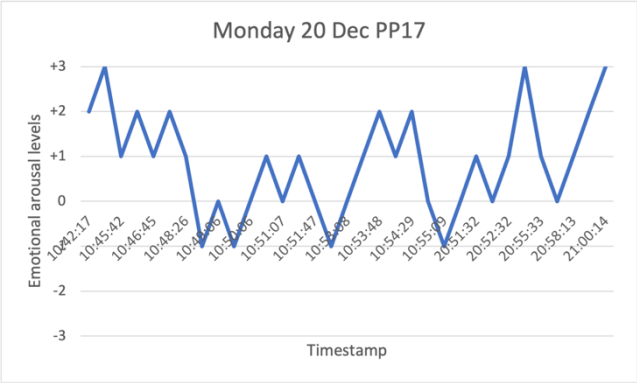


Figure 60 - Log data graph PP17 day 1

- PP18 mentions that the outliers usually happen after lunch and that might come from being alert to make everything ready for the zoom calls that are after lunch (see Figure 61 at 12:22 and 12:35).

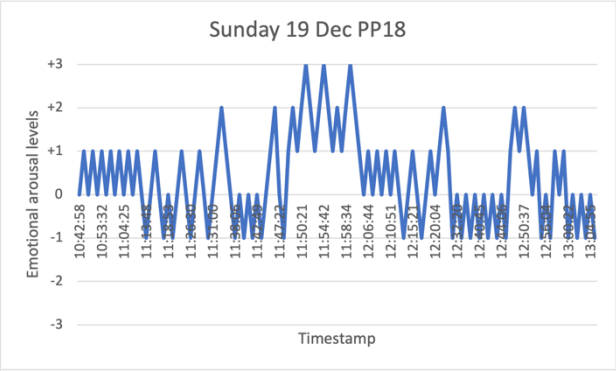


Figure 61 - Log data graph PP18 day 1

- PP19 mentions experiencing outliers on the active emotional arousal because of some family circumstances, and therefore might experience some stress.

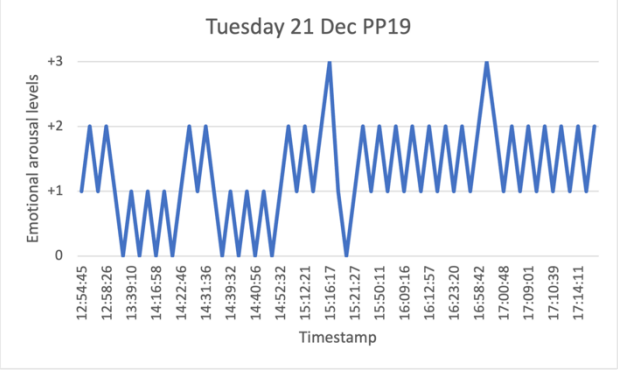


Figure 62 - Log data graph PP19

The graphs show the participants used the emotion regulation sound application differently during the testing days. There are differences in periods and amount of testing for the participants.

The log data from the application also shows the average heart rate, standard deviation, and sensitivity of each participant (see Table 50) that is used to calculate the emotional arousal level (as explained in Chapter 4 with Equation 2). The log data shows that the standard deviation for most participants might be high (seven participants with a standard deviation greater than 10). Thus, it means that there are variations in the heart rates where there might be a low accuracy of the heart rate variables and the data needs to be interpreted with caution.

Table 50 - log data participants

Participant #	Average heart rate	Standard deviation	Sensitivity
PP11	91	4.7	2
PP12	92.3	17.9	2
PP13	73.3	11.2	2
PP14	87.2	16.7	2
PP15	88.8	17.0	2
PP16	76	11.65	2
PP17	85.2	9.4	2
PP18	85.3	10.9	2
PP19	75.2	11.3	2

Equation 2 - Formula to measure emotional arousal levels [35]

$$average\ heart\ rate + \big((standard\ deviation * sensitivity) * x\big) < emotional\ arousal\ level < average\ heart\ rate + ((standard\ deviation * sensitivity) * (x + 1))$$

Theme 6: Personal & Control

Five participants (PP11, PP12, PP16, PP17, PP18) mentioned it was possible to make the Android prototype personal.

- PP11, PP12, PP17 & PP18 mention it was possible to make the Android prototype personal by adding music.

Two participants (PP11 & PP16) mention that they are still in control of how the Android prototype reacts.

Theme 8.7: Applicable for people with ASD

Six participants (PP11, PP14, PP16, PP17, PP18 & PP19) mention that the emotion regulation sound application usage depends on the personality and preferences of the user.

- PP11 mentions that the emotion regulation sound application applies to people who experience difficulties with their emotions.
- PP14 mentions the emotion regulation sound application especially applies to people who are more into music.
- PP16 likes the Android prototype and wants to use it again if it is further developed. The participant mentions that this is because their interest is already in music.
- PP17: *"It depends on the person whether they want to use the (emotion regulation sound) application. I think someone might like music but someone else doesn't like music. So, I think the (emotion regulation sound) application is suitable for people who like to listen to music."*
- PP18 mentions that the usage of the emotion regulation sound application depends on whether you would normally react to music.
- PP19 mentions already using music as an outlet when something is going wrong during their work, thus the participant thinks that the emotion regulation sound application would work for them with some improvements. But the participant mentions that this might not apply to others.

Six participants (PP11, PP12, PP13, PP14, PP15, PP16) mention that they think that the emotion regulation sound application is suitable for people with autism spectrum disorder (ASD).

- PP11: *"I would recommend the (emotion regulation sound) application to someone with ASD, because with the (emotion regulation sound) application you can better understand your emotions and get a better grip on them such that you won't have to experience any explosion, that bothers you and your environment, anymore. Thus, that you are in time out of the situation that makes you feel a certain way."*
- PP12 & PP14 mention that the emotion regulation sound application is recommendable for people with ASS when the Android prototype is further developed.
- PP18 mentions recommending the emotion regulation sound application to someone who has difficulties with their emotions when the Android prototype is further developed.

8.3 Conclusion

The information from the chapter translates into the following sections about the discussion & conclusion, limitations, persona, requirements, answers to research questions.

8.3.1 Discussion & Conclusion

The user tests show some differences in how the participants perceive different sounds/music. First, there is a diversity in the taste of the sounds/music from the participants (ABBA, Carnival Music, Christmas Music, Dutch Folk Music, George Michael, Kensington). There was also a preference for the sounds over music from three participants because 1) the sounds had a more calming aspect by not including any words, 2) the participant wanted to listen to something else than music, 3) the music reacted not properly according to one participant. For the latter, it was especially the case that the participants preferred to listen to the full song instead of a new song when the emotional arousal was changing.

Some recommendations for the changes in the music are: 1) longer duration of songs, 2) instrumental songs, 3) changes in the music itself, such as a beep, 4) the same song but on a different level or even 5) no change in the music at all when coping with feelings. Other recommendations about the music were 1) to create a playlist for the same emotional arousal level, and 2) to have recommendations of different songs that fit that emotional arousal level from the emotion regulation sound application.

The participants perceive the feedback from the device as a combination of vibrations, colors, and music/sounds. The vibrations, colors, music/sounds represent the emotional arousal level. However, the music/sounds are only present if the user clicks on the play button. The meaning of the colors was clear to the participants. However, there were some remarks about switching the dark green (-1) and mint green (0) color to better show the calmest color. Participants mentioned that the different feedback complements each other and that the feedback of only sounds is not possible, because in certain situations (like grocery shopping, in the classroom, or at work) the user does not want to hear the notification. The vibrations and colors can provide the user with insights into their emotional arousal and the sounds/music are a tool for coping with emotional outbursts.

Four participants mentioned that the Android prototype was easy to use. The participants understood how to add sounds and how to start the sounds. The participants also mention that it was possible to make the Android prototype personal because they selected personal music. Two participants also mention that the user is still in control of how the Android prototype should react.

In the context mapping, the participants mention they experienced active emotional arousal. The participants did not consciously experience anything lower than emotional arousal level -1. Graphs from the log data show that three participants experienced some passive emotional arousal levels that were no lower than emotional arousal level -1. The log data shows that interpreting the emotional arousal levels needs some caution because seven of the nine participants have a standard deviation higher than 10. It might mean that there is a low accuracy of the heart rate measurement because there is a great variation in the standard deviation. The context mapping data shows that for most participants, it helped to listen to sounds/music to decrease their emotional arousal level on the active side. One interesting finding is that the emotional arousal increased instead of decreased when being at the active emotional arousal for two participants. The participants explained this by getting active, energized from listing to music/sounds.

There also seemed to be some misunderstanding in certain tasks during the testing days. None of the participants changed the way the sounds/music reacts, so the sound reaction stayed on simulation (instead of nudge or alert) for all participants. The researcher notices that the tasks of adding sounds from the phone seemed overwhelming in the beginning. The participants differently filled in the context mapping. Even two participants forgot to connect with the phone and watch on their second testing day. Five participants mention the need of wanting to change vibrations, which was possible. However, the participants did not find out about the vibration setting. These discoveries might mean that: 1) the tasks might have been too complex for the testing days, 2) there might be a mismatch in the interests from the participant and what the Android prototype provided, and 3) the involved users have user's need that might have differed completely from the target user.

The main conclusion from the results is that the emotion regulation application is specific for people who like music and/or have difficulties with their emotion regulation. More research involving people with autism spectrum disorder (ASD) is crucial to understand the usefulness of the emotion regulation sound application for people with ASD. However, the user test shows that the participants perceive that the sounds/music in the Android prototype helps them to calm them down and for two participants helps them to get energized. The user test also shows that the participants mention that the Android prototype is easy to use, personalized, and the user is still in control of how the Android prototype should react.

8.3.2 Limitations

There are limitations in user testing relating to procedures. One limitation is that there was a change in the context's procedure mapping during the testing to make the use of the context mapping clearer. The change of procedure might affect the data from the context mapping. Another limitation is that the baseline measurements take

10–15 minutes instead of a full day. In the current study, this baseline measurement does not seem to be problematic as the participants confirm the graph data from the emotional arousal fluctuations from the SoundRate application (see Theme 8.5). However, the standard deviations of the log data show that there are great variations that might show a low accuracy of heart rate measurements. Thus, in a future study, it is better to investigate with a full-day baseline measurement that can improve the data. A full-day baseline measurement might give a more realistic measurement of the activities that the user would normally perform. Another limitation in the user testing is that some participants are relatives. The participants can unconsciously influence each other, which can be a positive or negative effect. A positive effect is that the participants are more involved in the study and come up with well-taught answers during the interviews. The negative effect is that the three participants might have biased answers in consecutive interviews where they were present in both interviews, such that it is uncertain whether their answers are truly from them. It is better for future work to consider the relations of the participants and whether this can influence the data. Another limitation is that the participants do not have the diagnosis of autism spectrum disorder (ASD). Thus, it is hard to answer how people with ASD perceive the emotion regulation sound application and what their requirements are for such an application. It is therefore uncertain whether the requirements from the user testing apply to people with ASD.

8.3.3 Persona

The demographic results translate into a persona (see Figure 63). A persona means a description of the typical user that eventually uses the emotion regulation sound application that comes from user data to create a better view of the actual user during the whole design and development process.

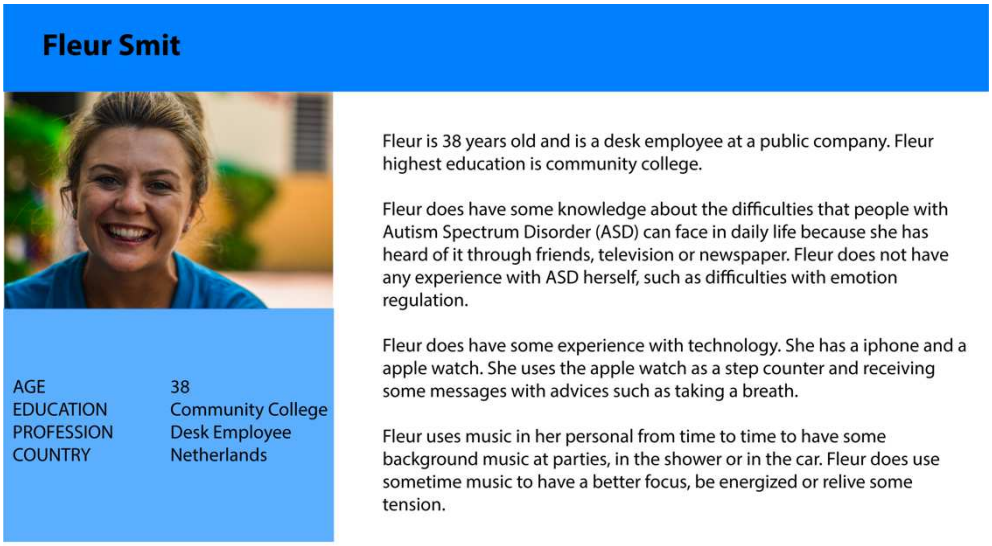


Figure 63 - Persona of a typical participant

Figure 63 shows a persona from the demographic information of the participants in the user testing phase with the Android prototype. The persona comprises a fictional name with some personal details (photo, age, education, profession, and country) that are based on some fictional data and the demographic information from the user studies. Next to the personal data, there is some text in the persona that describes the typical user in more detail. The text is based on the results from the interviews.

8.3.4 Requirements

The interview results give input to create some requirements for the emotion regulation sound application from the perspective of the users.

Table 51 shows the different requirements that are first categorized by the researcher into functional or non-functional requirements (what are the functions vs. how the emotion regulation sound application should work). The researcher prioritizes requirements with the Moscow (Must, Should, Could, Would) prioritization. Must-requirements are the ones that must require to be developed in a next iteration of the emotion regulation sound application because those requirements are based on the core of the emotion regulation sound application (which is the music/sounds part of the emotion regulation sound application) and those must-requirements are essential for making the emotion regulation sound application more usable. The should requirements are the ones that should require to be developed after all the must-requirements are in development. The should requirements are based on also improving the sounds/music part of the emotion regulation sound application, but if those improvements fail, the emotion regulation sound application is still usable. There is an urge to develop the should requirements to make the emotion regulation sound application better usable, but if the improvements fail, then it is still acceptable. Could-requirements are the ones that if there is time left, then those requirements are nice to include in the emotion regulation sound application. Could-requirements are nice to have, but those requirements are unnecessary for the emotion regulation sound application to succeed. At last, the would-requirements are the ones that are still based on the user's needs but might not be necessary for the emotion regulation sound application to be successful or achievable for development. For example, Table 51 shows a would-requirement that is about making the emotion regulation sound application standalone on the smartwatch. This is requirement might not be achievable in the current landscape of how smartwatches work. It is almost impossible to create an emotion regulation sound application for the smartwatch that does not need a connection with the smartphone. Besides, it is also not achievable to do a complete change of the current emotion regulation sound application that is built for smartphones. The following table includes the different requirements.

Table 51 – Requirements Third Iteration

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
8.1	Personalized sounds/ music	The emotion regulation sound application shall provide the option that the user can select their sounds/music to achieve that the user can select the sounds/music to their taste.	Functional	Must	Theme 8.1
8.2	Longer duration of the sounds/ music	The emotion regulation sound application shall provide the sounds and music with a longer duration to achieve that the same sound or song does not constantly repeat.	Functional	Must	Theme 8.1
8.3	Pay attention to sounds that are energetic or more relaxing to fit the passive and active emotional arousal levels	The emotion regulation sound application shall provide suggestions for the passive emotional arousal levels to listen to energized music/sounds and for the active emotional arousal levels to listen to relaxing music/sounds to achieve that the user is better nudged towards the calmest emotional arousal level (0).	Non-functional	Must	Theme 8.2
8.4	A distinct color at disconnection	The emotion regulation sound application shall provide a distinct color when there is no connection with the watch and phone to achieve that the user can understand that there is no connection.	Non-functional	Must	Theme 8.3
8.5	Switch Colors of Emotional Arousal 0 and -1	The emotion regulation sound application shall provide the colors of emotional arousal 0 with a dark green color and the color of emotional arousal -1 with a mint green color to achieve that the user can better distinguish the	Non-functional	Must	Theme 8.3

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
		calmest level and the levels towards the passive side.			
8.6	Readable text of sounds/ music	The emotion regulation sound application shall provide text that is not too long and/or ambiguous to achieve that the user understands which sound/song they select.	Non-functional	Must	Theme 8.3
8.7	Instrumental music	The emotion regulation sound application shall provide the addition of a preselection with instrumental music to achieve that music with text does not distract the user.	Functional	Should	Theme 8.1
8.8	Options of pre-defined sounds for each emotional arousal	The emotion regulation sound application shall provide a pre-defined selection of sounds for each emotional arousal level to achieve that the user can more easily choose a sound that fits the emotional arousal.	Functional	Should	Theme 8.1
8.9	Playlist on each emotional arousal	The emotion regulation sound application shall provide a playlist of sounds for each emotional arousal level to achieve that the user can listen to more sounds with a variety.	Functional	Should	Theme 8.1
8.10	Changes in emotional arousal have a smooth sound/music transition	The emotion regulation sound application shall provide a smooth transition in the sound/music to achieve that the sound/music is not abruptly changed when listening to the sound/music.	Non-functional	Should	Theme 8.1, Theme 8.2
8.11	Provide feedback from a combination of sound,	The emotion regulation sound application shall provide feedback from a combination of colors, vibrations, and sounds to achieve	Non-functional	Should	Theme 8.2

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
	color, and vibration	that the user realizes their emotional arousal without the feedback being intrusive.			
8.12	Consider the environment of the user	The emotion regulation sound application shall provide feedback with consideration of the environment of the user to achieve that the emotion regulation sound application does not disturb the user.	Non-functional	Should	Theme 8.2
8.13	Ability to change vibrations to preference	The emotion regulation sound application shall provide the ability for the user to change the vibration at their preferences for the different emotional arousal levels to achieve that the emotion regulation sound application gives vibrations during convenient moments for the user.	Functional	Should	Theme 8.2
8.14	Time on smartwatch	The emotion regulation sound application shall provide the current time on the smartwatch to achieve that the user can also use the smartwatch as a watch.	Functional	Should	Theme 8.3
8.15	Save the music selection	The emotion regulation sound application shall provide the option for the user to save the music selection as a recommendation to achieve that the user does not have the select all the sounds from the device after the user selects a recommended sound.	Functional	Should	Theme 8.3
8.16	Up-to-date design	The emotion regulation sound application shall contain a design that is up to date to the newest trends in emotion regulation sound application design to achieve that is more appealing.	Non-functional	Could	Theme 8.3

#	Requirement	Description	Functional or Non-functional	Priority (Moscow)	Source
8.17	Controls on smartwatch	The emotion regulation sound application shall provide controls on the smartwatch to achieve that the user can control the emotion regulation sound application also from the smartwatch.	Functional	Could	Theme 8.3
8.18	Change orange color	The emotion regulation sound application shall provide the orange color for emotional arousal +2 with a different hue to achieve that the color is more distinct from the yellow color at +1.	Non-functional	Could	Theme 8.3
8.19	Guide through functions	The emotion regulation sound application shall provide a guide of all the functionalities with the first usage to achieve that the user better understands the emotion regulation sound application.	Functional	Could	Theme 8.3
8.20	Standalone application on smartwatch	The emotion regulation sound application shall function as standalone on the smartwatch to achieve that user can use the emotion regulation sound application without the phone in proximity.	Functional	Would	Theme 8.3

8.3.5 Answers to research questions

This chapter tries to answer the sub-questions *"What are the requirements from people with ASD about the emotion regulation sound application?"* and *"How do users perceive an emotion regulation application that provides sound/music based on their emotional arousal levels?"* with the following sub-sub-questions.

- *Perceive users sound as suitable feedback to gain more insights into emotion regulation?*
- *Does sound help the users to calm down/energize?*
- *What are the opinions from the users about the sound reaction mimic, nudge, or alert?*

The table of the previous section gives a partial answer to the first sub-question: *"What are the requirements from people with ASD about the emotion regulation sound application?"*. To summarize, the requirements are alike the requirements from previous iterations about personalization, emotion regulation, and users are in control. There are also some new requirements for sound improvements. The following table shows the similar requirements from the different iterations.

Table 52 - Requirement's iteration 2

Similar Requirements from Chapter 3	Similar Requirements from Chapter 6	Requirements from Chapter 8
Requirement 3.1 - Emotion handling	Requirement 6.5 – Track emotional and physical feelings	Requirement 8.3 – Pay attention to sounds that are energetic or more relaxing to fit the passive and active emotional arousal levels
Requirement 3.4 – Personalization & Requirement 3.6 – In control of own life	Requirement 6.8 – Select the sound reaction & Requirement 6.10 – Personal data	Requirement 8.1 – Personalized sounds/music
Requirement 3.9 – Avoid words of emotions	Requirement 6.12 – Understandable words	Requirement 8.6 – Readable text of sounds/music
Requirement 3.10 – Ability to adjust	Requirement 6.17 – Sound reaction based on context	Requirement 8.12 – Consider the environment of the user & Requirement 8.13 – Ability to change vibrations to preference
Requirement 3.11 – Simple design	Requirement 6.2 – Minimalistic design	Requirement 8.16 – Up-to-date design
Requirement 3.13 – Learnability	Requirement 6.18 – Recognize patterns	

Table 52 shows similar requirements in comparison with the previous requirements from Chapter 3 and Chapter 6. It shows that there is still a need for the emotion regulation sound application to contain personalization, emotion regulation support, take the environment into account, and modernized design. The last requirement in Table 52 shows that during the last user involvement there are no interests mentioned about learnability and recognizing patterns. This might mean that there is no interest in learnability/recognizing patterns, but it might also mean that the

participants did not think about learnability/recognizing patterns. Future research is required. Other new requirements are about improving the sounds/music with:

- Longer duration of the sounds/music (Req 8.2)
- Instrumental sounds (Req 8.7)
- Options for pre-defined sounds for each emotional arousal (Req 8.8)
- Playlist on each emotional arousal (Req 8.9)
- Changes in emotional arousal have a smooth sound/music transition (Req 8.10)
- Save the music selection (Req 8.15)

Perceive users sound as suitable feedback to gain more insights into emotion regulation?
The participants mention the sounds do not solely provide feedback to the user; it is a combination of the vibrations, colors, and sounds/music. Vibrations and colors provide the notification, whereas the sounds/music is an emotion regulation mechanism for the user. The sounds/music currently applies to show the changes in the emotional arousal level. These changes in the music will not work well if someone goes constantly back and forth with different emotional arousal levels. The current participants experienced it as funny, but for the target user (ASD) this is not suitable as this should not be an extra trigger for them. Some suggestions from the participants were 1) to change the music to instrumental so the changes are less noticeable, 2) play the full song and no noticeable changes at all, 3) small changes in the song such as a beep. To conclude, the participants do not perceive sound/music solely as feedback to gain more insights into emotion regulation and emotional arousal, but as a combination of vibration, color, and sounds/music.

Does sound help the users to calm down/energize?
For most participants (six participants), the sound and music helped to calm them down. More participants used the bird and sea sounds (six participants) than music (four participants). Two participants showed an increase in their emotional arousal level when listening to the music/sounds, with the explanation of being more active, energized, awake. To conclude, sound helps people to calm down, but there is also some effect that it helps others to feel energized.

What are the opinions from the users about the sound reaction mimic, nudge, or alert?
The participants did not test the mimic, nudge and/or alert. The participants did not change the sound reaction to something else than mimic, which might come from the complexity of the tasks and/or a misunderstanding from the participants. One participant mentions thinking that the Android prototype would crash when using the different options. Another participant had a misunderstanding that the Android prototype would provide more feedback compared to how the application currently reacted. To conclude, there cannot be anything said about the opinions of the participants towards the sound reaction mimic, nudge, or alert.

Thus, an answer to the sub-question *"How do users perceive an emotion regulation application that provides sounds/music based on their emotional arousal levels?"* is:

- The sounds/music cannot solely provide feedback to the user because it might be inconvenient at certain moments to receive audio feedback. The feedback is therefore a combination of visual content (like colors), vibrations, and sounds/music.
- The sounds/music has a positive effect on the users to calm down and for two users even to get energized. Participants mostly liked to listen to sea and bird sounds. The participants also find the Android prototype easy to use, personalized, and the user can stay in control of how the Android prototype reacts.
- It is still uncertain whether there is a preference for the sounds to be present as mimic (sounds/music have the same intensity as emotional arousal), nudge (sounds/music are lower or higher in intensity as emotional arousal), or alert (sounds/music only present at certain emotional arousal levels). The participants did not test the different sound reactions. However, there might be a partial answer as participants commented on the sounds/music to be a bit off when the emotional arousal was changing. There is a preference for listening to the full song, which might show that the whole idea of using sounds/music as a representation of the emotional arousal might need some revisiting. Some tips from the participants are 1) a small notification like a beep in the sounds/music, 2) a different intensity of the same song, 3) no notification at all from the sounds/music. Thus, it is still uncertain whether the mimic, nudge, or alert can work. Therefore, there is still a lot to uncover for a next study.

Chapter 9 Discussion

The target user for this study is people with autism spectrum disorder (ASD) who might have problems with emotion regulation. The introduction mentions that current emotion regulation technologies do not embody emotion regulation or represent emotions. For example, a sense of embodiment means that the user can feel the emotions through the data, such as a blind man can feel the pavement through his stick. The idea for this research is to incorporate a sound modality as an embodiment of emotion regulation for users like people with ASD that might have problems with emotion regulation. Sounds have positive effects on emotion, with pleasant and natural sounds a listener can calm down. Music therapy helps with changes in tonal arrangements, tempos, and style to address and positively change emotions. The current sound technologies mentioned in the introduction for emotion regulation focus on awareness of sounds. This awareness makes sure that the user makes sounds from emotional data, has emotion regulation therapy, and relaxes by sounds. Thus, this study investigates how to create a sound application for emotion regulation including emotion representation and the ability to feel emotions (with emotional arousal) in co-creation with the target user through user interviews, co-design sessions, and user testing. The questions for this study are:

1. How can sound effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD?

    a. How do people with ASD experience emotion regulation, and what is missing in the emotion regulation for people with ASD?
    b. What are the requirements from people with ASD about the emotion regulation sound application?
    c. In which ways can sound give feedback about emotional arousal?
    d. How do users perceive an emotion regulation application that provides sound/music based on their emotional arousal levels?

9.1 Method/Approach and Answers to Sub-questions

The method for finding answers to the research question is the co-creation and user-centered design (UCD) approach. It means that the user is involved in the design and development process with a combination of products from the UCD approach that are made by the researcher from the user input. The user is involved in three stages in this research (user interviews, co-design with test sessions, and user testing) and gives input by giving their opinion in the interviews, testing, and designing. User input translates into requirements, personas, concepts, and prototypes. The

researcher iteratively designed and developed the prototypes and tested them by the user in the different stages.

How do people with ASD experience emotion regulation, and what is missing in the emotion regulation for people with ASD?
People with ASD lack understanding of all their emotions and might be unaware of them before they escalate into a meltdown (shouting) or shutdown (isolation from the environment) because of a stimuli overload. People with ASD use structuring techniques and they channel emotions towards music to prevent or redirect emotions. It is possible to improve the emotion regulation techniques from people with ASD by focusing on awareness and understanding of emotions. An emotion regulation application by sound could help people with ASD to help figure out their emotional arousal changes before they might escalate. There seems to be already some great interest from people with ASD about a sound application for emotion regulation to help.

In which ways can sound give feedback about emotional arousal?
The feedback ideas are 1) to present emotional arousal through sound, 2) sounds affect emotional arousal, 3) give the user the ability to choose the sounds, and 4) the user gets the ability to link sounds to the emotional arousal themselves.

What are the requirements from people with ASD about the emotion regulation sound application?
The researcher analyzes the requirements from the three user involvements and the following requirements are similar about the emotion regulation sound application to contain personalization, emotion regulation support, take the environment into account, and modernized design, see Table 53.

Table 53 - Requirement's emotion regulation sound application

Similar Requirements from Chapter 3	Similar Requirements from Chapter 6	Similar Requirements from Chapter 8
Requirement 3.1 - Emotion handling	Requirement 6.5 – Track emotional and physical feelings	Requirement 8.3 – Pay attention to sounds that are energetic or more relaxing to fit the passive and active emotional arousal levels
Requirement 3.4 – Personalization & Requirement 3.6 – In control of own life	Requirement 6.8 – Select the sound reaction & Requirement 6.10 – Personal data	Requirement 8.1 – Personalized sounds/music
Requirement 3.9 – Avoid words of emotions	Requirement 6.12 – Understandable words	Requirement 8.6 – Readable text of sounds/music
Requirement 3.10 – Ability to adjust	Requirement 6.17 – Sound reaction based on context	Requirement 8.12 – Consider the environment of the user & Requirement 8.13 – Ability to change vibrations to preference
Requirement 3.11 – Simple design	Requirement 6.2 – Minimalistic design	Requirement 8.16 – Up-to-date design

How do users perceive an emotion regulation that provides sound/music based on their emotional arousal levels?

The following text answers the above sub-question with results from the user testing with non-autistic participants.

- The sounds/music cannot solely provide feedback to the user because it might be inconvenient at certain moments to receive audio feedback. The feedback is therefore a combination of visual content (like colors), vibrations, and sounds/music.
- Sounds/music has a positive effect on the users to calm down and for two users even to get energized. The participants mostly liked to listen to sea and bird sounds. The participants also find the Android prototype easy to use, personalized, and the user can stay in control of how the Android prototype reacts.

- It is still uncertain whether there is a preference for the sounds to be present as mimic (sounds/music have the same intensity as emotional arousal), nudge (sounds/music are a little lower or higher in intensity as emotional arousal), or alert (sounds/music only present at certain emotional arousal levels). The participants did not test the different sound reactions. However, there might be a partial answer as participants commented on the sounds/music to be a bit off when the emotional arousal was changing. There is a preference for listening to the full song, which might show that the whole idea of using sounds/music as a representation of the emotional arousal might need some revisiting. Some tips from the participants are 1) a small notification like a beep in the sounds/music, 2) a different intensity of the same song, 3) no notification at all from the sounds/music. Thus, it is still uncertain whether the mimic, nudge, or alert can work, and therefore there is still a lot to uncover for a next study.

9.2 Contributions

Thus, the literature shows us:

1. people with ASD have trouble with emotion regulation by experiencing meltdowns (screaming to others) or shutdowns (isolating from surroundings [1],
2. current emotion regulation technologies [2], [5], [6], [7], [8], [9], [10], [11] do not embody emotion regulation or represent emotions,
3. sound shows promising results in combination with emotions [13], [14], [15], [16],
4. current sound technologies with emotions [17], [18], [19], [20], [21] do not include the representation or embodiment of emotion regulation,
5. emotional arousal is a useful approximation to determine if someone is over-aroused or under-aroused [2], and
6. the target users (people with ASD) are not always involved in studies about autism spectrum disorder that might cause a misunderstanding of people with ASD [23], [24].

For this research, I investigated how sound can effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD.

The user interviews confirm the insights from the literature [1] that people with ASD have difficulties with their emotional handling in their daily lives. Struggles arise from an overload of stimuli in the daily lives of people with ASD about emotion recognition requiring a bit of time, or the emotion recognition does not happen at all because of first processing prior stimuli. The emotions can eventually turn into an

escalation in which the person with ASD might have a meltdown (shouting) or shutdown (isolation). The user interviews showed that the target user (people with ASD) has a great interest in an application that helps people with ASD better handle their emotional arousal changes through sounds. New insights from the user interviews are that there are uses of sound that represent emotions for people with ASD, such as when being angry to listen to hard rock sounds to divert the angriness towards the music instead of the environment. The researcher implemented the findings from the user interviews in a design that helps the target user to have insights into their emotional arousal by simulating their emotional arousal through sounds. For example, angry music when being angry. In this way, the sounds are a mimic of emotional arousal. Another design aspect is to incorporate a way for the target user to calm down or energize by using a nudge of sounds. The nudge means that music/sounds nudge the target user unconsciously towards a calmer emotional arousal level via sounds that might be more active or passive than the actual emotional arousal level. For example, nudge can be a little happier music when being angry. Music Therapy with the iso-principle inspires both the mimic and nudge, where iso-principle means that the music addresses the listener at their emotional state with sounds in which the sounds gradually alter to a positive emotional state [16]. Emotional arousal means active/passive physiological sensations and mental processes. The user studies and co-creation sessions show that sound feedback can occur in both sound reaction mimic and sound reaction nudge. The target users mention gaining insights into emotions (via emotional arousal) with the mimic option or being at ease with the nudge option. Thus, the decision to mimic or nudge depends on what the user needs from the emotion regulation sound application. The Android prototype is easy to use, personal, and the Android prototype is reacting to what the user wants according to the non-autistic participants. Non-autistic participants' involvement differs from the literature [23], [24] that mentions involving people with ASD in studies about autism spectrum disorder to reduce misunderstandings about the target user. The working prototype shows to work for calming down users and for two users to get energized. User interviews, user studies with co-creation sessions, and user testing show that sounds/music may influence the emotional arousal of the user. The working prototype shows that emotion regulation is possible using vibrations, visualization (colors), and sounds/music. Representation of emotions is through emotional arousal with colors/thermometer of different emotional arousal levels. The participants mentioned that the feedback from the application is perceived as a combination of sounds, vibrations, and colors. Non-autistic participants mention sounds cannot solely provide the feedback, because some people might be visually, or it is not possible to listen to sounds in their (busy) environment. The non-autistic participants use the sounds as relaxation or getting energized. Therefore, the (non-autistic) users perceive the sounds as a tool to handle emotional outbursts but not to feel the

emotional outbursts through the sounds. Therefore, the non-autistic participants do partially perceive the sounds as the embodiment of emotion regulation.

9.3 Limitations and Future Work

One limitation of this study is that a few participants with ASD are in this research. Ten people with ASD are involved in the user studies of user interviews and co-design/test sessions. At the user testing, nine non-autistic participants took part in the research. Thus, it might be difficult to make generalized claims about the needs of people with autism spectrum disorder as the number of people that took part was not substantial. People with autism spectrum disorder are diverse in behavior and their needs. Thus, for a more generalized conclusion, it is better to involve more people with ASD and let them do the user testing with the actual prototype. There is also another limitation about the participant characteristics. The participants had an average to above-average level of education, such that the emotion regulation sound application might not be too complex for this group. However, there is also a disadvantage for the requirement of education level. There is a disadvantage that the emotion regulation sound application might not be suitable for people with a lower education because there are no insights into their opinions. Thus, it might be better for a more generalized conclusion to include people with ASD with a lower education for the upcoming studies. Another limitation in this study is that the gathered data depends on asked questions, which might influence the interpretation of the data. Especially during the user studies/co-design sessions, the target user also thinks that text (advice) or images can present the application feedback and not necessarily that the application feedback is present as sound. There might be skewness in the data because particular questions can facilitate the target user to think broadly about an emotion regulation sound application and not go into detail. The researcher might alter the data in the right direction with the help of other questions in future studies. Yet, the results and prototype might be more pleasing for the user if there is no restriction to the application as audio feedback. The desire to include textual or visual feedback might have been the real user needs, which is (maybe unfairly) discarded because the focus of the research is to investigate whether sound can be another representation of data. This should be addressed in future research. Another limitation is that this study took place during the COVID-19 pandemic, where video calling was the norm, such that the researcher only observed the participants with ASD through a screen. That might cause missed observations of behavior. Thus, improvements in further research are observations of the target user in their natural environment when using the emotion regulation sound application. Another limitation is that the target user did not test the working prototype. The exclusion of the target user happened of changes with the supervision. A benefit is that the researcher can discover any bugs or extra triggers from the emotion regulation sound application and improve the emotion regulation sound application before the target user does some testing. The improvements ensure that the target

user does not receive more unwanted stimuli from the emotion regulation sound application. The current user testing with non-autistic shows some improvements in the music/sounds on making the music/sounds smoother in their transition to changes in the emotional arousal. After the improvements in the emotion regulation sound application, it is interesting to investigate whether the emotion regulation sound application would work for people with ASD. The user testing shows that the Android prototype calms down and energizes people. However, there is still the following question left for future research. *"How can the sound feedback from an emotion regulation application work best to calm down people with ASD when they are at their active emotional arousal levels and energize when they are at their passive emotional arousal levels?"*. Another limitation might be that the focus of this study is on creating a working prototype with Android. This focus makes sure that the application contains elements that are typical for an application to work, such as buttons, visuals, and feedback (user interface). The user interface might conflict with the goal of embodiment. It shows that the participants notice the user interface, and this might shift their focus away from the sounds. The users might not consciously perceive the sounds as being an embodiment of emotion regulation. Thus, it is also interesting for future work to investigate whether an application that only contains sounds can be an embodiment of emotion regulation. It shows that the current application of sound might also be a limitation. The current sounds react to the changes in emotional arousal, so there is a different tune at a change in emotional arousal. However, it might be interesting for future work to investigate if it is possible to create sounds from the emotional arousal changes such that for each emotion change the sounds change instead of a change in tune. This might contribute to the embodiment of emotion regulation because the sounds directly represent what the user might be feeling. Thus, it shows that the following question is also for future research: *"How do we create an emotion regulation sound application that embodies emotions through creating sounds from emotions for people with ASD?"*

Despite all these limitations, this research is relatively a success because it was possible to gain insights into how sounds might best react to emotional arousal changes for people with ASD in their daily lives. This sound modality shows that it is possible to present (emotional) data unconventionally with sound. The standard presentation of data is in measurements like text, numbers, or graphics. This study shows it is possible to incorporate a modality of sound for presenting data. The study goes further than data presentation and shows that people with ASD can gain more insights into their emotional arousal changes using sounds/music, colors, and vibrations. This design project can teach us how sound can form a new way of presenting data to the user. Sound can form feedback in combination with vibrations and visuals (color and thermometer) about emotional arousal. Non-autistic participants perceive the sound as relaxation or getting energized. Thus, the study shows in this case, the non-autistic participants do not fully see the sounds as the

embodiment of the emotion regulation but as a tool to handle emotional outbursts. The study shows that the embodiment by sounds might still happen for relaxation/energizing, but not necessarily for feeling emotional arousal. Thus, the embodiment of emotion regulation by sounds happens partially in this study. Emotion regulation is the process of both feeling the emotions and being able to act on the feeling or change how to act. For example, when being angry that someone would just walk away from the situation. The second part of emotion regulation is that a person can act on emotions with certain techniques, and this is possible in this study. Thus, this design-research study contributes knowledge about the embodiment of emotion regulation with sounds that emotion regulation can partially embody sounds for non-autistic people.

Chapter 10 Conclusion

The question that I am answering with this research is:

1. *"How can sound effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD?"*

Different iterations with user studies provide insights to answer the question at hand. There are three moments where this study involves users. At first, users take part in this research during user interviews. Second, users take part during co-design and test sessions. At last, users take part in the study during user testing with a working prototype. The users are people with ASD and non-autistic people. The following describes the results of the user involvement.

The user interviews provide insights into the daily lives of people with ASD. Eight people with ASD take part in the user interview. The interviews show that people with ASD have daily difficulties with emotion regulation. The participants mention that emotion regulation can work for someone with ASD as a queue where the person handles one emotion at a time. However, this emotional handling evokes two difficulties. First, the number of emotions can increase where the person eventually becomes overwhelmed. Second, the person does sometimes not understand or recognize their feelings/emotions when it is too much. If emotions overwhelm the person, it might agitate them to a certain point where their emotions escalate. The person expresses the escalation into a meltdown (screaming) or isolating oneself from the (stressful) environment. It shows that people with ASD need help with emotion regulation. People with ASD can receive support from an emotion regulation sound application that gives them better insights into their emotional arousal changes. The participants during the user interviews mention being enthusiastic about the use of emotion regulation by sounds. Four out of eight participants also have some experience of using sounds to regulate emotions. For example, listening to hard rock when being angry seemed to be helpful to divert the angriness towards the music instead of the surroundings.

The co-design and test sessions show that people with ASD have ideas about emotion regulation by sounds. Five participants took part in the co-design and test sessions. The participants want the emotion regulation sound application to be 1) non-invasive where the user is still in control of how the emotion regulation sound application reacts, and 2) personal, including personal music. There is also a desire from the participants that the emotion regulation sound application contains a

minimalistic design such that it does not trigger extra emotions. The participants also mention that the emotional arousal presentation is best with a barometer that shows the passive emotions as cold and the active emotions as warm. Emotional arousal means active/passive physiological sensations and mental processes. The participants also think that the emotion regulation sound application can provide additional modalities apart from the sound. Other modalities might be something to investigate in further studies. This study investigates how the user perceives sounds as an embodiment of data. Co-design and test sessions show that sounds/music can present as 1) a representation of the emotional arousal (mimic), or 2) a little lower or higher than the intensity of emotional arousal (nudge). The mimic means that the sounds/music simulates the intensity of the emotional arousal, thus happy music when being happy. With the nudge option, the emotion regulation sound application pushes the user figuratively towards the calmest emotional arousal level (0) by having the sounds/music a little higher or lower than the actual emotional arousal level of the user.

The user testing with nine non-autistic people shows that the participants perceive the Android prototype as 1) easy to use, 2) personal, 3) the user is still in control of how the Android prototype reacts. The participants mentioned the following improvements to the Android prototype about a smoother transition in the music/sounds at changes in the emotional arousal.

- It shows that a longer duration can improve the music/sounds. Four participants had unpleasant experiences with the music/sounds: 1) certain sounds and music had a small duration, and 2) sounds looped constantly.
- Another improvement is to include instrumental music instead of music with text such that it does not distract the user during something like relaxation.
- Notification in the song can improve the music/sounds to be aware of the change in the emotional arousal of the user. This notification might be a simple beep.
- Another improvement is to have different intensities of the same song that represent the different intensities of emotional arousal.
- Participants also mention playing the complete song and maybe not a noticeable change in the sounds/music to not distract the user from calming down or energizing.
- Participants also recommend a playlist with songs/sounds for each emotional arousal level to let the user listen to more songs/sounds when being at a particular emotional arousal level without constantly hearing the same song/sound.
- Recommendations of which sounds/music could fit with certain emotional arousal levels can also improve the Android prototype. It can help users who struggle to place a sound or song on all the emotional arousal levels.

The user testing with the working prototype shows that the music/sounds from the Android prototype work for people to calm down. However, one interesting finding is that two out of nine participants got energized by the music/sounds. It is interesting for a future study to investigate how to make people calm down at the active emotional arousal levels and get energized at the passive emotional arousal levels. The participants mention they perceived feedback from the Android prototype as a combination of vibrations, colors (for emotional arousal levels), and music/sounds.

To conclude, an answer to the question of how can sound effectively give feedback about emotional arousal in a co-created emotion regulation application to people with ASD in which sounds embody emotion regulation such that the sounds represent emotion arousal, and the sounds can become part of the lives of people with ASD is as follows. First, there is a great interest in the emotion regulation sound application and the sounds/music to be personalized. Personalization helps the emotion regulation sound application be familiar to the user as the user already listens to those songs/sounds. The PCEA technique, where the emotion regulation sound application reacts to the heart rate measurements of the user, also achieved personalization. The emotion regulation sound application can become part of the daily life of people with ASD by personalization and familiarity. It shows that the emotion regulation sound application is specific to the needs of the user. Five out of nine participants from the user testing also mention that the emotion regulation sound application might only be suitable for people who like music/sounds in their daily life. The user testing also showed that the emotion regulation sound application might not fit people without ASD, as the emotional arousal levels are mainly on the active side for all the non-autistic participants. It shows that it is crucial to further investigate with people with ASD to understand how they perceive the emotion regulation sound application. A smoother transition to changes of emotional arousal can improve the music/sounds as being feedback of emotional arousal. Feedback is in-the-moment where a change of emotional arousal immediately presents with colors (as a thermometer), vibrations, and sounds, but the feedback by sounds is present if the user clicks on the play button so the sounds are not invasive. The Android prototype shows in the user testing that people could calm down or energize them when the sounds/music simulates the emotional arousal (mimic). The participants from the user testing (non-autistic people) also mention that the feedback of the Android prototype comes from a combination of vibrations, colors, and music/sounds. Thus, this research shows that sound can effectively present emotions (with emotional arousal) if the sound is a simulation of emotional arousal. Another conclusion is that with transition improvements of the sounds and the music, the application can serve as an emotion regulation for people with ASD. Then it shows that the emotion regulation sound application can provide insights into

emotional arousal changes. However, the target user should still test the emotion regulation sound application in future studies to gain insights into whether the application would work for them. Thus, the study shows that the application can be effective as emotion regulation in a manner where the feedback comes from a combination of sounds/music, vibrations, and visuals (colors) and not necessarily that the sounds solely represent or embody emotions (through emotional arousal). The non-autistic participants do not fully perceive the embodiment of emotion regulation through sounds because they see the sounds as a tool for relaxation/energizing rather than a tool to feel their emotional arousal. The embodiment through sounds might still happen for relaxation/energizing, but not necessarily for feeling emotional arousal.

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Appendix

A. Information Brochure and Consent Form

The following shows the information brochure and consent form for the three different user involvement sessions.

A1 User Involvement 1 (User Interviews)

English version

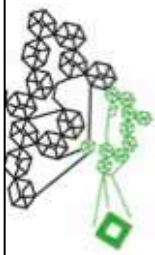
UNIVERSITY OF TWENTE. 1

DESCRIPTION:
You are invited to participate in a research study on how people with autism spectrum disorder (ASD) could handle their moods with the use of sound from wearables. The purpose of the research is to gain insights into the daily routines of people with autism and discussing wearables with sound that could be placed in the daily lives of people with autism.

Today, you take part in an interview. During the interview, you will be asked to explain your daily life in relation to emotions, stress and sound. You are also asked about the use of wearables in your daily life that might help to regulate your mood swings.

TIME INVOLVEMENT:
Your participation will take approximately 45 mins for the interview.

RISKS & BENEFITS:
The interview might be personal, thus there is a risk of discomfort. When you are feeling in discomfort, you are encouraged to express this and the researcher will try to make it more comfortable for you. You are free to not give answers to certain questions and do not take part of certain parts of this interview. An additional risk of taking part is that this interview might be too overwhelming for you and you need to take time afterwards to process all the things that happened. The researcher tries to make it as less overwhelming for you as possible.



There are no money or goods that can be giving by participating this research. Any benefits that might result from participating is a personal benefit of being part of a research that might improve the daily lives of people with autism in the future.

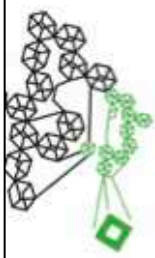
REQUIREMENTS TO PARTICIPATE:

- You must be diagnosed with autism according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). This means that you may experience difficulties in social communication and

repetitive behavior, including hyper- or hyposensitivity to sensory input.
- You have a normal or above normal intelligence.

PARTICIPANT'S RIGHTS:
If you have read this form and have decided to participate in this project, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without giving any reasons. You have the right to refuse to answer particular questions. You have the right to refuse afterwards to allow your data to be used for the research. The results of this research study may be presented at scientific or professional meetings or published in scientific journals. Your identity will not be made known in written materials resulting from the study. Any information that can be traced back to you, such as name or pictures are made anonymous.

CONSENT FORM:
I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned information brochure 'Mood regulations by wearables with sound for people with autism spectrum disorder'. My questions have been answered to my satisfaction. I agree of my own free will to participate in this research. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the research study at the end of the research and up to 24 hours thereafter. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my express permission. If I request further information about the research, now or in the future, I may contact the persons below.



If you have any complaints about this research, please direct them to the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, Hallenweg 19, Enschede (NL), telephone: +31534892085; email: ethics-comm-ewi@utwente.nl

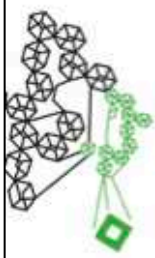
If you have any questions, concerns or complaints about this research, its procedures, risks and benefits, contact the researcher, M.M. Honcoop at m.m.honcoop-1@student.utwente.nl or supervisor J. van Dijk at jelle.vandijk@utwente.nl.

SIGNATURE PARTICIPANT: **DATE:**

_____ _____

I consent to be video-taped and for the video to be used for data analysis purposes.
Yes__ No___

I consent to be recorded on audio and for the audio to be used for data analysis purposes.
Yes__ No___



RESEARCHER SECTION:
I (the researcher) have provided explanatory notes about the research. I (the researcher) declare myself willing to answer to the best of my ability any questions which may still arise about the research.

SIGNATURE RESEARCHER: **NAME RESEARCHER:**

_____ _____

Dutch version

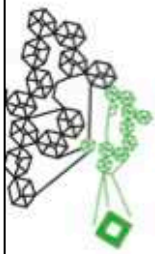
UNIVERSITY OF TWENTE.

BESCHRIJVING:
U bent uitgenodigd om deel te nemen in een onderzoek naar het gebruik van geluid via "wearable" apparatuur voor mensen met autisme spectrum syndroom (ass) met het doel om om te gaan met eventuele stemmingswisselingen en stress. Dit onderzoek is erop gericht om inzichten te verkrijgen in de dagelijkse bezigheden van mensen met autisme en het bediscussiëren van geluid dat in het dagelijkse leven geplaatst kan worden bij mensen met autisme.

Vandaag zult u deelnemen aan een interview. Tijdens dit interview, zal u gevraagd worden om uw dagelijkse leven te beschrijven in verband met emoties, stress en geluid. U zult ook bevraagd worden over het gebruik van "wearable" apparaten in uw dagelijkse leven die eventueel kunnen helpen om om te gaan met stemmingswisselingen.

TIJDSDUUR:
Uw deelname zal ongeveer 45 minuten duren voor het interview.

RISICO'S & VOORDELEN:
Het interview kan mogelijk persoonlijk worden, dus er is een risico van ongemakkelijkheid. Wanneer u niet op uw gemak voelt, wordt u aangemoedigd om dit aan te geven en de onderzoeker zal proberen om het interview zo comfortabel mogelijk te maken. U bent vrij om helemaal niet te antwoorden op bepaalde vragen en u bent vrij om niet deel te nemen aan bepaalde onderdelen van dit interview. Een extra risico bij deelname kan zijn dat het interview te overweldigend wordt en dat u nog tijd achteraf nodig heeft om het allemaal te verwerken. De onderzoeker zal proberen om het interview zo min mogelijk overweldigend te laten zijn.



Er kan geen geld of goederen worden gegeven bij deelname aan dit onderzoek. Het enige voordeel dat resulteert vanuit de

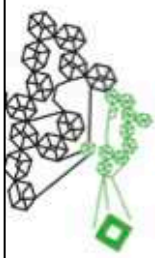
deelname is dat u onderdeel bent van een onderzoek dat in de toekomst het dagelijkse leven van mensen met autisme kan wellicht kan bevorderen.

VEREISTEN OM DEEL TE NEMEN:

- U moet gediagnosticeerd met autisme zijn volgens het "Diagnostic and Statical Manual of Mental Disorders" (DSM-5). Dit betekent dat je problemen kan ervaren in sociale communicatie en repetitief gedrag, met daarbij hyper- of hypo sensitiviteit naar sensorische prikkels.
- U heeft een normale tot boven-normale intelligentie.

RECHTEN DEELNEMER:

Als u dit formulier heeft gelezen en besloten hebt om deel te nemen aan dit project, dan is het belangrijk om te begrijpen dat uw deelname vrijwillig is en dat u het recht heeft om het toestemmingsformulier in te trekken of zelfs te stoppen met deelname op elk moment zonder enige reden. U heeft het recht om niet te antwoorden op bepaalde vragen. U heeft ook het recht om na deelname te weigeren dat uw data voor het onderzoek wordt gebruikt. De resultaten van dit onderzoek kunnen op wetenschappelijke of professionele bijeenkomsten gepresenteerd of in wetenschappelijke artikelen worden gepubliceerd. Uw identiteit zal niet worden weergegeven in geschreven documenten dat resulteert uit deze studie. Elk andere informatie dat kan worden gebruikt om u te identificeren, zoals naam of afbeeldingen, zullen anoniem worden verwerkt.



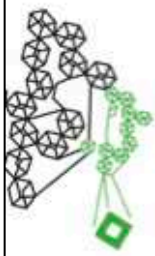
TOESTEMMINGSFORMULIER:

Ik verklaar dat ik ben geïnformeerd op een duidelijke manier over de aard en methode van dit onderzoek zoals beschreven in de voorgaande tekst. Mijn vragen zijn beantwoord naar mijn tevredenheid. Ik ben ermee eens dat ik vrijwillig deelneem in dit

onderzoek. Ik behoud mij het recht om mijn toestemming in te trekken zonder enige reden en ik ben ervan bewust dat ik mijn gegevens kan laten verwijderen tot 24 uur na het onderzoek. Als mijn resultaten worden gebruikt in wetenschappelijke publicaties of op een andere manier worden gepubliceerd, dan zullen mijn resultaten volledig anoniem worden gemaakt. Mijn persoonlijke data zal niet worden gedeeld met derden zonder mijn expliciete toestemming. Als ik verdere vragen heb over het onderzoek, nu of in de toekomst, dan kan ik de volgende personen benaderen.

Als u klachten heeft over dit onderzoek, dan kunt u die sturen naar de Ethische Commissie van de Faculteit Elektrotechniek, Wiskunde en Informatica aan de Universiteit Twente, Hallenweg 19, Enschede (NL), telefoonnummer: +31534892085; email: ethics-comm-ewi@utwente.nl.

Als je nog andere vragen, opmerkingen heeft over het onderzoek, de procedure of risico's en voordelen, dan kunt u contact opnemen met de onderzoeker, M.M. Honcoop op m.m.honcoop-1@student.utwente.nl of afstudeerbegeleider J. van Dijk op jelle.vandijk@utwente.nl



HANDTEKENING DEELNEMER: **DATUM:**

_____ _____

Ik geef toestemming voor een video opname en dat de video wordt gebruikt voor analyse doeleinde

Ja__ Nee___

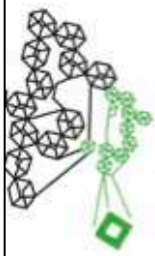
Ik geef toestemming om opgenomen te worden via de audio en dat de audio wordt gebruikt voor analyse doeleinde

Ja__ Nee___

ONDERZOEKSSECTIE:
Ik (de onderzoeker) heb toelichtingen gegeven over het onderzoek. Ik (de onderzoeker) verklaar dat ik antwoord naar mijn beste vermogen op vragen die wellicht ontstaan over dit onderzoek.

HANDTEKENING ONDERZOEKER: **NAAM ONDERZOEKER:**

_____ _____



A2 User Involvement 2 (Co-design and test sessions)

English version

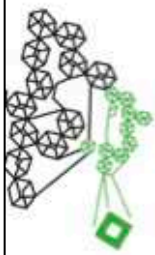
UNIVERSITY OF TWENTE. 1

DESCRIPTION:
You are invited to participate in a research study on how people with autism spectrum disorder (ASD) could handle their moods with the use of sound from wearables. The purpose of the research is to gain insights into the daily routines of people with autism and discussing wearables with sound that could be placed in the daily lives of people with autism.

Today, you take part in a co-design and user study with that means that you are co-creating and performing a user test. You will be asked to create a sketch for a product and provide your opinion on product. The product will be presented on digital medium in which you will listen to sounds and screen designs for the smartwatch and mobile. Afterwards, the researcher will ask certain questions.

TIME INVOLVEMENT:
Your participation will take approximately 60 minutes for the co-design and user test.

RISKS & BENEFITS:
A risk of taking part in the design and test session is that it might be too overwhelming for you and you need to take time afterwards to process all the things that happened. We try to make it as less overwhelming for you as possible.



If you are feeling in discomfort during the design and test session you are encouraged to express this and the researcher will try to make it more comfortable for you. You are free to not give answers to certain questions and you are free to decline participation in certain activities of the design and test session.

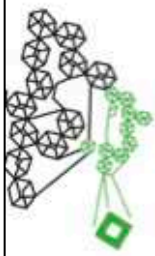
There are no money or goods that can be giving by participating this research. Any benefits that might result from participating is a personal benefit of being part of a research that might improve the daily lives of people with autism in the future.

REQUIREMENTS TO PARTICIPATE:

- You must be diagnosed with autism according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). This means that you may experience difficulties in social communication and repetitive behavior, including hyper- or hyposensitivity to sensory input.
- You have a normal or above normal intelligence.

PARTICIPANT'S RIGHTS:

If you have read this form and have decided to participate in this project, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without giving any reasons. You have the right to refuse to answer particular questions. You have the right to refuse afterwards to allow your data to be used for the research. The results of this research study may be presented at scientific or professional meetings or published in scientific journals. Your identity will not be made known in written materials resulting from the study. Any information that can be traced back to you, such as name or pictures are made anonymous.



CONSENT FORM:

I hereby declare that I have been informed in a manner which is clear to me about the nature and method of the research as described in the aforementioned text. My questions have been answered to my satisfaction. I participate in this research with my own free will. I reserve the right to withdraw this consent without the need to give any reason and I am aware that I may withdraw from the research study at the end of the research and up to 24 hours thereafter. If my research results are to be used in scientific publications or made public in any other manner, then they will be made completely anonymous. My personal data will not be disclosed to third parties without my expressive permission. If I request further information about the

research, now or in the future, I may contact the persons below.

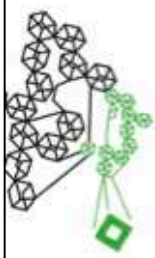
If you have any complaints about this research, please direct them to the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, Hallenweg 19, Enschede (NL), telephone: +31534892085; email: ethicscommittee-cis@utwente.nl

If you have any questions, concerns or complaints about this research, its procedures, risks and benefits, contact the researcher, M.M. Honcoop at m.m.honcoop-1@student.utwente.nl or supervisor J. van Dijk at jelle.vandijk@utwente.nl.

SIGNATURE PARTICIPANT: **DATE:**

_____ _____

I consent to be recorded on audio and video and for the audio/video material to be used for data analysis purposes.
Yes__ No___



RESEARCHER SECTION:
I (the researcher) have provided explanatory notes about the research. I (the researcher) declare myself willing to answer to the best of my ability any questions which may still arise about the research.

SIGNATURE RESEARCHER: **NAME RESEARCHER:**

_____ _____

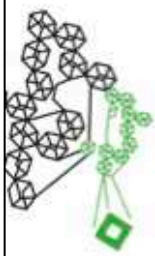
Dutch version

UNIVERSITY OF TWENTE.

BESCHRIJVING: U bent uitgenodigd om deel te nemen in een onderzoek naar het gebruik van geluid via "wearable" apparatuur voor mensen met autisme spectrum syndroom (ass) met het doel om om te gaan met eventuele stemmingswisselingen en stress. Dit onderzoek is erop gericht om inzichten te verkrijgen in de dagelijkse bezigheden van mensen met autisme en het bediscussiëren van geluid dat in het dagelijkse leven geplaatst kan worden bij mensen met autisme.

U zult deelnemen aan een co-design gebruikersonderzoek dat betekent dat u mee gaat denken en ontwerpen (co-creating) en een gebruikerstest zult uitvoeren. U zult gevraagd worden om een schets te maken voor een product en uw mening geven over een product. Het product zal digitaal worden gepresenteerd waarbij u zult luisteren naar geluiden en schermontwerpen voor een smartwatch en mobiel te zien krijgt. De onderzoeker zal na het beluisteren en bekijken een aantal vragen stellen.

TIJDSDUUR:
Uw deelname zal ongeveer 60 minuten duren voor de co-design en gebruikerstest.



RISICO'S & VOORDELEN:
Een risico van deelname aan de ontwerp- en testsessie is dat het wellicht te overweldigend kan worden en u wat tijd achteraf nodig heeft om het allemaal te verwerken. We zullen proberen om het zo min mogelijk overweldigend te maken voor u.

Als u zich ongemakkelijk voelt tijdens de ontwerp- en testsessie, wordt vriendelijk verzocht om dit te uitten zodat het onderzoek kan proberen om het wat meer comfortabel voor u te maken. U bent vrij om bepaalde vragen niet te beantwoorden en u bent vrij om bepaalde activiteiten niet uit te voeren tijdens de gebruikerstest.

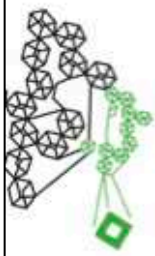
Er kan geen geld of goederen worden gegeven bij deelname aan dit onderzoek. Het enige voordeel dat resulteert vanuit de deelname is dat u onderdeel bent van een onderzoek dat in de toekomst het dagelijkse leven van mensen met autisme kan wellicht kan bevorderen.

VEREISTEN OM DEEL TE NEMEN:

- U moet gediagnosticeerd met autisme zijn volgens het "Diagnostic and Statical Manual of Mental Disorders" (DSM-5). Dit betekent dat je problemen kan ervaren in sociale communicatie en repetitief gedrag, met daarbij hyper- of hypo sensitiviteit naar sensorische prikkels.
- U heeft een normale tot boven-normale intelligentie.

RECHTEN DEELNEMER:

Als u dit formulier heeft gelezen en besloten hebt om deel te nemen aan dit project, dan is het belangrijk om te begrijpen dat uw deelname vrijwillig is en dat u het recht heeft om het toestemmingsformulier in te trekken of zelfs te stoppen met deelname op elk moment zonder enige reden. U heeft het recht om niet te antwoorden op bepaalde vragen. U heeft ook het recht om na deelname te weigeren dat uw data voor het onderzoek wordt gebruikt. De resultaten van dit onderzoek kunnen op wetenschappelijke of professionele bijeenkomsten gepresenteerd of in wetenschappelijke artikelen worden gepubliceerd. Uw identiteit zal niet worden weergegeven in geschreven documenten dat resulteert uit deze studie. Elk andere informatie dat kan worden gebruikt om u te identificeren, zoals naam of afbeeldingen, zullen anoniem worden verwerkt.



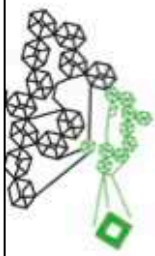
TOESTEMMINGSFORMULIER:

Ik verklaar dat ik ben geïnformeerd op een duidelijke manier over de aard en methode van dit onderzoek zoals beschreven in de voorgaande tekst. Mijn vragen zijn beantwoord naar mijn tevredenheid. Ik ben ermee eens dat ik vrijwillig deelneem in dit onderzoek. Ik behoud mij het recht om mijn toestemming in te

trekken zonder enige reden en ik ben ervan bewust dat ik mijn gegevens kan laten verwijderen tot 24 uur na het onderzoek. Als mijn resultaten worden gebruikt in wetenschappelijke publicaties of op een andere manier worden gepubliceerd, dan zullen mijn resultaten volledig anoniem worden gemaakt. Mijn persoonlijke data zal niet worden gedeeld met derden zonder mijn expliciete toestemming. Als ik verdere vragen heb over het onderzoek, nu of in de toekomst, dan kan ik de volgende personen benaderen.

Als u klachten heeft over dit onderzoek, dan kunt u die sturen naar de Ethische Commissie van de Faculteit Elektrotechniek, Wiskunde en Informatica aan de Universiteit Twente, Hallenweg 19, Enschede (NL), telefoonnummer: +31534892085; email: ethics-comm-ewi@utwente.nl.

Als je nog andere vragen, opmerkingen heeft over het onderzoek, de procedure of risico's en voordelen, dan kunt u contact opnemen met de onderzoeker, M.M. Honcoop op m.m.honcoop-1@student.utwente.nl of afstudeerbegeleider J. van Dijk op jelle.vandijk@utwente.nl



HANDTEKENING DEELNEMER: **DATUM:**

_____ _____

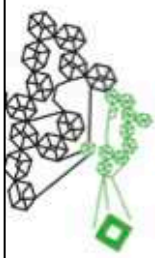
Ik geef toestemming voor een audio en video opname en dat de audio/video materiaal wordt gebruikt voor analyse doeleinde

Ja__ Nee___

ONDERZOEKSSECTIE:
Ik (de onderzoeker) heb toelichtingen gegeven over het onderzoek. Ik (de onderzoeker) verklaar dat ik antwoord naar mijn beste vermogen op vragen die wellicht ontstaan over dit onderzoek.

HANDTEKENING ONDERZOEKER: **NAAM ONDERZOEKER:**

_____ _____



A3 User Involvement 3 (User Testing Android Prototype)

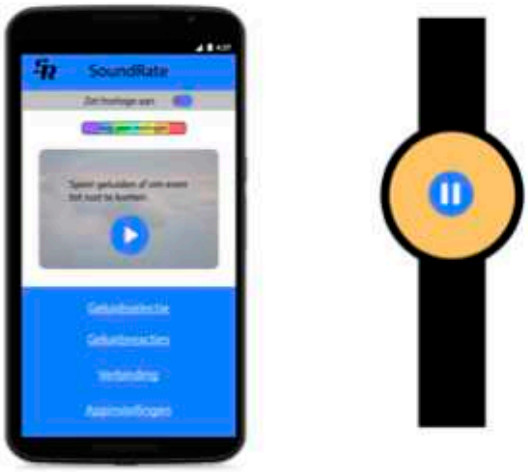
UNIVERSITEIT TWENTE DEPARTEMENT VAN INTERACTION TECHNOLOGY Onderzoek Toestemmingsformulier
Onderzoeker: M.M. Honcoop
Titel: Emotion regulation through sounds for people with autism spectrum disorder

Infoblad

BESCHRIJVING: U bent uitgenodigd om deel te nemen in een onderzoek naar het gebruik van geluid via "wearable" apparatuur voor mensen met autisme spectrum syndroom (ass) met het doel om met eventuele stemmingswisselingen om te gaan.

U neemt deel aan een gebruikerstest dat betekent dat u een product gaat testen (zie *Figuur 1*). U wordt gevraagd om een aantal taken uit te voeren met het product. Naderhand wordt u gevraagd wat uw ervaring is met het product.

Het doel van de gebruikerstest is om te onderzoeken wat 1) de effecten zijn van geluid op emotieregulatie (het adequaat omgaan met emoties en kunnen uitten van emoties), en 2) de gebruikerservaringen met een emotieregulatie geluidsapplicatie. De resultaten van de gebruikerstest kunnen wellicht meer inzicht bieden of een emotieregulatie geluidsapplicatie werkt voor mensen met ASS.



Figuur 1 - Prototype

1

UNIVERSITEIT TWENTE DEPARTEMENT VAN INTERACTION TECHNOLOGY
Onderzoek Toestemmingsformulier

Onderzoeker: M.M. Honcoop

Titel: Emotion regulation through sounds for people with autism spectrum disorder

TIJDSDUUR:
De testdagen duurt ongeveer 1 tot 2 dagen waarbij u zelf het product gaat testen in uw dagelijkse leven. U kan zelf beslissen hoe lang en hoe vaak u het product gaat testen in uw dagelijkse leven. Het is wenselijk dat het product op zijn minst voor 30 minuten wordt gebruikt en op zijn minst tijdens één specifieke activiteit die emoties kan oproepen. De onderzoeker bespreekt voorafgaand aan de testdagen bepaalde activiteiten met u die u tijdens de testdagen kan uitvoeren.

Na de testdagen, wordt er een afspraak ingepland waarbij de onderzoeker uw vragen stelt over uw ervaring met het product. Dit extra moment duurt ongeveer 30 tot 60 minuten.

VERZAMELEN & VERWERKEN VAN GEGEVENS:
U kunt in het interview de ervaring met de emotieregulatie geluidsapplicatie in uw dagelijkse leven beschrijven. De onderzoeker kan wellicht doorvragen om meer inzicht te vergaren. De onderzoeker kan ook andere onderwerpen aankaarten zoals gebruikersvriendelijkheid, gebruikersbeleving, functionaliteit/bruikbaarheid van de geluidsfeedback. De interviewvragen zijn daarom gebaseerd op het vergaren van inzicht in de gebruikersbeleving tijdens het gebruik van een emotieregulatie geluidsapplicatie in uw dagelijkse leven.

RISICO'S & VOORDELEN:
Tijdens het onderzoek vinden continue hartslag metingen plaats om te onderzoeken hoe de emotionele toestand van een persoon verandert door geluiden. De hartslag metingen geven een benadering van de emotionele arousal van een persoon weer, waarbij emotionele arousal voor hoe actief/passief de fysiologische sensaties (lichamelijke reacties) en mentale toestand van een persoon is. Er kan een risico van ongemak plaatsvinden bij de continue hartslag metingen doordat het persoonlijk kan overkomen. De hartslag metingen worden verwijderd binnen een maand nadat het onderzoek eindigt, zodat eventuele zorgen geminimaliseerd worden.

Als u enige ongemak voelt tijdens de gebruikerstest en/of interview, dan wordt u aangespoord om dit te uiten zodat de onderzoeker kan proberen om het wat meer aangenaam voor u te maken. U staat vrij om geen

antwoord te geven op bepaalde vragen of helemaal niet deel te nemen in bepaalde onderdelen van de gebruikerstest en/of interview.

Er kan geen geldbedrag of goederen worden gegeven bij deelname aan dit onderzoek. Het enige voordeel dat resulteert vanuit de deelname is dat u onderdeel bent van een onderzoek dat in de toekomst het dagelijkse leven van mensen met autisme spectrum syndroom wellicht kan bevorderen.

STOPPROTOCOL:
Bij het testen van het product in uw dagelijkse leven kunt u ten alle tijden de test stopzetten bij enige vorm van ongemak. U kunt geheel zelf bepalen of u het stopzetten voor een korte tijd doet of dat u de smartwatch niet meer gaat dragen in de gehele testperiode. Naderhand is het dan nog steeds mogelijk om mee te doen aan een interview. Dit interview kan ook ten alle tijden worden onderbroken, stopgezet, of helemaal niet plaatsvinden als u zich er niet prettig bij voelt. Als u bij enige vorm van stopzetten nog behoefte heeft aan contact met betrokkenen van dit onderzoek, kunt u gerust contact opnemen met één van de onderstaande personen.

VEREISTEN OM DEEL TE NEMEN:
- U moet 18 jaar of ouder zijn.
- U bent gezond, zoals geen medische aandoening.
- U heeft een normale tot bovennormale intelligentie.

UW RECHTEN:
Als u dit formulier heeft gelezen en besloten hebt om deel te nemen aan dit project, dan is het belangrijk om te begrijpen dat uw deelname vrijwillig is en dat u het recht heeft om uw toestemming tot deelname in te trekken of zelfs te stoppen met deelname op elk moment zonder enige reden. U heeft het recht om niet te antwoorden op bepaalde vragen. U heeft ook het recht om na deelname te weigeren dat uw data voor het onderzoek wordt gebruikt. De resultaten van dit onderzoek kunnen op wetenschappelijke of professionele bijeenkomsten gepresenteerd of gepubliceerd worden in wetenschappelijke artikelen. Uw identiteit wordt niet weergegeven in geschreven documenten dat resulteert uit deze studie. Elk andere informatie dat kan worden gebruikt om u te identificeren, zoals audio, wordt anoniem verwerkt.

UNIVERSITEIT TWENTE DEPARTEMENT VAN INTERACTION TECHNOLOGY Onderzoek Toestemmingsformulier
Onderzoeker: M.M. Honcoop
Titel: Emotion regulation through sounds for people with autism spectrum disorder

Toestemming

U verklaart dat u bent geïnformeerd op een duidelijke manier over de aard en methode van dit onderzoek zoals beschreven in de informatie brochure. Uw vragen zijn beantwoord naar uw tevredenheid. U bent ermee eens dat u vrijwillig deelneemt in dit onderzoek. U behoudt het recht om uw toestemming in te trekken zonder enige reden en u bent ervan bewust dat u uw gegevens kan laten verwijderen tot 24 uur na het onderzoek. Als uw resultaten worden gebruikt in wetenschappelijke publicaties of op een andere manier worden gepubliceerd, dan worden uw resultaten volledig anoniem gemaakt. Uw persoonlijke data wordt niet gedeeld met derden zonder uw expliciete toestemming. Als u verdere vragen hebt over het onderzoek, nu of in de toekomst, dan kunt u de volgende personen benaderen.

Als u klachten heeft over dit onderzoek, dan kunt u die sturen naar de Ethische Commissie van de Faculteit Elektrotechniek, Wiskunde en Informatica aan de Universiteit Twente, Hallenweg 19, Enschede (NL), telefoonnummer: +31534892085; email: ethicscommittee-cis@utwente.nl.

Als u nog andere vragen, opmerkingen heeft over het onderzoek, de procedure of risico's en voordelen, dan kunt u contact opnemen met de onderzoeker M.M. Honcoop (m.m.honcoop-1@student.utwente.nl), of onderzoeksbegeleider R. Klaassen (r.klaassen@utwente.nl), of onderzoeksbegeleider M.B. van Riemsdijk (m.b.vanriemsdijk@utwente.nl)

HANDTEKENING _____ **DATUM** _____

4

UNIVERSITEIT TWENTE DEPARTEMENT VAN INTERACTION TECHNOLOGY Onderzoek Toestemmingsformulier
Onderzoeker: M.M. Honcoop
Titel: Emotion regulation through sounds for people with autism spectrum disorder

[OPTIONEEL] U geeft toestemming voor een audio opname tijdens het interview en dat het audiomateriaal wordt gebruikt voor analyse doeleinde

Ja__ Nee___

ONDERZOEKERSSECTIE:
Ik (de onderzoeker) heb toelichtingen gegeven over het onderzoek. Ik (de onderzoeker) verklaar dat ik antwoord naar mijn beste vermogen op vragen die wellicht ontstaan over dit onderzoek.

_____ _____
Naam Onderzoeker Handtekening

5

B. Questionnaires

The following shows the pre-defined interview questions of the three different user involvement sessions.

B1 Questions User Involvement 1 (User Interviews)

ACTIVITEITEN MODEL BESPREKEN

1) Kunt u uitleggen voor elke activiteit waarom ze gelinkt worden aan die specifieke emoties?
   a) Kunt u uitleggen wat er gebeurt wanneer u van positieve naar negatieve emoties gaat?
   b) Welk aspect van de activiteit roept de negatieve emotie op?
2) Ervaart u moeilijkheden met de emoties bijvoorbeeld bij het herkennen, ervaren of uitten?
3) Welke emoties ervaart u als moeilijk?
   a) Kunt u uitleggen waarom u die emoties als moeilijk ervaart?
   b) Waarom vindt u dat moeilijk?
4) Zijn er enige aspecten van de activiteiten en/of de emoties dat gelinkt zijn aan bepaalde prikkelingen?
   a) Bij ja, kunt u uitleggen welk aspect en wat de prikkeling is?
5) Heeft u ooit ervaren dat uw emoties escaleren tot een uitbarsting (meltdown) of in isolatie gaan (shutdown)?
   a) Bij ja, kunt u een voorbeeld geven van een uitbarsting en/of isolatie dat u recentelijk heeft ervaren?
6) Heeft u op het moment enige coping-mechanisme om om te gaan met emoties?
   a) Bij ja, kunt u daar meer over vertellen?

GELUID & MUZIEK BESPREKEN

Eigen ervaring

1. Kunt u iets vertellen over hoe u reageert op geluid in uw dagelijkse leven?
    1. Zijn er bepaalde geluiden een bron van stress voor u?
    2. Zijn er geluid en/of muziek dat u leuk vindt, die ook verlichting brengen? Kunt u voorbeelden geven?
    3. Welke ervaringen heeft u met het verminderen van alle omgevingsgeluiden (zoals bij een noise-canceling koptelefoon)?

De kaart

1. Als we terugkijken naar de 2D kaart van stap 3:
    1. Kunt u beschrijven voor elke activiteit of u luistert naar geluid/muziek of een andere vorm van noise-canceling?
        1. Als u luistert naar geluid of muziek:
            1. Kunt u uitleggen welke geluiden of muziek?
            2. Waarom heeft u die geluiden of muziek gekozen?
            3. Welk effect hebben die geluiden op uw emotionele gemoedstoestand?

4. Veranderd de muziek of geluid ook wanneer uw emotionele gemoedstoestand veranderd tijdens de activiteit?
    1. Bij ja, kunt u uitleggen welke geluiden of muziek u voorkeur heeft bij welke emotionele gemoedstoestand?

ii. Als u een soort van noise-canceling gebruikt:

1. Waarom kiest u voor noise-canceling?
2. Welk effect heeft noise-canceling op uw emotionele gemoedstoestand?
3. Verandert u uw gebruik van noise-canceling wanner uw emotionele gemoedstoestand verandert tijdens een activiteit?

b. Kunt u voor elk kwadrant uitleggen welk muziek/geluid of anti-geluid (zoals noise-canceling) passen met de genoemde emoties in elk kwadrant?

Vragen na luisteren geluid:

1. Welk soort effect denk je dat deze geluiden kunnen hebben als u ook in diezelfde emotionele gemoedstoestand bent (zoals gefrustreerd, boos of gespannen)?
    1. Is het mogelijk dat deze geluiden meer betrekking op u kunnen hebben wanneer u in hetzelfde emotie gemoedstoestand zit?
        1. Waarom of waarom niet?

Ideeën voor geluidsapplicatie

1) Hoe denkt u dat een soortgelijk geluidssysteem kan passen in uw dagelijkse leven?
2) Wat denkt u dat een soortgelijk geluidssysteem moet kunnen doen?
3) Kunt u beschrijven hoe een soortgelijk geluidssysteem eruit zou moeten zien?
4) Wat voor functionaliteiten zijn echt noodzakelijk voor een soortgelijk geluidssysteem?
    a) Waarom?
5) Welke functionaliteiten denkt u dat moeten worden vermeden om te implementeren in een soortgelijk geluidssysteem?
    a) Waarom?

DISCUSS ACTIVITIES MODEL

1) Can you explain for each activity why they are related to those particular emotions?

a) Can you explain what happens in the activity when you go from positive to negative emotions?
b) What aspect of the activity would elicit negative emotions?

2) Do you experience difficulties in the way of handling these emotions (such as recognizing, experiencing or expressing)?
3) Which emotions do you experience as difficult?
   a) Can you explain what explain you find difficult?
   b) Why do you find this difficult?
4) Is there any aspect from the activities and/or emotions that are related to certain triggers?
   a) If so, can you explain what aspect and what trigger?
5) Did you ever experience that certain emotions escalated to a point of outburst *(meltdown)* or going into isolation *(shutdown)*?
   a) If so, can you give an example of outburst and/or isolation that you experienced recently?
6) Do you currently have any coping mechanism for dealing with emotions?
   a) If so, can you tell more about that?

DISCUSS SOUNDS & MUSIC

Own experience

1. Can you tell something about how you respond to sound in your everyday life?
    1. Are sounds a source of stress for you?
    2. Are there sounds and/or music that you like, that bring relief to you? Can you give examples?
    3. What kind of experiences do you have with reducing all sounds in the environment (like noise-canceling handphones)?

The card

1. If we look back at the 2D card from step 3:
    1. Can you describe for each activity if you listen to sound/music or use some sort of noise-canceling?
        1.If you listen to sound or music:
            1. Can you explain which sounds or music?
            2. Why did you choose those sounds or music?
            3. What effect do these sounds or music have on your emotional state?
            4. Does the music or sound change when your emotional state is changing during the activity?
                1. If so, can you tell which sound or music you prefer with which emotional state?

        ii.If you use some sort of noise-canceling:

1. Why do you choose noise-canceling?
2. What effect does noise-canceling has on your emotional state?
3. Do you change your use of noise-canceling when your emotional state is changing in the activity?

b.Can you describe for each quadrant which music/sound or anti-sound (such as noise-canceling) would fit with the emotions mentioned in the quadrants?

Questions after listening to sounds:

1. What kind of effect do you think these sounds could have on you when you are also in those emotional states (such as frustrated, angry or tense)?
    1. Is it possible that these sounds could relate more to you when you are in the same emotional state?
        1.Why or why not?

Ideas for sound application

1. How do you think such a sound system would fit into your daily life?
2. What do you think that such a sound system should supposed to do?
3. Can you describe how such a sound system should look like?
4. What kind of functionalities are really required for such a sound system?
    - Why?
5. What kind of functionalities do you think that should be avoided to implement in such a sound system?
    - Why?

B2 Questions User Involvement 2 (Co-design and Test sessions)

1. QUESTIONS ABOUT CHOSEN SOUNDS/MUSIC

NL

- Waarom heeft u voor deze geluiden en/of muziek gekozen?
- Wanneer luistert u naar de geluiden/muziek?
- Waarom ervaart u deze geluiden/muziek als kalmerend?

EN

- Why did you choose those sounds and/or music?
- When do you listen to the sounds/music?
- Why do you experience the sounds/music as calming?

2. QUESTIONS ABOUT MIMIC VS. NUDGE

NL

- Als u de simulatie (mimic) en nudge zou vergelijken, welke heeft u voorkeur en waarom?
- Welke van de geluidsreacties (mimic en nudge) denkt u dat het beste zou kunnen passen bij het op de hoogte brengen van de emoties bij de luisteraar?
    - Waarom?
- Welke van de geluidsreacties (mimic en nudge) denkt u dat het beste zou kunnen passen bij het stimuleren van de luisteraar om te kalmeren?
    - Waarom?
- Denkt u dat er ook andere manieren zijn over hoe het geluid zou kunnen reageren?
    - Bij ja:
        - Kunt u deze manier uitleggen?
        - Kunt u ook uitleggen waarom deze manier zou kunnen werken?

EN

- If you would compare the simulation (mimic) and nudge, which one has your preference and why?
- Which sound reaction (mimic and nudge) do you think would fit best to notify the listener of their emotions?
    - Why?
- Which sound reaction (mimic and nudge) do you think would fit best to stimulate the listener to calm down?
    - Why?
- Do you think the sound can also react in another manner?
    - If so:

- Can you explain this manner?
- Can you also explain why this manner would fit?

3. SOUNDS/MUSIC LINKED TO EMOTIONAL AROUSAL LEVELS

NL

- Kunt u uw keuzes uitleggen voor hoe het geluid reageert op een verandering in het emotioneel niveau?
- Waarom heeft u ervoor gekozen dat het geluid op die manier reageert?

EN

- Can you explain your decisions for how the sound reacts to a change in the emotional level?
- Why did you choose for the sound to react in that manner?

4. DESIGN OF EMOTION REGULATION APPLICATION BY SOUNDS

NL

- Kunt u uw keuzes uitleggen voor de schets dat u gemaakt heeft?
- Waarom heeft u ervoor gekozen dat de applicatie die elementen zou moeten bevatten?

EN

- Can you explain your decisions for the sketch?
- Why did you choose for those elements to be part of the application?

5. QUESTIONS ABOUT PROTOTYPE

NL

Mimic/ Simulatie

- Vind u dat mimic/simulatie u kan helpen om extreme emoties te voorkomen?
- Vind u dat mimic/simulatie u kan helpen om beter om te gaan met uw emoties?
- Vind u dat het geluid … voorspelbaar?
- Vind dat het geluid … herkenbaar?

Nudge

- Vind u dat nudge u kan helpen om extreme emoties te voorkomen?
- Vind u dat nudge u kan helpen om beter om te gaan met uw emoties?
- Vind u dat het geluid … voorspelbaar?
- Vind dat het geluid … herkenbaar?

Alert

- Vind u dat alert u kan helpen om extreme emoties te voorkomen?
- Vind u dat alert u kan helpen om beter om te gaan met uw emoties?
- Vind u dat het geluid … voorspelbaar?
- Vind dat het geluid … herkenbaar?

Personal

- Vind u dat persoonlijke geluiden u kan helpen om extreme emoties te voorkomen?
- Vind u dat persoonlijke geluiden u kan helpen om beter om te gaan met uw emoties?
- Vind u dat het geluid … voorspelbaar?
- Vind dat het geluid … herkenbaar?

EN

Mimic/ Simulatie

- Do you think that mimic you can help to prevent extreme emotions?
- Do you think that mimic would help you to better handle your emotions?
- Do you think that the sound .. is predictable?
- Do you think that the sound .. is familiar?

Nudge

- Do you think that nudge you can help to prevent extreme emotions?
- Do you think that nudge would help you to better handle your emotions?
- Do you think that the sound .. is predictable?
- Do you think that the sound .. is familiar?

Alert

- Do you think that alert you can help to prevent extreme emotions?
- Do you think that alert would help you to better handle your emotions?
- Do you think that the sound .. is predictable?
- Do you think that the sound .. is familiar?

Personal

- Do you think that personal you can help to prevent extreme emotions?
- Do you think that personal would help you to better handle your emotions?
- Do you think that the sound .. is predictable?
- Do you think that the sound .. is familiar?

NL

1. Als je de verschillende geluidsreacties (simulatie, nudge, alert en persoonlijke geluiden) moest vergelijken, welke heeft dan u voorkeur en waarom?
2. Vind u dat de geluidsreacties (simulatie, nudge, alert en persoonlijke geluiden) reageerde zoals u hebt bepaald?
3. Vind u dat de geluidsreacties (simulatie, nudge, alert en persoonlijke geluiden) aanpasbaar zijn naar uw eigen voorkeuren?
4. Welke soort geluid (natuur, meditatie, alert of persoonlijke geluiden) vindt u het beste passen bij het kalmeren en waarom?
5. Denkt u dat deze applicatie in uw dagelijkse leven zou kunnen passen? Waarom?
    a. Komt deze applicatie opdringerig over? Waarom?
    b. Heeft u nog controle over hoe u uw dagelijkse leven inricht als u deze applicatie in gebruik neemt? Waarom?
    c. Kunt u de applicatie gemakkelijk altijd en overal gebruiken? Waarom?
6. Denkt u dat u beter met uw emoties kan omgaan via deze applicatie? Waarom?
    a. Denkt u dat u helemaal geen extreme emoties zal ervaren door deze applicatie?
    b. Krijgt u beter inzicht in uw emoties via de applicatie? Waarom?
    c. Is het makkelijk te begrijpen wat de applicatie aangeeft over uw emoties? Waarom?
    d. Wat vindt u van de weergave van de emotie niveaus in bolletjes?
7. Raakt u afgeleid door bepaalde elementen in de applicatie?
    a. Is het ontwerp van de applicatie zo simpel mogelijk gemaakt?
8. Ervaart u de geluiden als herhalend? Zoja, ervaart u dat als positief? Waarom?
9. Vindt u de geluiden herkenbaar? Waarom?
10. Zou u de applicatie gebruiken met een koptelefoon? Waarom?
11. Is het voor u mogelijk om bepaalde instellingen te veranderen in de applicatie?
    a. Kunt u in de applicatie een persoonlijke voorkeur aangeven?
12. Denkt u dat het mogelijk is dat de applicatie zelflerend is? Waarom?

EN

1. If you compare the different sound reactions (mimic, nudge, alert, personal sounds), which reaction has your preference and why?
2. Do you think that the sound reactions (mimic, nudge, alert, and personal sounds) reacted in the way you decided?
3. Do you think that the sound reactions (mimic, nudge, alert, and personal sounds) are adjustable according to your own preferences?
4. Which type of sound (nature, meditation, alert, or personal sounds) would best fit with relaxation and why?
5. Do you think that this application would fit in your daily life and why?

    a. Do you think this application is experienced invasive and why?
    b. Are you still in control of organizing your daily life when using this application? Why?
    c. Can you easily use this application anytime and anywhere? Why?
6. Do you think you can better handle your emotions with this application and why?
    a. Do you think that would not experience extreme emotions anymore with this application?
    b. Do you gain insights about your own emotions with this application? Why?
    c. Is it easy to understand what the applications says about your emotions? Why?
    d. What did you think about the display of dots for the emotional arousal levels?
7. Do you get distracted by certain elements in the application?
    a. Is the design of the application simple?
8. Do you experience the sounds as repetitive? If yes, do you experience that as positive? Why?
9. Do the sounds give you a sense of recognition? Why?
10. Would you use the application with a headphone? Why?
11. Is it for you possible to adjust some settings in the application?
    a. Can you indicate your personal preference in the application?
12. Do you think it is possible that the application would be self-learning? Why?

Er kan worden doorgevraagd op de volgende onderwerpen:

- Als de participant extreme antwoorden geeft
- Als de participant tijdens de test opvallende dingen zegt

NL

- 1 Algemene vraag: Zou je deze applicatie aan iemand met autisme aanraden om beter met emoties om te gaan?
    - Waarom?

EN

- General question: Would you recommend this application to someone with autism to better handle their emotions?
    - Why?

B3 Questions User Involvement 3 (User Testing)

1. Hoe voelt u zich op dit moment?
2. Dus u voelt u zo .. , vindt u het makkelijk/moeilijk om uw gevoelens te herkennen en waarom?
3. Gebruikt u in uw leven ook manieren om tot rust te komen?
4. Heeft u wellicht ervaring met muziek/geluiden?
    - Kunt u daar meer over vertellen?
5. Wist u dat mensen met autisme spectrum syndroom (ass) heel erg moeite hebben om inzicht te krijgen in hun emoties en dat ze meestal pas inzicht hebben als het al te laat is via een uitbarsting, zoals schreeuwen of zichzelf juist afzonderen?
    - Wist u dat?
    - Wat vindt u ervan?
6. Denkt u dat de emotie regulatie applicatie met audio feedback (die u getest heeft) kan helpen bij de problemen die mensen met ass ervaren met emoties? Waarom wel/niet?
7. Denkt u dat het geluid een positief effect heeft op de emotie regulatie bij mensen met autisme?
8. Hoe heeft u de geluiden ervaren?
9. Vond u dat het geluid u hielp om inzicht te krijgen in uw emoties?
    - Werd u meer bewust van uw emoties door het geluid?
    - Waarom wel/niet?
10. Vond u dat het geluid u hielp om te kalmeren?
    - Waarom wel/niet?
11. In de data is te zien dat uw emotie arousal niveau hoog/laag was:
        - Wat gebeurde er toen?
        - Welke emotie had u op dat moment?
        - Heeft u op dat moment geluid gebruikt?
        - Bent u met de data eens?
            - Waarom wel/niet?
12. *Hoe makkelijk vond u het om:*
    - *Geluiden toe te voegen?*
    - *Restricties aan geluiden toe te voegen?*
    - *Geluiden te starten?*
    - *Een voorselectie van geluiden te selecteren?*
13. Vindt u dat er voldoende mogelijkheid is voor u om de applicatie persoonlijk te maken naar uw wensen?
    - Hoezo?
14. Vindt u dat u voldoende controle heeft in de applicatie over hoe de applicatie zou moeten reageren?
    - Hoezo?

15. Denkt u dat er wellicht nog wat toegevoegd kan worden (bijv. functies/ontwerpen) aan de emotie regulatie applicatie op basis van geluid?
    - Kunt u uitleggen wat en waarom?
16. Kunt u duidelijk een verandering in de emoties arousal horen?
    - Waarom?
17. Vond u dat de emotie regulatie applicatie op basis van geluid er uitnodigend uit zag om te gebruiken?
    - Waarom?
18. Zou u de emotie regulatie applicatie op basis van geluid vaker willen gebruiken?
    - Waarom?
19. Zou u de emotie regulatie applicatie op basis van geluid aan iemand met autisme spectrum syndroom aanraden om beter met emoties om te gaan?

C. Materials

The following shows the sound options, self-reported context mapping, and log data graphs.

C1 Table with Sound Options from literature and interviews

Table 54 - Table with Sound Options

Sound	Category	Reference
Hair Brushing	ASMR	[40]
White Noise	ASMR	[40], Interviews
Whispering	ASMR, Meditation	[40], [44]
Soft Speaking	ASMR	[40]
Crinkling	ASMR	[40]
Tapping	ASMR	[40]
Alpha Brainwaves	Meditation	[45]
Silence	Meditation	[45]
Ocean Waves	Meditation, Nature	[45], [38], Interviews
Bird Calls	Meditation, Nature, Notification	[45], [38], Interviews, [46]
Water (Dripping)	Meditation, Notification	[45], Interviews, [46]
Heartbeat	Meditation	[45]
Mantra 'OM'	Meditation	[44]
Humming Sound	Meditation	[44]
MMMM	Meditation	[44]
Frog	Nature	[38]
Wind	Nature, Notification	[38], [46]
Bonfire	Nature	[38]
Rivers	Nature	[38]
Footsteps on i.e. snow, rock	Nature	[38]
Tropical Rainforest	Nature	[38], Interviews
Crickets	Nature	[38]
Rain	Nature, Notification	[38], Interviews, [46]
Thunderstorms	Nature	[38], Interviews
Beep	Notification	[46]
Siren	Notification	[46]
Bell	Notification	[46]
Instrument	Notification	[46]
Bangle	Personal	Interviews
Voice	Personal	Interviews

Sound	Category	Reference
70s, 80s music	Personal	Interviews
Indie Folk	Personal	Interviews
New Age	Personal	Interviews
Classical Music	Personal	Interviews
Upbeat Music	Personal	Interviews
Dance	Personal	Interviews
Active Rock	Personal	Interviews
Hardcore	Personal	Interviews
Hardstyle	Personal	Interviews
Wagner	Personal	Interviews
Beethoven	Personal	Interviews
Catholic Music	Personal	Interviews

C2 Self-reported Context mapping

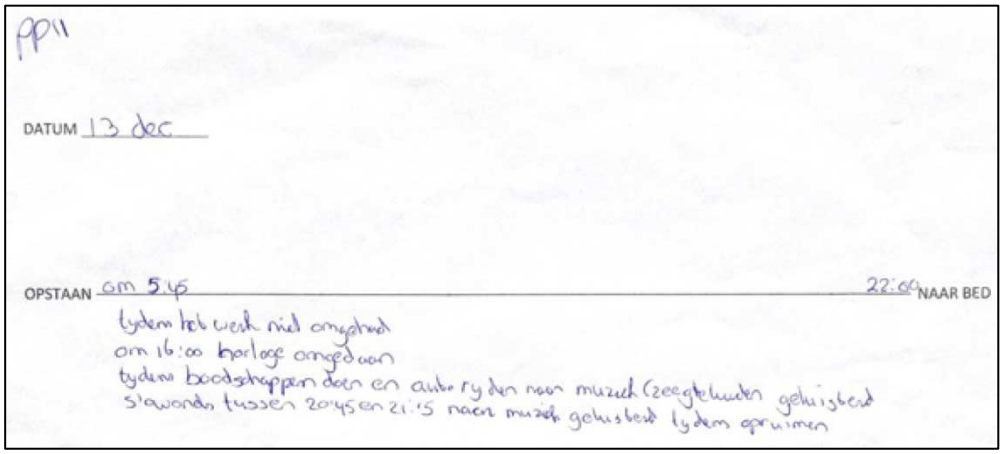


Figure 64 - PP11 self-reported context mapping

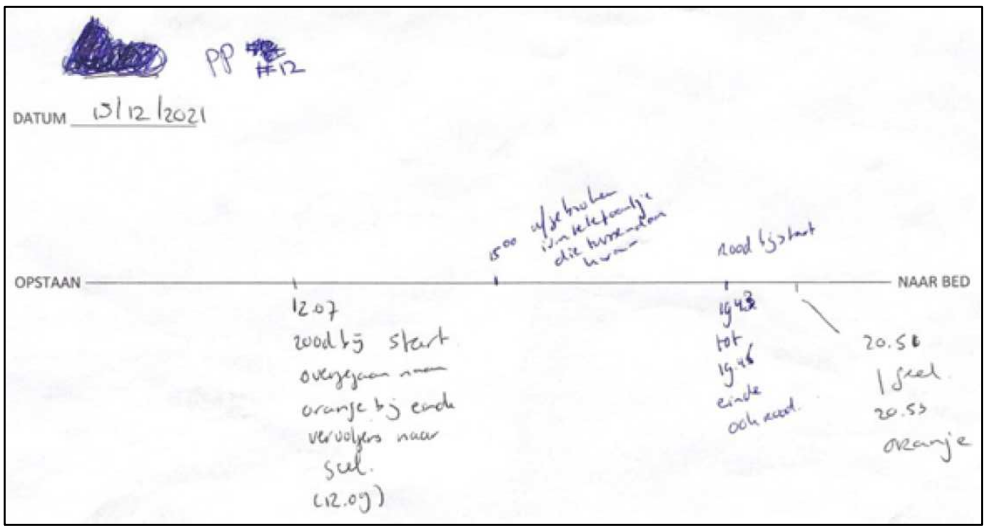


Figure 65 - PP12 self-reported context mapping day 1

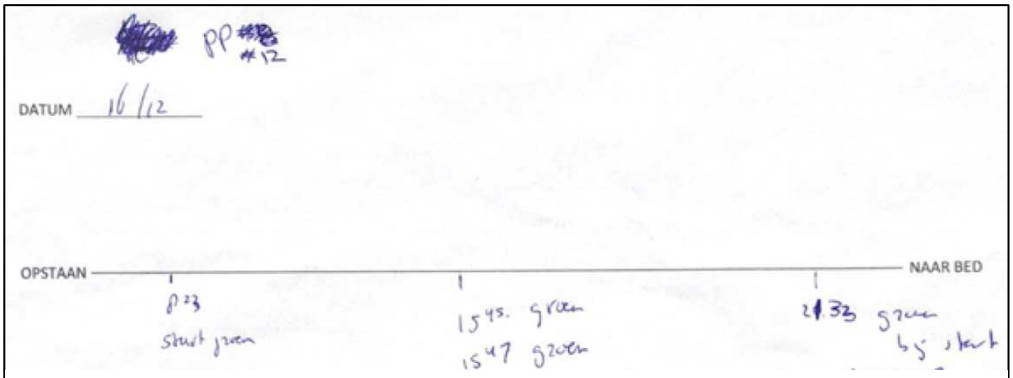


Figure 66 - PP12 self-reported context mapping day 2

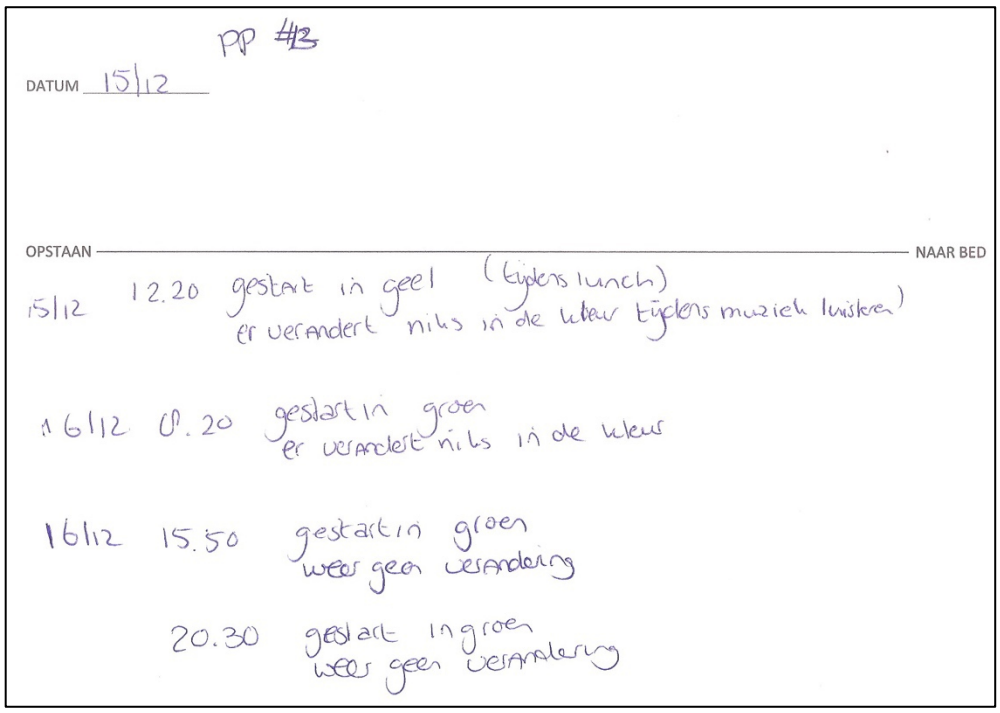


Figure 67 - pp13 self-reported context mapping

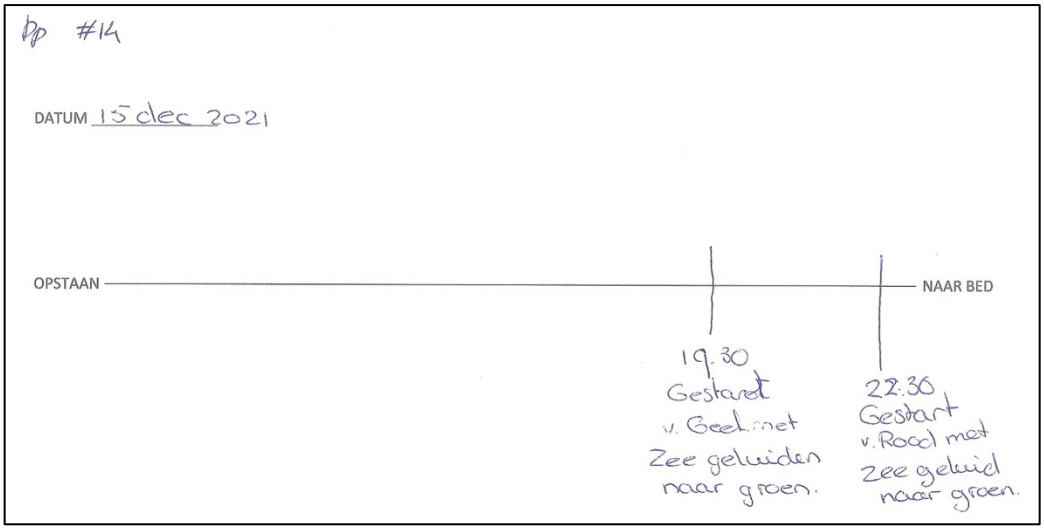


Figure 68 - pp14 self-reported context mapping day 1

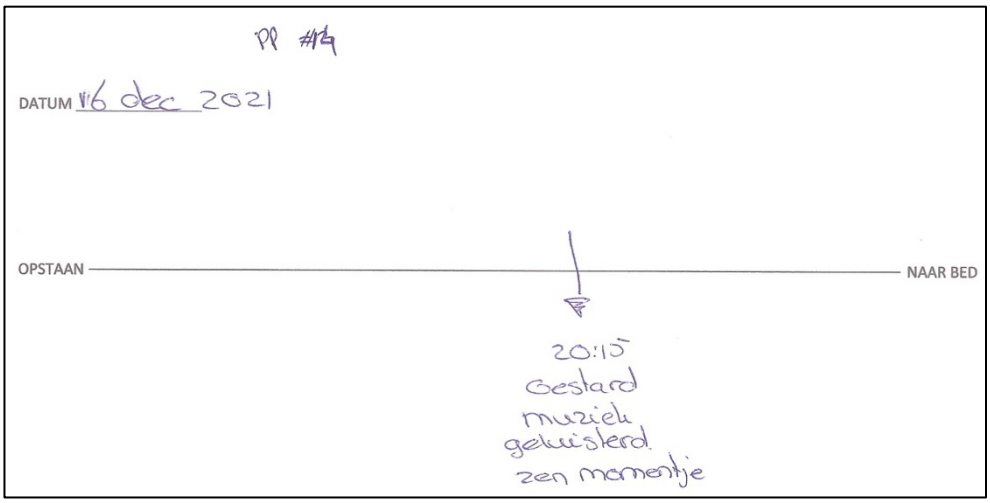


Figure 69 - pp14 self-reported context mapping day 2

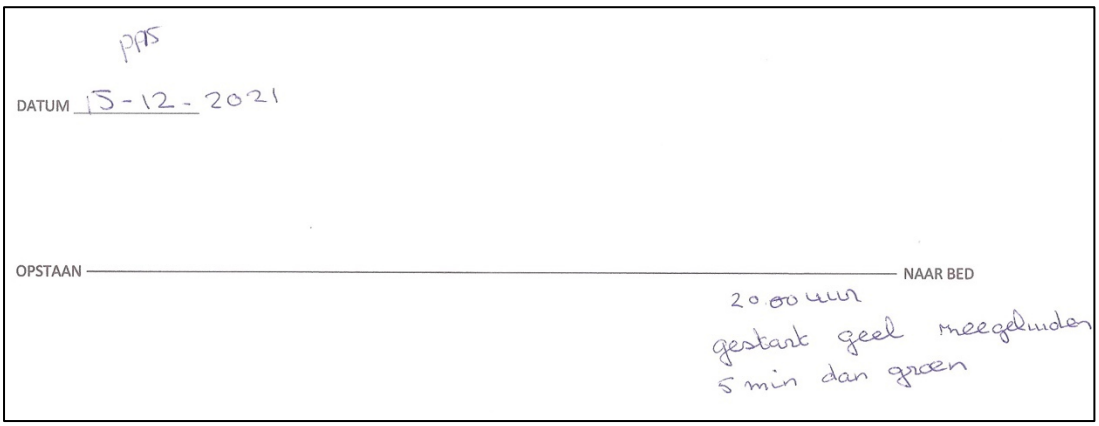


Figure 70 - pp15 self-reported context mapping day 1

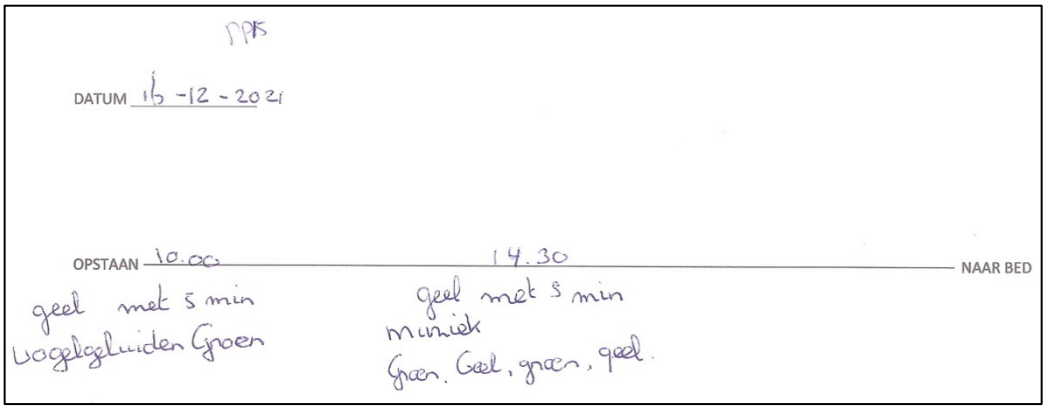


Figure 71 - pp15 self-reported context mapping day 2

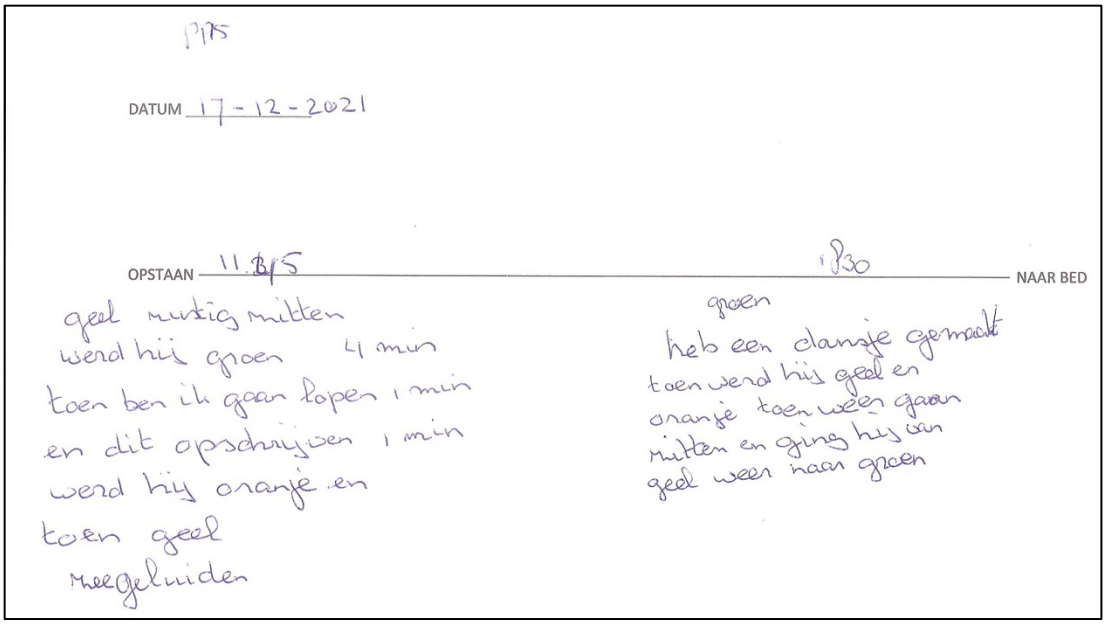


Figure 72 - pp15 self-reported context mapping day 3

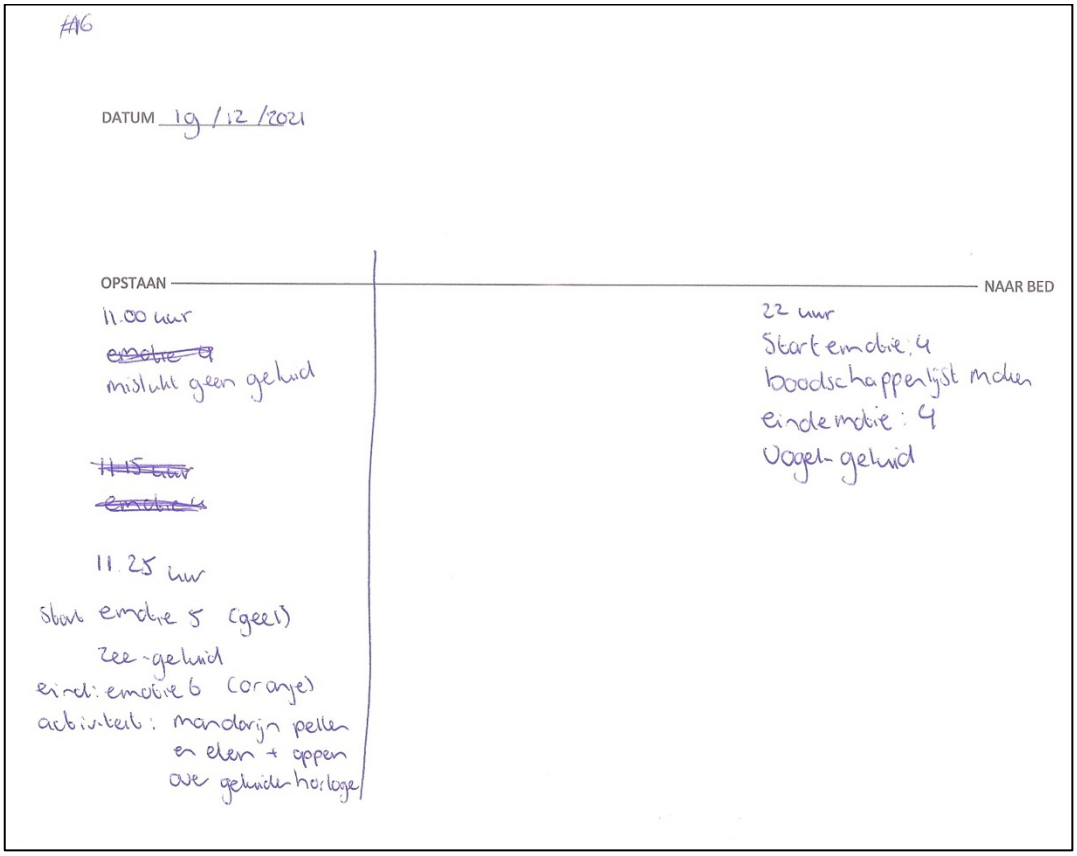


Figure 73 - pp16 self-reported context mapping day 1

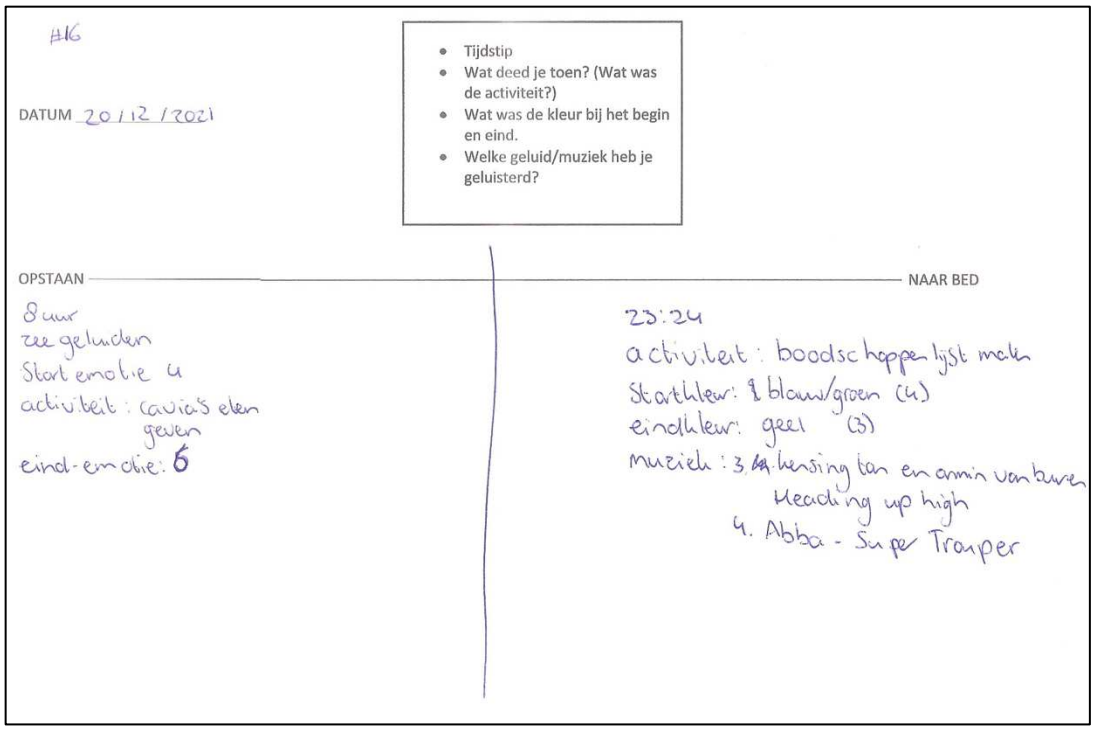


Figure 74 - pp16 self-reported context mapping day 2

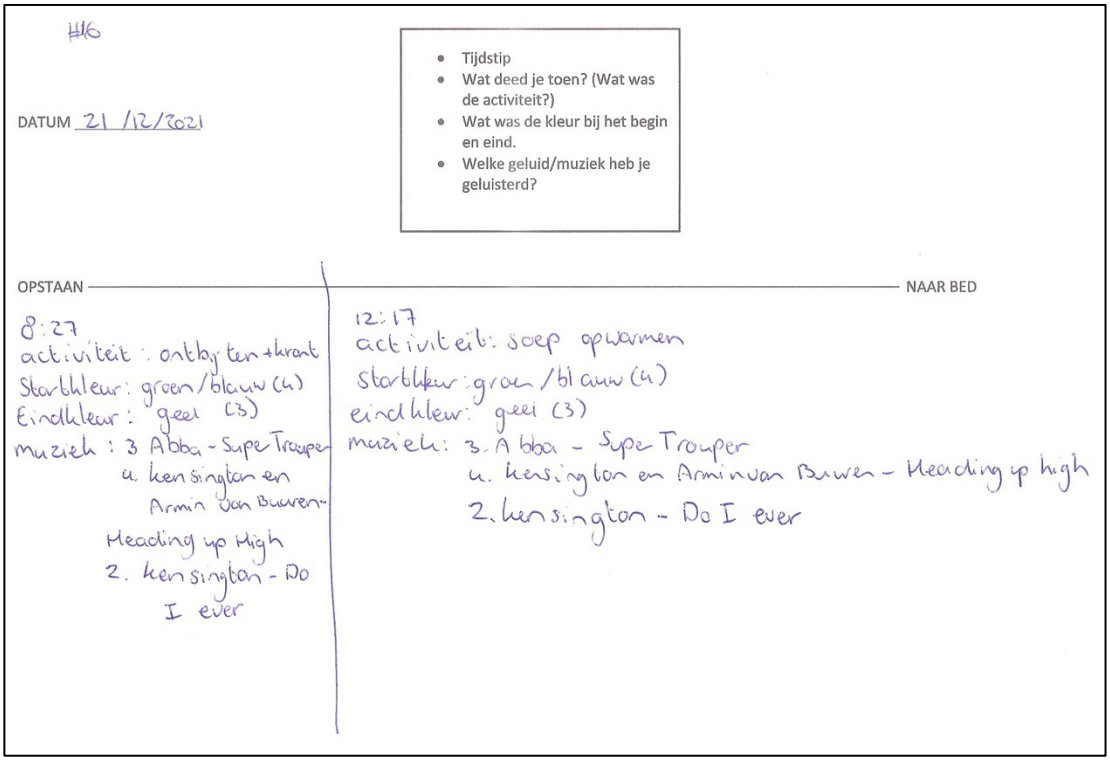


Figure 75 - pp16 self-reported context mapping day 3

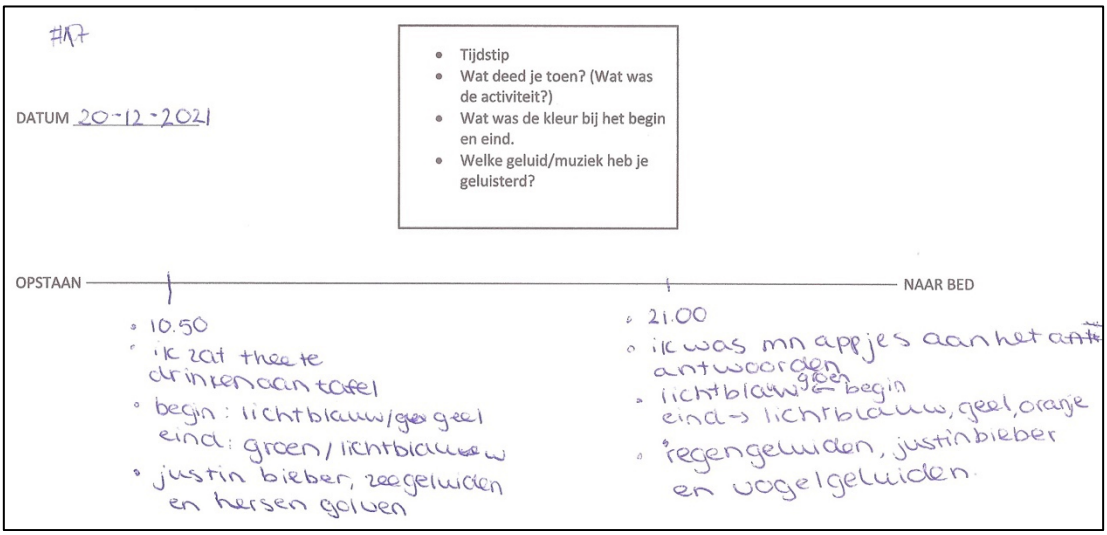


Figure 76 - pp17 self-reported context mapping day 1

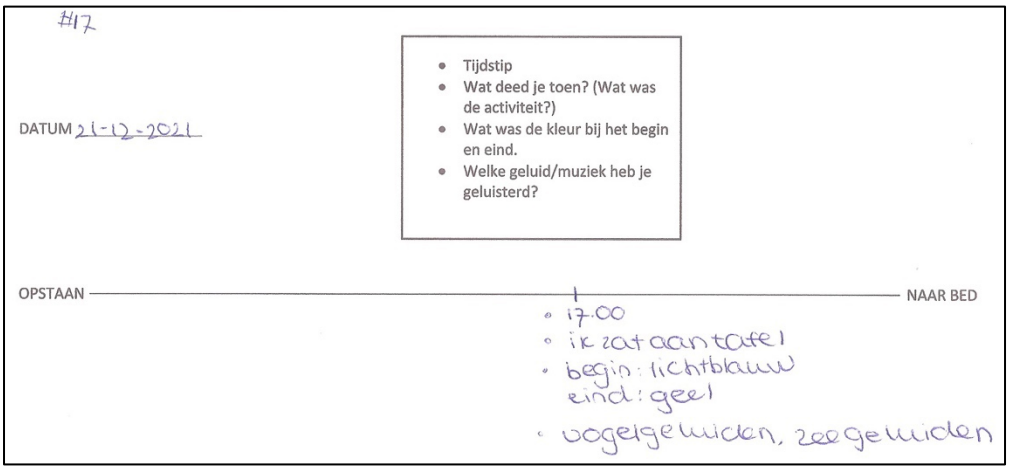


Figure 77 - pp17 self-reported context mapping day 2

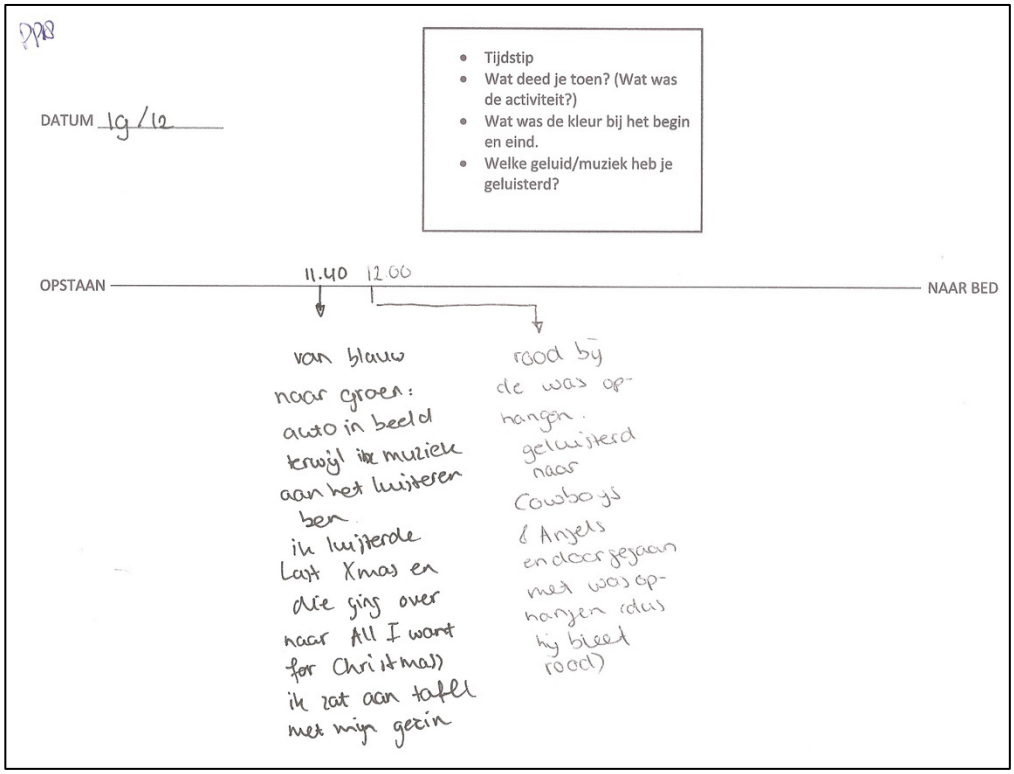


Figure 78 - pp18 self-reported context mapping day 1

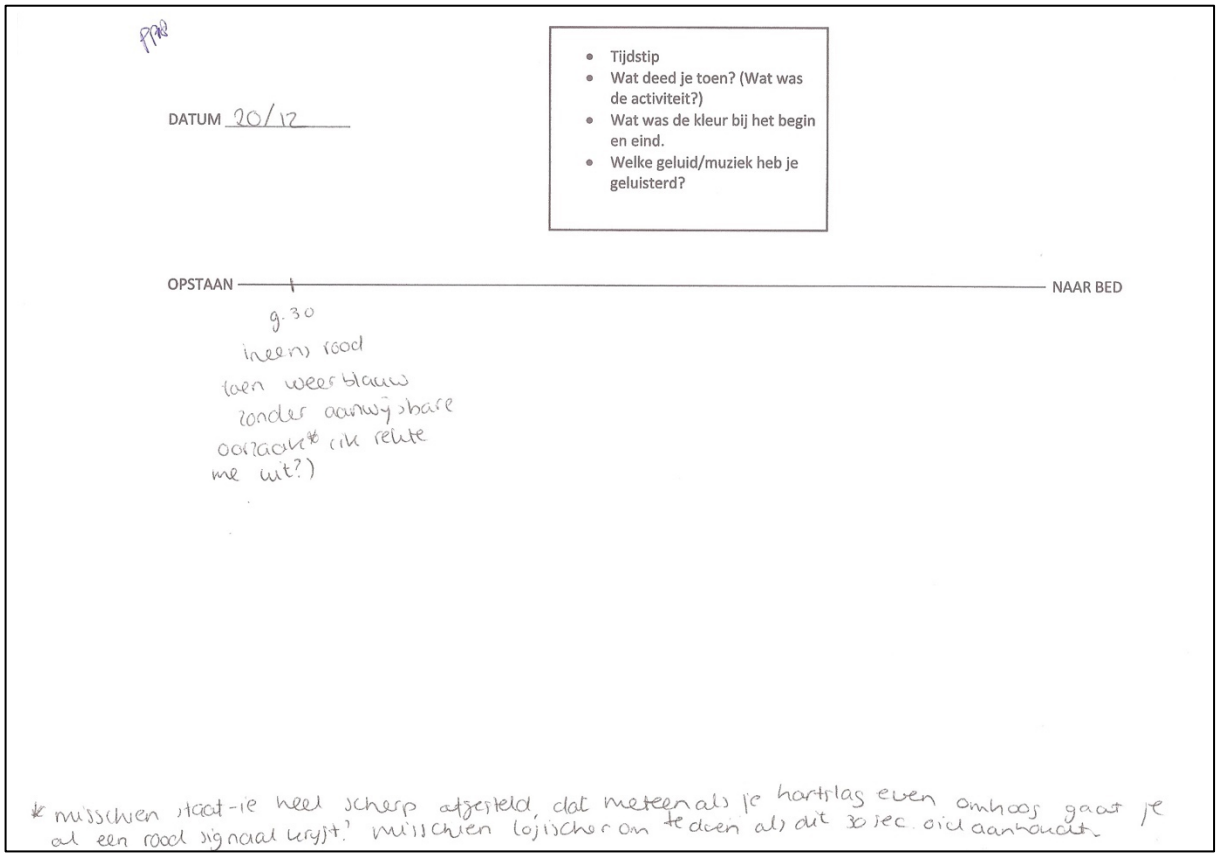


Figure 79 - pp18 self-reported context mapping day 2

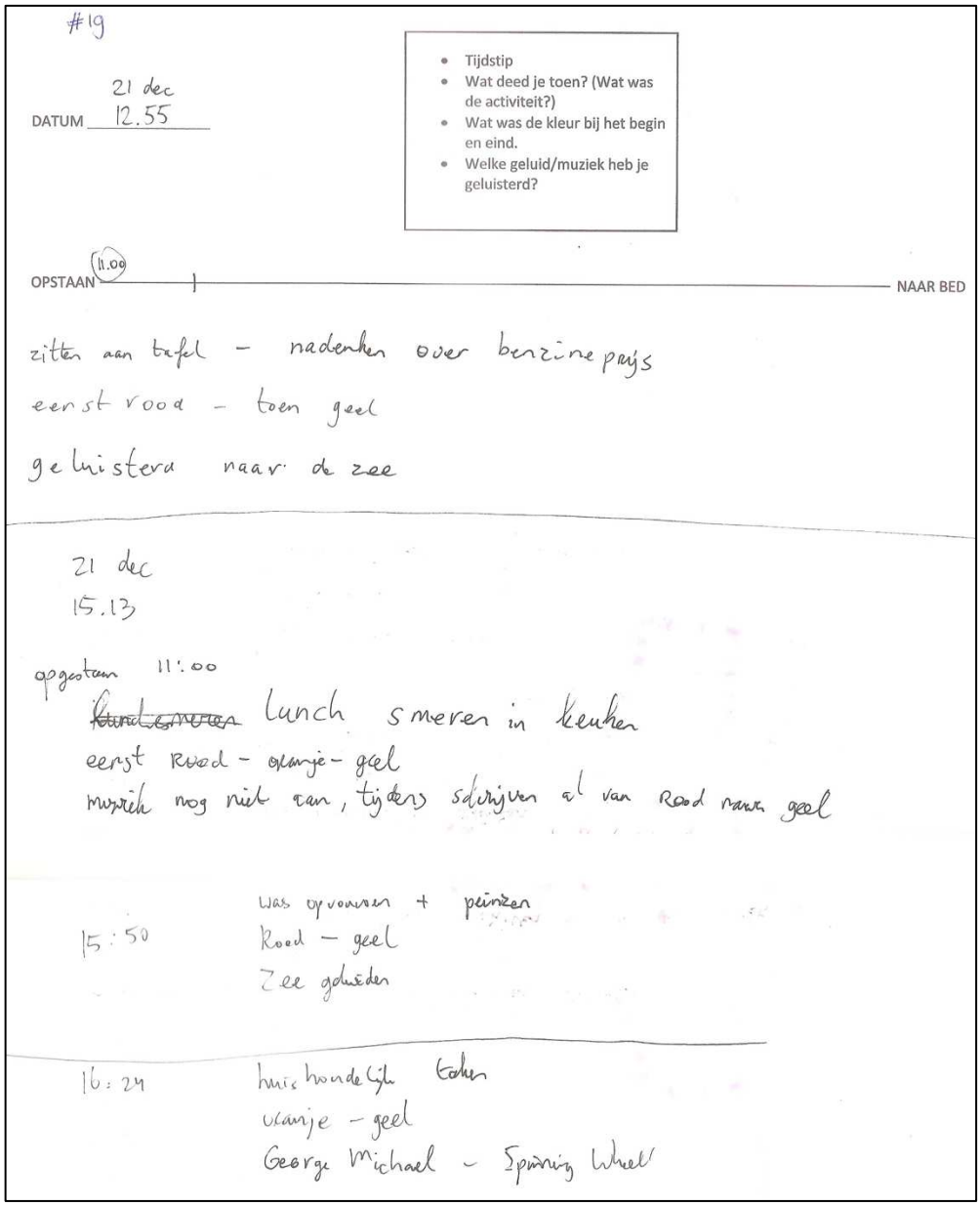


Figure 80 - pp19 self-reported context mapping

C3 Log data graphs from SoundRate application

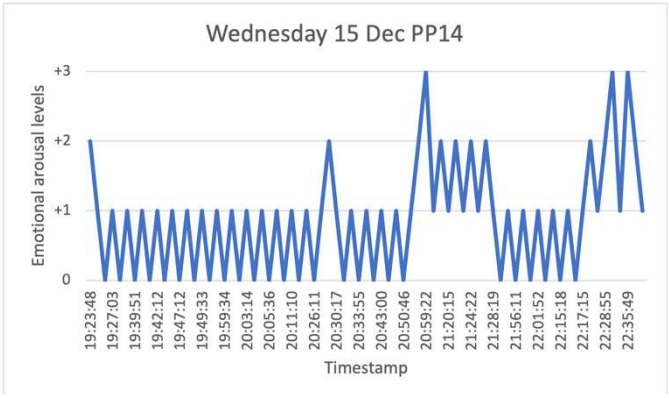


Figure 81 – Log data graph PP14 day 1

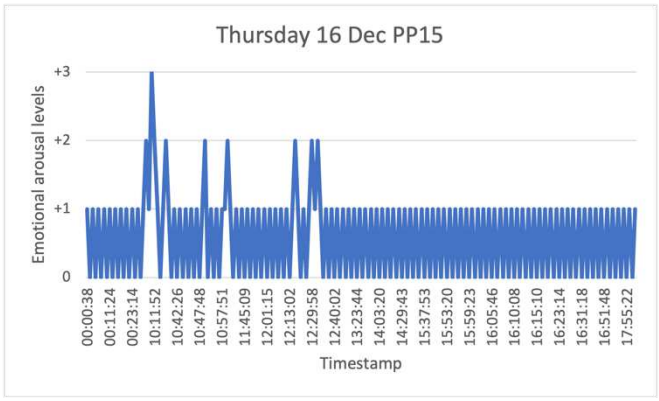


Figure 82 – Log data graph PP15 day 2

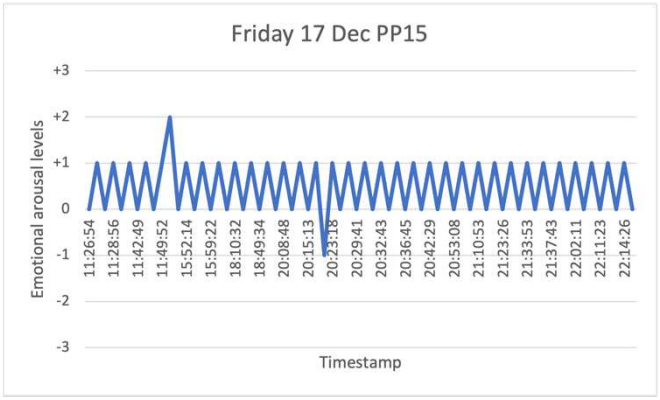


Figure 83 – Log data graph PP15 day 3

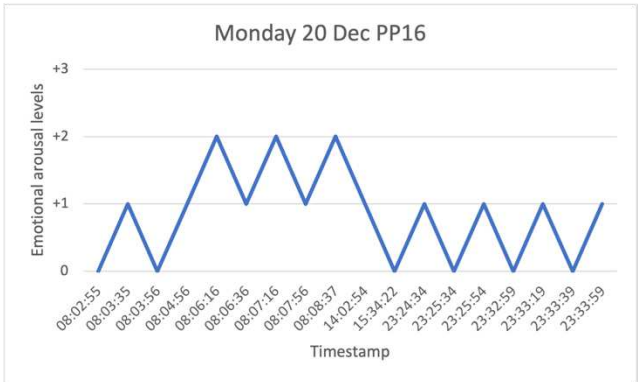


Figure 84 – Log data graph PP16 day 2

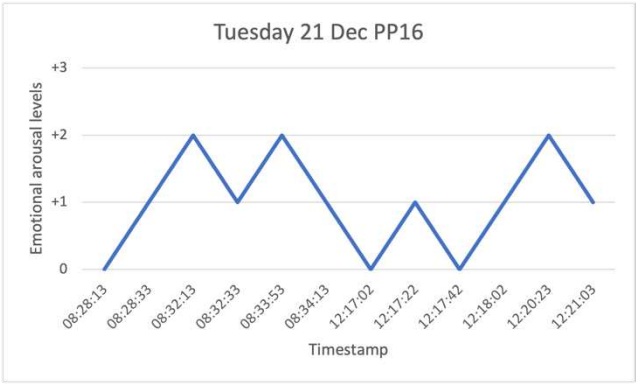


Figure 85 – Log data graph PP16 day 3

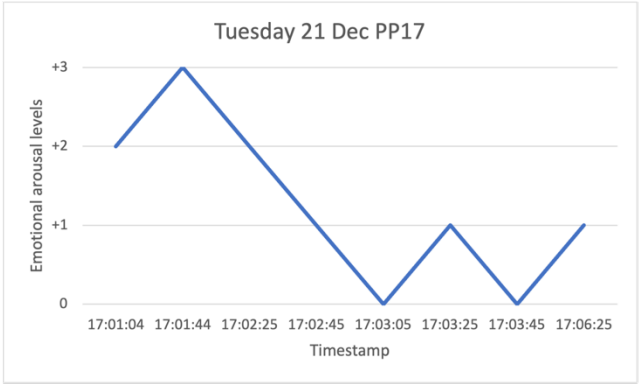


Figure 86 – Log data graph PP17 day 2

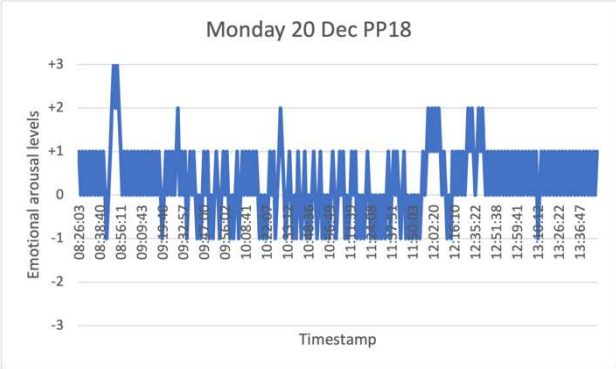


Figure 87 – Log data graph PP18 day 2

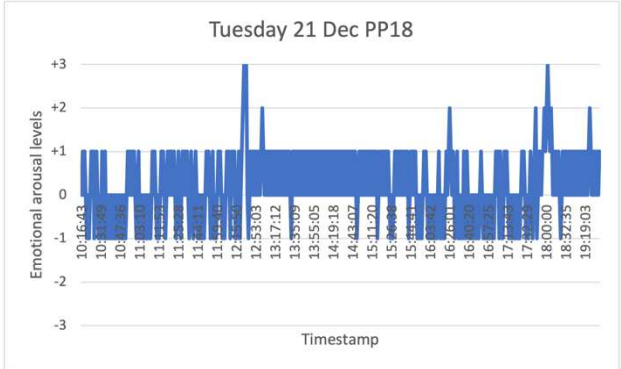


Figure 88 – Log data graph PP18 day 3