Developing A Tool To Monitor Stress Levels In Infants: An Explorative Research

A Graduation Project for Creative Technology

Daniela van Meggelen – s1839020
Supervisor: Randy Klaassen
Critical observer: Juliet Haarman

University of Twente
29-01-2021

Abstract

Chronic stress in infants is hard to accurately pinpoint but can have a significant impact on their development and long-term wellbeing. Currently, it is possible to monitor stress-levels by letting parents fill in a questionnaire, by taking cortisol samples to analyze in a lab, or by putting on wearable sensors. Such tools are lacking in reliability, accessibility, or are not fit for continuous use making them unfit for long-term monitoring of stress levels. Therefore, this research project aims to develop a more reliable tool that can be used to monitor stress levels in infants at home.

By aiming to create a solution that would provide such continuous use whilst guaranteeing reliable measurements, a wearable sock has been developed that would use heart rate variability, muscle tension, and electrodermal activity to reliably monitor an infant's stress levels. Accompanied by a mood tracking app which includes caregivers in the process, the product would collect both objective measurement data as well as contextual data concerning the caregiver's feelings and experiences. Evaluating the prototypes based on user experience and stability showed that the app was suitable and valued, ready to be worked out further. An addition would be to involve more positive aspects as to balance out the negativity such that users get a neutral experience; they are not actively influenced by the product. The evaluation of the wearable prototype showed inconclusive results, meaning that additional research would be needed to assess whether reliable measurements could be guaranteed on the ankle. Additionally, it would be very important to consider ethical aspects in this project: thinking thoroughly about the matter of transparency towards the caregivers regarding the collected data, and the responsibilities of all stakeholders when using these products. Overall, a solid foundation has been laid for this project to continue building on, so eventually, the reliability and effectiveness of these products can be guaranteed and the initial problem can be solved.

Acknowledgements

This project could not have been done without the support of my supervisors, my friends, and my family, keeping me motivated and (somewhat) calm during the process. As an enthusiastic and open person, it was really helpful to receive such positive reactions and social feedback, especially in these isolated times. Besides the general positive ambience, I would like to thank some people specifically.

A big thank you goes out to my enthusiastic clients, Zillah and Ellen, and my supportive supervisors, Randy Klaassen and Juliet Haarman, for helping me get the best out of this project through their feedback and suggestions. Besides this, I would like to thank my mother, Cristina, for thinking along with me both as a mother and as a professional, my friend, Peter, for being patient with my many (and perhaps a bit stupid) questions, and my boyfriend Frank, for listening to my endless stories (and worries) about this project. I hope you are happy with the result!

Table Of Contents

List Of Figures

List Of Tables

1. Introduction

This chapter will give insights into the background of the situation, the most important conflicts, and challenges that will be focused on throughout this project. Following this, the aim of the project and its supporting research questions are described and a brief outline of the thesis is given.

1.1 Background & Challenges

In the first few years, a child is going through the most important developments in their life while being highly sensitive to their environment and their experiences in life [1] [2]. Positive experiences ensure a smooth development, but negative experiences highly increase the risk of problems later on such as developmental delays or socio-emotional problems [3]. Children are mostly shielded from stressors by their caregivers, who act as a sort of “buffer” [4]. However, if their caregivers experience a lot of stress themselves or if other big things are going on in their environment (e.g. moving houses), this can result in a weaker bond between the caregivers and the child and their stress level can increase [5] [6] [7]. A caregiver could, for example, get home from a busy day and continue working at home because of deadline pressure, unknowingly bringing these stressed feelings home for the child to feel as well. Since the child is still very young, it is hard for them to communicate verbally with their caregivers that they are feeling stressed. This makes it difficult to reliably recognize when a child is stressed.

Paediatricians see the child’s development from up close while maintaining a professional and neutral view. As paediatrician Ellen van der Gaag stated, even though they are not qualified to focus on mental health issues such as stress, paediatricians often still recognize this at the side of the child (e.g. through behaviour such as excessive crying, passivity, or clinginess) [3] [8] [9]. They can advise caregivers on this topic, but being a sensitive topic to caregivers in general, they often feel attacked or insecure as if they have failed as a caregiver and/or they refuse to acknowledge it. This often leads to the paediatrician having to redirect the child to a psychologist, leaving the subject of stress recognition and treatment to them. The current process of redirecting, recognizing, and treating stress can be very time-consuming. However, as stress can lead to developmental delays and behavioural problems that persist throughout the child’s life, it is very important to recognize stress as soon as possible so the negative impact is minimized [6] [7] [10].

Though, as mental health remains quite an abstract part of the human body, there are no completely objective screening tools commonly used that are suitable for young children.

Currently, means available to objectively sense stress (e.g. measuring cortisol levels) are only used in a lab setting for scientific or purely medical purposes and are time-consuming [11]. The doctor-patient context does not have such methods and has to use less objective methods (e.g. surveys, observations) to recognize stress. This gap between these two worlds needs to be bridged to make it easier to reliably and timely recognize stress. Technology could play a role in this increased reliability.

1.2 Focus Of This Project

This project will aim to explore the possibilities technology could bring and develop a tool that can reliably and quickly sense stress, which can be used at home to gather data in a more realistic environment, and which is openly accessible to all professionals involved in the development of a child. This will make it easier to recognize stress in children and simultaneously narrow the gap between the medical and psychological worlds. Although this topic can cover all young children, a focus will be put on infants (0-12 months old) as Van Der Gaag stated they have different stress symptoms and factors playing a role in the prevalence of stress. For this project, the goal will be to develop a tool that caregivers and their child want to use and which does not induce stress, so they can get help as soon as possible and minimize the negative impact of stress on the child's development. Therefore, the main research question we will be focusing on is:

To what extent can a tool be developed that will reliably recognize stress in babies in their home setting?

To get to the development of a tool, background research is needed in the causes and effects of stress so we can get a hold of the methods that can be used to gauge stress. Additionally, it is important to analyse existing tools when it comes to monitoring and combating stress to see how they work and in what way they are lacking. Lastly, it is important to look at the experience of the users in this case. Since stress is a sensitive subject, the tool should put additional pressure on neither the caregiver nor the infant. It is of great value to keep this goal in mind when designing the tool. To summarize, the sub-questions that will be focused on are:

- What are the causes of stress in babies?
- How does chronic stress affect infants in life?
- What are the existing aids in recognizing and treating stress (symptoms)?
- How are the existing aids lacking?
- How can a tool be designed that monitors stress without putting pressure on the users?

- How can the data be presented in a comprehensible manner?

At the end of this project, we will look back at the research questions phrased to deduce to which extent the aim of this project has been met.

1.3 Outline Of The Thesis

Before diving into the possibilities, there will be some more in-depth explanation of the factors contributing to stress as briefly described in Section 1.1. A state of the art analysis and subsequently a stakeholder analysis are done to be able to understand the situation better, know which possible techniques are already available, and to comprehend what the potential users would like to see in this product. Methods and techniques used to get to this broad image are described in chapter 3 of this report. Using these insights, several concepts have been noted and a selection of these options has been further developed in chapter 4. Through an interview process, these ideas have been narrowed down to one idea to work on, which is described and specified in chapter 5. Then the concept ideas were realized into two prototypes that can be found in chapter 6, explaining the design choices made, which are evaluated and then discussed respectively in chapter 7 and 8. In the end, the research goal and its research questions are evaluated to see whether the project has succeeded in reaching its goal, leading to a conclusion in chapter 9.

2. Theoretical Framework

Whilst the problem and its background become apparent from the introductory paragraph, there is little elaboration on the factors that contribute to stress in infants, to what extent it impacts them throughout their lives, and what tools currently are available to combat or monitor stress. This chapter will focus on the theoretical framework behind stress; discussing what is known and what remains an unsolved problem that can be looked into during this research.

2.1 Background Research

As stated before, infants are mostly shielded from stressors and other negative experiences by their caregivers. This results in a safe environment in which the child is free to explore and discover the world, being beneficial to their development. However, when caregivers are unable to do this, stress can also reach their child [4]. This section will cover the factors contributing to such stress in infants, and the extent to which they are relevant in this research.

2.1.1 Stressors

While it often remains unclear whether a specific cause is the direct reason an infant has increased stress levels, it is helpful to divide causes into three stress-inducing situations they result: a weak bond between the caregiver(s) and the child, physical pain, and instability. A combination of these situations often leads to chronic stress, triggering each other, and creating a rippling effect that leads to increased stress and the feeling of being overwhelmed [5]. The first and most impactful stressor that can play a role in the infant's life is having a weak bond with their caregiver(s). For the infant to be able to develop and explore the world, they need to feel safe and comfortable. As described in the documentary produced by Maria Farinha Filmes [3], this feeling of comfort is mainly established through contact with the caregiver(s), creating a bond filled with love and attention that the child can always revert to. While the documentary highlights this ideal relationship elaborately, it also supports this ideal through interviews with a versatile group of experts. This ideal of having a strong bond is also supported by Palmer [6], describing research done on rats and macaques about the effect of separation from the mother on the young and correlating these results with human behavioural research to be able to extrapolate these findings to humans as well. The article states that a weak bond results in unestablished feelings of safety and comfort, which leads to the child not feeling comfortable exploring the world, experiencing high stress levels as a result. A weak bond can be caused by several factors, the most dominant of which is neglect.

Neglect is seen as a chronic lack of stimulation and affection for the child, which is caused by low-stimulation environments and inconsistent parenting. Spratt *et al* state [12] that this can occur both in situations where caregivers are present as well as in orphanage settings. For the former, it is implied that factors such as financial problems contribute to this. For the latter, they describe that neglect is common as there are no primary caregivers present for the child, leading to less one-on-one time spent with the child and the caregiver. The paper, however, remains critical of the reliability of these implications as the data is obtained by parental report, meaning it is sensitive to bias. This means that, although the factors contributing to neglective behaviour might be right, the extent to which they influence neglective behaviour is uncertain. Weir [13] does confirm the occurrence of neglect in orphanages, describing children as laying in cribs all day and experiencing little to no interaction unless needed. This is elaborated on by Palmer [6] and Spratt *et al* [12], describing avoidance of eye contact, having limited physical contact, stimulation, conversation, or play, not providing affection while the child is crying, inconsistent punishment and rewards as general examples of neglectful behaviour by caregivers that can result in stress in the child**.** Because of this lack of stimulation and affection, the child does not have a safe and familiar spot they know they can return to, making it hard and scary for them to explore the world around them and develop themselves.

A more specific problem resulting in a weaker bond with the child, occurring in mothers who have just given birth, is a postpartum depression or, in general, postpartum affective disorders (PPAD) which, according to Als and Butler [14], occur in 10-30% of women. They describe this range of disorders as types of depression or anxiety that are a result of the absence of pregnancy, which can differ in severity, and can result in the mothers losing interest or pleasure in activities, feeling worthless and/or guilty, and an overall inability to cope with the infant's care. Judge *et al* [15] confirm these findings, further stressing the significant effects PPAD can have on the cognitive and emotional development of infants. Whereas they state that this effect can be decreased through increased prevention and treatment of PPAD on the mother's side, Azghar and Amso [4] argue that focus should be put on infant stress interventions or on the mother and child simultaneously. However, both papers agree that PPAD has a great impact on the development and well-being of infants. Oyetunji and Chandra [10] take it a step further and describe the impact of PPAD as creating a ripple effect that influences the infant on many more aspects for years, which is confirmed by Lyons-Ruth [16] in their review on the effect of attachment behaviour on behavioural problems and increased stress levels. Overall, it can be concluded that

PPAD can significantly impact the well-being of infants in the longer term and that there are multiple ways to tackle this problem, both through the mother as well as through the infant itself. This factor, as well as neglective behaviour, leads to a weaker bond with the child which leads to stress and thwarts the opportunity for the infant to develop themself.

The second factor can be seen as a stressful response of the body itself: pain. The registration of pain in the brain can enable a stress reaction by activating the HPA (hypothalamic-pituitary-adrenocortical) axis, which is described by Palmer [6] and confirmed by Nachmias *et al* [17] as the interaction between the hypothalamus and pituitary gland in the brain and the adrenal glands, which increases the production of the stress hormone cortisol to help the body cope with the stressful situation. Pain is described by Hannibal and Bishop [18] as an indicator of threat or danger, which can be increased by an exaggerated psychosocial response and even lead to chronic pain and stress. The latter is also confirmed by Palmer [6], stating that while pain often leads to acute stress only, it could develop into chronic stress if no help is provided. Therefore, it is valuable to look at the origin of pain.

There are multiple causes of physical pain, some of which lead to stress already and some of which only cause stress through the infliction of pain. Palmer [6] describes abusive and neglectful behaviour (e.g. hitting or not feeding the child) as causes of pain, which have also been stated earlier as independent causes of stress. Other factors leading to physical pain such as medical conditions (e.g. colic or cradle cap), inoculation and sensitivity reactions to formula are described by Palmer [6] as well as Michigan Medicine [19]. Braarud and Stormark [20] zoom in on the effects of inoculation, observing how the infant's perception of pain is greatly influenced by the caregiver's perspective towards the situation. However, pain itself remains a big factor that indicates stress since it can have so many various causes that range from medical problems to abusive behaviour.

The final factor contributing to increased stress levels is the situation in which big changes in their life or family are going on. Ryan [8] states that these situations could be the birth of a family member or a divorce, but also moving houses and milestone transitions. The article claims that losing the comfortable feeling of safety and stability results in stress as it evokes an overwhelming feeling of anxiety. Umberson and Thomeer [5], however, claim that this unstable situation leads to

the caregiver's experiencing stress and tension which negatively affects the relationship between the child and the caregiver. Spratt *et al* [12] then state that this negatively affected relationship can even lead to neglectful behaviour towards the child, having an even bigger impact on the infant. While the first article is aimed more towards caregivers and is not written as a scientific paper, it has been medically reviewed and posted on a reliable publisher page. Rather than one of the two claims being right, it is more likely that a combination of anxiety in the child and a strained relationship with their caregiver caused by instability results in increased stress levels of the child. There are many other situations in which stress levels might rise, but as stated by Azghar and Amso [4], most of the time the infants are shielded from this through their caregiver acting as a buffer. This can also help clarify why the factors that do result in stress in infants usually also concern the caregiver(s), directly or indirectly.

2.1.2 Short-Term Effects

Stressors have direct, short-term effects that can either be measured or observed. Measurable symptoms can be described as biomarkers, which Califf [21] states as characteristics that can be measured to recognize biological states and changes. These can be used to quantify stress and recognize it reliably once limits and deviations are set. Cortisol, also known as the "stress hormone" is the primary biomarker for stress and affects other biomarkers as well. It is produced in the adrenal glands and this production increases as a direct result of stressors. This is done through interactions with the HPA axis as described thoroughly by Palmer [6] and confirmed by Nachmias *et al* [17]. Small and short rises of cortisol are completely normal and healthy for people, following acute stressors and the hormone's circadian rhythm with standard rise and fall moments, which stabilizes sometime after birth. There was no consensus as to when this happens, with studies varying between two weeks and nine months since birth. However, De Weerth *et al* [22] state after an experiment that the circadian rhythm of cortisol is already established in the first half-year of life.

Direct results from an increased cortisol level which are also biomarkers are described by Palmer [6], stating that they lead to an increased heart rate, elevated blood pressure, increased blood sugar, and interrupted digestive and kidney functions. Hannibal and Bishop [18] confirm this, further elaborating by describing the body's activated "fight or flight" response as a result of increased cortisol levels, which can be observed through increased perspiration levels, disrupted breathing patterns, and dilated pupils. The paper elaborates on this by describing the suppression of non-vital organ systems and the decrease of inflammation such that the body can manage the

stressor effectively. They make a distinction between acute and chronic stress responses, describing which responses are always apparent in stress and which are a result of chronic stress only. The symptoms described previously are seen as a result of acute stress, which are very well-suitable aspects of the human stress response. However, prolonged exposure to high levels of cortisol (i.e. chronic stress) can lead to cortisol dysfunction, risking problems like physical and mental problems such as bone and muscle breakdown, fatigue, or memory impairments. This means that besides cortisol there are other biomarkers such as heart rate and blood pressure that change as a result of changed cortisol levels and can serve as an indicator of chronic stress as long as they are measured over a longer period.

Following these biomarkers described above, studies describe several observable effects that can be seen in developmental and behavioural problems that infants experience as a direct result of stressors. Although these are not easily measurable and it is not always the case that stress can be seen in behaviour, it is still useful to research these problems that can occur as these signs can prove to be very useful when solidifying the presumption that an infant is suffering from stress. It should be noted that one cannot conclude stress from just looking at behaviour, as it has been proven by Jones *et al* [23] that stress can also be present without any behavioural indications. Looking at one of the biggest stressors, Oyetunji and Chandra [10] look at postpartum affective disorders (PPAD) and their effect on the infant in their literature research. They note an occurrence of delays in motor and cognitive development but discuss their duration and severity as there does not seem to be a consensus on this. However, a great majority of the sources described in the paper do confirm the negative impact of PPAD on the developmental process, which is also confirmed by Spratt *et al* [12] in their research on the effect of early neglect on the child. While neglect and PPAD are not necessarily the same, the first can be the cause of the latter, and both factors are described as stressors in this review. Oyetunji and Chandra [10] also describe growth issues and sleeping problems as a result of PPAD, the first of which occurs because the weak bond with the caregiver results in neglective behaviour from the caregiver as they care less for the child and have a hard time interpreting the infant's nonverbal communication, leading to a lack of nutrition and eventually growth problems. They state that this effect is even bigger when the mother does not breastfeed, although the paper does not clearly describe why this is the case.

Sleeping problems such as nocturnal awakenings and a short sleep duration are also stated by Ryan [8] and confirmed by Sorondo and Reeb-Sutherland [24], describing the effect of

maternal stress on the quality and duration of sleep of their infant. In their research, they describe the development of infant sleep patterns by comparing several studies and conducting an experiment. Concluding, they infer that maternal stress does significantly negatively affect this development, supporting the earlier statement Oyetunji and Chandra made.

Lastly, behavioural problems such as clingy and regressive behaviour are described by Ryan [8] as a symptom of stress. Although this is not a peer-reviewed paper, it has been medically reviewed and can be seen as reliable. Furthermore, Spratt *et al* [12] also describe behavioural problems as a result of stressors. They do remain critical about this occurrence, as it can also be the cause of it - leading to stress in the caregivers which is then reflected on the infant. Looking at the description of both measurable as well as observable effects of stressors on people, it is wise to use biomarkers to be able to diagnose stress and combine it with observations to solidify this diagnosis and rule out other causes.

2.1.3 Long-Term Effects

Short-term problems as a direct result of chronically high cortisol levels that persist for a long time can create a ripple effect in the development of the child, leading to bigger long-term problems. Besides the growth problems briefly stated before, Oyetunji and Chandra [10] examine the relationship PPAD has with poor social-emotional development in children up to two years later, which is fortified by Spratt *et al* [12] describing poor social functioning as a result of being in a neglective environment since the child misses out on social interaction and opportunity for play. This paper also states other long-term effects such as low scores on intelligence and language tests, and impaired attachment. Lastly, Palmer [6] further stresses the big impact experiences during infancy can have on adult hormone regulation, stress responses, and behaviour. This is supported by Loman and Gunnar [25], who state that negative experiences can shape the response system more reactively, making people more sensitive to stressors throughout their whole life. It can be seen that there are a variety of problems ranging from mental to physical issues that can continue influencing a person for years when short-term problems are not solved.

2.2 State Of The Art

While stress in infants, its resulting effects, and experiencing difficulty in locating it is an unsolved problem, some tools can solve a part of the problem or solve the problem for a different target group. To be able to think of new concepts and applications, it is important to get insights into such existing methods to see what can be used for this project and what has to be redesigned.

This state of the art will take a critical look at existing tools and those in development related to stress monitoring, which are divided into two categories: focusing on observation and registration to monitor stress or measuring biomarkers.

2.2.1 Observation & Registration

Observation-based tools look at behavioural cues to monitor stress by registering these signs in questionnaires, apps, or other registration tools. This category is the most commonly used way of monitoring stress by professionals, as they are accessible and affordable in a doctor-patient setting. This section will first look at non-technological tools and then provide an overview of the technological possibilities.

2.2.1.1 Non-Technological

The basis of all non-technological observation-based tools is to look and deduce. The most primary method of diagnosing stress mostly through observation is by looking at crying patterns, limb movements, and facial expressions to deduce whether the child is stressed [7].

2.2.1.1.1 Observing Pain

It is also possible to look at pain rather than stress when observing someone, as pain is often a by-product of stress. Therefore, it elicits a similar response in the body as stress does, meaning it can be used to monitor stress – as long as the method used for this does not inflict pain itself. Mörelius [26] describes several tools that are used for this. Firstly, the paper focuses on the *Premature Infant Pain Profile (PIPP)* which combines behavioural variables (brow bulge, eye squeeze, and nasolabial furrow) with physiological variables (changes in heart rate and oxygen saturation) and contextual variables (gestational age and state of arousal) to assess acute pain. The state of arousal can be assessed using, for example, the *Brazelton state*, which focuses on six states of the baby: deep sleep, light sleep, drowsy, alert with a bright look, both eyes open and considerable motor activity as well as brief fussy vocalizations, and crying. A slightly different method of assessing acute pain is the *Neonatal Infant Pain Scale (NIPS)*. This tool uses five behavioural variables instead of three (facial expression, cry, arm and leg movements, and state of arousal) and one physiological variable (breathing pattern). Both methods are described as reliable and valid for full-term and preterm infants.

Lastly, the paper describes crying patterns that can serve as indicators of pain, by looking at the time and power of cries in the four phases described (inspiration, exhalation/expiration, pause, and an inspiratory gasp). Chóliz *et al* [27] discuss a similar situation, focusing on different

crying patterns caused by fear, anger, and pain. In their research, they describe the differences in these patterns, observe the accuracy of adults to recognize them, and analyze the emotional impact of such crying behaviour on the adults. They describe differences in the state of the eyes (being closed in case of pain) and the intensity of the crying (which is at maximum intensity from the start in case of pain). However, they also state that adults have a hard time knowing the cause of crying.

While these behavioural cues can assist the process of pain and eventually stress diagnosis, there are some clear limits when it comes to conclusive reliability. As mentioned before, pain is not always present when one is feeling stressed. Additionally, it is also not a given that whenever one is experiencing pain, they are feeling stressed. Therefore, to ensure that stress is correctly noticed, one should not focus solely on measuring it through pain. Furthermore, behavioural cues are very open to interpretation and can differ per person, making them relatively unreliable, meaning that the message of a certain behaviour is not always understood by the interpreter [7]. Therefore we can conclude that while behavioural cues and pain specifically can prove quite useful when it comes to monitoring stress, it is too unreliable and ambiguous to use it by itself.

2.2.1.1.2 Questionnaires

Infants and their caregiver(s) have regular appointments with their paediatrician to observe the infant's development, behaviour, and growth. During these appointments, the paediatrician might see signs of stress or other problems. To diagnose this, they can ask the caregiver(s) to fill in a questionnaire based on their experiences and observations. These questionnaires focus on things such as social behaviour, personality, health problems, development, and much more [28]. While these screening tools are non-invasive and do not influence the behaviour of the child, they require the caregiver's perspective on their child's behaviour, meaning that the conclusions from these observations are highly sensitive to bias. An attempt to compensate for this is described by paediatrician Ellen van der Gaag [9], in which the observations made by the caregiver are judged by the paediatrician so the perspective of the medical expert is also included. This is still not a watertight solution, as conclusions are still based on observations rather than measured insights, meaning they can be interpreted differently per person. Furthermore, the screening tools are not always meant for the age group of babies and often do not specifically focus on stress, only looking at specific symptoms or problems and failing to capture the complete picture [28] [29]. Examples of screening tools used for such situations in the Netherlands are the *Child Behavior Checklist*

[30], *Infant and Toddler Quality of Life Questionnaire* [31], *Ontwikkelingsvolgmodel* [32], *Strength and Difficulties Questionnaire* [33], *Structured Problem Analysis of Raising Kids* [34], *Quality of Well-Being Scale* [35], and *Van Wiechenonderzoek* [36].

Nederlands Centrum Jeugdgezondheid [37] also describes interventions that can be used to strengthen the bond between the child and caregiver(s), acting as a tool to cope with stress symptoms rather than diagnosing stress. Examples of these interventions are *SamenStarten* [38], *GIZ-methodiek* [39], and *Stevig Ouderschap* [40]. Virtual Lab describes additional intervention methods such as the *Attachment and Biobehavioral Catch-up for Toddlers*, *Family Foundations Interventions*, and *Maternal Bonds* that have the same purpose [4]. The downside of these interventions is that they are only useful once problems have been identified.

By using the observations that caregiver(s) and professionals make and registering them using a questionnaire, it is possible to diagnose stress in infants. However, this method only relies on observations which can be interpreted inaccurately, meaning that although the professional's view is included in this method, it is still not a perfect way of monitoring stress in infants.

2.2.1.2 Technological

Technological advancements on the observational side of stress monitoring mainly aim to make the registration of stress signs easier and more accessible. It can also help with decreasing the amount of bias present in certain observations, which will result in more reliable conclusions.

2.2.1.2.1 Conversational Agents

A technology-based alternative to the questionnaires described above is to make use of interactive chatbots or conversational agents. These agents have human-like properties such as a name, physical appearance and a personality, and increase the interactivity of questionnaires. This interactivity can range from standard questions asked by an anthropomorphised software program to personified questions that change based on the user's answer.

A different way in which conversational agents appear in technology is in the shape of smart assistants such as Google Assistant, Siri, and Cortana. The difference between these assistants and the chatbot is that instead of conducting a survey or an interview, these assistants focus more on executing commands given by the user [41]. These human-like aspects could help people in giving answers and writing down the information that is required.

In their research, Sannon *et al* [42] compare the answers given in a regular survey to answers given through the chatbot to see whether this is the case. They observe that, contrary to their expectations, people are more inclined to share personal details with the survey rather than the personified chatbot. Additionally, the amount of detail in the answers given by the participants was also more in the survey compared to the chatbot. They suspect that this occurs because people see the human-like aspects of the chatbot as less trustworthy and less objective. Concludingly, Sannon *et al* suggest using simple, less personified conversational agents when it comes to sensitive topics. This means that, looking at this research, it is wise to be aware of the impact human-like technology could have on the willingness of users to give elaborate answers or input. While conversational agents can be a viable way of digitising questionnaires and making them more accessible, it shows that it is still not an ideal medium to monitor stress.

2.2.1.2.2 Mobile Apps

A different approach to digitising the observation-based tool of questionnaires is through stress-monitoring apps such as Headspace [43] and Moodfit [44]. These can be used to keep track of stressful feelings, mood changes, and to practice meditation as a remedy. Whereas Headspace focuses on coping with stress through meditation and mindfulness, Moodfit aims to make their users aware of their moods first, by letting them register mood readings and other activities so they can work on it themselves. While these apps are accessible and low-cost options for users to monitor stress levels, it remains hard to get reliable data from this medium as these are purely observation-based tools.

Researchers at the Dalhousie University in Canada, however, have developed a mobile app that does a little bit more than that. The app called PROSIT does not only register input that the users fill in themselves, but it also measures the user's emotions through the way they use their phones. Additionally, audio recordings are analysed to increase reliability in stating the user's mood. PROSIT can analyse the speed at which the user types, the amount of force used when doing so, the kind of apps they use, the music they listen to, and many other things. While this app is an example of a tool that is used passively whilst generating more reliable input compared to observation-based apps, there is a great risk of violating the user's privacy since every action on their phone is analysed. However, this is known by the researchers and covered by letting users sign a consent form and storing data in a secure location [45].

Although there are great possibilities when it comes to mobile apps, both in the ways of making it easy to monitor one's mental health as well as increasing reliability in doing so, there are still points for improvement. Additionally, looking at the scope of this research, the use of mobile apps is not very well-suitable to increase reliability since the user of the app would not be the person whose stress levels are being monitored – increasing the risk of misinterpreted information.

2.2.1.2.3 Facial Recognition

A completely different method of observation-based stress-monitoring is invented by Rice and Dunbridge [46], having created a camera with image processing software that analyzes stress and emotion through the user's facial expressions. The facial image generated through the camera is scanned and critical areas of the face are located. The parameters of these critical areas are then compared to those stored in the database to categorize the facial image created, creating an assessment report as a result. The reliability of the assessments made are also included in the report so the results can be appropriately interpreted. While this specific example is still in progress, several similar projects lead to the same thing: being able to read one's facial expressions through image recognition only. Although it is uncertain whether the software Rice and Dunbridge developed leads to reliable results, overall this technology is seen as reliable whilst being a non-invasive way of monitoring a person's mood. However, this method needs a database to compare the input with or to train the model with, and it is uncertain whether such a database for infants does exist. Concludingly, we can state that facial recognition software has great potential of being a reliable, non-invasive, observation-based tool that can be used to monitor stress levels should a database specifically for infants exist or be developed.

2.2.1.2.4 Motion Tracking

Focusing more on the target group rather than the target functionality, the *Nanit Sleeping Bag* has been developed specifically for infants and can monitor the infant's breathing motion by letting the supplied *Nanit Plus Camera* detect the pattern embedded on the sleeping bag. This information is then sent to the *Nanit* app so the caregiver can look at the overview of the baby's breaths per minute and receive a notification when there is a problem [47]. While this product is not specifically focused on monitoring stress levels, the product's technology usage can still prove valuable when it comes to doing this in a non-invasive way. No electrical components are

embedded in the sleeping bag itself and there are no small objects, making the product very baby-proof as well.

2.2.1.2.5 Baby Cry Detection

On GitHub, a baby cry detection model is posted that uses a machine-learning algorithm to distinguish a crying baby from other audio cues. When the model recognizes the baby is crying, it plays a lullaby to calm the baby down [48]. This model is not specifically focused on stress recognition, but crying can - just like pain - be a byproduct of stress and is thus interesting to focus on. This is a different way of monitoring emotions, and since it is specifically aimed at infants it is a good method to consider when including multiple factors to monitor stress.

2.2.2 Measuring Biomarkers

Besides observation-based tools, there are also many measuring-based tools that use biomarkers to monitor stress levels more reliably. Biomarkers are measurable characteristics that are used to recognize biological states and changes, such as (changes in) stress levels [21]. This section will cover the various biomarkers that can be measured to reliably sense stress and how science and/or technology is involved in it.

2.2.2.1 Samples

The most common way of measuring biomarkers is to use samples of bodily fluids or parts and examine these in a lab [49]. When measuring stress, such samples would be blood, saliva, urine, or hair as they all contain the “stress hormone” cortisol. This hormone is produced in the adrenal glands and can increase its production in case of stress [6] [17].

2.2.2.1.1 Analyzing Cortisol Samples

There are several ways of analysing such samples, dependent on the type of sample and the desired processing time. The most common method is to analyse cortisol with radioimmunoassay, in which an antibody and an amount of tracer are added to the cortisol sample so they can bind. Then, another antibody is added and the sample is centrifuged, after which the amount of tracer left can be quantified [26]. Depending on the type of sample, it can take one day up to multiple months to get the result of the test. Ehrenkranz *et al* have tried to decrease this processing time by developing a more accessible way of analyzing salivary cortisol samples. The smartphone app uses disposable strips that can be inserted into a reader and then read through the use of a

smartphone flash. While it is not the most accurate method, it is a quick and easy way to get the first indication of one's stress level [50] [51].

2.2.2.1.2 Types of Samples

As mentioned before, several types of samples can be used to quantify stress. Each type has its own properties:

- Blood samples require little effort to gather and include several hormones besides cortisol that can be used to monitor stress, but only result in a snapshot of the person's stress levels and can influence stress levels since collecting it can cause some pain and is done in an uncomfortable setting [7].
- Saliva samples are easy to collect in a non-invasive way, but also result in a snapshot of one's cortisol levels [52].
- Urine samples have to be collected over 24 hours, requiring more effort but providing more reliable insights into one's general cortisol levels [53]. Additionally, urine samples can be used to measure norepinephrine levels, another hormone which can also be used as an indicator of stress [7].
- Hair provides insights in chronic levels of stress, which is very usable but also time-consuming as samples grown over several months are needed and additional sample treatment steps are required in the process [7] [54].

While using cortisol to indicate stress has a high reliability score and is a very objective way to monitor stress levels, aside from the downsides mentioned before, a doctor's referral is often needed to get this test and it can be an expensive option to go for [7]. One exception to this is the at-home cortisol test in which users take a sample at home and then send it to a lab to get results a few weeks after [55]. This increases accessibility and reliability by letting the user buy the test online or in a shop and collect their sample in their natural environment.

Overall, we can state that there are several possibilities when it comes to reliable sensing using biomarker samples. However, one should be wary of the limitations in the representations of cortisol levels over time and the method of collecting these samples. By making the collection of samples non-invasive and effortless, and finding a way to represent stress levels over a longer period, biomarker samples would be very valuable for this research.

2.2.2.2 Wearable Sensors

There has been a lot of research on and experimentation with sensors that can monitor biomarkers more continuously. This has also been the case for monitoring stress levels, providing a wide range of possibilities for this research. While many options are promising and subtle, they often have limitations when it comes to reliability or affordability. Nevertheless, this category of measuring biomarkers will be a great source of inspiration for this research.

2.2.2.2.1 Sweat Sensor

Sweat is a heavily focused on biomarker when it comes to sensing stress levels, as it is a non-invasive and subtle way of doing so, requiring little to no effort from the user when it comes to collecting sweat and containing various materials that can be used to quantify stress levels. There are several sensors in development that can measure stress continuously.

- Kim *et al* of the department of Nanoengineering in California [56] have developed a wearable temporary tattoo sensor that can monitor zinc levels in perspiration through the use of electrodes. To acquire sufficient sweat, the user needs to exercise, which limits the sensor in its use as it cannot be used for all regular or daily activities. However, the researchers describe the versatility of this sensor and their plans of being able to monitor other metals in sweat as well. While this is a positive prospect for the sensor, it is doubtful whether this will be beneficial to this project.
- Alberto Salleo and his team from Stanford University [57], have developed a wearable patch that indirectly measures cortisol in sweat by looking at the charge of ions that are blocked by cortisol. By attaching the patch to the skin, it sucks in sweat and filters it so charged ions remain. The sensor does not measure cortisol itself as it does not have charge, making the process of measuring cortisol a bit more complicated. The research team seems to have a goal similar to this research project, stating that “a fast-working test like this could also reveal the emotional state of young - even non-verbal - children, who might not otherwise be able to communicate that they feel stress” [57], which makes this a good example to learn from. Although the prototype works well, the researchers have indicated that they want to increase reliability and make it reusable, possibly switching to measuring saliva so users do not have to exercise.
- Researchers at Caltech [58], have developed a sensor that does not require physical exercise from the user. The sensor includes cortisol antibodies that bind to cortisol so it

gets a charge and can be detected electronically. The team has successfully conducted two experiments proving the reliability and speed of the sensor: tracking the participant for a week to confirm the registration of the circadian rhythm of cortisol and checking real-time changes in cortisol levels by triggering big changes in cortisol levels through exercise and tipping hands in ice water. The biggest downside to this sensor is the material used to monitor stress levels: graphene. The material is expensive and processing it is also not cost-efficient, meaning that the sensor would be quite pricy if it gets produced on a bigger scale.

These sweat sensors show great potential for real-time, continuous stress-monitoring, although they are still in development and often need exercise to be able to do measurements. Should this be possible while keeping the sensor cost-effective, then sweat sensors would be one of the more fitting technologies that can be used to monitor stress levels in infants.

2.2.2.2.2 Brain Activity

In case of stress, the body's "fight or flight" response is triggered, meaning it prepares itself for emergencies by, for example, arranging an increased production of cortisol. This way one is more alert and can act quickly and strongly in case this is needed. This is all regulated through the brain, meaning that feelings of stress can also be monitored through the brain [59]. Several products have been developed which include sensors to measure brain activity and monitor stress.

Muse is a headband combined with an app that measures the brain activity using seven sensors divided over the headband. Users of this product can learn to control their brain states and become more focused. While it is not completely focused on monitoring stress, it aims to let users reach the opposite state: being calm and relaxed. Muse is extensively based on neuroscience and also used by neuroscientists in experiments in addition to the regular consumer use. Several types of headbands for specific uses are developed, and the costly headbands are supported by an app that visualizes the input it gets [60].

Besides this, there is also a smart ring made by V1bes that can measure heart rate and brainwaves to monitor one's stress level. It will measure heart rate continuously through the finger and can be held up to the forehead to also measure brainwaves, which increases accuracy [61]. While it is an easy and relatively comfortable way to monitor stress, it seems obtrusive and awkward to use. However, it is positive to see that they focus on several kinds of stress and made

their design choices based on disadvantages other tools have (such as interference by sweat, dirt, or hair).

While both examples do look promising looking at it technology-wise, these tools are not very subtle. They are striking and, in case of the V1bes ring, need active usage to be more accurate. By keeping these comments in mind, we can try to ensure this is not the case in the prototype.

2.2.2.2.3 Breathing Monitor

Besides analysing bodily fluids to monitor stress, it is also possible to observe one's breathing pattern and intensity as well as the oxygen saturation level. The brain's functioning and state are affected by one's heart rhythm, whereas the heart rhythm is affected by one's breathing pattern (and vice versa) [62]. This means that because of this domino effect, it is very useful to monitor stress levels through breathing patterns as this can be done in a non-invasive and subtle way. An example of a wearable sensor that focuses on this is the *Spire* breathing monitor*,* developed by *The Breath Effect* [63]*,* which monitors one's breathing patterns and notifies the user of this through an app on their smartphone**.** By attaching it to a piece of clothing that is close to the chest or belly, such as a belt or bra, the sensor will give immediate real-time notifications of high stress levels.

There have also been some developments in breathing monitors developed especially for infants, mainly to avoid the Sudden Infant Death Syndrome, the term used for infants suddenly dying without an explanation. This occurs usually during sleep and accounts for 25% of all deaths during infancy [64]. A few examples:

- Maiershon and Akstein [65], developed a combination of wearable sensors in which the caregiver wears a bracelet and the infant gets an ankle brace. The ankle brace contains sensors that can measure the oxygen saturation level of the infant and detect irregular breathing. Additionally, the device uses electrodermal activity sensors to sense changes in the electrical properties of the skin as these can be caused by stress or anxiety. Combining these sensors, the device can quickly notice when the infant is experiencing a stressful situation and then notify the caregiver. Furthermore, the data collected through this continuous monitoring can also be transferred so a medical professional can take a look at it.

- A similar product has been developed by Snuza [66]. This *Snuza Hero MD* baby movement monitor can be attached to the infant's diaper and, similarly to the development described previously, can detect irregular breathing and notify the caregiver of this.
- The *Owlet Smart Sock 2 Baby Monitor* [67] combines heart rate measurements with oxygen levels to notify caregiver(s) if something is wrong by lighting up the base station in a certain colour and giving a notification on the app.

While little is known about the scientifically-based accuracy of these products, they do show different ways of applying a similar technology, enabling us to be informed of how technologies for infants can be developed.

2.2.2.2.4 Monitoring Heart Rate (Variability)

As a result of increased cortisol levels, one's heart rate and blood pressure will increase. This makes that these factors can be used as biomarkers to quantify stress levels. The most common way of using heart rate to monitor stress is through the use of smartwatches such as the ones made by Garmin, Apple, or Fitbit that measure the wearer's heart rate variability (HRV) and can provide breathing exercises and data visualizations of the data gathered [68] [69].

Similar to the smartwatches, *WellBe* is a bracelet that monitors the user's heart rate to determine the stress and calmness levels based on time, location, and people you meet throughout the day. Through an algorithm, they can connect certain events and moments to moods so the user can see for themselves if there is a pattern. The data is visualized in a clear way for the user to comprehend. Besides stress monitoring, the app also provides mindfulness exercises and programs to get rid of the stress and can show popups with tips and advice [70].

A completely different kind of tool has been developed by HeartMath [71], which is the *Inner Balance* sensor that can indicate the user's mood through their heart pattern (i.e. heart rate variability). Their philosophy is to get people to become more positive by helping them create emotional balance and HRV coherence. They state that emotions are reflected in one's heart rate patterns, as the heart has a great impact on the brain's functioning, in which negative emotions are associated with chaotic heart rate patterns [62]. Supported by an app, the user is provided with guidance and tips to become a more positive and balanced person. The sensor has to be worn on the earlobe and connects to the phone through Bluetooth or a wire [71]. While it can distinguish positive from negative emotions, there does not seem to be any clear difference

between anger and stress in their measurements, indicating that precise monitoring and clear distinguishment is difficult.

The strength of using wearables such as the smartwatches or the *WellBe* bracelet is that they provide the opportunity for more continuous and natural sensing. The products can be used at home - in the natural environment of the user - and are often designed to stay in the background while sensing. The *Inner Balance* lacks in this, as it has to be used actively and is not designed to be worn all the time. Looking at possible risks, the first two examples have the risk of being either too expensive or unreliable to be used as a standard tool. The last product described seems to lack preciseness in monitoring stress specifically but does show another way in which stress can be monitored. Overall, HRV can be seen as a biomarker that can be monitored in many different ways and with moderate reliability.

2.2.2.2.5 Electrodermal Activity Sensors

Besides a change in one's heart rate or cortisol level, stress can also be measured by looking at the galvanic skin response or – in other words – the electrodermal activity (EDA), changes in conductance of the skin which is caused by the sweat glands located there. When one is feeling stressed, this results in an increase in arousal which leads to an increased skin conductance. However, other strong emotions such as fear or joy also lead to an increase in arousal [72]. Although this makes it difficult to reliably monitor stress using EDA, there are some examples of tools that have been developed using this kind of technology.

One example is The Pip, a droplet-shaped device that measures the body's EDA through the user's fingertips as they are holding the tool [73]. Fingertips have a high density of eccrine sweat glands, meaning that this is an excellent spot to measure small changes in [74]. Connected with an app, The Pip visualizes the data it retrieves understandably. The app also provides tips to effectively live a more relaxed life. Although the reliability of this product is doubtful since EDA represents the intensity of emotion rather than the type, several scientists endorse the product and applaud it for its possibility of stress awareness [73]. This shows that it is still a valuable method of sensing to look at.

Looking at a different kind of tool, Philips Electronics and ABN Amro have developed the *Rationalizer*, a wristband (*EmoBracelet*) and bowl (*EmoBowl*) combination that monitors the user's emotions. Specifically aimed at online investors, the product signals the user once their emotions get too intense so they do not make choices based on their emotions. Using EDA sensors, the

wristband measures the level of emotional arousal. This result is then visualized on the bracelet or the bowl to reflect and signal to the user how they are feeling. Again, this product can only show the intensity of emotions and not specific emotions themselves - meaning that it is difficult to distinguish between stress and anger, however, in the context of aiming to keep online investors rational when making decisions this tool certainly can be very useful [75].

It is not certain whether galvanic skin response or EDA can guarantee reliability when it comes to distinguishing feelings of stress from other emotions. These two examples show that there are possibilities both in the way of sensing the intensity of emotions, as well as sensing stress. While we have to stay critical should this method be used in this project, using EDA to measure arousal and stress is a method that can be implemented in different ways in a relatively non-invasive manner.

2.2.2.2.6 Movement and Tension

As another indicator of stress, it is common to have tense muscles which in infants often leads to overstretching. This muscle tension is the result of the body's preparation to survive the stressful situation, so they are more pain-resistant [74] [76]. There have been some technological advancements in the field of movement or tension sensing that can be used to monitor and indicate stress.

- Biswas *et al*, have developed an assistive sleeping bag that contains pressure sensors to detect awakening stages but also helps the child fall asleep. This sleeping bag was designed specifically for children with an autism spectrum disorder, but can also serve its purpose in monitoring stress. The sleeping bag assists the child by exerting deep touch and soothing sensation, to simulate deep pressure touch that is already proved to have a calming effect on children with psychiatric disorders. The sleeping bag can distinguish normal movement while asleep from movement while awake by looking at the frequency of changes in pressure sensor data [77]. This might make it interesting for stress-monitoring as well, as overstretching needs to be distinguished from the regular movement of the infant.
- Wijsman [74] has researched the use of electromyography (EMG) signals as parameters to detect stress by designing stress tests in which EMG signals of the upper trapezius muscle were measured. During the stress tests, participants had to do a calculation, logical puzzle, and a memory task, and their stress levels were measured. These measurements

were then compared with stress levels in a rest situation, after which Wijsman concluded that they were significantly different. The paper states that the parameter is useful, suggesting to use EMG in combination with other physiological sensors to increase reliability.

- Joint research of European engineers resulted in the development of a vest containing muscle tension sensors woven into the fabric, creating a non-invasive and comfortable wearable that can be used to monitor excitation of the muscles in real-time. Excitation of muscles can be translated into the twitching of muscles, which increases in case of stress [78]. While nothing is known about the accuracy of said muscle tension sensors, it is a fruitful method of monitoring stress that can be taken into account in this research.

This method of measuring stress seems to be quite unexplored but the research that has been done seems promising. As movement can be measured throughout the body, there are many opportunities in the developments of such tools. However, we should not be too positive, as there is little known about the accuracy of this method.

2.2.2.2.7 Blood Pressure

Stress can also be monitored by looking at the blood pressure and see whether it has increased [74]. One of the most common methods of measuring blood pressure is through the use of the blood pressure monitor, which measures the vibrations in the artery wall to gauge the user's blood pressure. While this is mostly done in the doctor-patient setting, this tool can also be bought and used at home. Additionally, it has been proven that measuring blood pressure on children is possible. However, it is not a very comfortable method of sensing, meaning that it can also increase stress levels [79]. Additionally, a high blood pressure can remain after a stressor has disappeared, meaning that it can give "false positives". Lastly, an increased blood pressure can also be the result of many other diseases, so it is wise to combine this biomarker with other methods.

2.2.2.3 Combining Biomarkers

Besides the single wearable sensors, there have also been developments in which a focus has been put on measuring multiple biomarkers to get more reliable results.

- Researchers at the Department of Computer Engineering at Boğaziçi University [80] have developed a stress-monitoring wearable that is meant to be used in daily life, which monitors heart activity by using a photoplethysmogram (PPG) sensor to look at blood

volume changes, keeps track of body temperature, and monitors skin conductance through EDA and an accelerometer. Using machine learning, this data is classified and three levels of stress were distinguished with high accuracy. While this research seems very promising, it is still in its concept phase and needs a lot of development to be openly available.

- The American company VitaLNK has developed a band-aid sensor called *Vital Scout* that monitors stress signals in the heart through the use of an electrocardiogram (ECG) sensor. The sensor monitors heart rate, breathing frequency, and keeps track of the interval between exercise and sleeping behaviour. This data is then communicated to an app, in which the user can see a clear visualization of this input. If the observed stress level is exceeding maximum levels, the user will also get a notification of this. Lastly, the sensor is designed to be watertight so it can be worn continuously. It is claimed to be more precise than other health trackers because of the use of the ECG sensor [81] [82].
- Ten Eyck *et al* have developed a system to monitor the physiological state of the infant, striving to indicate an infant's stress level. This infant care station uses motion sensors, environmental sensors (sound and light) to provide care and monitor the well-being of the infant. It is a combination of a hospital bed and sensing technology focused on neonates in an ICU [83]. This means that this exact product would not be suitable for regular use at home, but this way of using technology to monitor infants is an interesting perspective to use.

2.2.3 Relevance To This Project

From this state of the art research, it can be concluded that these two categories each have their own strengths and limitations. While methods focused on observation and registration ensure conclusions are drawn over time in a natural situation and include the caregiver(s) perspective, they lack reliability and can be very time-consuming. Technology-based solutions in this category can increase the efficiency of registering observations and in some cases also the reliability. However, these tools are often not developed for infants, meaning that the risk of caregivers or professionals wrongly interpreting observations still exists. Observation-based tools, like facial or motion tracking tools, would be very useful as supportive elements of monitoring stress, but most are too sensitive to subjective results to be used independently.

Measuring tools, however, often lack accessibility and can also influence the stress levels of the person themselves. Samples that need to be tested in a lab can take a long time to give

results, are often only accessible through doctor's referrals, are taken in unfamiliar settings (excluding at-home cortisol tests), can influence stress levels themselves, and only provide a snapshot of one's stress levels (excluding urine and hair samples). Measuring tools that are available for use at home then often lack reliability, are very expensive, or require certain actions such as exercise to get results. By combining both reliability with affordability and ensuring the technology would require little effort to use, biomarkers such as cortisol in saliva and sweat, heart rate variability, and possibly also EDA or EMG would be the most fitting biomarkers to focus on for this research.

Besides the limitations and the so-called gap that current technologies and thinking in the field have, it is also interesting to look at wishes regarding the functionality of the prototype that can be drawn from this. The prototype which is desirably used in a home-setting should be accurate like measuring tools while being user friendly, subtle and accessible like some of the at-home devices. Both the caregiver(s) perspective, as well as the professional's field of knowledge, should be included in the process. Lastly, as recommended by Peña-Bautista et al [7], it seems wise to combine both fields to get the most reliable stress monitoring data, meaning that physiological and biochemical parameters should both be included in the process of the project to guarantee correct assessment, which also contributes to the wish of involvement mentioned before.

3. Methodology

Following the design process for Creative Technology as described by Mader and Eggink [84], four iterative stages of development and assessment have been looped through to combine literature-based knowledge and expert feedback with the wishes and experiences of the target users. By continuously evaluating the conceptual phase and design of the product, the best possible solution can be made that can effectively solve the problem stated in Section 131.1.

3.1 Ideation

In this phase, a more clear image of the direct stakeholders was constructed. Additionally, many ideas were generated as possible solutions to the problem. Direct stakeholders were translated into personas using the website Xtensio [85], to get more humanized impressions of them. This was accomplished based on the research done in Section 2.1, through regular conversations with experts, but also by constructing a survey for caregivers to fill in. This survey can be found in *Appendix C - Survey Questions*, and its anonymised results in

Appendix D - Summary Of Survey Results, focusing both on the caregiver's current situation and perspective as well as the aim of this project. It was constructed in consultancy with the experts and supervisors so the phrasing would be appealing to the target group and the focus would be the most useful in this project. The specific target group for this survey was caregivers who were connected and/or interested in the fields related to Infant Mental Health, assuming that they would be more willing to have an open conversation on this topic (as it can be quite sensitive). Therefore, the survey was distributed by said experts on their public channels.

After the personas were made, the brainstorming process of this phase would start. By using the divergence and convergence models as described by Mader and Eggink [84], a wide variety of ideas was generated. This was done by looking at the strengths and weaknesses of the existing tools as analysed in Section 2.2**,** and by holding collaborative brainstorm sessions. Thinking of improvements or combinations of existing tools so they fit with the aim of this project enabled us to come up with a long list of possible technologies. Additionally, using the *Mix and Match* technique [86], a list of daily activities of infants and their caregivers was combined with the ways in which stress can be gauged to get to new applications of technologies. After diverging into a long list of concept ideas, the ideas were first proposed to the experts and supervisors to get a selection based on practicality and feasibility that could then be shown to the target users in user interviews to further specify which idea would be the most suitable to look into.

3.2 Specification

Whereas the ideation phase focused on generating many ideas and ended with a first selection out of these ideas, this phase focused on narrowing down these concept ideas so eventually, one concept could be chosen to develop into a prototype. This was done by conducting target user interviews in which concept ideas were proposed and requirements were gathered.

3.2.1 Target Group Interviews

Six parents (all mothers) were interviewed, focusing on their survey answers, their experiences with professionals, and the concepts and accompanying mobile phone app that would monitor stress in infants. Several research questions were formulated to stay focused on the right topics and get sufficient information from the participants. Divided over the three topics, the research questions were:

- What kind of behaviour do caregivers see as signs of stress?
- When would caregivers use a product to monitor stress in their child?

- What concept would caregivers prefer to use when monitoring stress in their child?
- What concept would caregivers prefer not to use?
- What features or focus points would be important in the concept?
- How would caregivers want to use a supporting app?
- What features would they like to see?

The interview structure and questions (which can be found in *Appendix G - Interview Questions (Translated)*) were first piloted with peers to ensure the interview would flow more naturally, logically, and would strike no wrong note. Participants were contacted via an e-mail in which they received the information brochure (see *Appendix A.1 Interviews With Caregivers)* and a suggestion to meet. All interviews were held online, either through Skype or Google Meet, and recorded if allowed. The consent forms (see *Appendix B.1 Interviews With Caregivers)* and recordings are anonymized or encrypted and stored on the student Drive to ensure privacy regulations are followed.

Table 1. *Colour coded themes for the target user interviews.*

RQ	Colour	Code	Description
1	a	Daily activities	Eating, sleeping
1	b	Development	Social, emotional, physical
1	c	Behaviour	Crying, clinginess, tantrums, passivity
2	d	How to know the product	On your own, advised, prescribed, contact professional
2/3/4	e	When/why to use product	Moment of day, after a certain experience
2/3/4	f	Features	Measuring methods, the goal of functionalities, functionalities, time investment, cost, aesthetics

3/4	g	Wellbeing	Safety, privacy, autonomy
3/4	h	Reliability	Objective results
3/4	i	Comfort	No pain, non-invasive, subtle
3/4	j	Practical matters	Normal use of product, hygiene, location
3/4	k	Workload	The effort of the caregiver, time investment

Using colour coding (see Table 1), patterns and categories were identified in the interviews. The categories are strongly related to the initial research questions: signs of stress (a-c), first contact with the product (d-e), comments and wishes about the ideas (f-k). The last category is divided into two parts: focusing on the product and focusing on the app. This can be seen in the structure of the summary. While the general themes were constructed a priori based on these research questions, the more specific themes (themes g-k) were formulated based on recurring answers. Because of the personal nature of the interviews, only the anonymized summary covering the relevant parts is included in this thesis. The colour codes used there have been extracted from the individual interviews. The summary can be read in *Appendix H - Summary Of Interviews*. Based on the comments per concept and the concept ranking, one idea was chosen to focus on in the remainder of the specification phase.

3.2.2 Requirements

The thematic analysis as described in Section 3.2.1 was also very useful in the acquisition of requirements, mainly user requirements, as caregivers were stimulated to talk freely about their thoughts and worries. They were phrased and organized using the MoSCoW method [87] and divided over the categories *User Requirements* and *Technical Requirements*. The *User Requirements* were mainly retrieved from the user interviews – looking at themes f-k, whereas the *Technical Requirements* were formulated by the researcher themselves, using the user interviews to confirm the need for some requirements. Within these categories, the requirements were not only divided based on the MoSCoW criteria but also based on the part of the concept it belonged to (app or product).

3.2.3 Preparation For Realization

Keeping the requirements in mind, sketches have been made for both the app and the wearable. Using the Remarkable 2 [88], these sketches could quickly be exported to a computer and then finalized in Adobe Photoshop [89]. For the wearable, Fritzing [90] was also used to create a schematic of the muscle sensor.

3.3 Realization

The sketches as mentioned in Section 3.2.3**,** provided the baseline for the realization of the prototypes. In Adobe XD [91], the app design has been constructed, looking at existing application designs for reference and using Adobe Color [92] to create a general style. The wearable consists of two parts: an Empatica E4 [93] covering the heart rate variability and electrodermal activity, and the MyoWare muscle sensor [94] covering muscle tension. Although the Empatica E4 is already a solid and well-developed wearable, its data visualization software E4 Connect [95] has been used to find out the best suitable location for the wristband to be worn on the ankle. Using fabric, Velcro, needle, and thread, a soft layer has been created to cover the wristband and allow for it to be sturdily attached to one's ankle (which is often thicker than a wrist). The muscle sensor has been built following the Fritzing schematic and the guide on the MyoWare website [96]. It has been tested on the arm first, to see if it worked at all, and then on the top side of the foot/ankle and Achilles heel to see if it also worked around the foot. A soft layer containing Velcro has also been developed for this sensor, adding an extra means of attaching the sensor to the body, increasing sturdiness compared to only using the electrodes.

3.4 Evaluation

Due to the COVID-19 lockdown, the evaluation phase has been executed in two parts: a digital part (using target users) and a physical part (using housemates). For both parts, a separate research question has been phrased to ensure a clear goal was kept in mind while testing. For the digital part, this was:

How do target users experience the simplistic and quick-to-use app design?

This question focused on user experience while keeping in mind the main goals of the app: being easy and quick to use, and not including too many features as to not distract the user from the main element – the wearable. Since the wearable is aimed to get the most objective data, it should be seen as the primary tool used to monitor an infant's stress levels. Hence, the physical part of testing focused on the following question:

To what extent can the sensors of the wearable be seen as stable and usable for stress monitoring?

This research question is focused on completely different elements – stability and usability. The focus is put on evaluating whether the ankle is deemed fit for stress-monitoring wearables that use heart rate, electrodermal activity, and muscle tension, so future research project can build on that idea. In both the digital and the physical part of the evaluation phase, the requirements as phrased in Section 5.2 were kept in mind to ensure they could be validated.

3.4.1 Physical Testing

For the physical testing phase, participants were recruited within the household, as to ensure no additional face-to-face contact would be necessary. After reading the information brochure which can be found in *Appendix A.2 Physical Tests Within The Household,* five household members participated, wearing the Empatica E4 and MyoWare muscle sensor on their right foot while

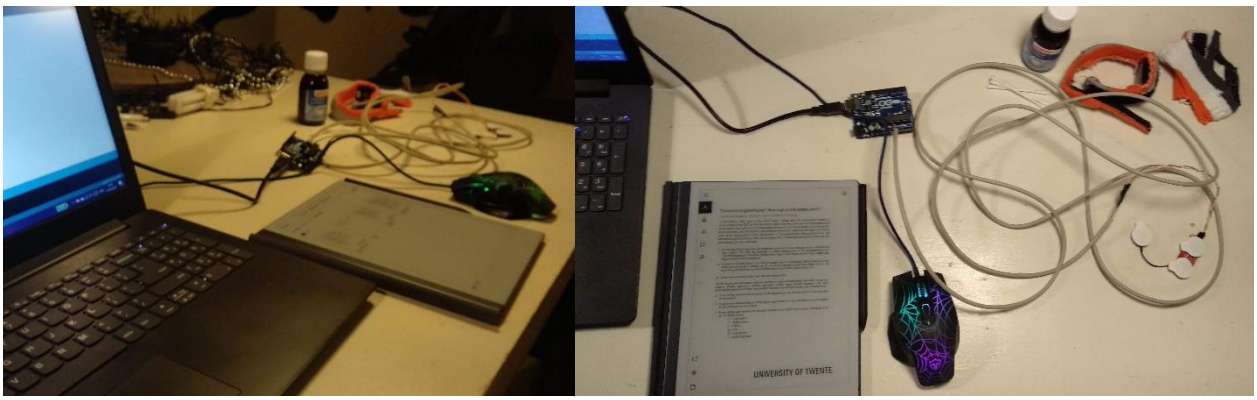


Figure 1. *Test setup for the physical prototype evaluations.*

performing specific tasks such as standing, running, and moving their foot up and down. In Figure 25, you can see the test setup.

Sitting was deemed as the most stable position and was therefore assumed to get the most realistic and stable results. Standing was expected to show peaks in muscle activity but should keep other biomarkers more stable, and running would probably cause big changes in all biomarkers that would be measured – probably the most unstable state. Because the Empatica E4 needs some time to stabilize its measurements, participants were asked to perform each resting task (sitting/standing) for one minute.

The muscle sensor was connected to the laptop through its USB port, so the Arduino code could run on it and the measurement data could be communicated every 5 milliseconds through the Serial Monitor. An E4 Connect session was also running in the background, so the Empatica E4 measurement data was also collected. Participants could read the information brochure and sign a consent form on the ReMarkable 2. Then the skin could be disinfected with alcohol and the sensors (on the right side of Figure 25) would be attached to the foot. In Figure 26 you can see photos of participants wearing these sensors.

Figure 2. *Participants wearing both the MyoWare muscle sensor and the Empatica E4 wristband.*

After having performed the tasks, the participants were asked questions about their experience when wearing the sensors and their thoughts on the concept idea. The measurement data that was collected through the Empatica E4 was also shown to them to see how they experienced gaining such insights. The complete testing procedure can be found in *Appendix L - Test Procedure Physical Testing*.

All user tests were audio-recorded to process their answers to the questions as well as possible. Some movements were also filmed, so they could be used when analysing the measurement data and showing its stability. The consent forms (see *Appendix B.2 Physical Tests Within The Household*) and recordings are encrypted and stored on the student Drive to ensure privacy regulations are followed. The interview results were summarized and can be found in *Appendix M - Summary Physical Testing*. These answers were used to acquire more recommendations for future research and assess the user experience of the sensors as they were. The measurement data that was acquired has been turned into separate graphs for each biomarker, and coloured areas have been added to indicate the type of movement at the time so one can better assess the stability and performance of the sensors. This has been done using

Google Sheets for the Arduino output of the muscle sensor, and the E4 Connect webpage for the other biomarkers.

3.4.2 Digital Testing

For the digital testing phase, participants were selected that would fit the target group: caregivers with young children (younger than four years old), preferably infants. This was done by contacting caregivers who had filled in the survey mentioned in Section 4.1 and indicated that they could be contacted for a testing procedure. Additionally, extra test participants were acquired through the personal network. In both cases, the potential participants were contacted through an e-mail in which they received an information brochure (see *Appendix A.3 Digital Tests With Caregivers*) and a suggestion to meet online. All user tests were recorded by audio or video, as to ensure that they could be processed as well as possible. The consent forms (see *Appendix B.3 Digital Tests With Caregivers*) and recordings are encrypted and stored on the student Drive to ensure privacy regulations are followed.

Six people (all mothers) were involved in this testing phase, in which they were asked to navigate through the app and complete specific tasks. Afterwards, questions were asked about their experience and their thoughts on the concept idea. The complete testing procedure can be found in *Appendix O - Test Procedure Digital Testing*. They were asked to say whatever came to mind, following the Thinking Aloud method [97]. The summary of the results can be seen in *Appendix P - Summary Digital Testing,* providing both general insights as well as specific remarks per page or task.

4. Ideation

During this phase, concept ideas were generated that could be developed into a prototype. Using the knowledge acquired in the explorative and orientating phase that is described in Section 2.1**,** personas could be derived from the stakeholders to set the basis for the diverging phase. As mentioned in Section 3.1, multiple concept ideas related to the topic of monitoring chronic stress in babies were generated before a selection was made.

4.1 Stakeholders

Four personas were constructed using Xtensio [85], covering the three important stakeholders involved in this research: infants, caregivers, and professionals. By humanizing these stakeholders into personas, their interests concerning the topic of this research could be understood better. Insights for the professionals were acquired through contact with the clients who also functioned as experts. They explained their view on the process of monitoring stress in infants and stated the problems that were encountered – as read in Section 1.1. To get an image of the position of caregivers and their children, a survey was distributed among the clients' social media platforms, which focused on general experiences of caregivers, as well as their experience concerning having a stressed child. The survey questions can be found in *Appendix C - Survey Questions* and the summary of the survey results can be read in

Appendix D - Summary Of Survey Results**.** A total of 37 caregivers responded (36 mothers, one father), out of which more than 50% indicated that their child is or has been stressed. In their answers, they explained how they had noticed that their child is or has been stressed, how that affected them, and what they tried to do to manage these stressful feelings (in both the child and the caregiver). This survey proved to be very helpful in understanding the position of the caregiver, as it is such a subjective and sensitive matter. It also helped see how the child would feel and behave when stressed, although that remains the perspective from the caregiver's side. We can not conclude for sure that the personification of the infant stakeholder is completely based on the truth, as they have not been questioned directly. However, through these methods, sufficient data was gathered to construct personas and understand the stakeholders better.

4.1.1 Infant

The position of the infant is – as stated before – the most difficult one to objectively describe. As concluded from the survey responses and literature research, infants experiencing stress often exhibit restless behaviour, cry a lot, and have eating- or sleeping problems. The persona of Bart (see Figure 3) has also been shaped this way, explaining his behaviour as his way of communicating with his caregivers – or at least trying to. Besides being stressed, Bart still likes to play and explore the world, something which is typical for infants [3].

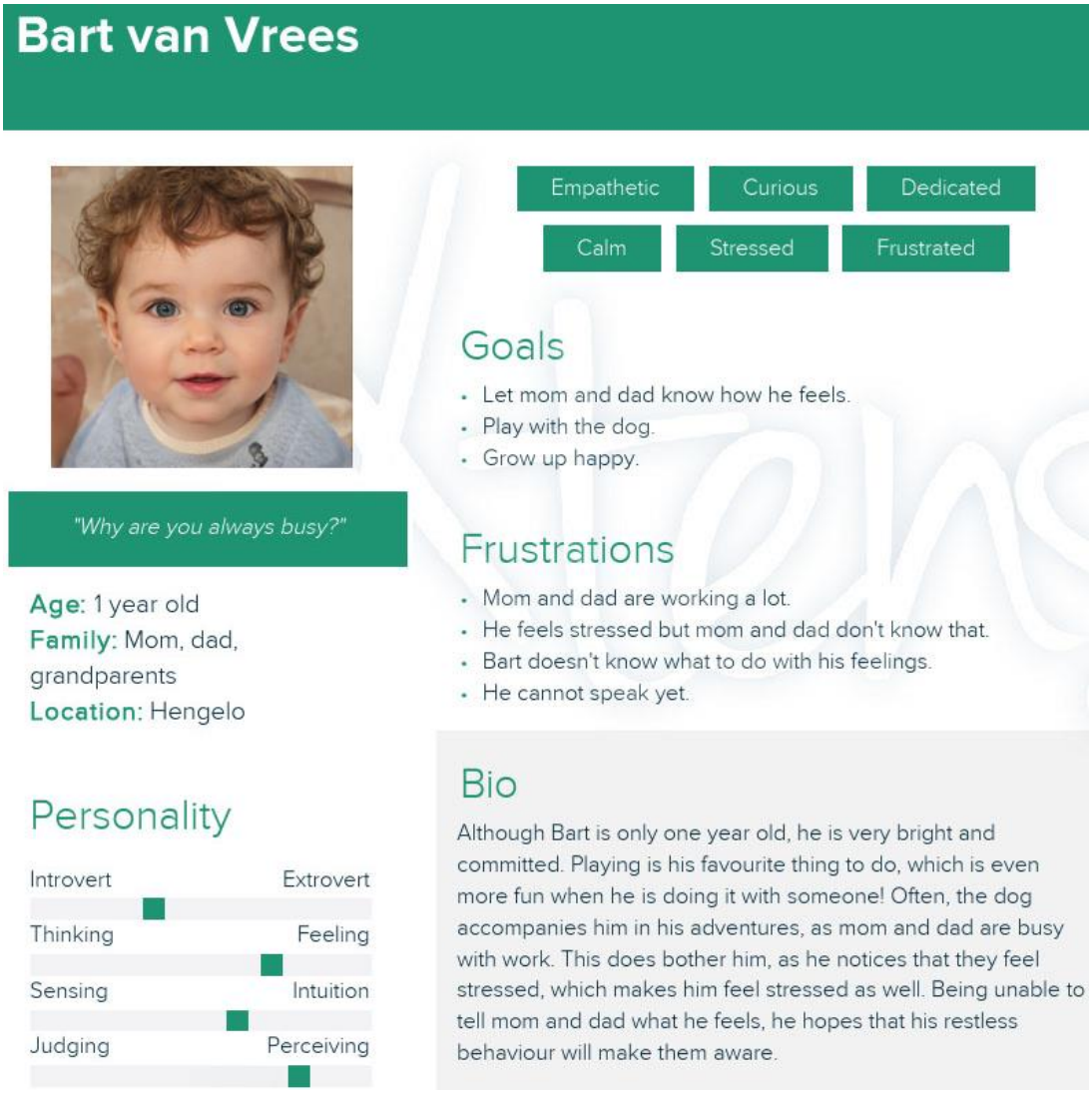


Figure 3. *The persona of the infant, Bart van Vrees.*

4.1.2 Caregivers

The role of the caregivers in case their child is acting stressed is two-edged. On the one hand, most caregivers want to find out what is wrong with their baby. They want to solve the problem for them but are unable to find out exactly what this problem is. On the other hand, caregivers are often also (part of) the cause of stress in their child. As stated in Section 2.1, having a weak bond or experiencing instability can result in stress. In the survey that was distributed amongst caregivers, several caregivers indicated also their worry that they were influencing their child's well-being with their own stressful feelings – indicating that some caregivers are aware of this possibility. Not all caregivers thought their child was feeling stressed, expressing their reasons to think so. From the survey it became apparent how connected caregivers want to be with their

child, writing down elaborately how they noticed that their child was or was not stressed. Additionally, some caregivers noted their view on asking for help or letting “outsiders” assess their children.

The two personas are based on the archetypes of caregivers that were identified. Rik (Figure 28) manifests the worrying caregiver, willing to try anything to find the cause and help their child.

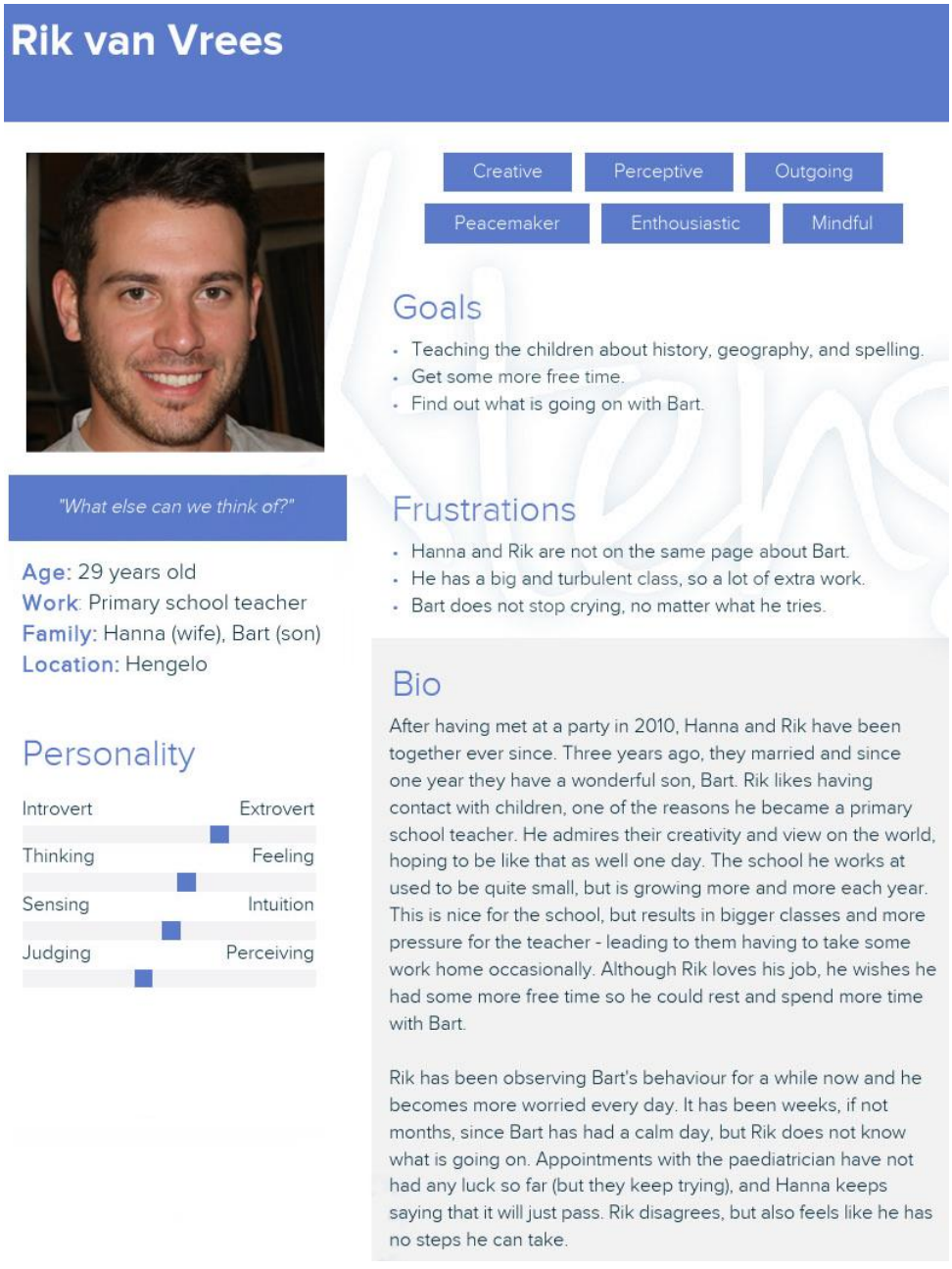


Figure 4. *The persona of one of the caregivers, Rik van Vrees.*

Hanna (Figure 5) is calmer and suspects that their child will grow out of it. She wants to be a more independent caregiver, relying on their capabilities only. Based on experiences as mentioned in chapter 0, caregivers do not always take professionals seriously if they think that their advice falls beyond their education. Hanna resembles one of these caregivers, whereas Rik trusts the professional and hopes they will provide a solution since he has none.

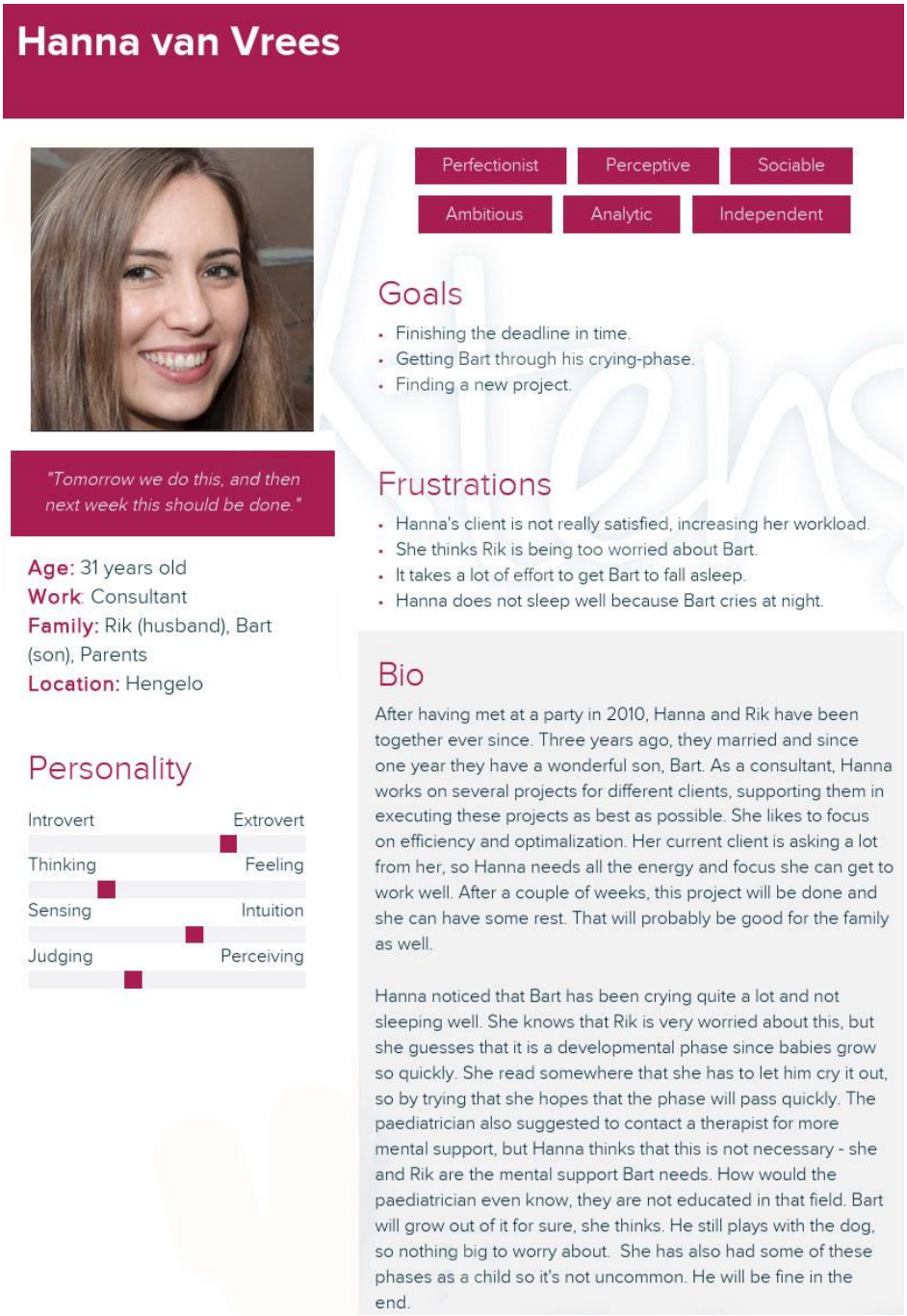


Figure 5. *The persona of one of the caregivers, Hanna van Vrees*.

4.1.3 Professional

As stated before, professionals experience challenges when it comes to open communication with caregivers. They sometimes give advice that is not completely within their field, and because of that it is sometimes not believed. Additionally, discussing the possible cause of stress with the caregivers is a sensitive topic that can easily offend or discourage them. While it is the professional's duty and aim to help their patients or clients, this is not always appreciated. Additionally, it is very difficult to diagnose stress in infants without objective and accessible tools to use. Through conversations with experts, their struggles and wishes have been manifested in the persona of Eline (see Figure 6). She is described as a caring and motivated paediatrician, who is frustrated because she cannot always help their patients as much as she would like – for the reasons described above.

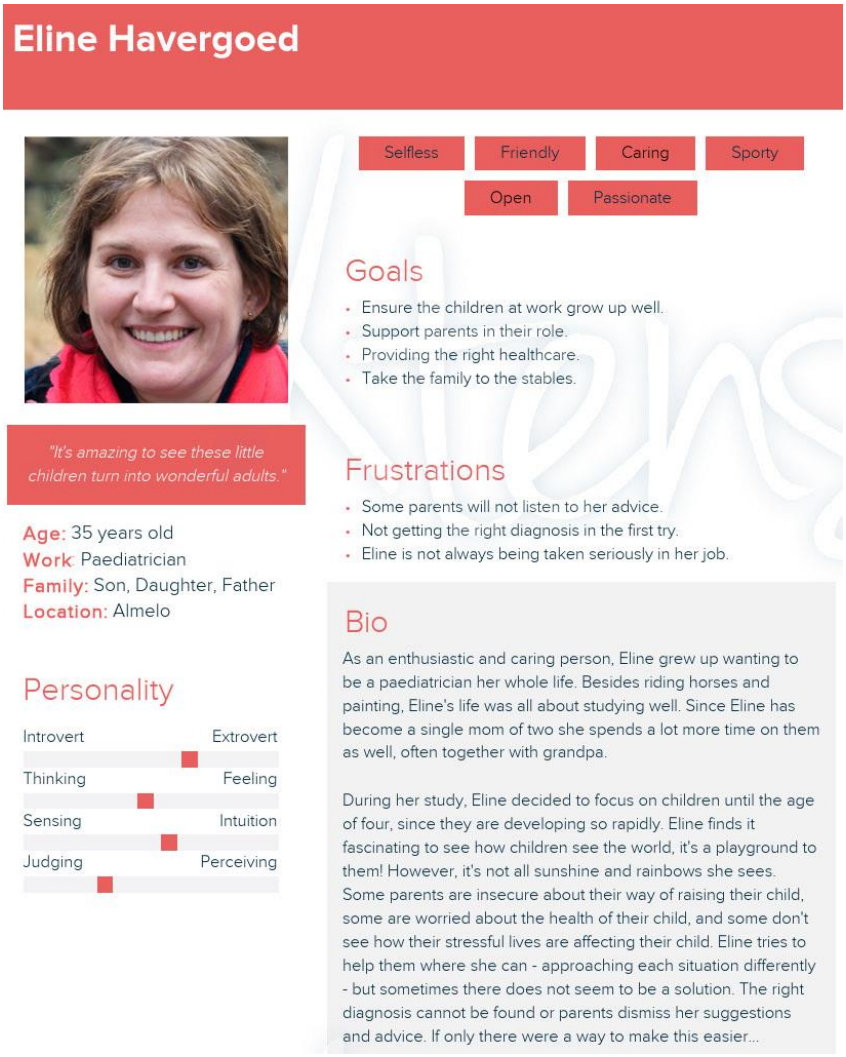


Figure 6. *The persona of the professional, Eline Havergoed.*

4.2 Diverging

Using the method as described in Section 3.1, ideas were generated taking the personas and existing tools as the basis. The initial concept ideas were divided into three categories: Observation and Registration-based ideas, Measurement-based ideas, and O*ther Applications*. Table 2 shows the ideas based on *Observation and Registration*, describing the idea as well as the probable technological application for each concept. This category focuses on monitoring stress indirectly, to ensure that the tool is non-invasive and safe for the target users to utilize. These ideas are, however, limited in the sense of reliability.

Table 2. *Concept ideas based on observation and registration.*

ID	Concept Idea	Technological Application
OR1	A tool that can recognize the infant's symptoms and then translate it so caregivers also know what the child is experiencing.	Using sound- and/or image recognition to read the child's emotions.
OR2	A tool that helps caregivers listen better to their infant's symptoms.	An app that asks focused questions.
OR3	A diary that can ask more specific questions based on the caregiver's input and create an overview of this input (statistics, data visualizations). • Examples of questions could be to ask about the symptoms of the child, food eaten that day, how busy the caregivers are, what they are feeling, etc.	A conversational agent that changes their response based on the input.
OR4	An app in which symptoms and behaviour can be noted in a schedule so patterns and possible stressors can be identified.	Gamify the app so that it is more attractive to use regularly.
OR5	An app in which the child can indicate how they are feeling by for example letting them touch colours, record sounds or video images.	An app containing voice- and image recognition which can connect these "vague" types of input and get to a reliable conclusion
OR6	Keeping track of the number of times a certain activity happens that can help indicate stress (for example: how many times does the child cry, do they play with their toy, are their diapers changed in spot X, etc.). • Downside of this is that this would require a complete Smart Home transformation.	Using sensors in specific places/on specific products to keep track.

	However, making a small attachable sensor would make it more feasible.	
OR7	A robot or app that acts as a basis doctor that caregivers can consult and describe their observations to. This tool could in response provide tips or highlight focus points for the observations.	Developing a conversational agent that responds to the caregiver's input.
OR8	Develop an app similar to the period tracker app Clue [98], which helps caregivers observe, supporting them in interpreting the symptoms of their child, but also gives tips and has the room for caregivers to also write down how they are feeling.	Developing a dynamical app that responds to the input given.
OR9	Similar to a Google Home [99], implementing such a voice recognition system so that audible symptoms can be registered and analysed, and caregivers also have the possibility of giving verbal input instead of writing everything down.	Voice recognition and analysis, speech-to-text.
OR10	A baby monitor that uses its camera to analyse the emotions or movements of the child to gauge whether they are stressed.	Facial recognition or motion tracking.
OR11	Visualize the feelings of the child so caregivers can more easily connect specific behaviour to specific causes, so they can understand their child better. • For example, if the child is experiencing a high blood pressure and a low cortisol level, this would give a different colour than when the child is experiencing both a high blood pressure and a high cortisol level. Although the child might be crying in both cases, there is a difference.	Using sensors such as blood pressure and cortisol sensors to observe bodily functions, using LEDs to communicate these measurements to the caregiver.

Focusing on reliability rather than comfort, the ideas seen in table Table 3 look at the possible technologies that can be used to measure and/or monitor stress without inflicting pain on the user. This means that, while the ideas do not specifically focus on invasiveness, the product should not pose the risk of increasing stress through its use. However, this does not mean that the product cannot be attached to or positioned in the body.

Table 3. *Concept ideas based on measurements.*

ID	Concept Idea	Technological Application
M1	A mattress that can measure stress while the infant is sleeping. This is non-invasive and requires little effort, while also being used a lot since babies sleep a lot of hours a day.	Using sensors to measure temperature, movement, or sweat cortisol. Sensor could be in or on the mattress.
M2	A toy containing sensors that can be used to measure stress through saliva, as infants put everything in their mouth so they will likely drool over the toy.	Catch the saliva and measure using a salivary cortisol sensor at the bottom of the toy.
M3	A smart diaper that can measure cortisol through urine, while being able to filter poop and being replaceable. • Maybe design it like a pad so it is reusable and does not have to be replaced.	Integrating a urine cortisol sensor in/near the bottom part of the diaper.
M4	A bib that can catch and take in saliva so it can measure its cortisol.	Integrating sensors in the cloth or developing a detachable salivary cortisol sensor device that can be put in the bib.
M5	Develop a pacifier that can measure stress using the salivary cortisol.	Integrate sensors in the teat part so it can directly measure, or integrate a strip that can catch and take in the saliva so it can be measured elsewhere.
M6	Create smart clothing that can measure stress (socks, pyjamas, bodysuit, sleeping bag).	Integrate sensors in the cloth so it can subtly monitor muscle tension, body temperature, movement, etc.
M7	A teat for baby bottles that can also use saliva to measure cortisol.	Integrate a salivary cortisol sensor.
M8	A smartwatch or smart band that can monitor stress. Since the baby is very small, it might be wiser to let it be worn somewhere else (e.g. ankle).	Measure sweat cortisol, heart rate variability, muscle tension.
M9	Sensor near the changing table that can use the urine of the diaper to “scan” or measure cortisol.	Install a scanner/measuring device through which the cortisol in the diapers can be measured.
M10	A smart tool such as a blanket, Maxi-Cosi, or stroller that is commonly used and can sense stress.	Measure temperature, muscle tension, or movement.

Lastly, some ideas were generated that did not specifically fall in either the category of registration or measurements or which did not focus on monitoring stress but rather a cause or related problem. These ideas can be seen in

Table 4.

Table 4. *Concept ideas with a different focus or combined technological application.*

ID	Concept Idea	Technological Application
OA1	A tool that can distinguish symptoms of illness from symptoms of stress.	A software application that would compare caregiver's input or measurement data with symptoms and thresholds of illnesses.
OA2	Combining the wearables described before with an app that can give tips, aid caregivers in registering symptoms, and can indicate alarm values.	Sensors as described in **[Table X]** and an app which can adapt its tips and registering options based on the caregivers.
OA3	Visualize the data input the child gave next to the diary input the caregiver gave.	Combined data visualization of OR3 and OR5.
OA4	A tool that does not monitor stress, but rather acts as a buffer from stress - aiding caregivers in this role.	An affective toy or stuffed animal that would use a voice recognition and analysis system to know when it is needed, as well as capacitive sensors to know where it is being touched.

4.3 Converging

The initial ideas as described in Tables 3-5 were discussed with the supervisors and clients for technical feasibility and functionality. As the main wish of the clients was to get a reliable tool, hence the focus of the main research question of this project, their preference went out to the *Measurement* ideas as described in Table 3**,** combined with ideas OR3 and OA2, to get broad results. Additionally, they indicated their approval of idea OR10 as it is subtle and seen as most reliable from the observation-based ideas. Some other ideas were discarded because they would not get sufficient or reliable data (e.g. M1), and eventually, their preferences resulted in a list of eight functional ideas that would be proposed to the caregivers in the user interviews. The ideas have been worked out and visualized in several drawings, which can be seen in Figure 31Figure 38 below and more high-quality in *Appendix E - Full-Size Sketches Of The Eight* Ideas.

4.3.1 Swaddle/Romper Suit

When making sketches of the swaddle or romper suit idea as seen in Figure 31, the sensors were drawn to be integrated with the fabric, similar to an electric blanket. Thinking about both safety and costs, it might also be an idea to only integrate sensors in the most useful spots that can be used to monitor stress levels. The location of the transmitter, which will send data to the application, would have to be on a place that the infant would not be able to reach - such as the shoulder.

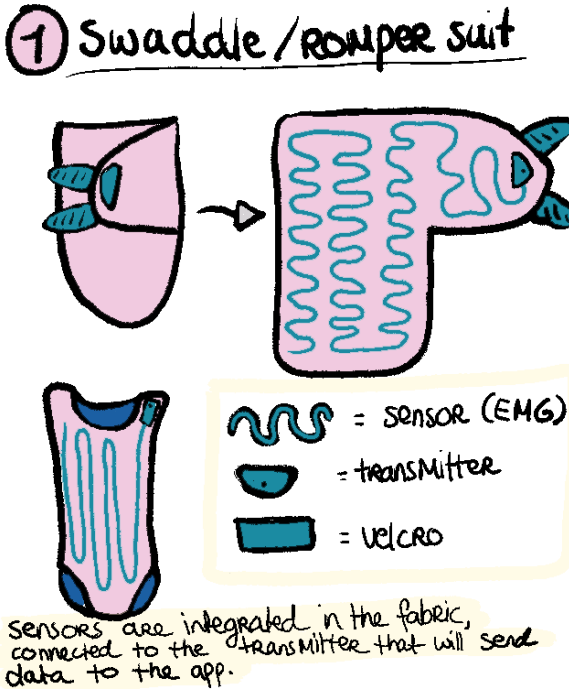


Figure 7. *Drawing of the swaddle/romper suit idea.*

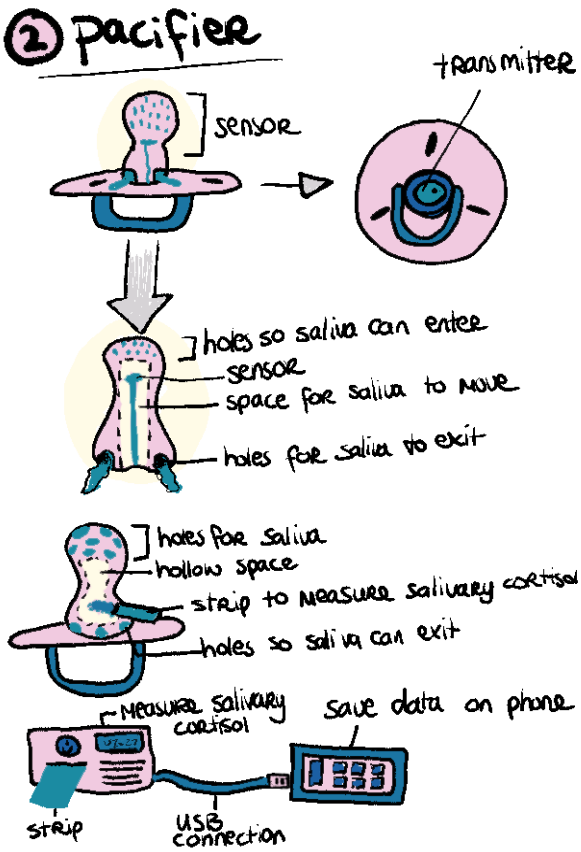


Figure 8. Drawing of the pacifier ideas.

4.3.2 Pacifier

The pacifier sketches (Figure 32) focused on two options: having an integrated sensor (top sketch) or external sensor (bottom sketch). The integrated sensor would be more efficient; through the holes in the pacifier, saliva would be able to enter and touch the sensor. Measurement data would

be sent to the app using the transmitter that is subtly integrated into the pacifier design. A thought that did emerge when working on this idea was the worry that the sensor might get saturated easily. Therefore, a second solution was thought of, the external sensor. Using “old-fashioned” strips to collect saliva, this strip could be inserted in a reader machine that would analyse the cortisol level in the saliva. A downside to this method is the increased number of steps that need to be taken, and the risk for irregular cortisol measurements.

4.3.3 Patch

The sketches covering the third idea (see Figure 33), the patch, focused on the way it would convey information, the way it would be attached to the skin, and a possibility for a more comfortably-worn patch. A possibility with the patch would be to give direct feedback through lighted colours or patterns on the patch, that could help inform the caregiver about the infant’s emotion. The top two sketches showcase a way in which this information can be given. The middle two sketches show two possible shapes when it comes to the patch, followed by a more technical sketch of the components in the patch. Lastly, the drawing shows an idea to cover the sensor in a soft fabric to make it more comfortable to the infant and make it washable. A general worry regarding this concept would also be the risk of (early) saturation which would make getting continuous measurements difficult.

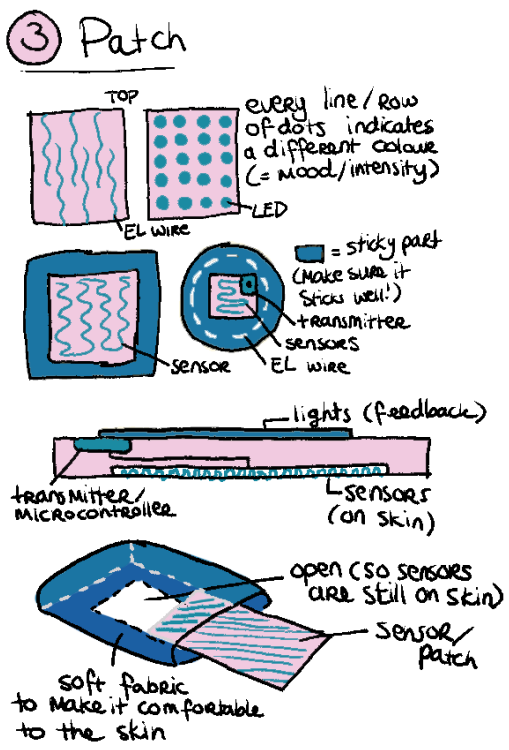


Figure 9. Drawing of the patch idea.

4.3.4 Baby Monitor

The only observation-based idea, the baby monitor, was thought to have two options when it comes to stress-monitoring: emotion and movement recognition (see Figure 34). The first option would use face recognition software to sense the emotion of the infant, using three cameras (two on the sides and one at the top) to ensure the monitor would still work when the infant would turn in their sleep. The camera at the top would be able to move along with the position of the infant's face to increase functionality. The second option would require the infant to wear pyjamas or a band with a specific pattern that a camera would be able to recognize. Through reading this pattern, the software behind the camera would be able to observe the infant's movements and sense disruptions or irregularities in breathing, overstretching behaviour, and other stress indicators.

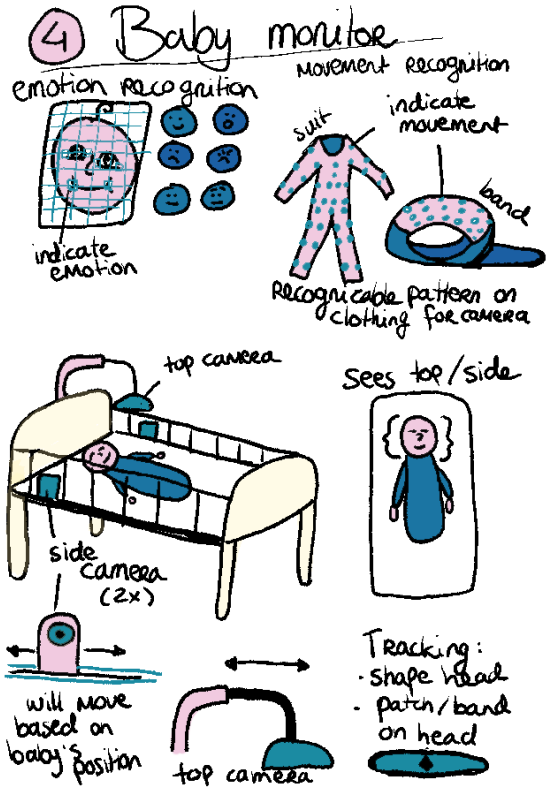


Figure 10. *Sketches of the baby monitor idea.*

4.3.5 Bib

The bib sketches (see Figure 35) also explored two options, depending on whether a spill pocket would be present. In case of a spill pocket, the sensor could be attachable to the bottom of the bib so it could catch, filter, and measure salivary cortisol through there. This would make it easier to clean and more accessible to use (being able to use it on different bibs). The bib without spill pocket would either need sensors integrated with the fabric (similar to the swaddle or romper suit), which would then be positioned as close to the mouth of the infant as possible with a transmitter in a location that would not be easily reached by the infant, or a filter or strip-like element (similar to the second pacifier idea) that could be put in the bib to catch saliva and then be put in a machine to read its cortisol values. The main concern regarding the bib would be the extent to which saliva can be filtered from other fluids that might end up on the bib as well.

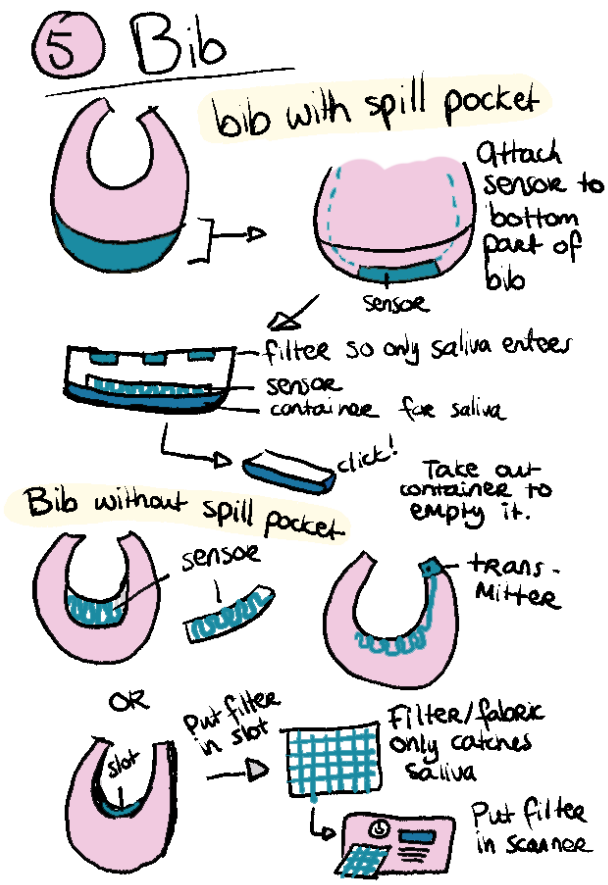


Figure 11. *Sketches of the bib ideas.*

4.3.6 Toy

The sketches for the toy showcase three designs, each with their own possibilities (see Figure 36). The first idea (top sketch), is based on a teether and contains a system similar to the pacifier to collect and measure salivary cortisol. This idea contains a USB-port instead of a wireless transmitter that can be used to send the data to a device. Using a silicone cover, the port would stay free of fluids and be completely safe. The second idea (middle sketch) is shaped like a stuffed animal and would contain salivary cortisol sensors in the fabric to ensure that no matter where the saliva would end up, it could be used and measured. Again a side note: looking at safety and costs, it might be better to concentrate the sensors into one spot. The transmitter would subtly be integrated into the design of the toy. The third and last idea (bottom sketch) would use a strip similar to the second pacifier idea to collect saliva and read its cortisol values. The shape of the toy resembles a rattle.

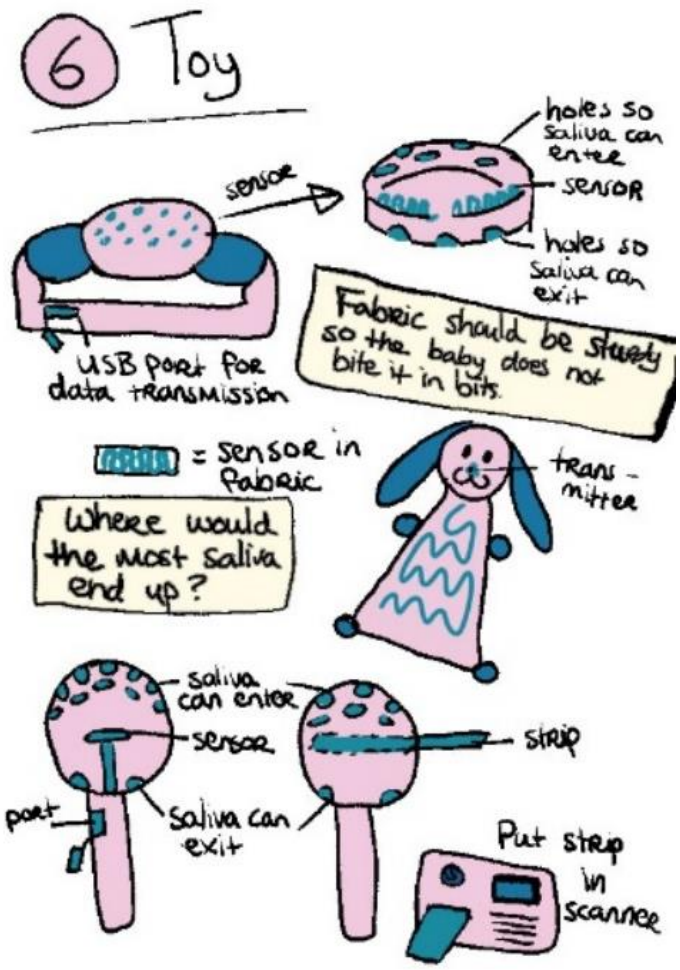


Figure 12. *Sketches of the toy ideas.*

4.3.7 Diaper

The diaper sketches all focus on the same kind of sensor: a pad-like sensor that can be attached to the diaper and measure cortisol through urine. The drawing as shown in Figure 37 explores how this sensor can be attached and cleaned, to try and find the most optimal way for caregivers to use and reuse the sensor while also keeping it comfortable and subtle to the infant.

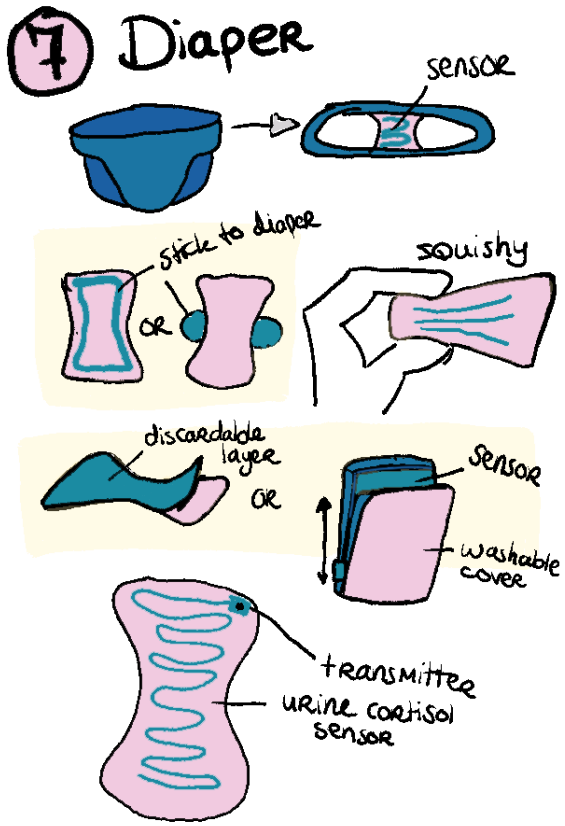


Figure 13. *Sketches of the diaper idea.*

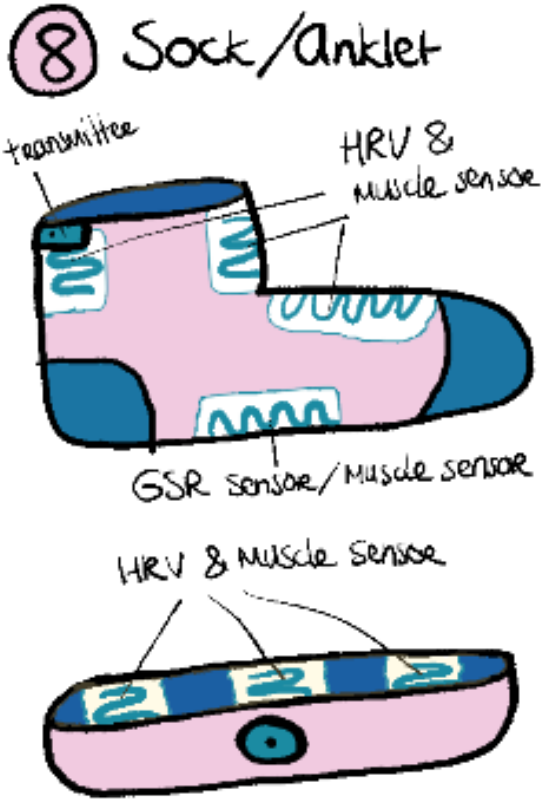


Figure 14. *Sketches for the sock or anklet idea.*

4.3.8 Sock/Anklet

Lastly, the sock or anklet idea. This sketch in Figure 38 showcases the two options and locations of the sensors in the respective options. The sock would contain three types of sensors, using the ankle for heart rate variability and muscle tension data, and using sensors on the foot to measure the skin conductance and possibly also muscle tension. The anklet would only focus on heart rate variability and muscle tension, as it is only positioned on the ankle.

4.3.9 Overview For Caregivers

The eight ideas have been summarized in one overview that would make them more easily comprehensible when shown to the caregivers in the target user interview. This was done by sketching infants using or wearing the ideas, while simultaneously providing a textual description of each idea to give more detailed insights. The drawing can be seen in Figure 39, which was accompanied by information as shown in Table 5. The table describes the options (if multiple) per idea in a few key words, then provides a more elaborate description and lists the main actions that need to be taken to use the product. The aim is to give caregivers quick insights into the idea behind the sketch while still keeping it understandable. Both the table and the figure have been translated into English for this thesis. The original image used can be found in *Appendix F - Dutch Overview As Shown To Parents*, which is written in Dutch but is the same content-wise.

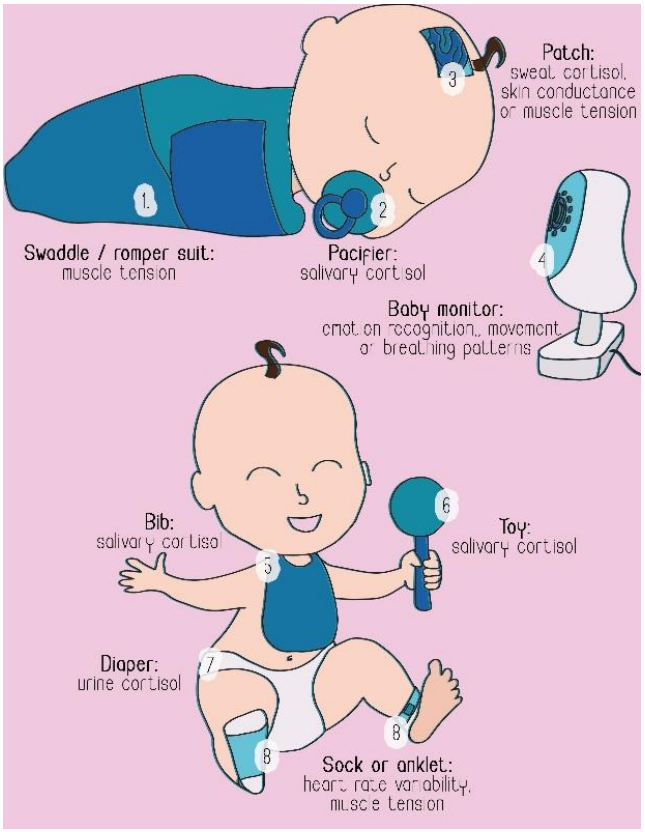


Figure 15. *Drawings of eight concept ideas as shown to parents.*

Table 5. *Description of eight concept ideas as proposed to the caregivers.*

No.	Product	Description	Use
1	**Swaddle/romper suit**		
	Sensors in the fabric	Contains sensors that will measure the infant's muscle tension, as well as a transmitter to send the data.	Put swaddle/romper suit on infant and turn it on.
2	**Pacifier**		
a	Internal sensor	Collects saliva and can read through the sensor in the pacifier whether the baby is stressed. It sends data through a transmitter.	Give to baby, turn on.
b	Strip	Collects saliva on a strip which can be put in a machine to read the cortisol values. The	Give to baby, put strips in the machine and

		machine can be connected to devices so it can share data.	read, connect to a device.
3	**Patch**		
	Sensors in the patch	Contains sensors that read several bodily functions and send the data. The colour of the patch can give immediate feedback to the caregiver regarding the child's mood.	Attach to baby, turn on.
4	**Baby monitor**		
a	Emotion	Recognize emotion by recording the baby's face. By focusing on specific locations in the baby's face it can distinguish emotions.	Mount the camera, position it the right way, turn it on.
b	Movement/ breathing patterns	Recognize stressful movements (overstretching) or stressful breathing (irregular) by giving the baby clothing with a pattern that enables the camera to read such behaviour.	Mount the camera, position it the right way, turn it on. Put the clothing with the pattern on the baby.
5	**Bib**		
a	Attachable sensor	An object that can be put at the bottom of the bib so it can collect saliva, filter it and read it through a sensor. The information will be sent through a transmitter.	Put the sensor in the bib, put the bib on the infant.
b	Internal sensor	Sensors at the top part of the bib that can read cortisol through the saliva it will collect. It will send data through the transmitter.	Put the bib on the infant, turn it on.
6	**Toy**		
	Sensor at the bottom of a hollow part	Collects saliva and reads it. The toy can be connected with a device through a coverable port so information can be read.	Give to baby, plug in.
7	**Diaper**		
	Attachable sensor	A pad-like sensor with a protective layer that can be attached to the diaper so it can analyse urine. When changing the diaper, the sensor can be detached, the protective layer can be replaced, and the sensor can be reused in a different diaper.	Put the sensor in the diaper, change the protective layer.
8	**Sock/anklet**		
	Sensor in the fabric	The sock or anklet contains sensors that would measure heart rate and muscle tension through the dorsum of foot or the ankle. Through the transmitter, data will be sent.	Put sock/anklet on baby and turn it on.

5. Specification

In the specification phase, the list of ideas was further narrowed down in another converging step, ultimately leading to one concept idea that would be developed into a prototype. User interviews were held to acquire requirements and decide on a concept to focus on and sketches were made to get detailed insights into the components and elements needed for the prototype.

5.1 Choosing One Concept

The ideas as visualized in Figure 39 and Table 5 in Section 4.3.9 have been used to give people quick insights into the ideas that I was working on. They were first shown to several acquaintances both familiar and unfamiliar with the topic of this project to ensure that the overview was clear enough to understand. Subsequently, the overview has been shown to six parents (mothers) in the target user interviews. This interview was focused on caregivers that had filled in the previously mentioned survey (see Section 4.1**)** and revolved around three topics: their survey answers (to get more insights and understand their answers better), their experience with a professional (to find out how they would like to be approached for help), and their opinions on the concept ideas and app idea. The complete summary of the interview can be seen in *Appendix H - Summary Of Interviews*. Several research questions were formulated (see Section 3.2.1**)** to get clear focus points as to what information shall be retrieved from the interviews. They were focused on caregivers' ideas of stress symptoms, their experiences with professionals, and their preferences regarding a stress-monitoring tool.

The most named signs of stress were: excessive crying, sleeping problems, not finding a rhythm, being tense or restless, being sensitive or overstimulated, acting clingy, or having developmental delays. These do confirm our findings in Section 2.1 and show the extent to which caregivers notice signs of stress - mainly focusing on behavioural factors. They also expressed their need for a more objective tool that would sense bodily functions so it could support the aforementioned observations caregivers would make.

When looking at the caregivers' experiences with professionals and their wishes regarding getting to know the product, it became clear that caregivers would try anything if it would help their child. Most of the caregivers indicated they look for solutions themselves, but would prefer if a professional would guide or advise them, as long as they could adjust the solution to their child

and would still be able to rely on their intuition - staying involved. It was suggested to pre-emptively use the product since it is not always easy to see if a child is stressed.

Talking about the concepts one-by-one, as well as discussing the idea of a tool that could monitor stress, caregivers had very specific wishes, concerns, and expressions. These helped to choose the most suitable concept to work on and helped result in an overview of requirements that can be read in Section 5.2. Besides commenting on the ideas, the participants were asked to rank the concepts based on a specific criterion (e.g. ease of use). The complete ranking can be seen in Table 6. The green cells represent the top-3 per category, meaning that the swaddle/romper suit was in the top-3 in two categories, whereas the sock/anklet was in the top-3 in all categories. The sum shows the overall score of the product throughout all categories. The top-3 in this category nicely aligns with the "General preference" category, meaning that there are no big differences in scores among categories. This is also reflected in the near-constant pattern of the baby monitor, diaper, and sock/anklet being in the top-3. Out of these three best-ranked concept ideas it was decided to focus on the sock/anklet concept as it was received most positively and evoked no extreme reactions from caregivers.

Table 6. *Summary of the product ranking.*

Product \ Category	Comfort (child)	Comfort (parent)	Easy to use	Clear in use	Added value	Subtle functioning	General preference	Sum
1: Swaddle / romper suit	31	20	22	19	21	25	32	170
2: Pacifier	22	21	23	25	27	24	34	176
3: Patch	42	35	22	21	18	26	35	199
4: Baby monitor	10	17	16	25	13	21	25	127
5: Bib	28	28	26	24	21	23	40	190
6: Toy	28	28	29	24	24	25	40	198
7: Diaper	24	30	17	19	16	13	24	143
8: Sock/anklet	16	13	14	13	12	19	12	99

Besides consulting the clients involved in this project, the concept ideas have also been discussed with other experts: paediatrician and neonatologist Ageeth Kaspers, and medical pedagogical care provider Annemiek Dalhoeven. They indicated that a previous project focused on measuring

salivary cortisol had shown no successful result, and that not all ideas would be ideal to use continuously. Kaspers stated that the pacifier, bib, and toy would not collect sufficient saliva to be able to measure it. Dalhoeven explained her preferences for the pacifier (although it uses saliva to measure cortisol), diaper, and sock/anklet because of their more continuous use and the bodily functions that are measured. They did both see the potential of the ideas, however, and stressed the importance of involving caregivers in the process [100]. These discussions also helped confirm the conclusion that was drawn based on the user interviews, making the sock/anklet option the most suitable.

5.2 Gathering Requirements

From initial research, contact with experts, and lastly the target user interviews, a list of requirements has been drawn. Using the MoSCoW-method [87], this list has been properly defined. The *"Must-haves"* (M) provide the baseline for the realization phase of this research, prioritizing what has to be finished as a bare minimum and what additional parts can be worked on to build on the basis. Many requirements are beyond the scope of the start-up phase of this project but remain relevant for follow-up research and development regarding a stress-monitoring device for infants.

In Table 7, the design requirements can be seen, the technical requirements are found in Table 8. The ID values indicate which part of the prototype the requirement focuses on – the app (A), the wearable (W), or both (B). The MoSCoW indication can be seen in the "Priority" column, and the "Source" column specifies where this requirement stems from: expert contact (E), user interviews (U) or literature research (R).

Table 7. *User requirements for the product, categorized by priority (MoSCoW). The type of product is indicated in the ID (app (A) or wearable (W)), and reason for the requirements is seen in the source (expert contact (E), user interviews (U), or literature research (R)).*

ID	Priority	Source	Requirement
A1	M	U	Use simple language when communicating results so the app is clear.
A2	M	U	Only integrate essential options and functionalities (registering and viewing observations, statistical insights, contact with a professional, connection to wearable), so the app is not distracting.
A3	M	U	Use intuitive feature labels when navigating through the app so it is easy to use.

A4	M	U	Provide scales and check boxes instead of text boxes that caregivers can use to input their observations, to make the use of the app as effortless as possible.
A5	M	U	Be optional to use.
A6	M	U	Allow the user to elaborate on their observations by text if they wish.
A7	M	U	Need a maximum of 5 minutes per entry.
W1	M	U	Be made of fabric that is comfortable and non-irritating to the skin.
W2	M	R	Use soft fabric so the product is barely noticed by the baby when worn.
W3	M	E	Give the infant a neutral experience, not influencing them nor putting pressure (both physically as well as mentally) on them.
W4	M	U	Be able to put on in 5 minutes, requiring little effort from the caregiver.
W5	M	E	Be worn on the body to gather the most usable measurements.
W6	M	U/R	Be aesthetically attractive so it is not associated with negative things.
B1	M	E	Not increase stressful feelings in the caregivers nor the infant.
B2	M	E	Be used at home.
A8	S	U	Allow the user to write down their observations for specific times of the day.
A9	S	U	Provide the possibility to contact a professional to make them more accessible.
W7	S	R	Be able to withstand biting, pulling, and crawling from an infant so it is safe and stable to use.
W8	S	U	Be designed in a gender-neutral way to make it attractive to all infants.
W9	S	U	Containing a CE mark **[source]** so the safety, especially regarding radiation when transmitting data, is guaranteed and there are no health risks.
A10	C	U	Provide tips and suggestions to help the caregiver learn to read their child.
A11	C	U	Provide the possibility to chat with a professional to make them more accessible.
A12	C	U	Ask the user to assess whether behaviour is abnormal or normal.

W10	C	R	Be watertight so the electrical components are unharmed in case of contact with water.
W11	C	U	Provide the option to wash the fabric without harming the components.
B3	C	U/R	Be affordable to all caregivers, regardless of their income.
A13	W	U	Have an alternative to the app so caregivers without smartphones can also use this.
A14	W	U	Adjust the phrasing of tips and suggestions to the caregiver.
W12	W	U	Be designed specifically for an age stage so it fits their size and needs.

The user requirements describe the functionalities that target users expect or wish to see in the final product. These are more focused on what interactions there should be, how the user should experience utilizing the tool, and features it should contain. The technical requirements focus more on how these features should be made, what steps need to be taken to show the user a result or data. Requirements in the "Must have" category are deemed essential for this project, whereas "Should have" and "Could have" requirements would improve the validity of the concept idea but are not as essential as the first category. Lastly, some requirements have been categorized as "Will not", meaning that they are not included in this research. Although they are interesting to this project, they are not essential and require additional research to integrate well in the concept idea.

Table 8. *Technical requirements for the product, categorized by priority (MoSCoW). The type of product is indicated in the ID (app (A) or wearable (W)), and reason for the requirements is seen in the source (expert contact (E), user interviews (U), or literature research (R)).*

ID	Priority	Source	Requirement
W13	M	U/R	Measure heart rhythm continuously.
W14	M	U/R	Measure muscle activity continuously.
A15	S	U/R	Combine measurement data into data visualizations.
A16	S	U/R	Convert observation data into statistics and data visualizations.
A17	S	R	Store observation and measurement data for as long as needed to get the diagnosis (at least 2 weeks).
W15	S	R	Use a light to indicate when the battery is low.

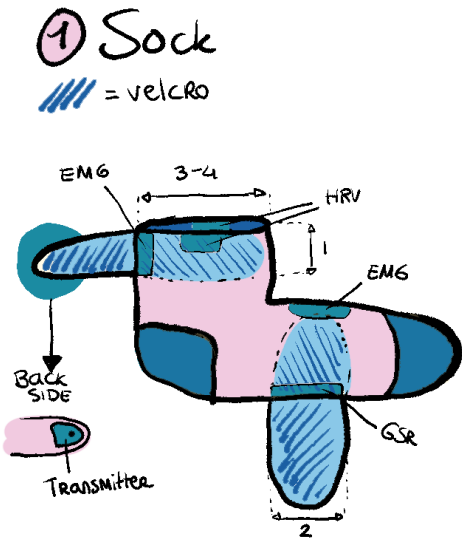
W16	S	R	Convert heart rhythm data into heart rate variability (HRV) measurements.
W17	S	R	Convert muscle activity into muscle tension measurements.
B4	S	R	Be able to export data into an insightful overview for professionals to assess.
A18	C	R	Provide a settings menu so the use of the app can be adjusted on a case-to-case basis.
A19	C	U	Be connected to a calendar function to allow more specific data collection and more specific use.
W18	C	R	Last for at least one week without charging.
W19	C	U/R	Measure the electrodermal activity (galvanic skin response) continuously.
W20	C	R	Use a light to indicate when it is attached correctly.
A20	W	U	Customize the topics discussed when noting the observations based on their personal information and previous entries to increase reliability.
W21	W	E/U	Measure cortisol levels continuously.
W22	W	R	Be rechargeable within 1 hour so it can be used as much as possible.
W23	W	U	Time the appearance of certain activities to get more realistic insights into the infant's behaviour.
W24	W	U	Measure the caregivers' stress levels as well to be able to draw more founded conclusions.
B5	W	R	Send measurements to the app so the data can be stored there.

Based on these requirements, the wearable and app concept ideas could be worked out more concretely so a roadmap-like procedure could be worked out to follow in the realization phase.

5.3 Wearable

Initially, three sock or anklet-like wearable designs were made, which can be seen in Figure 40, Figure 41, and Figure 42. Looking at the user requirements, all designs made sure to include the "Must have" priorities that were phrased in Table 7. They would all be made out of (organic) cotton as it is regarded as a comfortable, non-irritating fabric that is relatively cheap to retrieve [101]. Some requirements, such as W3, W4, W6, W7 have been kept in mind but should be evaluated to prove. Other requirements, like W9, W10, W11, and W12 have not been actively turned to as they

are assumed to be included in the process or suitable for future research. For example, a CE mark should be visible on the sensors themselves, and since this research is not focused on designing a *new* sensor it is assumed that the sensors that will be used comply with this requirement. Research on watertight components, washable (anklet) socks, and designs for age stages are only useful once a solid basis has been constructed – i.e. when it is known exactly which sensor models are used where.



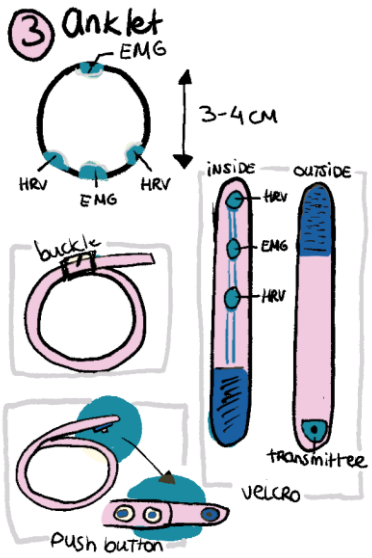


Figure 16. *Sock and its components.* **Figure 17.** *Ankless sock designs.* **Figure 18.** *Anklet designs and components.*

5.3.1 Three Options

The three designs that can be seen above each had their own properties. Whereas the sock would be more subtle and normal to wear, it would also cover non-necessary parts of the foot and be unpractical in hot weather or dirty scenarios. However, it would be able to measure three different types of bodily functions (heart rate variability, muscle tension, and skin conductance) which is assumed to result in more reliable data and complies with requirements W13, W14 and W19 in the technical requirements (see Table 8). It uses Velcro to avoid it being pulled off by the infant, but there is still a risk of it moving around.

The "ankless sock" uses only the necessary parts of the foot, with several options visualised. This way, it uses its space efficiently so it can measure three bodily functions as well.

Because of the attachment of the ankle part to the foot part, it will stay still when worn – ensuring more reliable and stable measurement data. It is less subtle but can be covered by a sock if necessary.

The anklet is only worn around the ankle, not taking up too much space and allowing the wearer to choose their own socks to wear. There are several options on how to tighten it, through a buckle, push-button, or Velcro. The anklet would only measure heart rate variability and muscle tension, as it is only worn around the ankle (and not the foot). Looking at the technical requirements W13 and W14 as specified in Table 8**,** this is the minimal amount of data that should be collected. Additionally, it could also move around the ankle when worn, causing disruptions in the measurements since they would not be attached to the right part of the ankle.

5.3.2 Final Design

Out of these designs, one type was chosen to work out in a prototype: the ankless sock. It can measure three bodily functions but is more room-efficient than the sock and is assumed to be more still than the other two designs. Two drawings have been made for this design as well, looking at the components as well as the outside view of the ankless sock (see Figure 43 and Figure 44**)**.

The part that is worn around the ankle contains three sensors: two heart rate sensors on the sides and a muscle sensor at the front – which would measure muscle tension of the muscle at the top of the foot/ankle. Figure 44 shows how and where these sensors would be integrated into the visual design that is seen in Figure 43**.** A simple circuit containing a (rechargeable) battery and a microcontroller would connect the sensors to a power source and transmitter so the data can be collected and sent to a receiver (in this case, an app).

The part that is worn around the foot would contain two electrodermal activity sensors as well as a power supply and transmitter. This means that there would be two circuits in this *Socklet*, so it is not necessary to implement one heavy power supply but instead go for two smaller ones. Additionally, this ensures that more extreme movement is possible without harming the circuit (e.g. if it would be connected into one big circuit it would have to be completely flexible, now this is much less so).

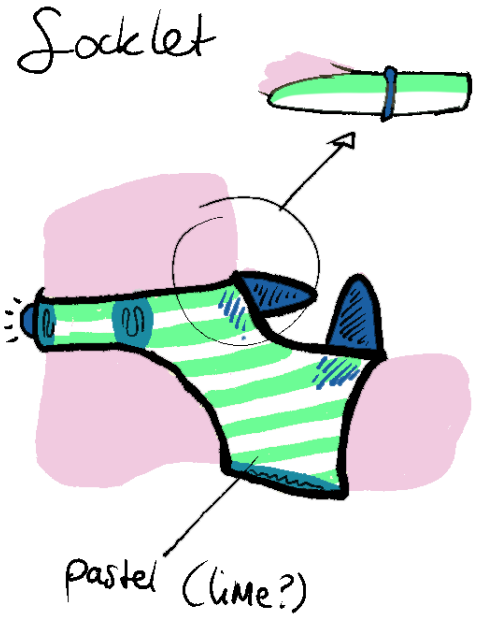


Figure 19. *Design of the chosen ankless sock.*

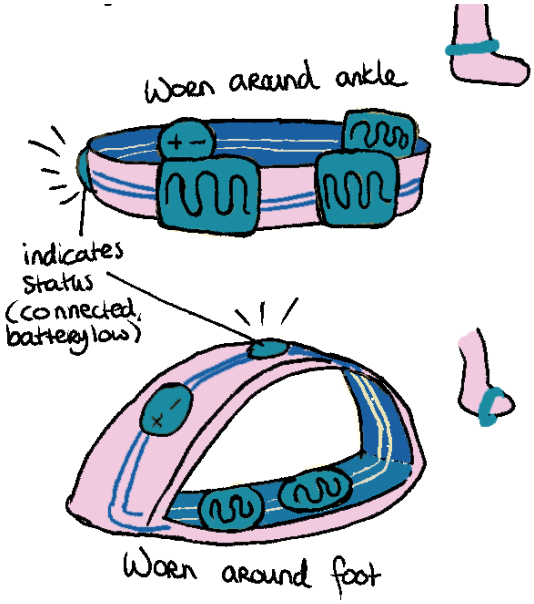


Figure 20. *Components in the ankless sock parts.*

The *Socklet* would also include an LED at the back side of the product (see Figure 43, on the left side of the drawing), which is meant to indicate whether it is connected (requirement W20 in Table 8) and whether the battery is low (requirement W15 in Table 8). The *Socklet* would be charged in a way similar to the Empatica E4 (see Figure 45), attaching the charger to the surface of the sock so it does not need to be ejected when charging. In future work, additional research would probably be needed to put on a charging system which would also enable the product to be washable. That is, however, not included in this research.

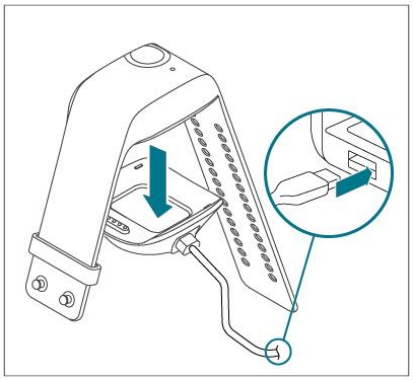


Figure 21. *Charging component of the Empatica E4* [112].

Regarding the prototype, it was decided not to focus on requirements W18, W22, B4, and B5 of Table 8 as they would be useful to implement at a later stage of the development of this product, not in the prototyping phase. Requirements W21, W23, and W24 have already been categorized as requirements that can be included in follow-up research because these propose extra features and options to the wearable that are not needed to evaluate the initial idea. The remaining requirements of Table 8 (W15 and W16) will be attempted to cover in the realization

phase of this research, but if – due to time constraints and other priorities – this is not possible, it will be phrased as a recommendation for future research.

5.3.3 Components

For this product to be made several components and fabrics are necessary. The main technical components needed to be able to monitor stress levels are a heart rate sensor, electrodermal activity sensors, and an electromyography muscle sensor with accompanying electrodes. Both the heart rate sensor and electromyography muscle sensor would need post-processing to ensure heart rate *variability* and muscle *tension* are measured. To communicate the prototype's status to the user (connected, battery low, etc.), LEDs can be included that can indicate such states. Other elements needed to produce the prototype are fabric, Velcro, needle and thread.

5.4 Application

Using a Remarkable 2 [88] and Adobe Photoshop [89], design sketches have been made about the app interface which will later be remade using Adobe XD and Adobe Illustrator [89]. These sketches cover all essential parts of the app: a starting point (e.g. logging in), a main page (overview of entries), an options page, entering new entries, viewing statistics, and contacting a professional. No sketches have been made in this phase about the "Tips" page, although the button leading to this page is visible in the navigation bar at the bottom. When creating these design sketches, the intuitiveness and clarity of the labels and elements have been kept in mind as to insure the use of the app is accessible to all kinds of users. This is done according to the requirements A1 and A3 in Table 7. Not all requirements are visible in the design very explicitly. For example, requirements A5 and A7 are hard to see from a design sketch but have definitely been kept in mind in the design process. This can be seen in the general way the wearable is the leading tool when it comes to stress-monitoring (i.e. the app is supportive and therefore optional), and the fact that the page for a new entry (see Figure 49) shows limited options to ensure quick use. Some options will only be included if there is time, such as requirement A8, A10, and A12, or are already prioritized as "Will not", meaning that none of them are essential for this focus of the project. This means that, although it is good to include all these requirements in the concept idea and prioritize them based on the value they would add to this idea, no focus will be put on them during the realisation phase. An exception for this are requirements A16 and A18 since these will be included in the app – although the statistics and data visualizations will be made based on fake data.

5.4.1 Home Screen

When opening the app, the user will initially be taken to the log-in screen and asked to either register or log-in. This is done to show how the app data will be shielded from the public via a log-in (e.g. verification) step. No focus has been put yet on what information the user will need to create an account but elements needed for sure are: name, e-mail address, and name of the child. It would also be wise to include the age of both the caregiver and the child, language and/or country, and possibly some background information such as physical/mental health issues, occupation, and even hobbies. This would help increase understanding the contextual data that will be collected. The design for the home screen can be seen in Figure 46 and shows a simple setup containing only the essential elements: a logo (to recognize the app), and a login and register button. Tapping "Log-in" would lead the user to the Log-in page in which they need to provide their e-mail address and password to be able to continue.

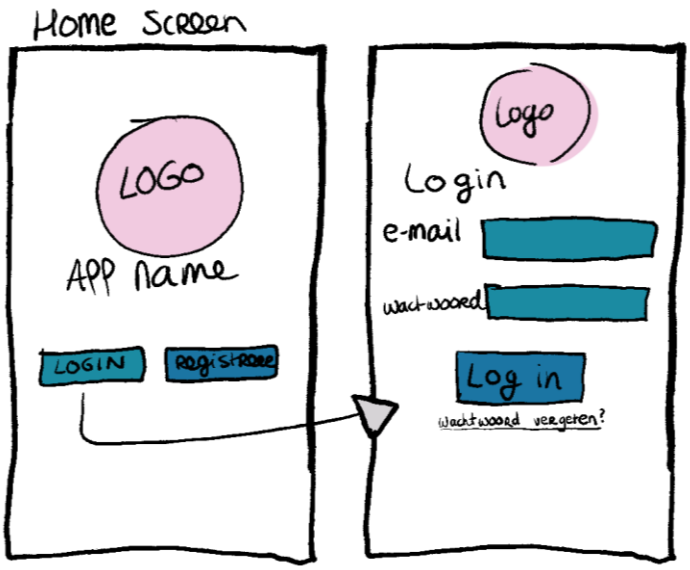


Figure 22. *Design sketch of the home page.*

5.4.2 Main Page & Profile Options

After logging in, the user is then taken to the main page which shows summaries of previously filled in entries (see Figure 47). The general style of this page is also visible in the other pages as well: a Title bar at the top which names the page that the user is currently on and shows the profile icon which can be tapped to get to the "Profile Options" page (Figure 48), and a navigation bar at the bottom which shows the several pages the user can visit (the main page, statistics, new entry, contact a professional, and tips pages).

The summary of an entry shows the day and month it was entered, the mood of both the caregiver and the baby at that moment, and textual information on their mood and situation at that time. Tapping an entry would allow it to expand in a more detailed overview, showing exactly what was filled in.

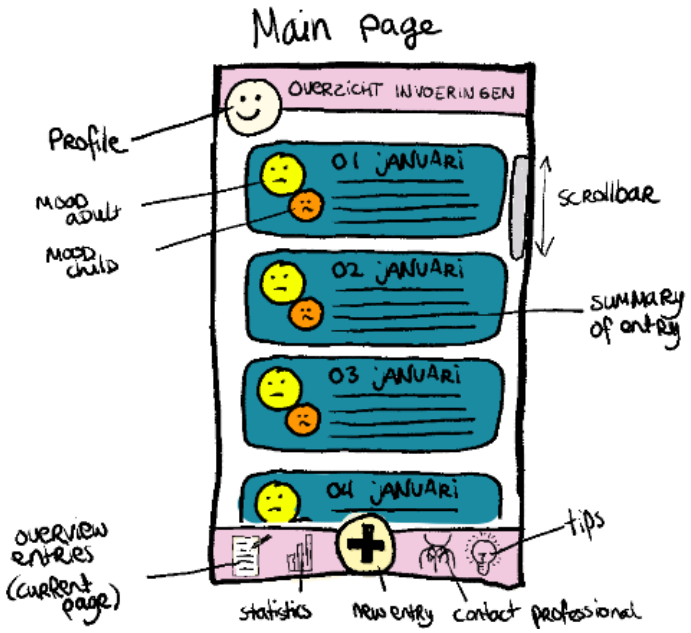


Figure 23. *Sketch of the main page containing the entry summaries.*

The profile options as mentioned before are accessible through every page, simply by tapping the profile icon at the top left of the screen. Here, the user would be able to change profile information, import and manage calendars, set-up and manage professionals, change specific settings of the app, set and manage reminders and other notifications, get information about the app and see contact information for both the manufacturer of the app as well as medical services in case something bad has happened. The latter has been included to make sure that, should caregivers panic because of something they see, hear, or think while using the app, that seeing the word "Help" would also lead them to such kind of help. However, this is something that should also be evaluated with target users once the app nears finished production so it can be guaranteed that it is ethically responsible to do this.

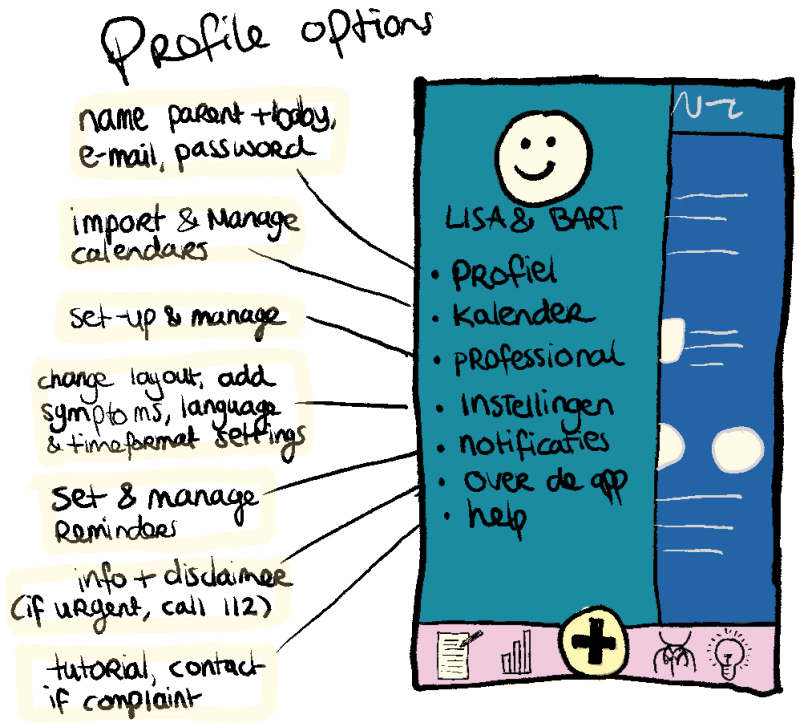


Figure 24. *Profile options overlay that is shown when the profile icon is tapped.*

5.4.3 New Entry

When the user wants to fill in their perspective, emotions, and observations, they can tap the big plus at the bottom middle of the screen. This will take them to the screen as seen in Figure 49. The user can fill in both for themselves as well as for their child how they are feeling. This way, the mental state of the caregiver is known – something which is highly influential on the well-being of their child – and caregivers can confirm or question stressful feelings that might be measured by the wearable.

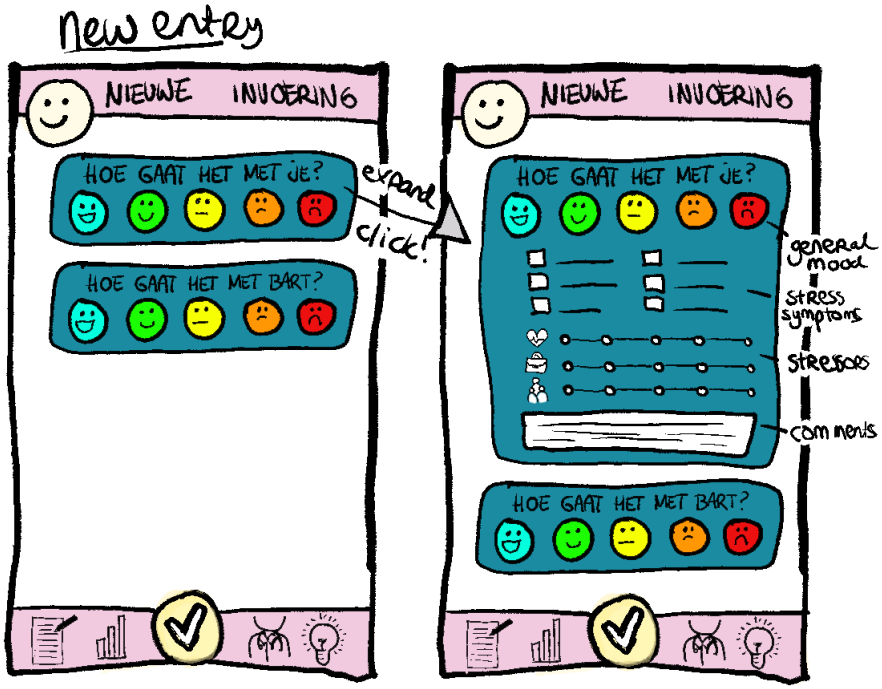


Figure 25. *Design of the New Entry page. If the user fills in a mood, the block will expand and allow them to fill in more specific feelings.*

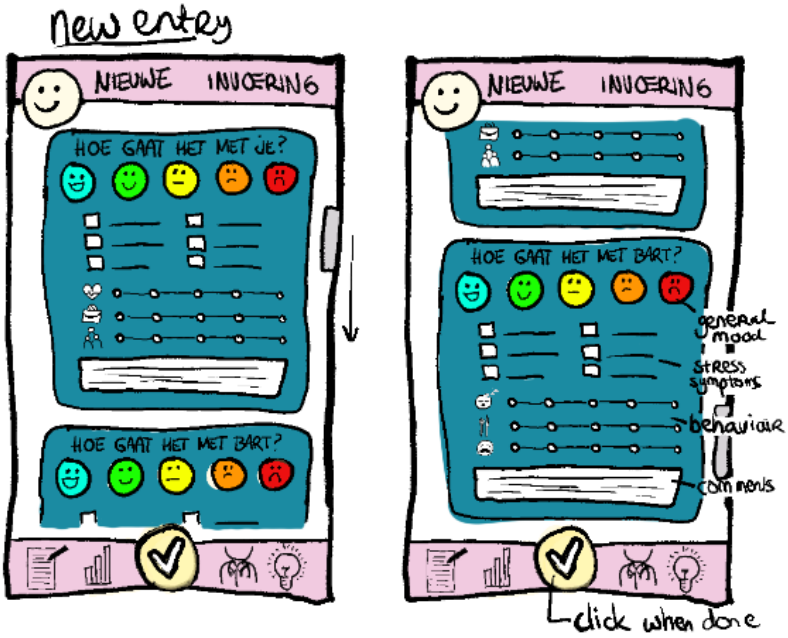


Figure 26. *More expanded version of the New entry page.*

Smileys and colours were used to indicate overall mood, as that is a very intuitive way to do so. When tapping on a smiley the block will expand (see Figure 50) and show more options, asking whether they feel specific stress symptoms (e.g. headaches, a stiff neck, depressed feelings, heart palpitations, etc.), and to what extent specific contextual stressors are influencing their life (health, work, family). Caregivers are also free to provide extra information if they think it is necessary or want to spend

more time doing so. When filling in a new entry, caregivers are free to fill as much as they like. This means that even while using the app, it is not obligatory to spend a minimum amount of time using it.

5.4.4 Statistics & Data Visualizations

Once a user has filled in multiple entries, they can visit the “Statistics” page and see data visualizations of their entries. Using the Daylio application as an inspiration [102], visualizations such as graphics of feelings over time in which caregiver and child are compared, most occurring feelings in a specific timeframe, relations between moods and stress symptoms, the impact of contextual factors on the caregiver and infant can be shown to the user. This aims to provide real-time insights to the caregiver but also support measurement data that is retrieved from the wearable.

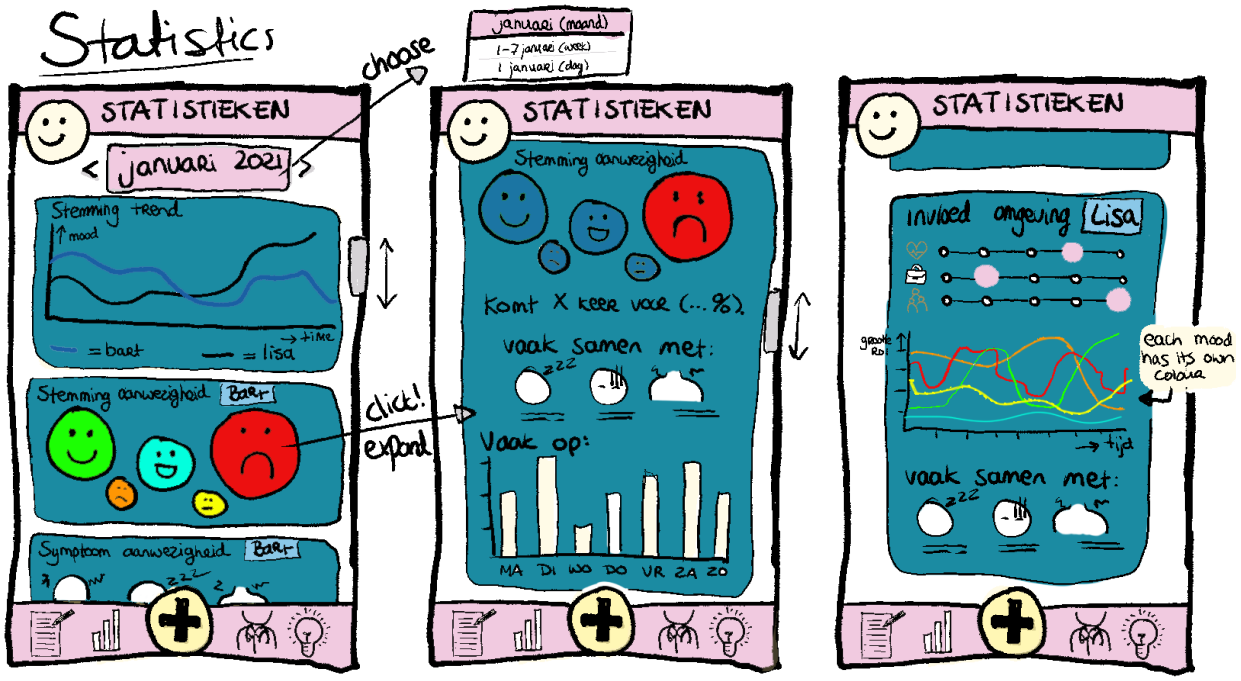


Figure 27. *Design sketch of the Statistics page, showing all kinds of summarized information to the user.*

The user would be able to access more specific data visualizations by tapping on a mood (see the middle sketch in Figure 27), or selecting the person it is about (see the right sketch in Figure 27). This way, the main page for statistics would not be too cramped.

5.4.5 Contacting A Professional

Following the suggestions given during the target user interviews, the app also provides the user with the opportunity to contact a professional (see Figure 52). This has been suggested to incorporate in a chat function, but because general contact information is also valuable to have, the professional's telephone number and email address would also be included. In reality, it is dependent on the professional what kind of information would be provided. Users would be able to add and manage the professionals that they would be able to contact here through their profile options.

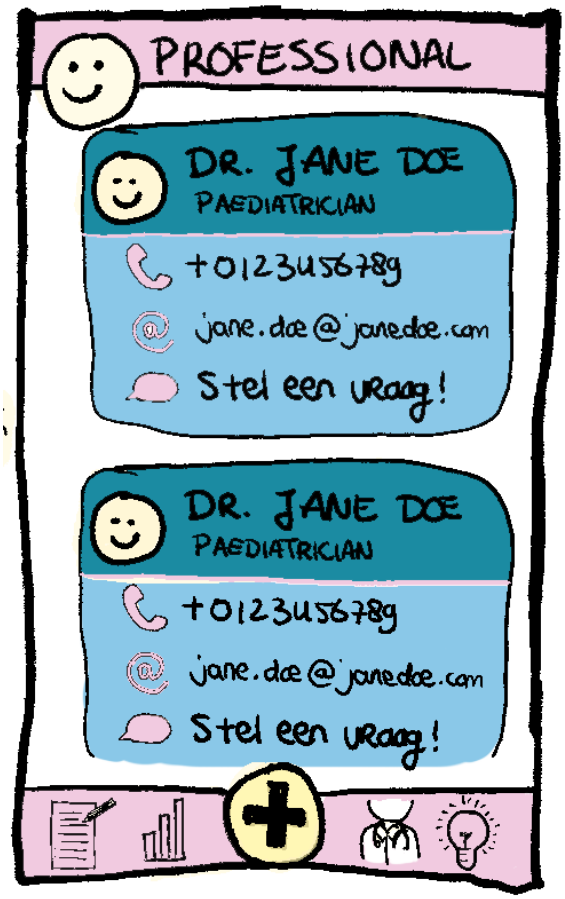


Figure 28. *"Contact a Professional" page design.*

5.4.6 Tips

Lastly, a tips page can be created. Although visible in the navigation bar at the bottom, the page itself has not been sketched since it was no priority to focus on. However, the general idea would be to provide a list of tips that are categorized based on their topic so fairly specific questions can be answered.

6. Realization

In the realization phase, the wearable and app prototypes have been developed so that they can be tested in the user evaluation phase. For the wearable, this means that three types of sensors have been made and/or acquired that seem to be functioning around the ankle and foot area. For the app, it means that there is an interactive app design that can showcase the key interactions it would have. At the end of this phase, both prototypes are ready for user evaluation.

6.1 Wearable

The wearable did not focus on aesthetics, but rather on functionality. Therefore, the design sketch as created in Figure 43 in Section 5.3.2, has not been executed in reality but still provides a visualization of the envisioned end product. The wearable prototype focuses on the sensors that would be needed, doing so by combining an Empatica E4 wristband that measures heart rate and electrodermal activity with a MyoWare Muscle Sensor which measures muscle activity. A self-made soft layer with Velcro has been used to cover the wristband and muscle sensor so it would be attached well to the ankle. Especially for the Empatica E4, this is necessary since the band has been developed for wrists and ankles are often thicker.

6.1.1 Empatica E4 Wristband

The Empatica E4 is developed for the wrist and will also give an error when it senses that it is not connected to the wrist. Since the ankle has a significantly different shape, several positions had to be tried out to find the right position for the Empatica E4 to be worn without getting an error. This was done by self-testing the wristband and seeing whether they would give such an error,

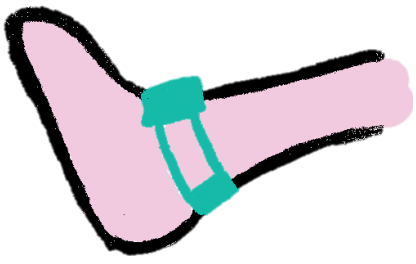


Figure 29. *Empatica E4 worn with the case (big part) at the top, and snaps at the bottom.*

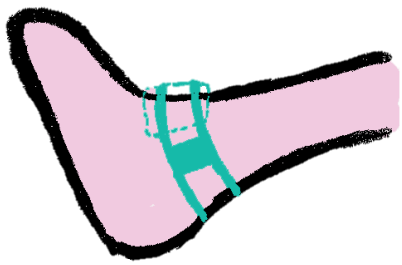


Figure 30. *Empatica E4 worn with the case at the top right and the snaps at the bottom left.*

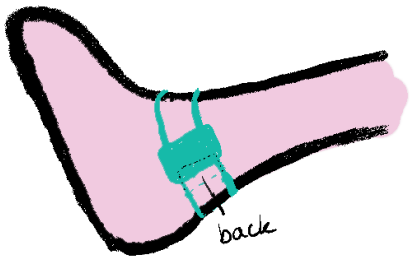


Figure 31. *Empatica E4 worn with the case at the left side, and the snaps at the bottom right side.*

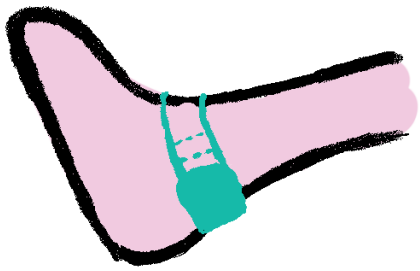


Figure 32. *Empatica E4 worn with the case at the bottom left and snaps at the top right.*

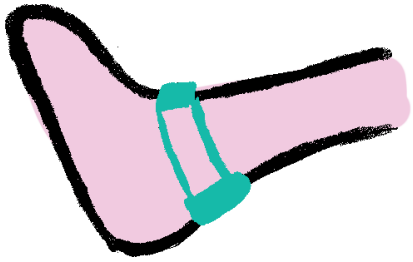


Figure 33. *Empatica E4 worn with the case at the bottom and snaps at the top.*

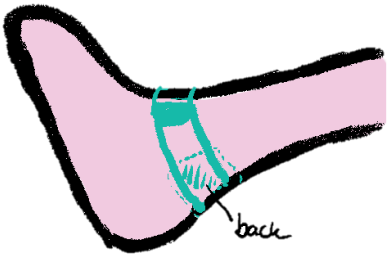


Figure 34. *Empatica E4 worn with the case at the bottom right and snaps at the top left.*

but also check whether the values that were measured and visualized in the Empatica E4 Connect Platform [95] were realistic. This was mostly done by looking at the heart rate (HR), using a Xiaomi Mi Band 2 [103] to compare heart rate values. Fout! Ongeldige bladwijzerverwijzing. - Figure 60 show the positions that were tried out on the right foot, and in Table 9 the results of this self-test can be seen. The most stable positions are the last two figures (Figure 59 and Figure 60), which gave both EDA and heart rate values, the latter both after movement and when resting. Regarding comfort, the last position has been chosen to use as the common position for the Empatica E4, as it did not press excessively on the Achilles heel (which the position in Figure 59 did).

Table 9. *Results of the self-test looking for the right position of the Empatica E4 (E) around the ankle. A Xiaomi Mi Band 2 was used to compare heart rate (HR) values.*

Figure	Error?	EDA value	HR-E (rest)	HR-X (rest)	HR-E (movement)	HR-X (movement)
Top left	Yes	Not possible.	Not possible.	Not relevant.	Not possible.	Not relevant.
Top middle	Yes	Not possible	Not possible	Not relevant.	Not possible	Not relevant.
Top right	No	0.03 µS	Not possible.	Not relevant.	Not possible.	Not relevant.
Bottom left	Yes	0.03 µS	75 BPM	70BPM	Not possible.	Not relevant.
Bottom middle	No	0.09 µS	67 BPM	64-68 BPM	75-77 BPM	67-68 BPM
Bottom right	No	0.08 µS	67 BPM	67 BPM	76 BPM	77-90 BPM

After the position of the wristband on the ankle had been decided, a soft cover has been sewn which would enable the user to wear the wristband comfortably but firmly – using Velcro to tighten the bands well and ensure that the sensors could function properly. In Figure 61, Figure 62, and Figure 63, the process and result of this can be seen.

Figure 35. *Fabric and Velcro needed for the cover.*

Figure 36. Process of making the cover.

Figure 37. *End result of sewn cover with Velcro attached to both sides.*

6.1.2 MyoWare Muscle Sensor

The second part of the wearable prototype is the muscle sensor. This component had to be integrated separately since the Empatica E4 did not contain any sensors for that. A MyoWare Muscle Sensor as seen in Fout! Verwijzingsbron niet gevonden. was bought as well as four sets of six electrodes so plenty of electrodes would be available for the testing phase. A Fritzing sketch has been made to show how it would be connected to the muscle sensor (see Figure 64). Following the step-by-step guide as provided by Adafruit [96] in addition to the aforementioned Fritzing sketch, the sensor was connected to the Arduino Uno microcontroller so it could be tested. It needed only three wires to be connected:

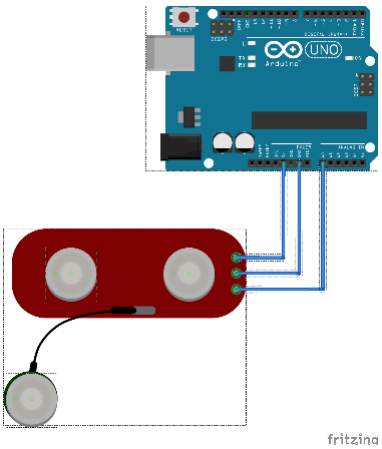


Figure 38. *Fritzing schematic of the muscle sensor connected to the Arduino.*

- Arduino 5V to MyoWare Muscle Sensor + (red)
- Arduino GND to MyoWare Muscle Sensor – (white)
- Arduino A0 to MyoWare Muscle Sensor SIG (yellow)

Three electrodes were needed to use the sensor: two on the sensor itself, for the middle and end part of a muscle, and one on the black wire – away from the muscle.

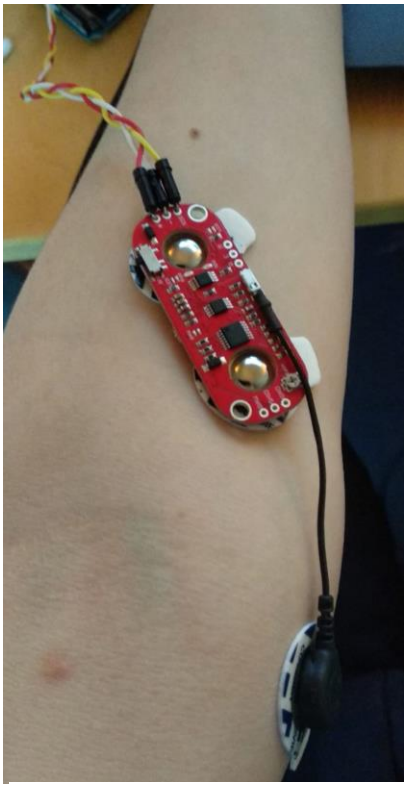


Figure 39. *First test with the muscle sensor, on the lower arm.*

To see whether the sensor functioned appropriately, it needed to be tested. First, the muscle sensor was tested on the lower arm, similar to the example test provided by the Adafruit guide (see Figure 66). While the sensor was attached to the lower arm, several movements were done to see what impact it would have on the measurement data. In Figure 40, a graph can be seen which visualizes the movement of the arm over time. At several moments, the arm has been bent or stretched, and the fist has been clenched, which can also be seen in the graph – the peaks showing the moments when the arm was bent or the fist was clenched.

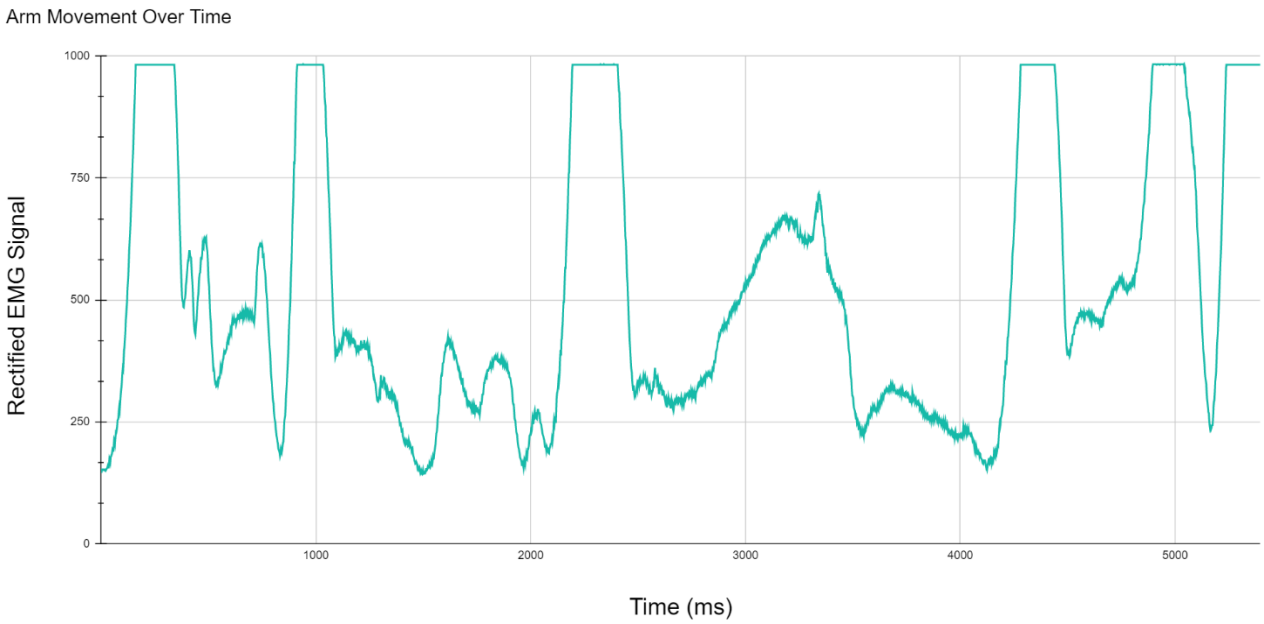


Figure 40. *Results of the first test with the MyoWare muscle sensor on the lower arm.*

After having tried out the sensor on the arm, it was attached to the top of the foot/ankle to see how it would work there (see Figure 68). Moving this foot up and down, and wiggling it to the sides resulted in a graph visible in Figure 42. Moving the foot up resulted in a peak and wiggling the foot to the sides would result in the highly different values at the end of the graph which shows a somewhat thicker graph part. This shows that the placement of the sensor on this part of the body shows up and downward movement the best, but does still register sideways movements. This can be expected since the muscle at the top flexes much more when moving upwards than it does when moving sideways.

Figure 41. *Second test with the muscle sensor, on the top of the foot/ankle.*

This test showed that it would be very well possible to test the sensor on the foot, getting similar results compared to the arm in terms of values reacting to movement. To check whether there were more options for measuring muscle activity on the foot, the muscle was also tested on the Achilles heel. The setup for this test can be seen in Figure 70,

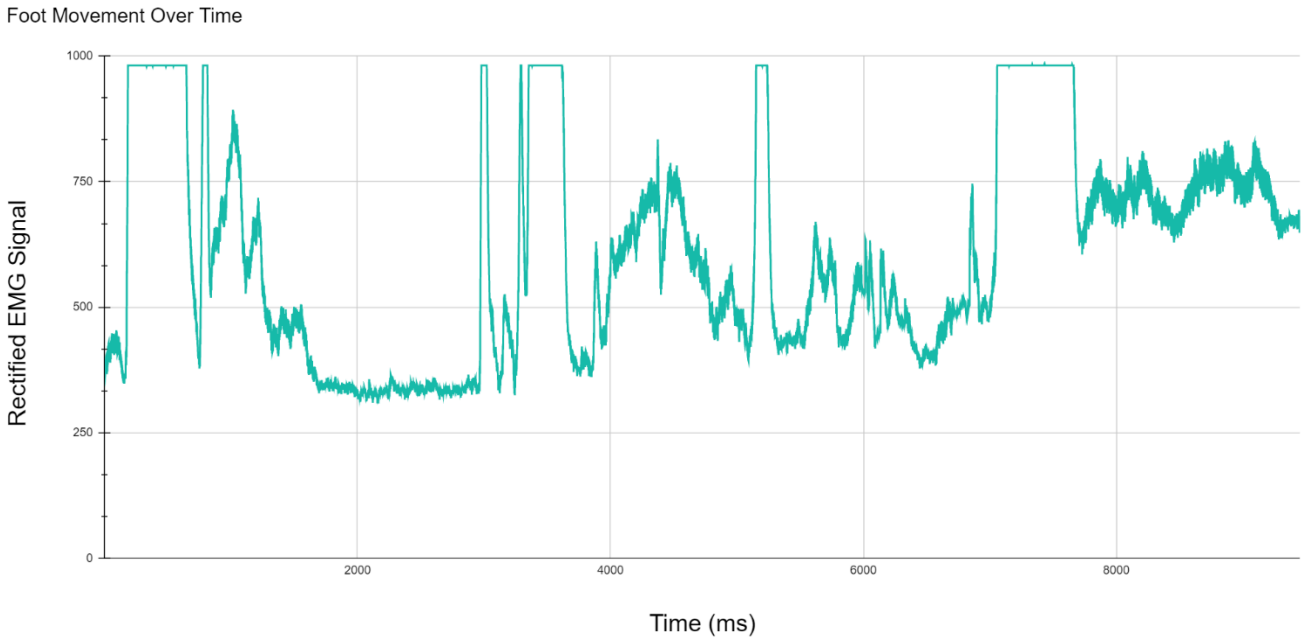


Figure 42. *Results of the second test with the MyoWare muscle sensor on the top of the foot/ankle.*

with a graph visualizing the muscle activity in Figure 71. This location also seemed promising, with a graph showing similar peaks when moving upwards. However, this graph shows many more peaks although the amount of flexion/extension movements was similar to those done in the second test. It is not certain why this is the case. It might be because of the Achilles heel itself, being more activated than the muscle at the top of the foot. Because of this and the fact that the Empatica E4 would need to be worn around the Achilles heel as well, possibly interfering with the measurements of the muscle sensor, it was decided to stick to the setup as shown in Figure 68 since it gave good results. Additionally, this also conforms to the *Socklet* sketch as seen in Figure 43 of Section 5.3.2.

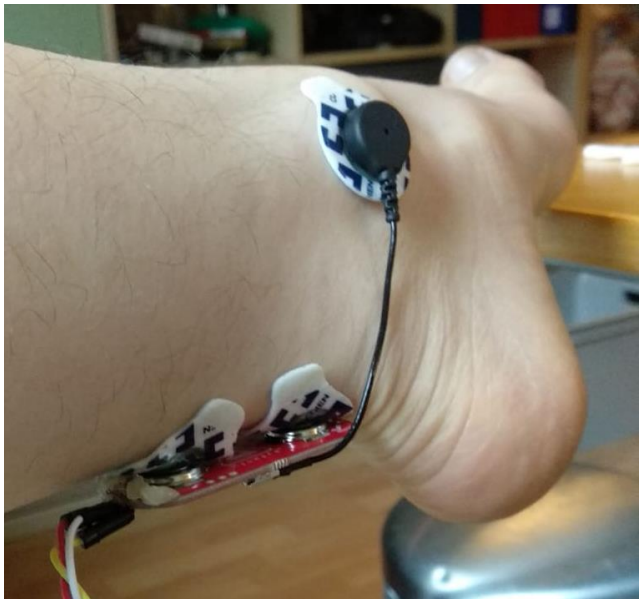


Figure 43. *Third test with the muscle sensor, on the Achilles heel.*

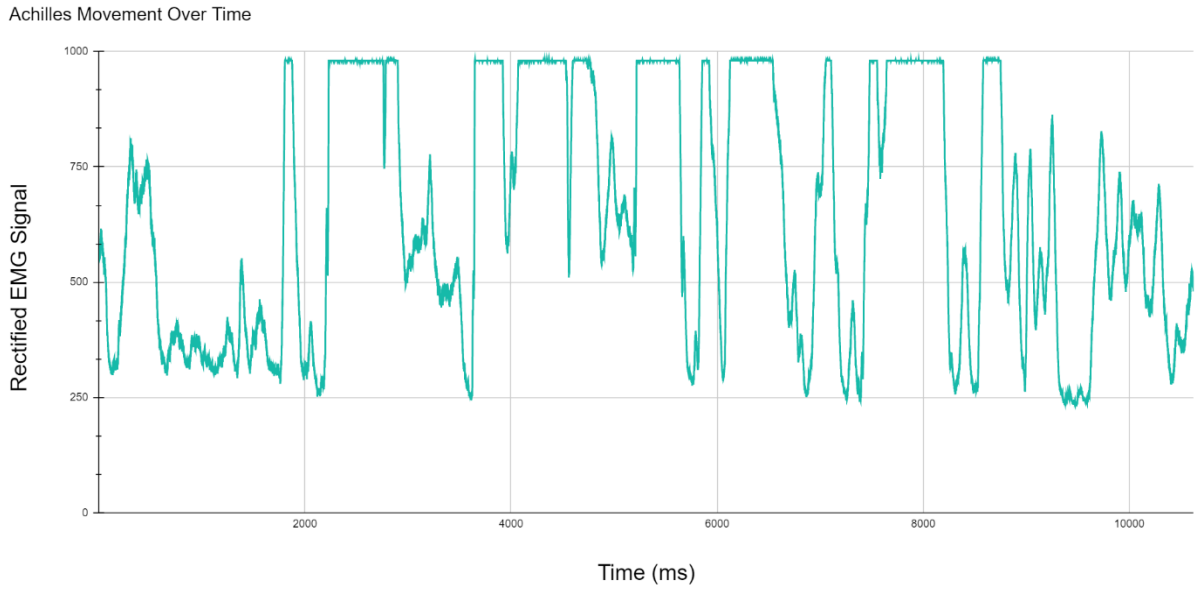


Figure 44. *Results of the third test with the MyoWare muscle sensor on the Achilles heel.*

After the location for the muscle sensor had been decided, the wires connecting the sensor to the Arduino needed to be extended. This was done using a cable containing multiple wires, so there was no need for additional cable management. The cable was connected to the existing wires using male connectivity pins, heat shrinking tubes, and a soldering iron and tin. This resulted in the final setup of the sensor as seen in Figure 72, with a nearly three-meter long cable connecting the sensor to the Arduino, providing the user with plenty of space to move while keeping the Arduino safely near the computer.

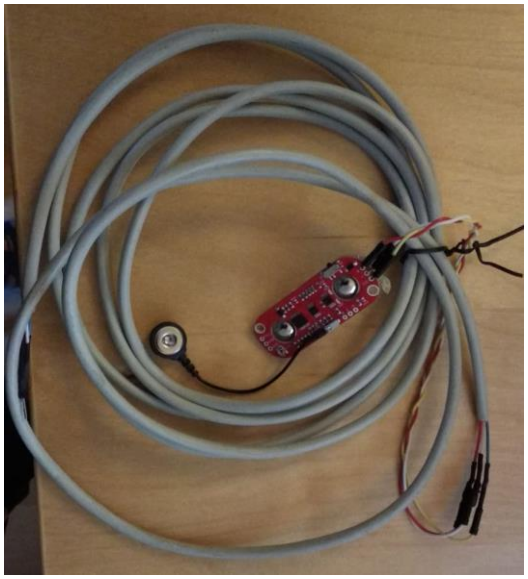


Figure 45. *Final setup of the muscle sensor, containing a 3 meter long cable and three wires to connect to the sensor.*

6.2 App

The design for the app has been made in Adobe XD [91]. This design tool is fitting for creating user interactions without using code to program these. Using a 360 x 640px (5.5 inch) sized grid, the app has been designed for most mobile screens [104]. While being unable to input data, it is possible to nicely show how the app should work if it were to be made in real life. Not all

interactions were completely worked out. The main focus has been put on several elements: being able to view and read entries, being able to create a new entry, and getting statistics out of the entered data.

6.2.1 General Style and Assets

First, the general outline for the app was made. In Figure 46, you can see the basis for the pages that had to be included. No colour scheme had been decided on yet, and icons were not yet made. In this process, it was decided where what information should be put, and what the template would look like: creating components like the navigation bar and the Title bar.

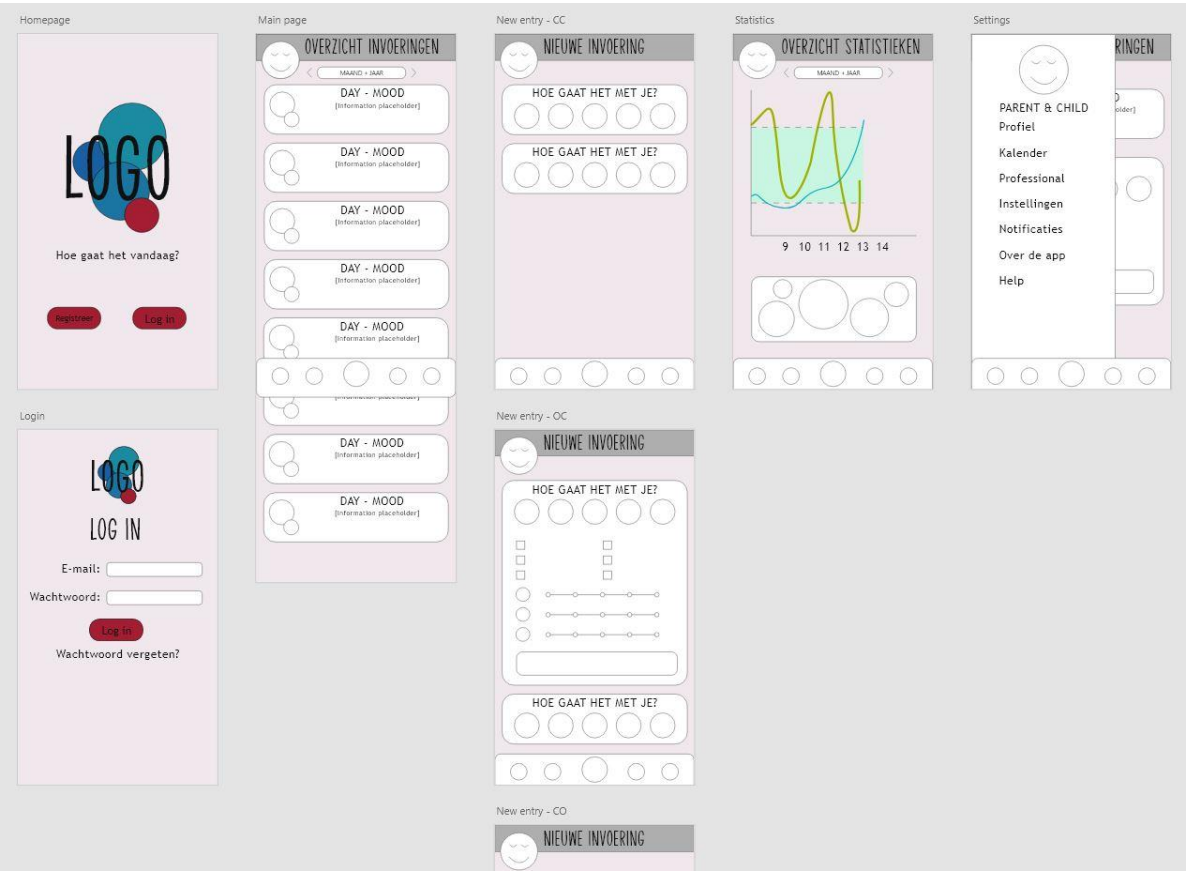


Figure 46. *The general structure of the app pages.*

Then, several colour schemes were explored. Looking at colours used in the previous designs (soft pink and blue), other colours were added to the design which resulted in the colour scheme as seen in Figure 47.

Figure 47. *The initial colour scheme used for the app design. Made in Adobe Color* **[92]**.

This scheme was implemented in the app design (see Figure 48), using burgundy for the buttons, aqua for the navigation and Title bar, and soft pink for the background and the titles. The darker blue was used in case contrast with the aqua was needed. Black was used for body text.

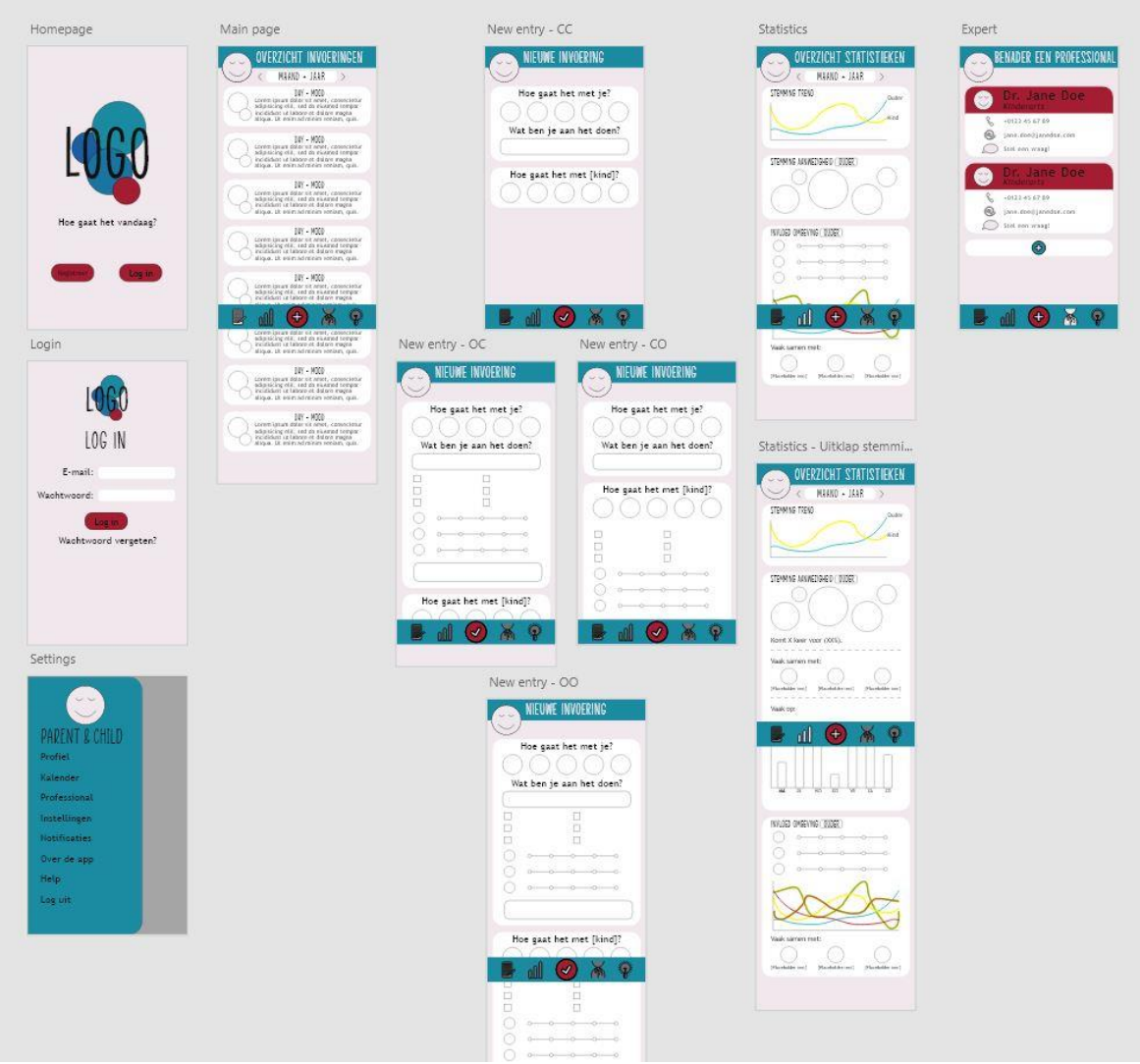


Figure 48. *First coloured design of the app, using burgundy and aqua as main colours.*

This design did not seem calm enough, mainly because of the striking burgundy, so a new colour scheme was constructed, which can be found in Figure 49**.** This scheme replaced burgundy with green for the buttons soft pink for background elements, aqua blue for the navigation and Title bar, lighter blue for icons, and green for other accents.

Figure 49. *The final colour scheme used for the app design. Made in Adobe Color* **[92]**.

This was then implemented in the app design as seen in Figure 77, which immediately looked a lot clearer. It was also decided to leave out as many border lines as possible so it would look more professional.

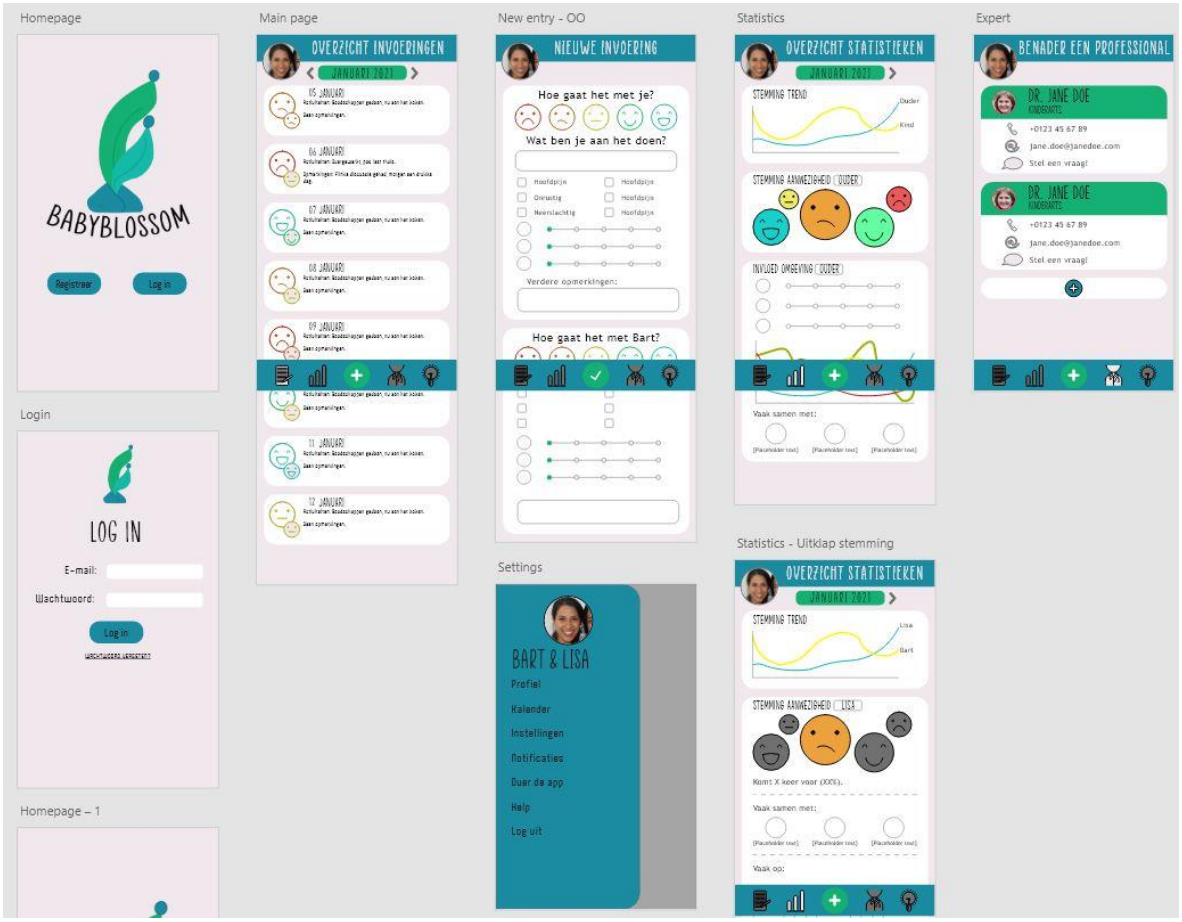


Figure 50. *App design containing the new colour scheme.*

Using this colour scheme, a logo and accompanying name were also designed which gave an identity to the app design. Visualizing both a plant sprout as well as a caregiver together with their child, the *BabyBlossom* logo exhibits the goal of this project: to enable children to grow up well in a process that also involves the caregivers. Through an explorative sketching process (see Figure 78), the design has been finalized into the logo that is showcased in Figure 79 and Figure 80. This logo can be seen in the first few pages of the app (see Figure 77).

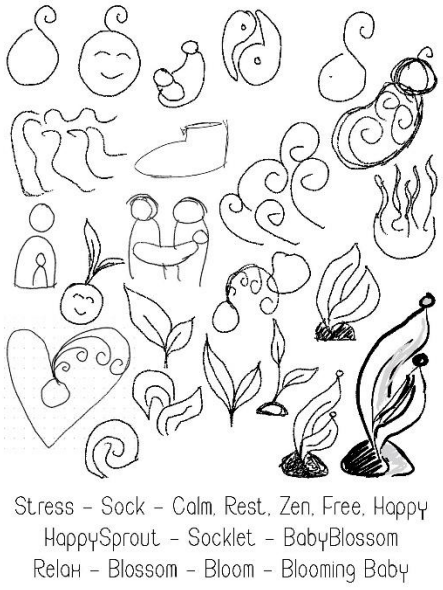


Figure 51. *Sketches of the logo.*

Figure 52. *Final logo design sketch.*

Figure 53. *BabyBlossom logo. Made in Adobe Illustrator and Photoshop.*

After the style had been developed and the logo had been made, all assets for the mobile app had to be designed. Sticking to a calm and modern look, the icons are designed to be simple and clean. Only one colour is needed to convey the idea of the icon. These assets have been made in Adobe Illustrator and were then coloured in Adobe XD once they were added to the app file. All assets can be found in *Appendix J - App Icons*, and are integrated with the app pages which can be seen in Figure 81 - Figure 92 below.

6.2.2 Main Page

The main page (see Figure 81) is the first page one sees after logging into the application. It contains an overview of all entries that have been made in a month, allowing the user to move forward and backwards in time using the arrows at the top. The top and bottom of the screen are the same for everyone; containing a profile picture which can be tapped to get to profile options

and a page name which indicates which page the user is visiting. This can also be seen in the navigation bar at the bottom, where the icon of the current page is coloured, whereas the other icons are empty. An exception is made for the “New Entry” button, as it should be quickly accessible for the user if they want to create a new entry. Therefore, this button is also coloured green instead of the grey and white colours used in the other four icons.

If a user wants to see a summary of their entries, they can simply tap on the specific entry they would like to see, resulting in an expanded entry overlay as seen in Figure 82. This detailed overlay shows all entered information, using icons to quickly convey the message. This is done to limit the amount of text that needs to be read since it was indicated that caregivers want to be able to use the app quickly and mindlessly. However, text has still been added to the icons so the message is clear in case an icon is not completely understood.

Figure 54. *Final design of the main page.*

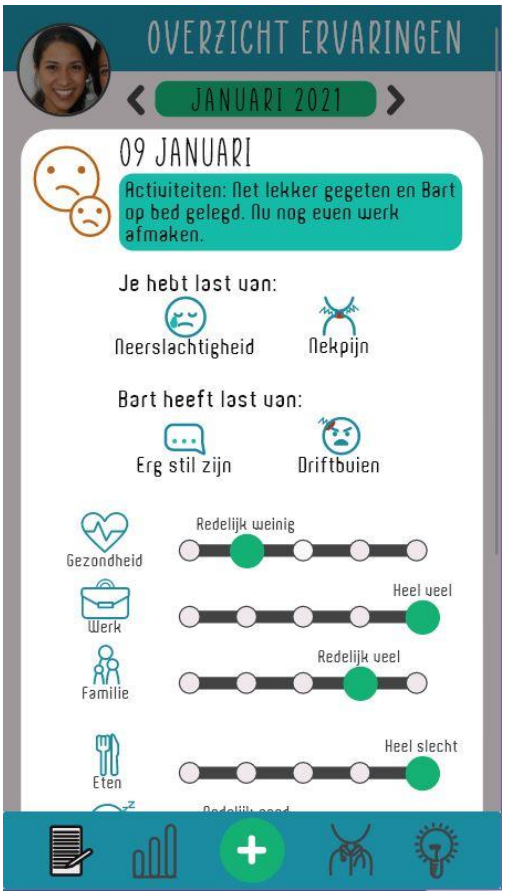


Figure 55. *Detailed view of a specific entry.*

6.2.3 New Entry

When the user taps on the green button, they can create a new entry. Initially, it was designed to be a relatively empty screen first (see Figure 84), with expandable boxes once an emotion had been chosen. This proved to be very complicated to prototype in Adobe XD (e.g. ensure that the user would be able to do this and input data), so it was decided to leave out. Instead, it was attempted to make the design more clean and calm as to compensate for the amount of information that would directly be available on the page. This was done by using the fill colour for the emotions as line colours instead, and by increasing the spacing between the specific elements. In Figure 83, the final design for the New Entry page can be found. It asks the user to tap on an emotion they feel, fill in what they are doing right now, check boxes that apply to them based on stress symptoms, move the slider to indicate the how much a stressor impacts them, and finally write down additional comments if they feel it is

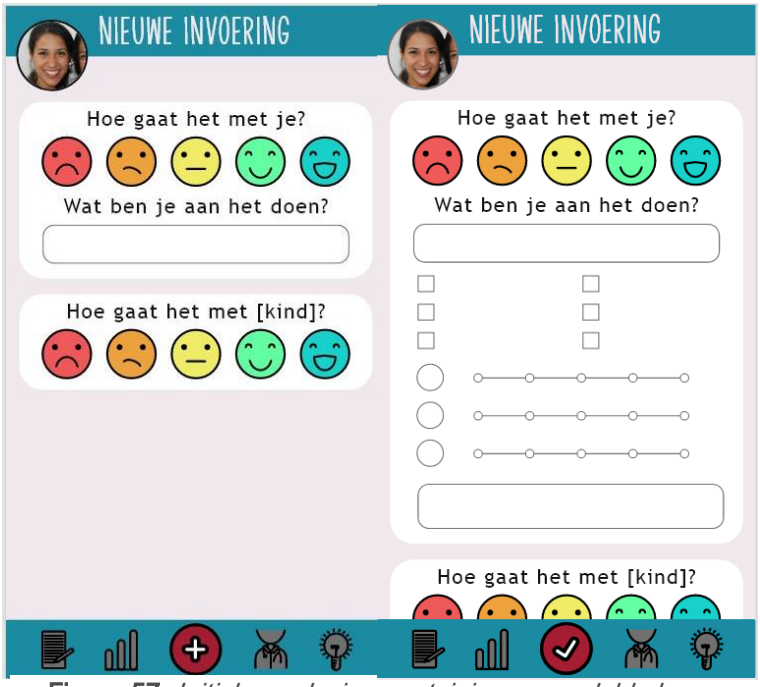


Figure 57. *Initial app design containing expandable boxes.*

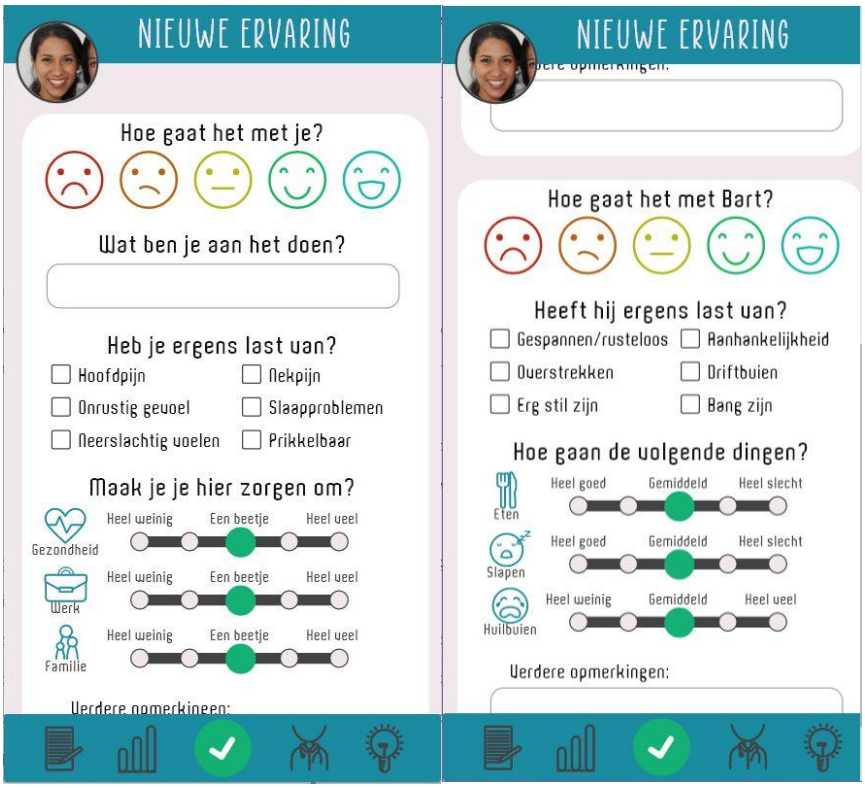


Figure 56. *Final design for the New Entry page.*

necessary. In the settings menu, users can create custom stress symptoms or stressors to check, so it can be adapted more on the individual user over time.

6.2.4 Statistics

Besides viewing their individual entries in a more detailed manner, the app also contains a statistics page that provides data visualizations of their entries over time (see Figure 85). It will show a graph of their mood compared to their child's mood, inform the user of their most dominant

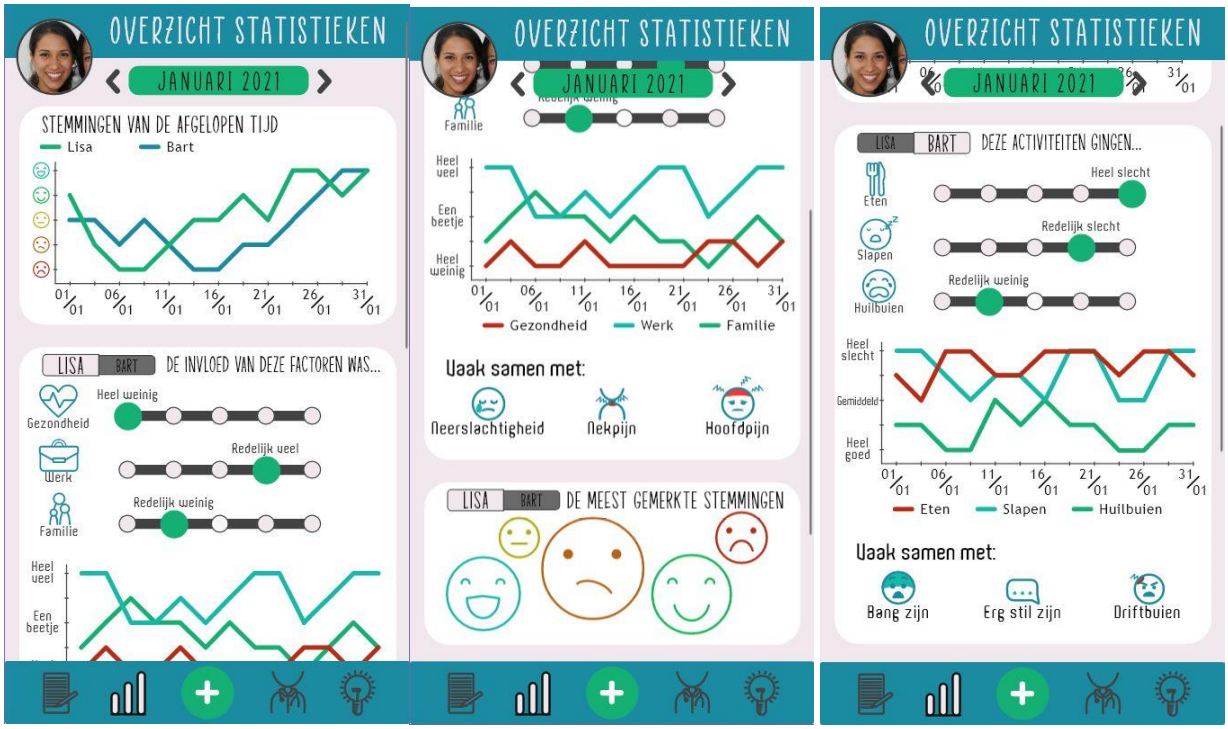


Figure 58. *Statistics page showing all kinds of information to the user. In the second graph you can choose whose data to showcase.*

moods, and shows averages and graphs on their stressor slider input data. Tapping an emotion would expand the box (see Figure 86), showing more specific information about the user's mood compared to stress symptoms and moments of the week. In the second and third graph, the user can choose whose information they would like to see. This way, the page is not cramped with information from the start.

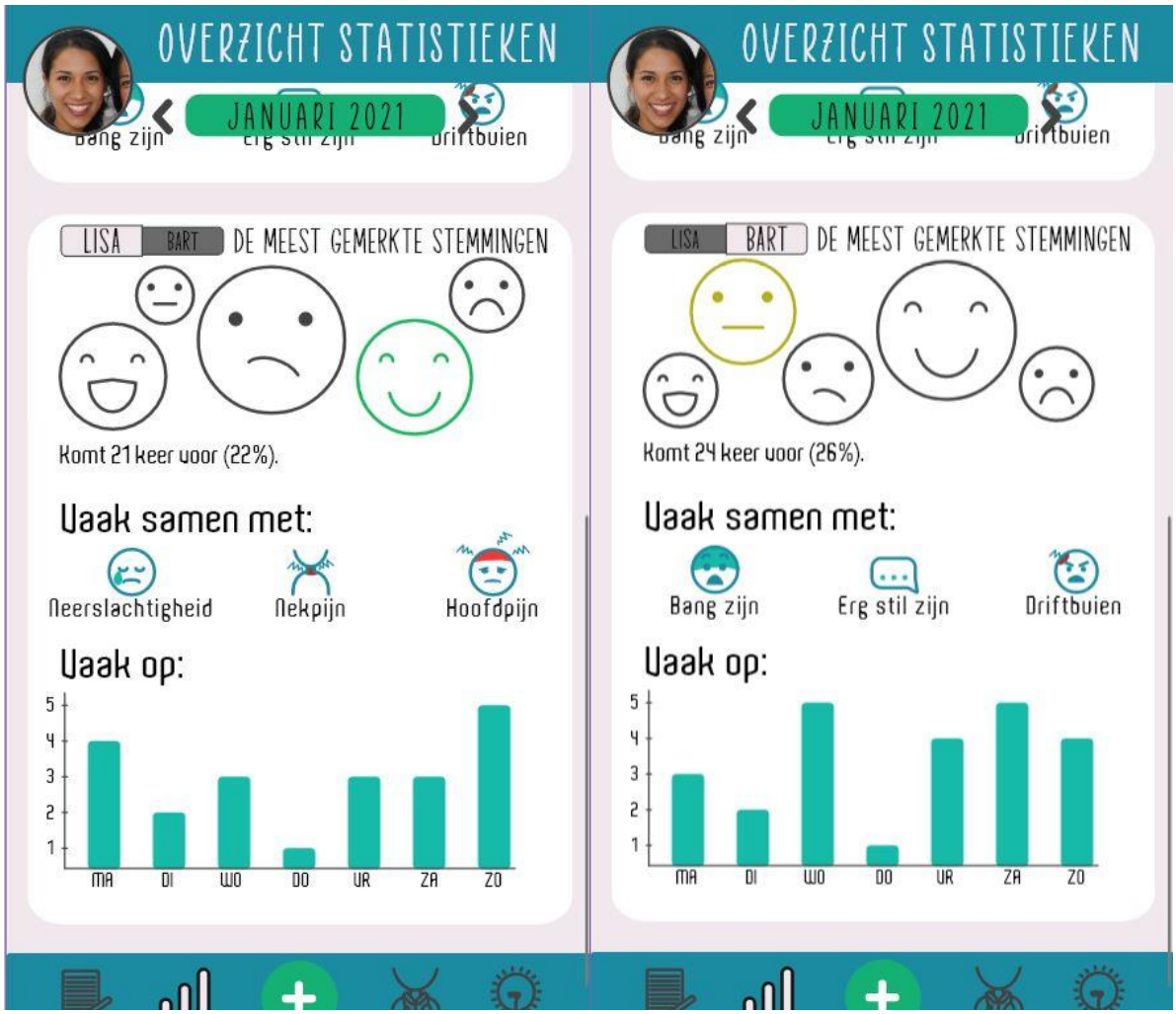


Figure 59. *Expandable option for the most prevalent emotions.*

This page is meant to provide the user insights in their feelings but also allow professionals to get a quick overview of the user's feelings and interpretations without having to read all entries one by one. In the end, this page enables professionals and caregivers to combine measurement data from the wearable with contextual data and discuss the results.

6.2.5 Other Pages

Besides the three key pages in the app, additional pages were designed that either increased the realistic functioning of the app or added another feature to it. These will be explained and showed briefly here, but the full-size images can be seen in *Appendix K - Full-Sized App* Pages**.** The extra pages are:

- The log-in pages (see Figure 87), enabling the user to connect their input data to an account so it is not publicly available.

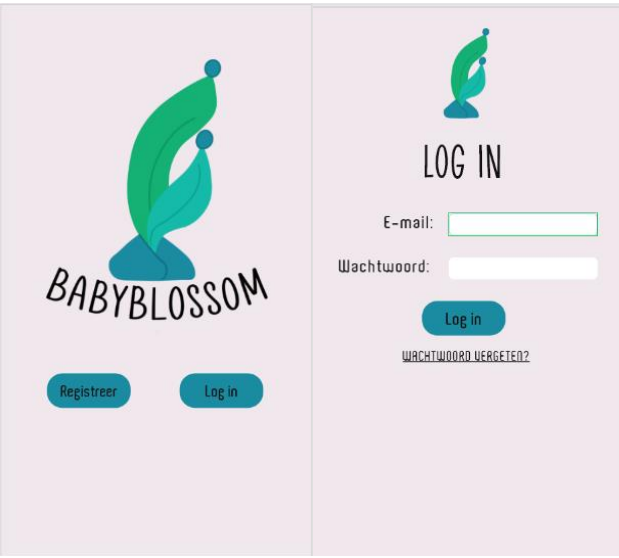


Figure 60. *Final designs of the log-in screens.*

Figure 61. *The page that can be used to contact a professional in various ways.*

Figure 62. *Page that provides general tips about parenting and stress.*

- The page to contact a professional (Figure 88), which would provide the phone number and email address of their doctor or therapist so they can be contacted in case of questions. Besides this, there is also an option to chat with them through the app, making it a more accessible communication tool.
- The page to read a tip (see Figure 89), which can be useful when a caregiver would not know what to do but is hesitant to ask for help by contacting the professional. Personalized tips could be added so that they are more effective towards the user of the app.

- In Figure 90, the profile options can be seen. They would enable the user to modify the app to their needs and preferences. Things that could be changed would be their password, caregiver and child name, the colour scheme of the app, turn on night mode, etc. These would be very generic options that are available in most apps. Besides these options, the user would also be able to connect the product to their app so its measurement data could be stored there.

Figure 63. *The profile options overlay.*

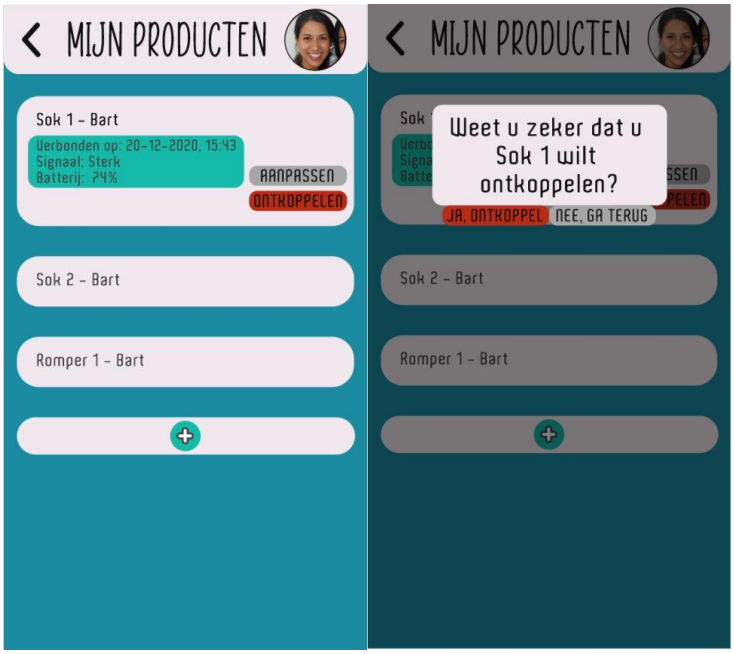


Figure 64. *Overview of connected products.*

- As mentioned briefly above, the pages inside the profile options that would allow the user to connect their *Socklet* to the app so it could store its data there. The pages show an overview of the connected devices and allow the user to manage them by removing or adding devices (Figure 91). It shows multiple products and while that is not the case in the initial idea (caregivers would only use the sock for a limited amount of time and no other ideas have been worked out), it has been added to the design to see how test users would react to it and keep the future perspective of a possible more commercially-used product in mind.

- When clicking on the plus, the user would be redirected to the New Product page and be given instructions on how to connect the device (see Figure 92). Again, here the app shows other products as well. This is again done to see what test users would think and keeping future perspectives in mind.

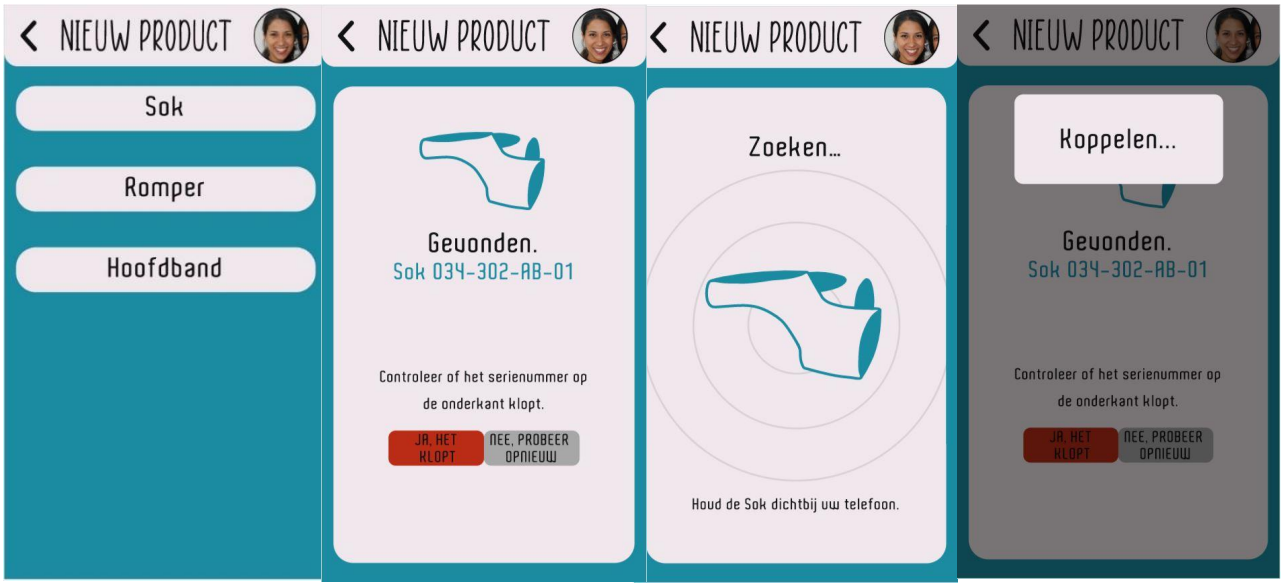


Figure 65. *Process of connecting a new device.*

7. Evaluation

After having realized the concept ideas into prototypes, these needed to be evaluated so we would be able to assess to what extent the prototypes fulfilled the general ideas as described in Section 5.1 and the requirements as set in Section 5.2, so recommendations could be derived and phrased that would be useful for future work. Because of the COVID-19 pandemic measures, this evaluation phase needed to be executed in two parts, testing the physical element of the prototype (the *Sockiet*) within the household and the digital element (the *BabyBlossom app*) with actual target users.

7.1 Physical Testing

The main aim of the physical evaluation was to see whether the ankle would be the right place for the product to focus on when monitoring stress-levels in an infant. It was not possible to use infants for the evaluation of the prototype constructed in Section 6.1 due to ethical concerns. Instead, peers were recruited that would wear the prototype and perform tasks. Following the aforementioned setup, as stated in Section 3.4.1, the evaluation was executed. Its results will be described here.

7.1.1 Measurement Results

Five housemates participated in the physical testing, wearing the Empatica E4 and MyoWare Muscle sensor around their right ankle. They were asked to perform specific tasks so it could be evaluated to what extent the sensors registered these movements. The following sections will highlight the results, focusing on the differences between the measurement data of the Empatica E4 and the MyoWare Muscle Sensor. All measurement results can be found in *Appendix N - Measurement Results Physical Testing.* The first product measures electrodermal activity (EDA), blood volume pulse (BVP), and heart rate (HR). Respectively, these biomarkers can be defined as conductance of your skin which increases in case of arousal (extreme emotions), the volume of blood flowing through one's veins with each heartbeat, and one's heart rate which is often derived from the blood volume pulse [105]. The second tool measures muscle activity (EMG rectified signal) over time.

7.1.1.1 Body Movements

During this phase of the testing, participants were asked to sit (blue areas in the graph), stand still (yellow areas in the graph) or run in their spot (red areas in the graph). There was a clear

difference between the Empatica E4 data and the muscle sensor data. Both tools did register body movement, but the measurements retrieved from the Empatica E4 are more incoherent both within and between the participants. Graphs often showed no measurements in the heart rate data (bottom graph), and EDA values (top graph) were also often very low with some random spikes in between. Figure 93 highlights some of these occurrences. Sometimes, sudden drops in the graphs are seen, which is probably because of the device showing the “Device not on wrist”-error and failing to measure sufficient data. In Figure 67 you can also see that the heart rate (bottom graph) suddenly disappears.

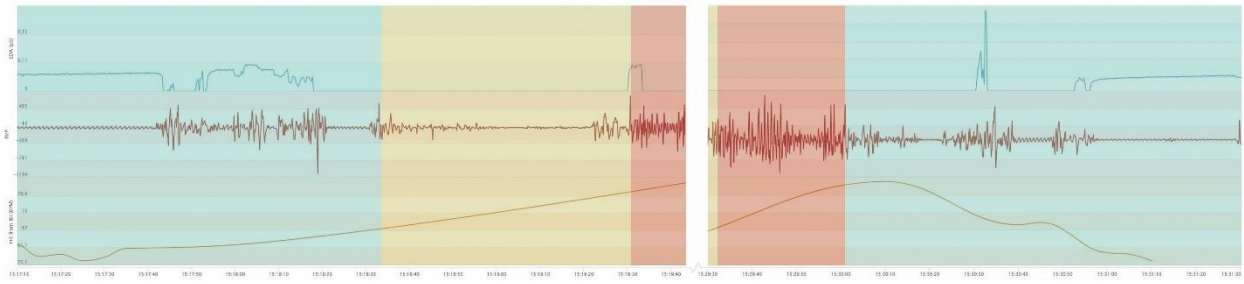


Figure 66. *Empatica E4 measurement data of test two. Blue is sitting, yellow is standing, and red is running.*

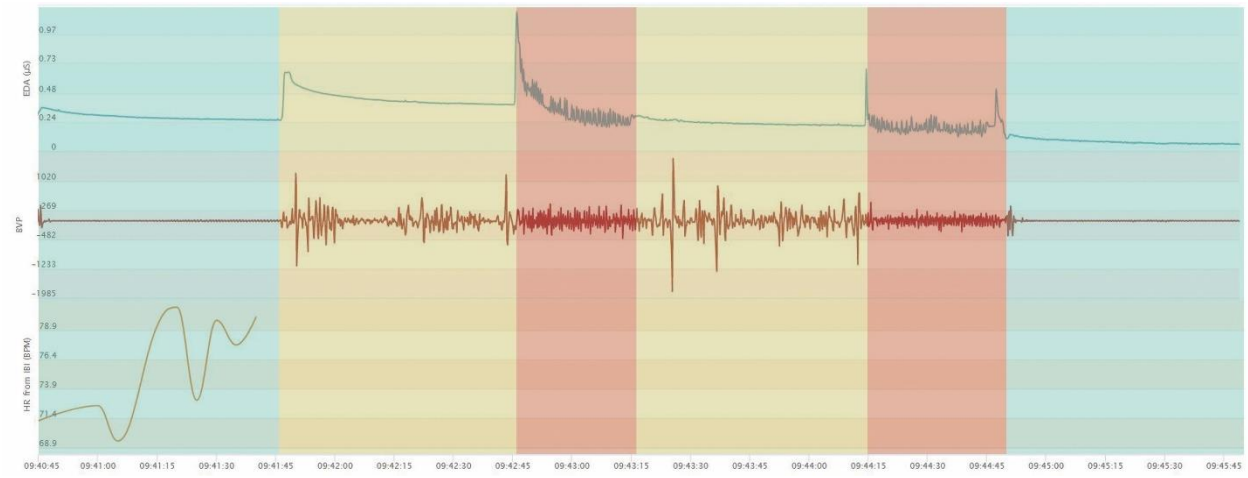


Figure 67. *Empatica E4 measurement data of test five. Blue is sitting, yellow is standing, and red is running.*

Looking at the muscle activity, however, we can see clear changes in the data based on the task the participant is performing. A spike is seen when the participant transitions from a sitting to a standing position, and almost continues peaks are seen in the read areas. Some measurement data showed random spikes when they should not occur, which is probably caused by participants

twitching their feet. Figure 68 highlights both the stability in the measurements but also the random spikes probably caused by feet twitching.

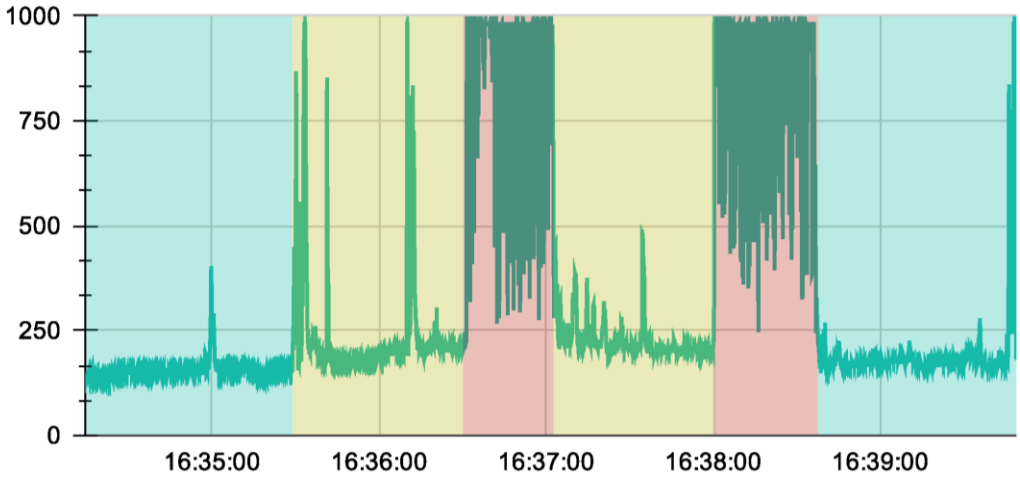


Figure 68. MyoWare Muscle Sensor measurement data of test three. *Blue is sitting, yellow is standing, and red is running.*

Looking at the other tests done, we can see similar results. Each individual test is shown in *Appendix N - Measurement Results Physical Testing* but they are not repeated here. There were, however, some problems that did occur in specific tests and are worth mentioning. During the second test, the muscle sensor fell off the foot, explaining the gap seen in Figure 93. During the fourth test, the sensor also suddenly stopped sending its measurement data after a few minutes. This went unnoticed during the testing since the sensor seemed operational, and has therefore not been solved – resulting in very limited muscle activity data from this test (see Figure 96. *MyoWare Muscle Sensor measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

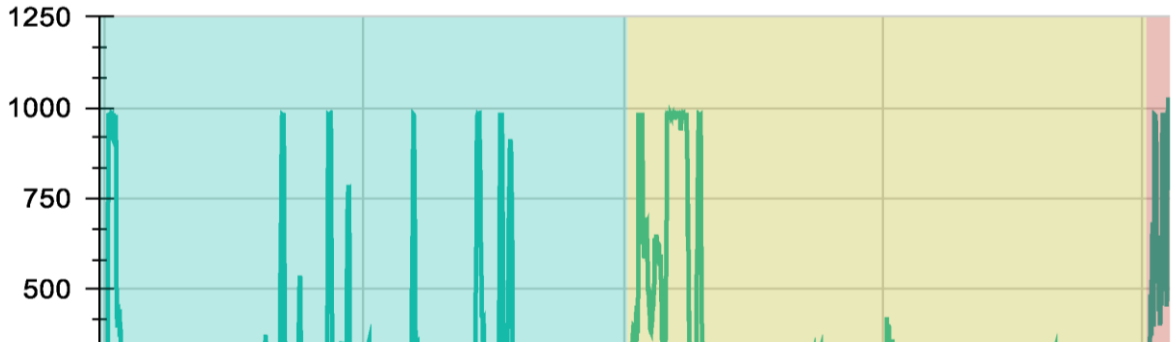


Figure 69. *MyoWare Muscle Sensor measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

Figure 70. *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.***Figure 71.** *MyoWare Muscle Sensor measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

Figure 97. *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*Figure 96).

7.1.1.2 Foot Movements

This part of the testing also showed similar inconsistencies when it came to the EDA and HR values, often also failing to measure heart rate values. Figure 98. *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

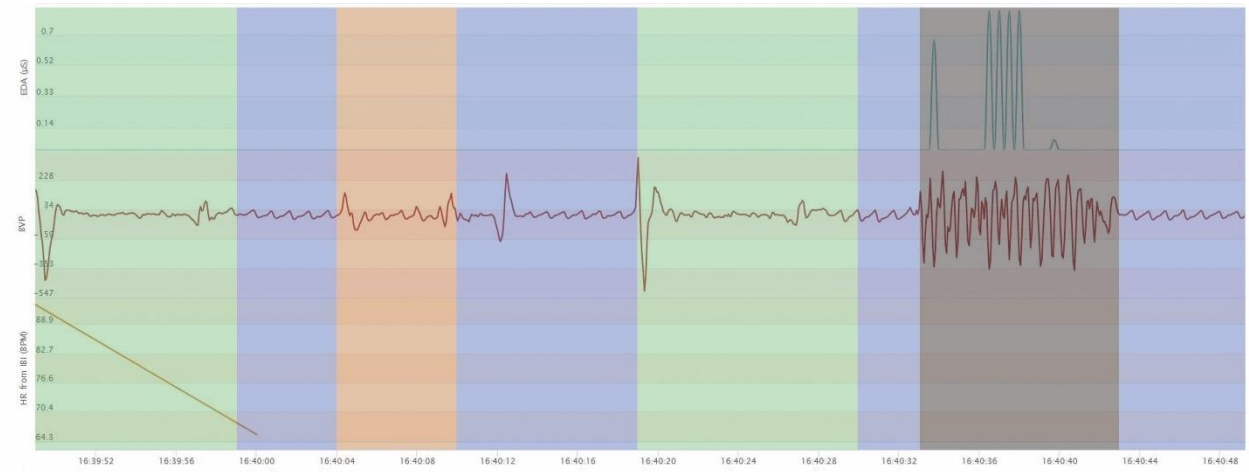


Figure 75. *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 76. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.***Figure 77.** *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

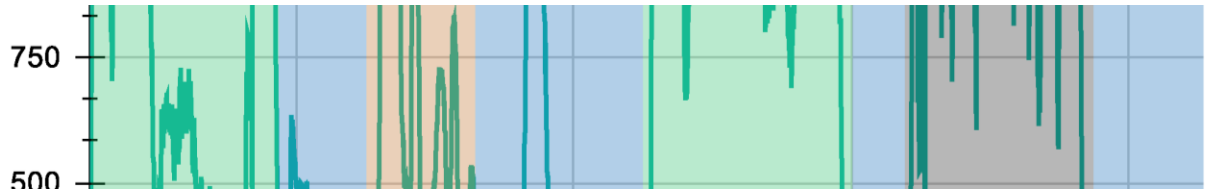


Figure 72. *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 73. *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.***Figure 74.** *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 99. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.***Figure 98 clearly shows that there are no EDA and HR measurements except for some outliers. This might be because the device lost contact with the skin because it was not tight enough. The data from the muscle sensor does give some information (see Figure 97.** *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

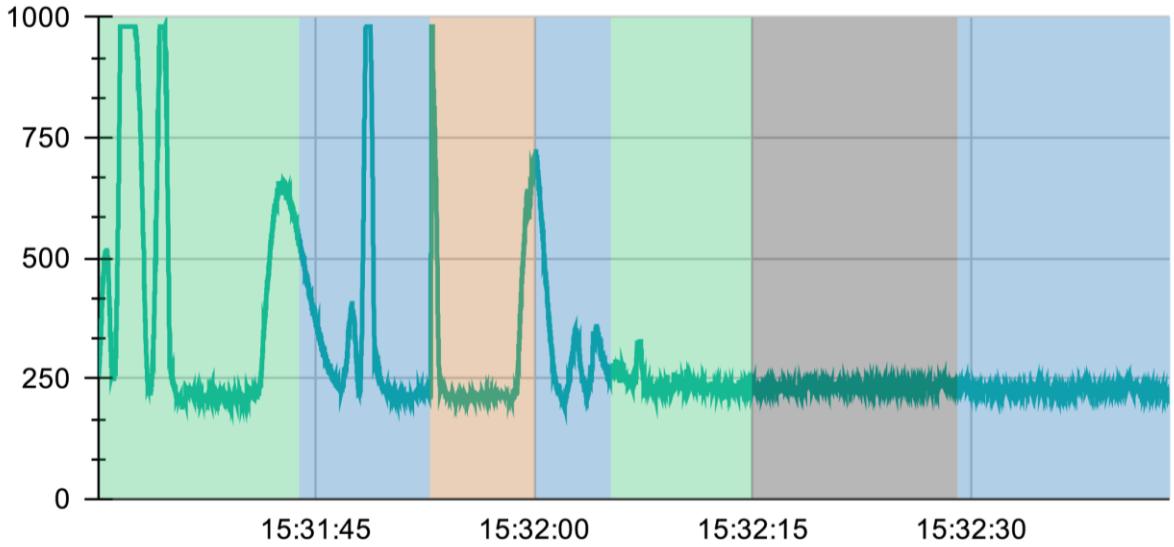


Figure 78. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 79. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.***Figure 80.** *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 98. *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*Figure 97). It can be seen that the muscle is activated both when the toes are moved up- and downwards and that wiggling the foot gives a similar result. Maintaining these positions for several seconds does shows a continuous peak. When trying to assess muscle *tension* rather than *activity,* this means that we should look at such continuous peaks since they indicate that the muscle is constantly activated. Resting moments show much lower activity levels, although it might take a few seconds before this is the case. This further shows how a constant lower activity level can indicate relaxation whereas a constant higher activity level (e.g. continuous peak) indicates tension.

Again, individual tests are not repeated but can be found in *Appendix N - Measurement Results Physical Testing*. Some noticeable errors that occurred are still mentioned here. During both test two and five (Figure 99. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

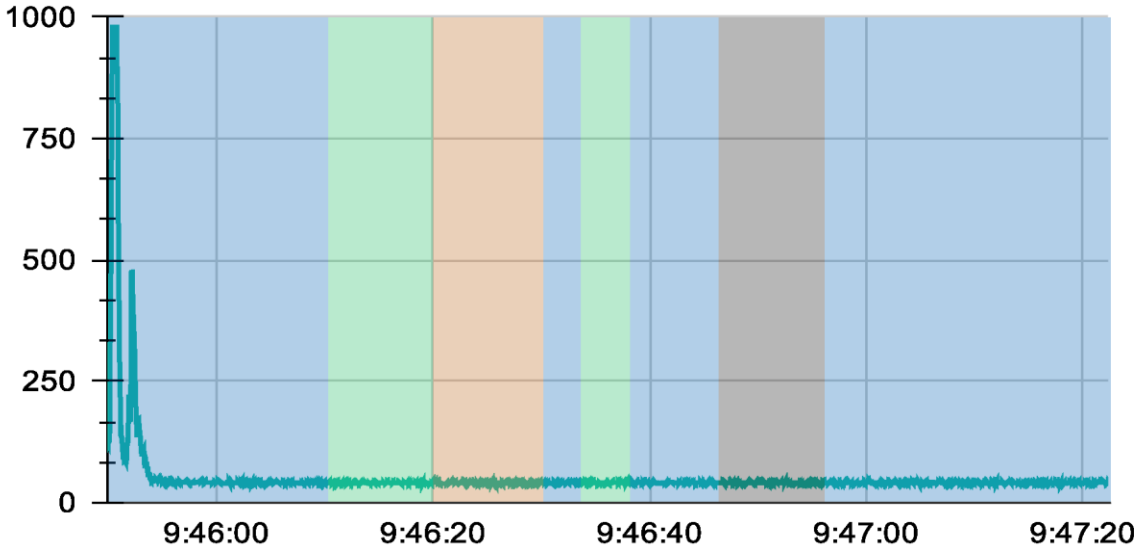


Figure 81. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 82. *Self-test on the arm and ankle to see whether the Empatica E4 was indeed not tight enough on the skin. Blue is sitting, red is exercise.*Figure 83. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 100. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*Figure 99 and Figure 100. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure 101. *Self-test on the arm and ankle to see whether the Empatica E4 was indeed not tight enough on the skin. Blue is sitting, red is exercise.*Figure 100), it was seen that the muscle sensor values dropped and stayed low regardless of the muscle activity that was performed. Presumably, the sensor lost contact with the foot or experienced a different technical error that caused it to be unable to measure well enough. Data has been registered, meaning that the sensor did send data to the Arduino. However, it shows no change based on movement.

7.1.1.3 Self-Test

After these test results, the Empatica E4 has also been self-tested again without the soft layer, to see if it would show similar results. In Figure 101. *Self-test on the arm and ankle to see whether the Empatica E4 was indeed not tight enough on the skin. Blue is sitting, red is exercise.*

Figure 101, you can see the results of these tests. First, the wristband has been tested on its intended location to have a basis to compare with. As can be seen, the EDA values are quite

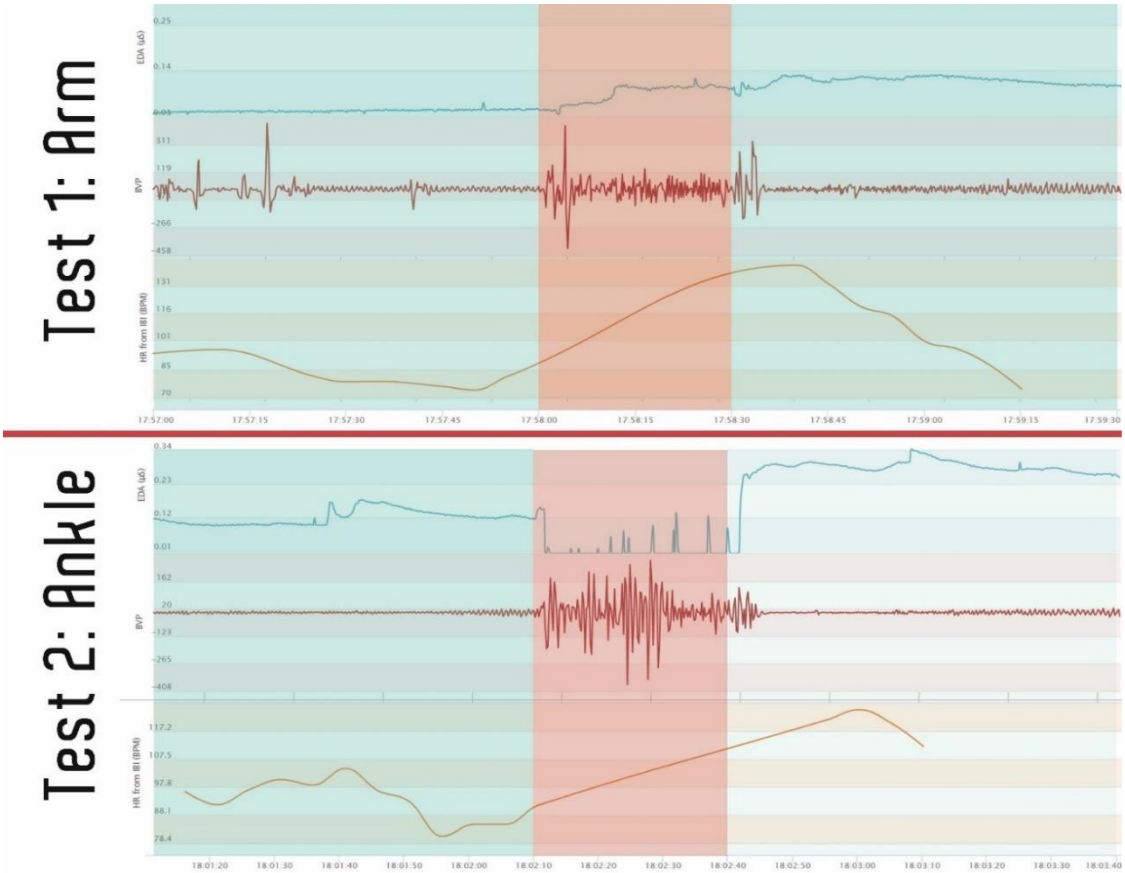


Figure 84. *Self-test on the arm and ankle to see whether the Empatica E4 was indeed not tight enough on the skin. Blue is sitting, red is exercise.*

Figure 85. *Self-test on the arm and ankle to see whether the Empatica E4 was indeed not tight enough on the skin. Blue is sitting, red is exercise.*

stable, increasing a bit during and after exercise. The HR values are normal and increase during exercise, which is to be expected. The second test shows similar stability, with normal HR values that increase during exercise and a relatively stable EDA graph that increases after exercise. The greatest difference between these two graphs is the instability of the EDA values during exercise

when the Empatica E4 is worn around the ankle. Apart from that, this self-test would suggest that stable measurements with the Empatica E4 are possible and it was indeed the (lack of) tightness on the skin that caused the previously mentioned incoherent results.

7.1.2 Interview Results

After having worn the sensors, participants were asked questions about their overall experience and their view on the project idea. All results can be found in *Appendix O - Summary Physical Testing*. Generally, participants expressed that wearing the sensors felt alright, not extremely noticeable but fairly tight on the skin. They stated that the ankle would be the right location on the body to measure since it was also relatively out of reach for the infant. However, one participant stated that it should still be possible for the infant to indicate whether the sock was too tight or leading to other negative sensations. Regarding the general idea of wearing sensors, participants expressed their enthusiasm over wearing such technologies but also pointed out that it was quite normal in today's society. Comparing this sock idea with the body scans in a hospital, a participant stated that this tool would be much more accessible and less risky.

When looking at their measurement data, participants expressed that it was fascinating to see but also very hard to interpret. They stated that seeing such data as a caregiver might be insightful but could also cause extra stress; a dilemma which has been identified before and is again uncovered here.

The most important aspects the sock would need to have were described as:

- The sock should be safe on a technical side but also pose no physical/mental side effects.
- Measurement data should be reliable and processed well so that is can be insightful.
- It should be a subtle and sturdy product that requires little to no extra attention from the caregivers.

Some new suggestions were also made, like looking at the creation of a romper suit or making a complete sock to have a "normal" product, but also integrating tight spots similar to sport socks such that Velcro would not be needed.

Overall, a participant stated that they would use the product on their child if it was necessary, given that it would give reliable measurements, grading the idea with an average of a 9/10. The addition of the app was also seen as valuable and appealing.

7.2 Digital Testing

During the digital part of the evaluation phase, the design of the app was assessed to see whether it was intuitive, user-friendly, and valuable. For this phase, target users were asked to navigate through the app, perform specific tasks, and answer some questions about the design and user experience. The complete summary of the digital testing phase can be found in *Appendix P - Summary Digital Testing*. Six people participated in the digital testing phase, four of which had been contacted through their survey input (see Section 4.1 and

Appendix D - Summary Of Survey Results for more information). Out of these four, two people had also previously participated in the target groups interviews as described in Section 5.1 and *Appendix H - Summary Of Interviews.* The remaining two participants were recruited through the personal network. All participants were mothers, between the age of 32 and 36 years old. They had an average of two children and most of them had a background related to this project, meaning that they were very familiar to the topic of stress in infants.

7.2.1 General Results

In general, participants were very happy with the result of the app, stating that they would definitely use it if it were referred to them (9.2/10 on average from five parents, one did not give a graded answer). This is not only because of the design of the app but also because of the purpose it would fulfil.

The participants liked the clear and aesthetically pleasing ambience of the design and described it as a friendly and calm app, often relating to the fake entries that were put there. Interaction with the app appeared to be quite natural and the number of features included in the app was sufficient. Participants liked how there were personal aspects in the app: a profile picture for the mom, and personal names used to address the mother and the child. There was not a lot of text, which was appreciated because it enabled people with all kinds of backgrounds and capabilities to understand the app.

Something that should be taken into consideration, however, is the general tone of the app. A participant pointed out that questions and topics discussed were generally aimed at negative things (“Is one of these things bothering you?”, “I am unable to calm down my child”) and suggested implementing more positive aspects as well as rephrasing some of the questions asked to get a more neutral experience.

Other suggestions that were made where:

- Including a forum or an option to add people in your network, so you can share experiences and provide each other with tips.
- Implementing a zoom-in function for the statistics so you can look more closely at data over time
- Enabling the user the not fill in some data, by leaving the scales empty until the user taps on a scale.

- Include additional information about the development of infants so it can reassure caregivers and teach them what is normal behaviour.
- Customizing the stress symptoms for the child so it can be adapted to the age of the baby.
- Being more specific about the stress factors, so it is less openly interpretable.

Include a way to add pictures or text about small accomplishments, since caregivers would like to share and capture such moments.

7.2.2 Tasks

Participants were asked to perform eight tasks, which would lead the user to the main functionalities of the app. In general, performing these tasks went well and went as expected. Some notable observations, however, were also made:

- Participants were mostly unable to find the “My Products” feature in the app because they were only focused on the navigation bar at the bottom of the screen. This could be solved by opening the app on with the Profile Options screen opened, or by pointing users to this screen when they use the app for the first time.
- When asking participants to get more information about specific entries, some caregivers visited the main page for the textual information, and some went to the statistics page. Although participants understood the difference between these pages, it is interesting to see that both pages are seen as providing extra information.
- Some participants missed that they could click on an emotion in the “Most prevalent emotion” graph to expand it and see more information. They did like the way this information was hidden until one clicked on it, however.
- When asking participants what they would do if they had a question about their entries, they had different responses. Some went straight to the Professional page, whereas other participants visited the Tips section. They often explained that small matters would be solved by going to the Tips section, but specific questions or matters that were not solved by going to the Tips page would rather be discussed with a professional.

7.2.3 Pages

There were also some insights about the specific pages. The most important elements are highlighted here. Starting with the overview page (main page), participants appreciated the diary-like structure of the page and the use of icons. The popup feature, although sometimes

overlooked, was seen as attractive and insightful. It was a good way to provide more information without cramping the page.

Moving on to the statistics page, it was suggested to move the third graph more to the top so emotion-focused graphs would be grouped. Furthermore, the second graph (which focuses on the impact of stressors on one's feelings) was not always seen as clear. The label could be hard to interpret and the graph lines could be coloured more clearly and coherently. Lastly, the "Often on..." statistics at the second and third graph were not really clear. It was suggested to include some text to explain how these would relate to the information above. Additionally, it felt weird to see negative icons there when other information was quite positive (especially at the third graph).

For the new entry page, participants stated that it would be best to fill this in on standard moments during the day – using notifications to be reminded to fill it in. They suggested customizing the stress symptoms that users could fill in so the symptoms they would see would be more relatable. This could, for example, be done by having a list of symptoms on a different page that users choose a selection from which would be displayed when filling in a new entry. Participants did like the structure and style of the page, similarly to the main page. However, to make it a bit more clear and easy to use, a participant suggested to rephrase the "What are you doing?"-question to "What have you been doing in the past X hours?" so it is better to interpret. A general confirmation after filling in the entry was also missed, but the checkmark was seen as a clear button to use for saving the entry. Lastly, it was also pointed out that some questions (e.g. the impact of stress factors) might be a bit superfluous to fill in for multiple times per day. Maybe it would be nice to ask that only once per day.

The contact and tips pages were seen as valuable and complementary. A specific question could be asked using the contact page, and more general tips could be found on the Tips page. Some participants would like to have multiple professionals registered in the app, whereas others stated that they would only like to include the specific professional working on this project. It was also suggested to only implement tips of valuable sources, and provide a link to get more information so that the tips are informing and reliable.

7.3 Concluding Remarks

At the beginning of this phase, two research questions were asked. Looking back, we can now answer these questions and debate what this means for the future. First, let's look at the physical testing phase. This part was aimed at discovering to what extent the sensors of the wearable could

be seen as stable and usable for stress monitoring. Five people were asked to participate and each round of tests resulted in very different conclusions. From this, we can state that this phase is not sufficiently conclusive to state that the sensors are stable and usable. Additional research would be needed to conclude the stability of the sensors on the ankle since it is not known exactly what has caused these irregularities in the measurement data. Comparing the tests with the two self-tests done afterwards implies that much more clarity would be gained by ensuring that the sensors are sufficiently tight against the skin. This was presumably not the case during this evaluation phase. Furthermore, the muscle sensor seemed to have some connectivity issues at least two separate times. Finding out what would be the cause of that would also provide more clarity. In the end, we can see that the muscle sensor is somewhat stable since patterns are clearly seen. However, nothing conclusive can be said about the EDA and HR data other than that the results did not show reliable and realistic data. This means that additional research is needed to be able to answer the research question to a more satisfactory degree.

Looking at the second part of the evaluation phase, the digital user testing, we can draw another conclusion. This part looked at the user experience and evaluated to what extent the aims of creating an easy and quick to use app design were reached. In general, participants were really positive about the app design and structure. It was clear, insightful, friendly, and appealing, with sufficient possibilities regarding the use of the app. There were some suggestions and remarks, like including more positive elements to get a more neutral experience, and tweaking the phrasing and positioning of certain elements to increase clarity (e.g. moving the third graph up to group graphs about emotion). The app was seen as simplistic and easy to use, but it is uncertain whether the app would also be able to use quickly. Navigating through the app went rather smoothly, but filling in a new entry, and especially filling in multiple entries on a day would still consume quite some time. However, this was not seen as a bad thing, rather as an obligation. Concludingly, we can state that target users have positively experienced the app and appreciate both its design and structure, as well as its purpose – making it a valuable addition to the wearable.

8. Discussion & Suggestions for Future Work

At the start of this project, it became known that since this is only the tip of the iceberg, there is a lot of work that can only be thought out. This research has aimed to solidify the focus in creating a solution and assessing to what extent it would be a real, functioning solution. An idea for a smart sock combined with a diary-like app was worked out and prototypes were made. For the smart sock, the focus was put on evaluating the stability of the sensors, and the app focused on showcasing interactions that the real app would also have.

Through a thorough state of the art research, many similar products, techniques, and solutions have been identified that could play a role in increasing reliability when monitoring stress levels. By stating that observation-based techniques were lacking in reliability, a focus was put on the measurement-based tools. From these tools, three methods were taken that could be used to monitor stress: heart rate variability (HRV), electrodermal activity (EDA), and muscle tension. Measuring stress through HRV is a more commonly used method, so this step seemed logical - it requires technologies that already exist. The use of EDA is a bit more uncertain; it is often used for mood indicators, but cannot stand alone as a way to monitor stress since it only provides information about the intensity of stress. Therefore, additional biomarkers are needed to distinguish happiness from stress or depression. Lastly, muscle tension is a relatively new factor to consider when measuring stress. As stated in Section 2.2, the researches that have been done using muscle tension show promising results, but it is not as watertight as the use of HRV yet. Therefore, we can debate whether the use of these three biomarkers would result in sufficiently reliable results. The reason why we still chose to opt for those three was that they were assumed to strengthen each other in their functionalities. Measuring muscle tension could indicate tension and possibly stressful feelings, which would be supported by EDA measurements stating whether this is a neutral or extreme feeling, and HRV data could indicate to what extent this originates from stress. Additionally, this data can – from theory – be gathered from multiple parts of the body, making it a very flexible method of monitoring stress. However, there might still be other methods such as measuring cortisol or including data on breathing patterns that can increase the reliability of the tool. However, these methods are not as versatile or still heavily in development. Since this still is a topic with many possibilities and outcomes, it was very important to evaluate the stability of measuring HRV, EDA, and muscle tension on the ankle so we could see if it was indeed suitable

(as we suspected), or if other parts on the body or other techniques needed to be used to monitor stress levels.

When evaluating the wearable prototype, it was quickly noticed that the results were significantly different per participant and also showed little realistic results. This was unexpected because the measurement conditions had been the same. The wristband and muscle sensor had been self-tested before so its functionality was guaranteed, they were not broken. However, putting these sensors on oneself and putting them on others is a different action which might result in wearing it differently. Furthermore, the self-tests of the wristband were done using the band it already contained, but the user tests were using the self-made band to attach the wristband tightly to the ankle. This was suspected as the most influential flaw in the setup; the wristbands were possibly not tight enough, which would make it more difficult for the sensors to measure the bodily functions well. This also became apparent during another self-test, in which the original bands were used around the wrist and ankle. This test showed more coherent and realistic measurement data, implying that it was indeed the tightness of the band around the ankle that caused these irregularities.

The muscle sensor performed better and more stable as well, as it was not part of the wristband and therefore not experiencing this problem. The problems the muscle sensor encountered, however, were also impactful. Two times, the sensor lost connection with the body and/or the Arduino which resulted in unusable data. While it is understandable in the sense that this muscle sensor is used for prototyping only and is therefore not of the greatest quality, it might have been taken into consideration when designing the test set-up; maybe asking participants to run was asking too much of the sensors.

One had hoped that at the end of this project a clear statement could be formulated about the validity of measuring stress using the ankle as a focal point on the body, however, this is not yet the case. Additional research is absolutely necessary so human errors can be ruled out and the results can only be influenced by the performance of the sensors. Therefore, it would be wise to evaluate the effectiveness of separate heart rate and electrodermal activity sensors, so they can be assessed individually. If the sensors would then seem to be unreliable when it comes to measuring stress, then it would be good to focus on different parts of the body such as the head, shoulders, or torso, since these body parts have also been focused on in previous stress-monitoring research. Additionally, considering the inclusion of cortisol samples could also help

increase the reliability of stress-monitoring devices. However, it remains a different hormone to focus on since the technologies that would be able to read cortisol samples continuously are still in development. Once sensors are deemed stable and reliable, a focus can be put on adjusting the prototype to the target user: the infants. The sensors can be integrated into the fabric, and the actual sock can be made and tested. Signal values can be determined so the sensors can not only measure stress levels, but the stress levels can also be interpreted. Lastly, the connection with the app needs to be made, so its measurement data can be collected and stored.

The second prototype, the app design, has had fruitful results. Participants liked the idea and would be open to using it, which would mean that this prototype could be worked out into an actual mobile app – taking into consideration the remarks and suggestions provided. That would mean that the addition of more positive aspects needs to be considered, and other adjustments regarding phrasing and structure need to be implemented. Once the app has been developed, its long-term use can be evaluated, seeing whether caregivers actually use the app regularly, whether it would impact them in their daily life or not, and other – for now – hypothetical situations that were brought up throughout this project. Additionally, a big focus should be put on the ethical implications of this product. Contact with several stakeholders has shown that there are some dilemmas that should be handled with care to ensure that the product only has a positive effect on one's well-being. Giving caregivers continuous insights into the measurement data might be transparent, but can also negatively influence them. Furthermore, one should be mindful about the impact the app and wearable results could have one the lives of both the caregiver and their child. Transparency is necessary about this impact, and a clear overview should be made about the responsibilities of respectively the tool, the professional, and the caregivers in this process. It remains a sensitive and personal subject that we try to help with.

Next to the evaluation results, there are also additional focus points that need to be looked at. These have been identified in the conceptualization phase and formulated in Section 5.2. A long list of requirements was formulated which were categorized based on priority. Several of those were labelled "Will not", meaning that – although valuable or interesting for this project – they would not be implemented in this research. Near the end of the specification phase and during the realization phase, it also became clear which ones of the "Could have" and "Should have" requirements would stay put as a concept requirement. Eventually, some "Must have" requirements were also only included in theory. Looking back at this list, we can name a lot of

aspects and features in this project that still need to be looked at. Some of the requirements have been taken into account when developing the concept but are not realized in the end result.

Regarding the wearable, more focus should be put on the type of fabric that will be used in the final product. It should be subtle and comfortable so it does not impact the infant, but also sturdy and stable so it does not impact the measurement data. Allowing caregivers to put on the sock easily would also be very valuable as it, again, would minimize the negative impact of the product on its users (e.g. not causing frustration). Research needs to be done on the possibilities of integrating sensors in the fabric so they are watertight but also washable. To increase user experience, it should be clear when the wearable is connected/transmitting data or when it needs to be charged. If possible, the battery should last for a long time and charging should be done efficiently so the wearable can be used with little breaks. The data it will collect needs to be sent to the app and stored there. Research is needed into efficient methods in which this can be done, to avoid data being slow or unsafely stored. The data that is collected also needs to be processed well, so stress-levels can be derived from the information that is retrieved. Through several data analyses scripts, this would be possible, creating insightful data visualizations as a result. Lastly, the design that has been made needs to be worked out in reality so the sock combined with the sensors can be evaluated on an aesthetical level as well.

For the app, this means that the workload of the app for caregivers needs to be assessed so it takes only a maximum of five minutes to fill in an entry. Implementing a calendar function would allow the user to write down their observations for specific times of the day so moods and experiences can be related to specific activities or moments in the day. Furthermore, the app is stated to be optional to use. Through contact with target users, this need and exact definition will need to be further phrased. Should the sock alone be sufficient, or would it be fine if caregivers can fill in entries in the app as specifically as they would like? Furthermore, the psychological effect of both the app and the wearable on the target users should be assessed. They should be neutral products that would have a little effect on their users as possible. Through user evaluations and observations, this should still be examined.

Some suggestions provided by the target users that are still worth considering and looking into are some extra or customizable options:

- Creating a wearable specifically for an age stage so it fits the infant’s size and needs.

- Using machine learning techniques in the app to adjust the phrasing of tips, suggestions, and questions asked in entries to the user and their needs.
- Adapting the stress symptoms focused on in the app to the age of the baby so these are different per age stage/developmental stage.
- Measure stress levels of caregivers as well to be able to draw more founded conclusions.
- Time the appearance of certain activities automatically or manually (e.g. press a button if the baby is crying) to get more realistic insights into the infant's behaviour.
- Additional factors can be discussed in the app when the caregiver fills in a new entry (e.g. stress in general, sports, affection, diaper quality).

Lastly, some general ideals need to be taken into account in future work on this project. The product idea is meant to assist both professionals and caregivers in finding out whether the infant is experiencing chronic stress and should therefore be accessible to all who need it. In the development of this product into its final stage, this should be taken into account looking at the costs of components that would be needed. Additionally, it would be worth looking into an alternative to the app in case caregivers want to use it but do not have the smartphone to use it on. Implementing it into a website would be one way to do this.

This chapter shows how there is still a lot of work to be done before this concept idea nears the final product stage. Through constant evaluation and iteration, step by step, the concept needs to be worked out and adjusted so that it functions well without harming or burdening the user in the process.

9. Conclusion

This project has laid the foundation for the development of a device that would monitor stress-levels in infants. Currently, it is difficult to efficiently diagnose chronic stress in infants, which often finds its root in their environment. Stress in infants is usually the result of instability in their environment or having a weak bond with their caregivers, which can lead to developmental delays and behavioural problems later on in their life. Methods used nowadays to diagnose stress are unreliable or inaccessible, making it hard to paint a realistic picture of the factors involved in the infant's life. Caregivers filling in surveys or questionnaires can give insights on the experience of life at home but are influenced by their perspective and emotions. Taking lab samples to measure stress levels will result in a snapshot image of one's stress levels, not continuous ones. Additionally, the way these samples are acquired can also influence the infant's stress level, making these insights less reliable as well.

This project focused on exploring the possibilities of stress-monitoring devices which could be used on infants at home so more reliable insights would be acquired without burdening the child nor the caregivers. The focus was put on one main research question:

To what extent can a tool be developed that will reliably recognize stress in babies in their home setting?

Many ideas were generated and a selection of eight ideas was made, using the technical backgrounds of the supervisors and the medical and psychological knowledge of the clients as reference for what would be the most effective and achievable ideas. Involving target users in this part of the process enabled us to choose and work out a desirable idea for a wearable sock that was regarded as the most user-friendly and safe, hence finding a balance between user experience and effectiveness. Instead of the "stress hormone" cortisol, the focus was put on using multiple biomarkers – heart rate variability, electrodermal activity, and muscle activity – to gain stable insights in the stress-levels of the user. Since caregivers had indicated that they would like to be involved in this stress-monitoring process, the idea of using a supportive app has been worked out as well – enabling caregivers to show their side of the story without affecting the reliability of the wearable.

During the realization phase of the project, the focus was put on creating the functionality of the stress-monitoring device rather than the wearable as a whole. Because of the limited time

for the project, the priority was put on assessing whether the core of the idea – using sensors at the ankle to monitor stress-levels – would be realistic to further implement into a more finalized product. Simultaneously, the interactions of the supportive app were created, focusing on the functionalities it should provide rather than the software implementations it would need. These prototypes were evaluated with the following questions in mind:

Would the ankle be a suitable location for a stress-monitoring device?
Would an app sufficiently involve caregivers and support the measurement data?

In the end, only part of an answer can be given to these questions. The measurement data that was retrieved during user testing came back inconclusive and showed little stable caregivers. It was suspected that the sensors were not attached tightly enough to get stable results, which was evaluated using a self-test. The latter showed much more stable results, leading us to state that this might indeed be the cause and that it is therefore too early to completely discard the idea and start anew with a different concept and a different focus. Additional tests are needed to further evaluate the functionalities of the sensors. Ending on a more positive note, the app was experienced much more positively – caregivers were able to easily navigate and make use of the app, but also acknowledged its value and stated that they would definitely use both the app and the wearable if it was necessary.

Therefore, we can conclude that – although the reliability and stability of the sensors cannot be guaranteed yet – a solid basis has been created for a possible way to monitor stress-levels in infants more reliably and continuously, so chronic stress can be diagnosed easier and quicker, and negative effects of stress are minimized. The extent to which a tool has been developed that can reliably recognize stress in infants in their home setting is greater in theory, but the practice is now unfolding and with additional research, we foresee that a solid product can be developed that will fulfil this goal.

References

[1] Centre for Educational Neuroscience, “Most learning happens in the first 3 years,” n.d.. [Online]. Available: http://www.educationalneuroscience.org.uk/resources/neuromyth-or-neurofact/most-learning-happens-in-the-first-3-years/.

[2] Centers for Disease Control and Prevention, “What is a Developmental Milestone?,” 2020. [Online]. Available: https://www.cdc.gov/ncbddd/actearly/milestones/index.html.

[3] Maria Farinha Filmes, “The Beginning of Life: The Series,” 2016. [Online]. Available: Netflix Nederland.

[4] Z. Azghar and D. Amso, *Stress In Infancy And Early Childhood,* n.d..

[5] D. Umberson and M. Thomeer, “Family Matters: Research on Family Ties and Health, 2010 to 2020,” *Journal of Marriage and Family,* vol. 82, no. 1, pp. 404-419, February 2020.

[6] L. Folden Palmer, “Stress in Infancy - The Natural Child Project,” 2004. [Online]. Available: https://www.naturalchild.org/articles/guest/linda_folden_palmer2.html.

[7] C. Peña-Bautista, R. Escrig, I. Lara, A. García-Blanco, C. Cháfer-Pericás and M. Vento, “Non-invasive monitoring of stress biomarkers in the newborn period,” *Seminars in Fetal and Neonatal Medicine,* vol. 24, no. 4, August 2019.

[8] M. Ryan, “How to Spot Signs of Stress and Anxiety in Your Toddler,” 2020. [Online]. Available: https://www.verywellfamily.com/how-to-spot-signs-of-stress-in-your-toddler-289858.

[9] E. Van der Gaag, *Personal Communication,* 2020.

[10] A. Oyetunji and P. Chandra, “Postpartum stress and infant outcome: A review of current literature,” *Psychiatry Research,* vol. 284, 2020.

[11] K. Hogenelst, M. Soeter and V. Kallen, “Ambulatory measurement of cortisol: Where do we stand, and which way to follow?,” *Sensing and Bio-Sensing Research,* no. 22, 2019.

[12] E. G. Spratt, S. L. Friedenberg, C. C. Swenson, A. LaRosa, M. D. De Bellis, M. M. Macias, A. P. Summer, T. C. Hulsey, D. K. Runyan and K. T. Brady, "The Effects of Early Neglect on Cognitive, Language, and Behavioral Functioning in Childhood," *Psychology,* vol. 2, no. 3, pp. 175-182, February 2012.

[13] K. Weir, "The lasting impact of neglect," *Monitor on Psychology,* vol. 6, no. 45, June 2014.

[14] H. Als and S. Butler, "Screening, Newborn, and Maternal Well-Being," *Encyclopedia of Infant and Early Childhood Development,* pp. 66-78, 2008.

[15] M. P. Judge, A. F. Diallo and C. T. Beck, "Chapter 11 - The Effects of Omega-3 Polyunsaturated Fatty Acids on Maternal and Child Mental Health," *Omega-3 Fatty Acids in Brain and Neurological Health,* pp. 121-129, 2014.

[16] K. Lyons-Ruth, "Attachment relationships among children with aggressive behavior problems: the role of disorganized early attachment patterns," *Journal of Consulting and Clinical Psychology,* vol. 1, no. 64, pp. 64-73, February 1996.

[17] M. Nachmias, M. Gunnar, S. Mangelsdorf, R. H. Parritz and K. Buss, "Behavioral inhibition and stress reactivity: the moderating role of attachment security," *Child Development,* vol. 2, no. 67, pp. 508-522, 1996.

[18] K. E. Hannibal and M. D. Bishop, "Chronic Stress, Cortisol Dysfunction, and Pain: A Psychoneuroendocrine Rationale for Stress Management in Pain Rehabilitation," *Physical Therapy,* vol. 12, no. 94, pp. 1816-1825, December 2014.

[19] Michigan Medicine, "Pain and Your Infant: Mediccal Procedures, Circumcision and Teething," 2007. [Online]. Available: http://www.med.umich.edu/yourchild/topics/paininf.htm.

[20] H. C. Braarud and K. Stormark, "Maternal soothing and infant stress responses: Soothing, crying and adrenocortical activity during inoculation," *Infant Behavior and Development,* vol. 1, no. 29, pp. 70-79, January 2006.

[21] R. M. Califf, “Biomarker definitions and their applications,” *Experimental Biology and Medicine,* vol. 3, no. 243, pp. 213-221, 2018.

[22] C. de Weerth, R. H. Zijl and J. K. Buitelaar, “Development of cortisol circadian rhythm in infancy,” *Early Human Development,* Vols. 1-2, no. 73, pp. 39-52, August 2003.

[23] L. Jones, L. Fabrizi, M. Laudiano-Dray, K. Whitehead, J. Meek, M. Verriotis and M. Fitzgerald, “Nociceptive Cortical Activity Is Dissociated from Nociceptive Behavior in Newborn Human Infants under Stress,” *Current Biology,* vol. 24, no. 27, pp. 3846-3851, December 2017.

[24] B. M. Sorondo and B. C. Reeb-Sutherland, “Associations between infant temperament, maternal stress, and infants' sleep across the first year of life,” *Infant Behavior and Development,* no. 39, pp. 131-135, May 2015.

[25] M. M. Loman and M. Gunnar, “Early Experience and the Development of Stress Reactivity and Regulation in Children,” *Neuroscience & Biobehaviour Reviews,* vol. 6, no. 34, pp. 867-876, May 2010.

[26] E. Mörelius, *Stress in infants and parents: studies of salivary cortisol, behaviour and psychometric measures,* 2006.

[27] M. Chóliz, E. G. Fernández-Abascal and F. Martínez-Sánchez, “Infant Crying: Pattern of Weeping, Recognition of Emotion and Affective Reactions in Observers,” *The Spanish Journal of Psychology,* vol. 15, no. 3, pp. 978-988, 2012.

[28] Nederlands Jeugdinstituut, “Zoek een instrument,” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument.

[29] Richtlijnen jeugdhulp en jeugdbescherming, “KOPP: Screenen op risico's,” n.d.. [Online]. Available: https://richtlijnenjeugdhulp.nl/kopp/screenen-op-risicos/verdere-screening-van-emotionele-problemen-gedragsproblemen-en-gezinsfunctioneren/.

[30] Nederlands Jeugdinstituut, “Child Behavior Checklist (CBCL),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument/Child-Behavior-Checklist-(CBCL).

[31] Nederlands Jeugdinstituut, “Infant and Toddler Quality of Life Questionnaire (ITQOL),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Infant-and-Toddler-Quality-of-Life-Questionnaire-(ITQOL).

[32] Nederlands Jeugdinstituut, “Ontwikkelingsvolgmodel (OVM),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument/Ontwikkelingsvolgmodel-(OVM).

[33] Nederlands Jeugdinstituut, “Strengths and Difficulties Questionnaire (SDQ),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument/Strengths-and-Difficulties-Questionnaire-(SDQ).

[34] Nederlands Jeugdinstituut, “Structured Problem Analysis of Raising Kids (SPARK),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Structured-Problem-Analysis-of-Raising-Kids-(SPARK).

[35] Nederlands Jeugdinstituut, “Quality of Well-Being Scale (QWB),” n.d.. [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument/Quality-of-Well-Being-Scale-(QWB).

[36] Nederlands Jeugdinstituut, “Van Wiechenonderzoek (VWO),” [Online]. Available: https://www.nji.nl/nl/Databank/Databank-Instrumenten/Zoek-een-instrument/Van-WiechenOnderzoek-(VWO).

[37] Nederlands Centrum Jeugdgezondheid, “Innovatie- en Kenniscentrum voor Professionals in de Jeugdgezondheidszorg,” n.d.. [Online]. Available: https://www.ncj.nl/.

[38] Nederlands Centrum Jeugdgezondheid, “SamenStarten,” n.d.. [Online]. Available: https://www.ncj.nl/samenstarten/.

[39] Nederlands Centrum Jeugdgezondheid, “GIZ-methodiek,” n.d.. [Online]. Available: https://www.ncj.nl/giz/.

[40] Nederlands Centrum Jeugdgezondheid, “Stevig Ouderschap,” n.d.. [Online]. Available: https://www.ncj.nl/stevigouderschap/.

[41] M. Slesar, “Emotion-Sensing Technology in the Internet of Things,” n.d.. [Online]. Available: https://onix-systems.com/blog/emotion-sensing-technology-in-the-internet-of-things.

[42] S. Sannon, D. J. Difranzo, B. Stoll and M. Jung, “How Personification and Interactivity Influence Stress-Related Disclosures to Conversational Agents,” October 2018. [Online]. Available: https://www.researchgate.net/publication/328683235_How_Personification_and_Interactivity_Influence_Stress-Related_Disclosures_to_Conversational_Agents.

[43] Headspace, “Be kind to your mind,” n.d.. [Online]. Available: https://www.headspace.com/.

[44] Moodfit, “Fitness for Your Mental Health,” n.d.. [Online]. Available: https://www.getmoodfit.com/.

[45] J. Fingas, “App tracks mental health by studying your phone usage,” July 2020. [Online]. Available: https://www.engadget.com/prosit-phone-app-tracks-mental-health-230311179.html.

[46] R. R. Rice and B. Dunbridge, “Robust and low cost optical system for sensing stress, emotion and deception in human subjects,” 2005. [Online]. Available: https://patents.google.com/patent/US20050089206A1/en.

[47] Nanit, “Nanit Sleeping Bag,” 2019. [Online]. Available: https://www.nanit.com/products/sleeping-bag?pack=one-pack&size=small&color=pebble-grey .

[48] G. Bianchi, “Baby cry detection - Building the model,” August 2019. [Online]. Available: https://github.com/giulbia/baby_cry_detection.

[49] J. Fletcher, “What does a cortisol level test show?,” 2018. [Online]. Available: https://www.medicalnewstoday.com/articles/322330#what-is-the-procedure.

[50] J. Gomez, “Researchers Develop New Smartphone Technology and App to Diagnose and Monitor Adrenal Gland Diseases,” Intermountain Healthcare, n.d.. [Online]. Available:

https://intermountainhealthcare.org/news/2014/06/researchers-develop-new-smartphone-technology-and-app-to-diagnose-and-monitor-adrenal-gland-diseases/.

[51] L. Borreli, "Smartphone Stress Hormone Test App May Be Able To Measure Cortisol Levels: What Are Signs Of Stress?," Medical Daily, July 2014. [Online]. Available: https://www.medicaldaily.com/smartphone-stress-hormone-test-app-may-be-able-measure-cortisol-levels-what-are-signs-stress-291664.

[52] B. A. Kalman and R. E. Grahn, "Measuring Salivary Cortisol in the Behavioral Neuroscience Laboratory," *Journal of Undergraduate Neuroscience Education,* vol. 2, no. 2, pp. 41-49, June 2004.

[53] J. Huizen, "What to know about 24-hour cortisol urine tests," February 2019. [Online]. Available: https://www.medicalnewstoday.com/articles/324573#uses.

[54] NOS op 3, "Hoe het echt zit met stress en onze generatie," December 2019. [Online]. Available: https://www.youtube.com/watch?v=7kspa9CIjMc.

[55] Mijn Labtest, "Cortisol dagprofiel test," n.d.. [Online]. Available: https://mijnlabtest.nl/cortisol-dagprofiel-test.html.

[56] J. Kim, W. R. de Araujo, I. A. Samek, A. J. Bandodkar, W. Jia, B. Brunetti, T. R. L. C. Paixão and J. Wang, "Wearable temporary tattoo sensor for real-time trace metal monitoring in human sweat," *Electrochemistry Communications,* no. 51, pp. 41-45, February 2015.

[57] T. Kubota, "Wearable device from Stanford measures cortisol in sweat," Stanford News, July 2018. [Online]. Available: https://news.stanford.edu/2018/07/20/wearable-device-measures-cortisol-sweat/.

[58] Medgadget, "First Noninvasive Cortisol Detector to Monitor Stress, Mental Conditions," February 2020. [Online]. Available: https://www.medgadget.com/2020/02/first-noninvasive-cortisol-detector-to-monitor-stress-mental-conditions.html.

[59] A. Pietrangelo, "The Effects of Stress on Your Body," March 2020. [Online]. Available: https://www.healthline.com/health/stress/effects-on-body#1.

[60] Muse, “Brain Sensing Headbands That Improve Your Meditation Practice,” n.d.. [Online]. Available: https://choosemuse.com/.

[61] M. Moore, “V1bes Wearable Looks To Your Finger To End Stress,” March 2015. [Online]. Available: https://www.silicon.co.uk/e-innovation/v1bes-wearable-ring-stress-detector-164229.

[62] HeartMath, “The Science of HeartMath,” n.d.. [Online]. Available: https://www.heartmath.com/science/.

[63] The Breath Effect, “Spire - Monitor Your Breathing,” n.d.. [Online]. Available: https://www.thebreatheffect.com/spire-breathing-tracker/.

[64] C. E. Hunt and F. R. Hauck, “Sudden infant death syndrome,” *Canadian Medical Association Journal,* vol. 13, no. 174, pp. 1861-1869, June 2006.

[65] D. Maiershon and O. Akstein, “Device and Method for Providing Information Indicative of a Stress Situation in a Human”. United States Patent PCT/B2O13A056O13, 23 July 2015.

[66] Babydump, “Snuza Hero MD Ademhalingsbabymonitor,” n.d.. [Online]. Available: https://www.baby-dump.nl/product/babyfoons/53/snuza-hero/54224/snuza-hero-md-ademhalingsbabymonitor/122969/.

[67] Amazon, “Owlet Smart Sock 2 Baby Monitor, Green,” n.d.. [Online]. Available: https://www.amazon.com/Owlet-Baby-Care-BM03NNBBYC-Socken-2-Baby-Monitor/dp/B06ZZXYD6S.

[68] M. Sawh, “Stress wearables: best devices that monitor stress and how they work,” 2020. [Online]. Available: https://www.wareable.com/health-and-wellbeing/stress-monitoring-wearables-explained-7969#stress.

[69] N. S, “Stressed out? Try one of these wearables for stress detection and management,” 2020. [Online]. Available: https://www.myhealthyapple.com/wearables-offering-stress-detection-management/.

[70] WellBe, “How the WellBe works,” n.d.. [Online]. Available: https://thewellbe.com/pages/features.

[71] HeartMath, “Inner Balance - An unparalleled window into your emotional wellbeing,” n.d.. [Online]. Available: https://www.heartmath.com/the-inner-balance/.

[72] B. Farnsworth, “What is GSR (galvanic skin response) and how does it work?,” July 2018. [Online]. Available: https://imotions.com/blog/gsr/.

[73] Pip, “The Science Behind The Pip,” n.d.. [Online]. Available: https://thepip.com/en-eu/science/.

[74] J. L. P. Wijsman, “Sensing stress: stress detection from physiological variables in controlled and uncontrolled conditions.,” *Enschede: Twente University Press (TUP),* 2014.

[75] L. Edwards, “'Rationalizer' bracelet tells traders when they're stressed,” November 2009. [Online]. Available: https://phys.org/news/2009-11-rationalizer-bracelet-traders-theyre-stressed.html.

[76] G. Blackett, “EMG or Muscle Tension Biofeedback For Stress & Anxiety Management and Mindfulness Support,” Stress Resilient Mind, n.d.. [Online]. Available: https://www.stressresilientmind.co.uk/articles/emg-muscle-tension-biofeedback-stress-anxiety-mindfulness#:~:text=Measuring%20Muscle%20Tension,the%20stronger%20the%20muscle%20contraction..

[77] T. T. Biswas, R. Sardo Infirri, S. Hagman and L. Berglin, “An assistive sleeping bag for children with autism spectrum disorder,” *Fashion and Textiles,* vol. 5, no. 18, 2018.

[78] G. Weigelt, “A vest to measure stress,” Fraunhofer IZM, July 2008. [Online]. Available: https://www.izm.fraunhofer.de/en/news_events/tech_news/weste_meldet_stress.html.

[79] Máxima MC, “Bloeddrukmeting,” n.d.. [Online]. Available: https://www.mmc.nl/kindergeneeskunde/aandoeningen-en-behandelingen/bloeddrukmeting/#:~:text=Uw%20kind%20krijgt%20een%20stuwband,de%20activiteiten%20van%20uw%20kind..

[80] Y. S. Can, N. Chalabianloo, D. Ekiz and C. Ersoy, “Continuous Stress Detection Using Wearable Sensors in Real Life: Algorithmic Programming Contest Case Study,” *Sensors,* vol. 8, no. 19, p. 1849, 2019.

[81] P. Schilperoord, “Sensor Meet Stressniveau,” December 2018. [Online]. Available: https://www.deingenieur.nl/artikel/sensor-meet-stressniveau.

[82] VivaLNK, “Wellness quantified Vital Scout,” n.d.. [Online]. Available: https://www.vivalnk.com/vitalscout.

[83] L. G. Ten Eyck, A. Katakam and K. Starr, “System and Method of Monitoring the Physiological Condition of an Infant”. United States Patent US 8,617,043 B2, 31 December 2013.

[84] A. Mader and W. Eggink, “A Design Process for Creative Technology.,” *Proceedings of the 16th International conference on Engineering and Product Design, E&PDE 2014,* pp. 568-573. (E&PDE), 2014.

[85] Xtensio, “User Persona Template and Examples,” n.d.. [Online]. Available: https://xtensio.com/user-persona/.

[86] M. Meurisse, “Vier brainstormtechnieken waar wij fan van zijn,” Medium, 2017. [Online]. Available: https://medium.com/creativelab/vier-brainstormtechnieken-waar-wij-fan-van-zijn-26bd961b09f6.

[87] ProductPlan, “MoSCoW Prioritization,” n.d.. [Online]. Available: https://www.productplan.com/glossary/moscow-prioritization/.

[88] reMarkable, “reMarkable 2 - The next-generation paper table,” n.d.. [Online]. Available: https://remarkable.com/.

[89] Adobe, “Adobe: Creatieve, marketing- en documentbeheeroplossingen,” n.d.. [Online]. Available: https://www.adobe.com/nl/?mv=search&sdid=88X75SL2.

[90] fritzing - electronics made easy, “Fritzing,” n.d., [Online]. Available: https://fritzing.org/.

[91] Adobe, “Adobe XD - Design like you always imagined,” n.d.. [Online]. Available: https://www.adobe.com/nl/products/xd.html.

[92] Adobe Color, “Kleurenwiel,” n.d.. [Online]. Available: https://color.adobe.com/nl/create/color-wheel.

[93] Empatica, “E4 Wristband - Real-time physiological data streaming and visualization,” n.d.. [Online]. Available: https://www.empatica.com/en-eu/research/e4/.

[94] Kiwi Electronics, “MyoWare Muscle Sensor,” n.d.. [Online]. Available: https://www.kiwi-electronics.nl/myoware-muscle-sensor?gclid=Cj0KCQiAIsv_BRDtARIsAHMGVSZl-zmvz1p82VmBE1iYuAmhitmqtMk2qFPwbmeFGmyqt9GW6rgVNQAaAqYZEALw_wcB.

[95] E4 connect, “Sessions,” n.d., [Online]. Available: https://www.empatica.com/connect/sessions.php.

[96] K. Hartman, “Getting Started with MyoWare Muscle Sensor,” Adafruit, 27 January 2016. [Online]. Available: https://learn.adafruit.com/getting-started-with-myoware-muscle-sensor/about-emg.

[97] J. Nielsen, “Thinking Aloud: The #1 Usability Tool,” NN/g Nielsen Norman Group, 15 January 2012. [Online]. Available: https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/.

[98] Clue, “Track your period and ovulation with Clue to understand how your body works.,” n.d.. [Online]. Available: https://helloclue.com/.

[99] Android Planet, “Google Home,” n.d.. [Online]. Available: https://www.androidplanet.nl/google/home/.

[100] A. Kaspers and A. Dalhoeven, *Personal Communication,* 2020.

[101] B. Hodakel, “What is Cotton Fabric: Properties, How its Made and Where,” Sewport, 17 January 2021. [Online]. Available: https://sewport.com/fabrics-directory/cotton-fabric.

[102] Daylio, “Self-Care Bullet Journal with Goals Mood Diary & Happiness Tracker,” n.d.. [Online]. Available: https://daylio.net/.

[103] Xiaomi Products, “Xiaomi Mi Band 2 - Hét sporthorloge van 2018,” n.d.. [Online]. Available: https://www.xiaomiproducts.nl/xiaomi-mi-band-2.html.

[104] DeviceAtlas, “Viewport, resolution, diagonal screen size and DPI for the most popular smartphones,” 4 October 2019. [Online]. Available: https://deviceatlas.com/blog/viewport-resolution-diagonal-screen-size-and-dpi-most-popular-smartphones.

[105] Empatica Support, “E4 data - BVP expected signal,” January 2020. [Online]. Available: https://support.empatica.com/hc/en-us/articles/360029719792-E4-data-BVP-expected-signal.

[106] Passie voor Jeugd en Gezin, “Welkom op deze website,” n.d.. [Online]. Available: https://www.pjg.nu/.

[107] Reviewgigant, “Beste bloeddrukmeter kopen TOP 10,” n.d.. [Online]. Available: https://www.reviewgigant.com/beste-bloeddrukmeter-kopen-tips/.

[108] E. Smith, “Dal researchers create app that monitors mental health by measuring user's emotions,” July 2020. [Online]. Available: https://www.cbc.ca/news/canada/nova-scotia/dalhousie-university-researcher-prosit-study-smartphone-app-mental-health-treatment-1.5653705.

[109] *Baby Communication Webinar.* [Film]. 2019.

[110] Search Man, “Moodfit,” n.d.. [Online]. Available: https://searchman.com/ios/app/us/1054458809/en/roble-ridge-software-llc/moodfit/.

[111] Alle Kabels, “Arduino UNO REV.3,” n.d.. [Online]. Available: https://www.allekabels.nl/arduino/11445/1267313/arduino-uno-rev.3.html?gclid=Cj0KCQiAlsv_BRDtARIsAHMGVSZQ0HjusMKz8XKlRdaynaSS9S0Vb6rD78S9GOmrGqoysBD7ywxuyE0aArdzEALw_wcB.

[112] Empatica, “Get started with your new E4 wristband,” n.d.. [Online]. Available: https://www.empatica.com/get-started-e4.

[113] TinyTronics, “Bluetooth HC-05 module RF transceiver Master en Slave,” n.d.. [Online]. Available: https://www.tinytronics.nl/shop/nl/communicatie/bluetooth/bluetooth-hc-05-module-rf-transceiver-master-en-slave.

[11 D. van Meggelen, “Correlation between foot movements and sensor values.,” 2021. [Online].
4] Available:
https://docs.google.com/presentation/d/14bjabRIiQKFfV9dO7_tyzmSpIePZbPxuZCkFP14i0JQ/edit?usp=sharing.

Appendix A – Information Brochures For User Confrontations

A.1 Interviews With Caregivers

Informatiebrochure: How high is the stress level?

In deze brochure staat informatie over het onderzoeksproject: “How high is the stress level?”. Dit project wordt geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, en doet onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress bij baby’s.

Het is erg belangrijk voor de ontwikkeling van een kind dat deze goed voelt. Maar hoe weet je dit als ouders, als je kind nog niet kan praten? Je kind kan zich gestresst voelen, wat zich kan uiten in bijvoorbeeld huilgedrag, erg stil zijn, weinig eten, enzovoorts. Maar dit is niet altijd stress, soms kan het ook iets anders zijn. Het is vaak lastig voor ouders om te begrijpen wat er aan de hand is, wat veel zoekwerk en zorgen kan opleveren.

Om te begrijpen wat hierbij voor ouders een grote rol speelt, willen we naast de eerder ingevulde vragenlijst nog een aanvullend interview houden. Deze vragen gaan over uw kind(eren) en uw ervaring van uw kind(eren) met betrekking tot stress. Onder stress wordt hierbij chronische stress of negatieve gevoelens (zoals angsten en depressies) verstaan. Acute stress veroorzaakt door bijv. een plots hard geluid valt hier niet onder. Verder zal er ook worden gevraagd naar eventuele wensen die u kunt hebben bij de ontwikkeling van een product dat kan meehelpen in het herkennen van stress bij baby’s. Deze brochure helpt u beslissen of u mee wilt werken aan het onderzoek.

Onderzoeksprocedure

Door middel van een interview zal informatie worden verzameld over het perspectief van ouders ten opzichte van (mogelijke) stress bij hun kind(eren) en hun leefsituatie. Deze informatie is nodig om een helder beeld te krijgen van de positie waarin ouders zich verkeren op het moment dat hun kind gestresst kan zijn.

In deze folder leggen we uit wat het voor u betekent om aan het onderzoek mee te doen. U beslist zelf of u wilt deelnemen aan het onderzoek. Voor vragen kunt u contact opnemen met Daniela van Meggelen, zie contactgegevens onderaan dit document.

Deelname

Deelname is geheel vrijwillig en het interview zal niet langer dan 30 minuten duren. U kunt op ieder moment, zonder opgaaf van reden, aangeven dat u niet meer wil meedoen aan het onderzoek. Toestemming voor deelname hoeft slechts eenmalig verleend te worden en is geldig tot 48 uur na deelname.

Wat gebeurt er tijdens het interview?

Het interview is bedoeld om te begrijpen wat het doen en laten van een ouder is op het moment dat hun kind gestresst kan zijn. Aangezien stress een gevoelig onderwerp is, willen we zorgen dat we de wensen en grenzen van de potentiële gebruiker van het product meenemen en respecteren bij het ontwerpen van dit product. Dit doen we door vervolgvragen te stellen naar aanleiding van de online vragenlijst die is ingevuld, die wat meer op de details ingaan. Er kunnen gevoelige onderwerpen aangekaart worden, maar daarin ben u vrij om te kiezen of u daarop in wilt gaan of niet. Deze vragen zijn alleen voor onderzoek en hebben niet als doel hulp te verschaffen. Mocht u zoveel stress ervaren dat professionele hulp nodig zou kunnen zijn kan u misschien ook beter niet aan dit interview deelnemen. Drie hoofdonderwerpen worden behandeld: het contact met een arts of andere professional, het beeld van uw kind, en het potentiële product.

Welke gegevens worden er verzameld?

Tijdens het interview worden vragen gesteld en zullen er audio en/of video opnames gemaakt worden om de antwoorden goed te kunnen samenvatten en zo goed mogelijk te interpreteren.

Hoe worden de gegevens bewaard?

De data en videobestanden worden zo anoniem mogelijk verwerkt en veilig bewaard volgens AVG richtlijnen. Onderzoeksgegevens worden volgens VSNU richtlijnen 10 jaar bewaard.

Wie heeft er toegang tot de data?

De antwoorden op de interviewvragen en de audio/videobestanden zijn toegankelijk voor mensen betrokken bij dit onderzoek (zie contactgegevens onderaan het document) en worden

verwijderd na het samenvatten en anonimiseren van de data, indien anders aangegeven door de deelnemer zelf.

Hoe worden de gegevens gebruikt?

De gegevens worden geanalyseerd voor wetenschappelijk onderzoek, inclusief een afstudeeropdracht van de University of Twente student. Dit kan gepubliceerd worden in wetenschappelijke artikelen en in de 'gewone' media, waarbij volledig anonieme resultaten op basis van de gegevens gepresenteerd worden. De gegevens worden mogelijk ook gebruikt door de onderzoekers van dit project voor vervolgonderzoek, passend binnen de kaders van deze brochure. Verder worden de resultaten gebruikt als inspiratie voor het ontwikkelen van de technologie, al dan niet opgepakt door bedrijven die ons wetenschappelijke werk lezen.

Worden er gegevens van mij publiek gemaakt?

De materialen zullen niet zonder toestemming publiek getoond worden of beschikbaar worden gesteld. Het materiaal zal niet ingezet worden voor promotiedoeleinden tenzij hier expliciet apart toestemming voor gegeven is.

Kan ik mijn gegevens laten verwijderen?

Als u tijdens of tot 48 uur na deelname aan dit activiteit besluit dat u niet (meer) wilt meedoen, worden al de gegevens van die sessie verwijderd. Als een sessie is afgerond worden de gegevens van die sessie definitief toegevoegd aan de onderzoeksdata en kunnen ze niet meer verwijderd worden.

Meer informatie en onafhankelijk advies.

Wilt u graag onafhankelijk advies over deelname aan dit onderzoek, of wilt u een klacht indienen? Dan kunt u terecht bij de secretaris van de Ethische Commissie (ethics-comm-ewi@utwente.nl). Deze bestaat uit onafhankelijke deskundigen van de universiteit en is beschikbaar voor vragen en klachten rondom het onderzoek.

Voor inhoudelijke vragen over dit onderzoek kunt u verder terecht bij Daniela van Meggelen, en de andere onderzoekers.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

A.2 Physical Tests Within The Household

Informatiebrochure Testfase Meting: How high is the stress level?

In deze brochure staat informatie over het onderzoeksproject: “How high is the stress level?”. Dit project wordt geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, en doet onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress bij baby’s.

Het is erg belangrijk voor de ontwikkeling van een kind dat deze goed voelt. Maar hoe weet je dit als ouders, als je kind nog niet kan praten? Je kind kan zich gestrest voelen, wat zich kan uiten in bijvoorbeeld huilgedrag, erg stil zijn, weinig eten, enzovoorts. Maar dit is niet altijd stress, soms kan het ook iets anders zijn. Het is vaak lastig voor ouders om te begrijpen wat er aan de hand is, wat veel zoekwerk en zorgen kan opleveren.

Naar aanleiding van een onderzoeksproces waarin een vragenlijst en verscheidene interviews zijn afgenomen, hebben we een prototype kunnen ontwikkelen dat in een thuissituatie continu stress zou kunnen meten bij baby’s. Deze metingen zouden naar een app op de mobiele telefoon van de ouder gestuurd kunnen worden. Verder kan de ouder ook diens eigen ervaring en gevoel in de app invoeren en deze inzien. Op deze manier willen we ouders ondersteunen in het herkennen van het gedrag van hun baby, en het makkelijker maken voor zowel ouders als artsen om te kunnen vaststellen of een baby leidt aan stress zodat zo snel mogelijk de juiste hulp geboden kan worden. Deze testfase focust zich op uw ervaring bij het

gebruik van het prototype. Deze brochure helpt u beslissen of u mee wilt werken aan het onderzoek.

Onderzoeksprocedure

Door middel van deze testfase wordt informatie verzameld over de stabiliteit en werking van het prototype. Op deze manier willen we zien of de focus van dit prototype realistisch is, en plus- en minpunten formuleren die gebruikt kunnen worden in een opvolgfase van dit onderzoek.

In deze folder leggen we uit wat het voor u betekent om aan het onderzoek mee te doen. U beslist zelf of u wilt deelnemen aan het onderzoek. Voor vragen kunt u contact opnemen met Daniela van Meggelen, zie contactgegevens onderaan dit document.

Deelname

Deelname is geheel vrijwillig en de testprocedure zal ongeveer 30 minuten duren. U kunt op ieder moment, zonder opgaaf van reden, aangeven dat u niet meer wil meedoen aan het onderzoek. Toestemming voor deelname hoeft slechts eenmalig verleend te worden en is geldig tot 48 uur na deelname.

Wat gebeurt er tijdens het testen?

Het testen is bedoeld om in te zien of het prototype met sensoren stabiele informatie weergeeft die bruikbaar is voor vervolgonderzoek. Hierbij kijken we naar de plek waar gemeten wordt en naar de metingen die we krijgen. Bij het product is er een risico op een lichte elektrische schok door spiersensor op het lichaam. Dit is echter een laag voltage en zal een compleet veilige lading zijn (vergelijkbaar met een schok door wrijving). Mocht u zich niet prettig hierbij voelen, of gezondheidsproblemen hebben die eventueel hierdoor verergerd zouden kunnen worden dan adviseer ik u om niet mee te doen aan deze testprocedure. Als u een pacemaker heeft kunt u hierdoor helaas niet mee doen aan dit onderzoek.

Welke gegevens worden er verzameld?

Tijdens het testen worden vragen gesteld over uw ervaring met het prototype en zullen er audio- en/of video-opnames gemaakt worden om de antwoorden goed te kunnen samenvatten en zo goed mogelijk te interpreteren. Verder worden de meetgegevens van de sensoren

(hartslag, huidgeleiding, lichaamstemperatuur, en spierspanning) verzameld en geanonimiseerd opgeslagen om de stabiliteit en werking van het prototype te kunnen inzien.

Hoe worden de gegevens bewaard?

De data en videobestanden worden zo anoniem mogelijk verwerkt en veilig bewaard volgens AVG richtlijnen. Onderzoeksgegevens worden volgens VSNU richtlijnen 10 jaar bewaard.

Wie heeft er toegang tot de data?

De antwoorden op de vragen en de audio/videobestanden zijn toegankelijk voor mensen betrokken bij dit onderzoek (zie contactgegevens onderaan het document) en worden verwijderd na het samenvatten en anonimiseren van de data, indien anders aangegeven door de deelnemer zelf.

Hoe worden de gegevens gebruikt?

De gegevens worden geanalyseerd voor wetenschappelijk onderzoek, inclusief een afstudeeropdracht van de Universiteit Twente student. Dit kan gepubliceerd worden in wetenschappelijke artikelen en in de ‘gewone’ media, waarbij volledig anonieme resultaten op basis van de gegevens gepresenteerd worden. De gegevens worden mogelijk ook gebruikt door de onderzoekers van dit project voor vervolgonderzoek, passend binnen de kaders van deze brochure. Verder worden de resultaten gebruikt als inspiratie voor het ontwikkelen van de technologie, al dan niet opgepakt door bedrijven die ons wetenschappelijke werk lezen.

Worden er gegevens van mij publiek gemaakt?

De materialen zullen niet zonder toestemming publiek getoond worden of beschikbaar worden gesteld. Het materiaal zal niet ingezet worden voor promotiedoeleinden tenzij hier expliciet apart toestemming voor gegeven is.

Kan ik mijn gegevens laten verwijderen?

Als u tijdens of tot 48 uur na deelname aan dit activiteit besluit dat u niet (meer) wilt meedoen, worden al de gegevens van die sessie verwijderd. Als een sessie is afgerond worden de gegevens van die sessie definitief toegevoegd aan de onderzoeksdata en kunnen ze niet meer verwijderd worden.

Meer informatie en onafhankelijk advies.

Wilt u graag onafhankelijk advies over deelname aan dit onderzoek, of wilt u een klacht indienen? Dan kunt u terecht bij de secretaris van de Ethische Commissie (ethics-comm-eemcs@utwente.nl). Deze bestaat uit onafhankelijke deskundigen van de universiteit en is beschikbaar voor vragen en klachten rondom het onderzoek.

Voor inhoudelijke vragen over dit onderzoek kunt u verder terecht bij Daniela van Meggelen, en de andere onderzoekers.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

A.3 Digital Tests With Caregivers

Informatiebrochure Testfase App: How high is the stress level?

In deze brochure staat informatie over het onderzoeksproject: “How high is the stress level?”. Dit project wordt geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, en doet onderzoek naar de rol die technologie kan spelen in het herkennen van stress bij baby’s.

Het is erg belangrijk voor de ontwikkeling van een kind dat deze goed voelt. Maar hoe weet je dit als ouders, als je kind nog niet kan praten? Je kind kan zich gestrest voelen, wat zich kan uiten in bijvoorbeeld huilgedrag, erg stil zijn, weinig eten, enzovoorts. Maar dit is niet

altijd stress, soms kan het ook iets anders zijn. Het is vaak lastig voor ouders om te begrijpen wat er aan de hand is, wat veel zoekwerk en zorgen kan opleveren.

Naar aanleiding van een onderzoeksproces waarin een vragenlijst en verscheidene interviews zijn afgenomen, hebben we een prototype kunnen ontwikkelen dat in een thuissituatie continu stress zou kunnen meten bij baby's. Deze metingen zouden naar een app op de mobiele telefoon van de ouder gestuurd kunnen worden. Verder kan de ouder ook diens eigen ervaring en gevoel in de app invoeren en deze inzien. Op deze manier willen we ouders ondersteunen in het herkennen van het gedrag van hun baby, en het makkelijker maken voor zowel ouders als artsen om te kunnen vaststellen of een baby leidt aan stress zodat zo snel mogelijk de juiste hulp geboden kan worden. Deze testfase focust zich op uw ervaring bij het gebruik van het prototype. Deze brochure helpt u beslissen of u mee wilt werken aan het onderzoek.

Onderzoeksprocedure

Door middel van deze testfase wordt informatie verzameld over de gebruiksvriendelijkheid en de duidelijkheid van het prototype. Op deze manier willen we zien of de uitvoering van dit project gewenst is, en plus- en minpunten formuleren die gebruikt kunnen worden voor het verbeteren van dit project.

In deze folder leggen we uit wat het voor u betekent om aan het onderzoek mee te doen. U beslist zelf of u wilt deelnemen aan het onderzoek. Voor vragen kunt u contact opnemen met Daniela van Meggelen, zie contactgegevens onderaan dit document.

Deelname

Deelname is geheel vrijwillig en de testprocedure zal ongeveer 30 minuten duren. U kunt op ieder moment, zonder opgaaf van reden, aangeven dat u niet meer wil meedoen aan het onderzoek. Toestemming voor deelname hoeft slechts eenmalig verleend te worden en is geldig tot 48 uur na deelname.

Wat gebeurt er tijdens het testen?

Het testen is bedoeld om in te zien hoe het gebruik van het prototype wordt ervaren en hoe duidelijk de terugkoppeling van informatie overkomt op de gebruiker, om inzicht te krijgen in verbeteringen die nodig zijn voor dit prototype. Dit wordt gedaan door u door de app te laten navigeren en achteraf vragen te laten beantwoorden over uw ervaring. U krijgt een link

toegestuurd naar een webpagina die u kunt openen op uw computer. Er hoeft dus niks gedownload te worden.

Welke gegevens worden er verzameld?

Tijdens het testen worden vragen gesteld over uw ervaring en wensen m.b.t. het prototype en zullen er audio en/of video opnames gemaakt worden om de antwoorden goed te kunnen samenvatten en zo goed mogelijk te interpreteren. Verder zal u worden gevraagd om uw scherm te delen en uw gedachten uit te spreken terwijl u gebruik maakt van de app, zodat ik beter kan zien waar u opmerkingen over heeft.

Hoe worden de gegevens bewaard?

De data en videobestanden worden zo anoniem mogelijk verwerkt en veilig bewaard volgens AVG richtlijnen. Onderzoeksgegevens worden volgens VSNU richtlijnen 10 jaar bewaard.

Wie heeft er toegang tot de data?

De antwoorden op de vragen en de audio/videobestanden zijn toegankelijk voor mensen betrokken bij dit onderzoek (zie contactgegevens onderaan het document) en worden verwijderd na het samenvatten en anonimiseren van de data, indien anders aangegeven door de deelnemer zelf.

Hoe worden de gegevens gebruikt?

De gegevens worden geanalyseerd voor wetenschappelijk onderzoek, inclusief een afstudeeropdracht van de Universiteit Twente student. Dit kan gepubliceerd worden in wetenschappelijke artikelen en in de ‘gewone’ media, waarbij volledig anonieme resultaten op basis van de gegevens gepresenteerd worden. De gegevens worden mogelijk ook gebruikt door de onderzoekers van dit project voor vervolgonderzoek, passend binnen de kaders van deze brochure. Verder worden de resultaten gebruikt als inspiratie voor het ontwikkelen van de technologie, al dan niet opgepakt door bedrijven die ons wetenschappelijke werk lezen.

Worden er gegevens van mij publiek gemaakt?

De materialen zullen niet zonder toestemming publiek getoond worden of beschikbaar worden gesteld. Het materiaal zal niet ingezet worden voor promotiedoeleinden tenzij hier expliciet apart toestemming voor gegeven is.

Kan ik mijn gegevens laten verwijderen?

Als u tijdens of tot 48 uur na deelname aan dit activiteit besluit dat u niet (meer) wilt meedoen, worden al de gegevens van die sessie verwijderd. Als een sessie is afgerond worden de gegevens van die sessie definitief toegevoegd aan de onderzoeksdata en kunnen ze niet meer verwijderd worden.

Meer informatie en onafhankelijk advies.

Wilt u graag onafhankelijk advies over deelname aan dit onderzoek, of wilt u een klacht indienen? Dan kunt u terecht bij de secretaris van de Ethische Commissie (ethics-comm-eemcs@utwente.nl). Deze bestaat uit onafhankelijke deskundigen van de universiteit en is beschikbaar voor vragen en klachten rondom het onderzoek.

Voor inhoudelijke vragen over dit onderzoek kunt u verder terecht bij Daniela van Meggelen, en de andere onderzoekers.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

Appendix B – Consent Forms For User Confrontations

B.1 Interviews With Caregivers

Toestemmingsformulier: How high is the stress level?

Daniela van Meggelen - Bachelor Student Creative Technology

In het project “How high is the stress level?”, geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, doen we onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress bij baby’s. Om te begrijpen wat daarbij voor ouders belangrijk is, willen we naast een vragenlijst nog een aanvullend interview houden. Informatie over dit interview staat beschreven in de gelijknamige informatiebrochure. Dit toestemmingsformulier is er om vast te leggen dat u voldoende bent geïnformeerd en wilt mee werken aan dit onderzoek.

- ❑ Ik verklaar hierbij dat ik ben geïnformeerd over de vorm en inhoud van dit onderzoek op een manier die voor mij duidelijk is, zoals beschreven in de informatiebrochure “Informatiebrochure: How high is the stress level?”. Mijn vragen zijn naar tevredenheid beantwoord.

- ❑ Ik stem er vrijwillig mee in om deel te nemen aan dit onderzoek. Hierbij behoud ik het recht om me terug te trekken uit dit onderzoek zonder opgaaf van reden. Ik ben me ervan bewust dat ik me op elk moment mag terugtrekken uit dit onderzoek.

Als de onderzoeksresultaten gebruikt worden in wetenschappelijke publicaties, of op een andere manier openbaar worden gemaakt, zullen deze geheel anoniem zijn. Mijn persoonlijke gegevens zullen niet gedeeld worden met derden zonder mijn toestemming.

- ❑ Ik ga ermee akkoord dat er audio wordt opgenomen om de informatie zo juist mogelijk te verwerken.

❑ Ik ga ermee akkoord dat er video wordt opgenomen om de informatie zo juist mogelijk te interpreteren en verwerken.

❑ Ik zou graag wel herkenbaar vermeld worden of zichtbaar zijn in deze publicaties (vink aan in welke vorm).

- ❑ Voornaam
- ❑ Achternaam
- ❑ Citaat
- ❑ Foto
- ❑ Videobeeld
- ❑ Audiofragment

Als ik, nu of in de toekomst, meer informatie over dit onderzoek wens te krijgen, dan kan ik Daniela van Meggelen benaderen (zie contactgegevens onderaan).

Als ik klachten heb over dit onderzoek, kan ik deze sturen naar de secretaris van de Ethische Commissie van de Faculteit Electrotechniek, Wiskunde en Informatica bij de Universiteit Twente, P.O. Box 217, 7500 AE Enschede (NL), email: ethics-comm-ewi@utwente.nl.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

_____

Dubbel ondertekend op (datum) …….:

…… ……

Naam deelnemer Handtekening

Ik heb uitleg gegeven over het onderzoek en ben bereid om zo goed mogelijk vragen te beantwoorden die nog over dit onderzoek kunnen ontstaan.

…… ……

Naam onderzoeker Handtekening

B.2 Physical Tests Within The Household

Toestemmingsformulier: How high is the stress level?

Daniela van Meggelen - Bachelor Student Creative Technology

In het project “How high is the stress level?”, geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, doen we onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress bij baby’s. Om te bepalen of de uitvoering van dit project in dit prototype gewenst is, willen we dit testen. Informatie over deze testprocedure staat beschreven in de gelijknamige informatiebrochure. Dit toestemmingsformulier is er om vast te leggen dat u voldoende bent geïnformeerd en wilt mee werken aan dit onderzoek.

❏ Ik verklaar hierbij dat ik ben geïnformeerd over de vorm en inhoud van dit onderzoek op een manier die voor mij duidelijk is, zoals beschreven in de

informatiebrochure “Informatiebrochure Testfase Meting: How high is the stress level?”. Mijn vragen zijn naar tevredenheid beantwoord.

❑ Ik stem er vrijwillig mee in om deel te nemen aan dit onderzoek. Hierbij behoud ik het recht om me terug te trekken uit dit onderzoek zonder opgaaf van reden. Ik ben me ervan bewust dat ik me op elk moment mag terugtrekken uit dit onderzoek.

❑ Ik ben me bewust van het risico op een milde schok.

Als de onderzoeksresultaten gebruikt worden in wetenschappelijke publicaties, of op een andere manier openbaar worden gemaakt, zullen deze geheel anoniem zijn. Mijn persoonlijke gegevens zullen niet gedeeld worden met derden zonder mijn toestemming.

❑ Ik ga ermee akkoord dat er audio wordt opgenomen om de informatie zo juist mogelijk te verwerken.

❑ Ik ga ermee akkoord dat er video wordt opgenomen om de informatie zo juist mogelijk te interpreteren en verwerken.

❑ Ik zou graag wel herkenbaar vermeld worden of zichtbaar zijn in deze publicaties (vink aan in welke vorm).

- ❑ Voornaam
- ❑ Achternaam
- ❑ Citaat
- ❑ Foto
- ❑ Videobeeld
- ❑ Audiofragment

Als ik, nu of in de toekomst, meer informatie over dit onderzoek wens te krijgen, dan kan ik Daniela van Meggelen benaderen (zie contactgegevens onderaan).

Als ik klachten heb over dit onderzoek, kan ik deze sturen naar de secretaris van de Ethische Commissie van de Faculteit Electrotechniek, Wiskunde en Informatica bij de Universiteit Twente, P.O. Box 217, 7500 AE Enschede (NL), email: ethics-comm-eemcs@utwente.nl.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

_____

Dubbel ondertekend op (datum) ……:

……	……
Naam deelnemer	Handtekening

Ik heb uitleg gegeven over het onderzoek en ben bereid om zo goed mogelijk vragen te beantwoorden die nog over dit onderzoek kunnen ontstaan.

……	……
Naam onderzoeker	Handtekening

B.3 Digital Tests With Caregivers

Toestemmingsformulier: How high is the stress level?

Daniela van Meggelen - Bachelor Student Creative Technology

In het project “How high is the stress level?”, geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, doen we onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress bij baby’s. Om te bepalen of de uitvoering van dit project in dit prototype gewenst is, willen we dit testen. Informatie over deze testprocedure staat beschreven in de gelijknamige informatiebrochure. Dit toestemmingsformulier is er om vast te leggen dat u voldoende bent geïnformeerd en wilt mee werken aan dit onderzoek.

❏ Ik verklaar hierbij dat ik ben geïnformeerd over de vorm en inhoud van dit onderzoek op een manier die voor mij duidelijk is, zoals beschreven in de informatiebrochure “Informatiebrochure Testfase App: How high is the stress level?”. Mijn vragen zijn naar tevredenheid beantwoord.

❏ Ik stem er vrijwillig mee in om deel te nemen aan dit onderzoek. Hierbij behoud ik het recht om me terug te trekken uit dit onderzoek zonder opgaaf van reden. Ik ben me ervan bewust dat ik me op elk moment mag terugtrekken uit dit onderzoek.

Als de onderzoeksresultaten gebruikt worden in wetenschappelijke publicaties, of op een andere manier openbaar worden gemaakt, zullen deze geheel anoniem zijn. Mijn persoonlijke gegevens zullen niet gedeeld worden met derden zonder mijn toestemming.

❏ Ik ga ermee akkoord dat er audio wordt opgenomen om de informatie zo juist mogelijk te verwerken.

❏ Ik ga ermee akkoord dat er video wordt opgenomen om de informatie zo juist mogelijk te interpreteren en verwerken.

❏ Ik zou graag wel herkenbaar vermeld worden of zichtbaar zijn in deze publicaties (vink aan in welke vorm).

- ❏ Voornaam
- ❏ Achternaam
- ❏ Citaat
- ❏ Foto

- ❑ Videobeeld
- ❑ Audiofragment

Als ik, nu of in de toekomst, meer informatie over dit onderzoek wens te krijgen, dan kan ik Daniela van Meggelen benaderen (zie contactgegevens onderaan).

Als ik klachten heb over dit onderzoek, kan ik deze sturen naar de secretaris van de Ethische Commissie van de Faculteit Electrotechniek, Wiskunde en Informatica bij de Universiteit Twente, P.O. Box 217, 7500 AE Enschede (NL), email: ethics-comm-eemcs@utwente.nl.

Contactgegevens onderzoeksteam:

Daniela van Meggelen, bachelorstudent (Creative Technology) en hoofdonderzoeker

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

Dubbel ondertekend op (datum) …….:

…… ……

Naam deelnemer Handtekening

Ik heb uitleg gegeven over het onderzoek en ben bereid om zo goed mogelijk vragen te beantwoorden die nog over dit onderzoek kunnen ontstaan.

…… ……

Naam onderzoeker Handtekening

Appendix C – Survey Questions

Onderzoek UT: Stress bij baby's

Het is erg belangrijk voor de ontwikkeling van een kind dat deze goed voelt. Maar hoe weet je dit als ouders, als je kind nog niet kan praten? Je kind kan zich gestresst voelen, wat zich kan uiten in bijvoorbeeld huilgedrag, erg stil zijn, weinig eten, enzovoorts. Maar dit is niet altijd stress, soms kan het ook iets anders zijn. Het is vaak lastig voor ouders om te begrijpen wat er aan de hand is en dat kan veel zoekwerk en zorgen opleveren.

In dit project, geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, doen we onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress (spanning, onrust) bij baby's. Om te begrijpen wat daarbij voor ouders belangrijk is, willen we u graag een aantal vragen voorleggen. Deze vragen zijn alleen voor onderzoek en hebben niet als doel hulp te verschaffen. Mocht u zoveel stress ervaren dat professionele hulp nodig zou kunnen zijn kan u misschien ook beter niet aan deze vragenlijst deelnemen. U kunt op elk gewenst moment stoppen met deze vragenlijst en hoeft niet te verklaren waarom.

Ik wil u vragen deze vragenlijst in te vullen. Dit zal ongeveer 10 minuten duren. Achteraf krijgt u ook de mogelijkheid om aan te geven of ik u later kan benaderen voor een opvolg interview en/of een testprocedure van mijn uiteindelijke product. Wees zo open als u wilt zijn in het beantwoorden van deze vragen, het gaat om uw perspectief in deze situatie.

De inhoud van de vragenlijst zal vertrouwelijk worden behandeld en alleen worden ingezien door het onderzoeksteam van de Universiteit Twente. Informatie zal altijd anoniem worden verwerkt en niet terug te leiden zijn tot individuele personen. Contactgegevens van het onderzoeksteam en de Ethische Commissie staan hieronder en aan het eind van de vragenlijst.

Contactgegevens

Daniela van Meggelen, bachelorstudent (Creative Technology)

[redacted]

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

Ethische Commissie (Zilverling 1051, Faculteit EEMCS, Universiteit Twente):

Om verder te gaan met deze vragenlijst geeft u aan dat u duidelijk bent geïnformeerd over de vorm en inhoud van de vragenlijst en het bijbehorende onderzoek, en geeft u aan te weten dat deelname aan dit onderzoek vrijwillig is en u op elk gewenst moment kan stoppen met deze vragenlijst.

☐ Ik ben geïnformeerd en weet dat mijn deelname vrijwillig is.

Om verder te gaan met deze vragenlijst geeft u toestemming dat uw antwoorden worden verwerkt en gebruikt worden in het onderzoek. Als dit gepubliceerd wordt, zal dit compleet anoniem zijn, tenzij u anders aangeeft.

☐ Ik geef toestemming hiervoor.
☐ Ik geef geen toestemming hiervoor.

Algemene vragen

Wat is uw geslacht?

○ Man
○ Vrouw
○ Zeg ik liever niet

Wat is uw leeftijd?

- *Open vraag*

Leefsituatie

Wat voor cijfer zou u uw leven geven?

- *Cijfer van 1 (slecht) tot 10 (perfect).*

In hoeverre zorgden de volgende factoren in de afgelopen **12 maanden** voor stress in uw leven?

- *Cijfer van 1 (helemaal niet) tot 10 (heel erg), ruimte per categorie om uitleg te geven.*
- Familie
- Gezinssamenstelling
- Woning
- Werk
- Financiële situatie
- Mentale gezondheid
- Fysieke gezondheid

Indien er andere factoren bijdroegen aan stress in uw leven, kunt u dat hier uitleggen.

- *Open vraag*

Kinderen

Deze vragen gaan over uw kind(eren) en uw ervaring van uw kind(eren) met betrekking tot stress. Onder stress wordt hierbij chronische stress of negatieve gevoelens (zoals angsten en depressies) verstaan. Acute stress veroorzaakt door bijv. een plots hard geluid valt hier niet onder.

Hoeveel kinderen heeft u?

- Open vraag

Wat is het geslacht van uw kind(eren)?

- *Open vraag*

Wat is de leeftijd van uw kind(eren)? (vink aan wat van toepassing is)

- ☐ Jonger dan 1 jaar
- ☐ 1-2 Jaar
- ☐ 3-4 jaar
- ☐ Ouder dan 4 jaar

Heeft u het idee dat (één van) uw kind(eren) gestresst is/zijn (geweest)?

- ○ Ja, daar kwam ik zelf achter

- ○ Ja, dat hoorde ik via een professional
- ○ Nee
- ○ Anders, namelijk…

Stress bij uw kind

→ *Indien "Ja, daar kwam ik zelf achter":*

Hoe bent u daar achter gekomen?

- *Open vraag*

→ Indien "Ja, dat horde ik via een professional":

Hoe bent u bij de professional gekomen?

- *Open vraag*

Wat was de functie deze professional?

- *Open vraag*

Op welke wijze heeft deze professional dit aangegeven?

- *Open vraag*

→ Indien "Nee":

Waardoor heeft u dat idee? (bijv. bepaald gedrag van uw kind, onderzoek naar stress kwam niet tot die conclusie, etc.)

- *Open vraag*

→ Indien "Anders, namelijk...":

Kunt u hier wat meer over vertellen?

- *Open vraag*

Daarna weer door met de volgende vraag:

Maakt u zich wel eens zorgen over de stress van uw kind(eren)?

- ○ Ja
- ○ Nee

→ Indien “Ja”:

Hoe ervaart u dat?

- *Open vraag*

Hoe gaat u met deze zorgen om?

- *Open vraag*

Product

Het uiteindelijke doel van dit project is om een product te ontwikkelen dat stress kan herkennen bij baby's. Dit zou thuis gebruikt kunnen worden en makkelijk in gebruik moeten zijn, zodat het ouders ook kan ondersteunen bij de zorgen die ze hebben over hun kind.

Denkt u dat u gebruik zou maken van zo'n product?

- ○ Ja
- ○ Nee
- ○ Anders, namelijk...

Hier kunt u kort toelichten waarom.

- *Open vraag*

Ter afsluiting

Zou ik contact met u op mogen nemen om aanvullende vragen over dit onderzoek te stellen? U kunt hieronder contactgegevens (emailadres of telefoonnummer) achterlaten indien u dat wilt.

- *Open vraag*

In de komende weken zal ik een prototype maken dat in januari getest zal worden. Dit zal allemaal veilig gebeuren, maar het is daarbij wel handig dat ik testpersonen heb. Bent u geïnteresseerd in deelname of wilt u wat meer informatie? U kunt hieronder contactgegevens (emailadres of telefoonnummer) achterlaten.

- *Open vraag*

Heeft u verder nog opmerkingen, vragen, of overige zaken die u graag aan mij mee wilt geven omtrent dit onderwerp?

- *Open vraag*

Einde uragenlijst

→ Indien “Ik geef toestemming hiervoor.” is aangevinkt:

Heel erg bedankt voor het invullen van deze vragenlijst. Dat helpt mij enorm verder bij mijn afstudeerproject! Hieronder staan de contactgegevens van het onderzoeksteam en de ethische commissie, mocht u nog vragen of opmerkingen hebben.

Daniela van Meggelen, bachelorstudent (Creative Technology)

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

Ethische Commissie (Zilverling 1051, Faculteit EEMCS, Universiteit Twente):

→ Indien “Ik geef geen toestemming hiervoor.” is aangevinkt:

Bedankt voor het overwegen van deze vragenlijst. Mocht u vragen of opmerkingen hebben dan kunt u hieronder contactgegevens van het onderzoeksteam en de ethische commissie vinden.

Daniela van Meggelen, bachelorstudent (Creative Technology)

[redacted]

Randy Klaassen, assistent professor (Human Media Interaction) en begeleider

[redacted]

Juliet Haarman, onderzoeker (Human Media Interaction) en begeleider

[redacted]

[redacted]

Ethische Commissie (Zilverling 1051, Faculteit EEMCS, Universiteit Twente):

Appendix D – Summary Of Survey Results

Het is erg belangrijk voor de ontwikkeling van een kind dat deze goed voelt. Maar hoe weet je dit als ouders, als je kind nog niet kan praten? Je kind kan zich gestresst voelen, wat zich kan uiten in bijvoorbeeld huilgedrag, erg stil zijn, weinig eten, enzovoorts. Maar dit is niet altijd stress, soms kan het ook iets anders zijn. Het is vaak lastig voor ouders om te begrijpen wat er aan de hand is en dat kan veel zoekwerk en zorgen opleveren.

In dit project, geleid door de Universiteit Twente in samenwerking met ZGT en IMH Nederland, doen we onderzoek naar de rol die technologie kan spelen in het sneller en betrouwbaarder herkennen van stress (spanning, onrust) bij baby's. Om te begrijpen wat daarbij voor ouders belangrijk is, willen we u graag een aantal vragen voorleggen. Deze vragen zijn alleen voor onderzoek en hebben niet als doel hulp te verschaffen. Mocht u zoveel stress ervaren dat professionele hulp nodig zou kunnen zijn kan u misschien ook beter niet aan deze vragenlijst deelnemen. U kunt op elk gewenst moment stoppen met deze vragenlijst en hoeft niet te verklaren waarom.

Ik wil u vragen deze vragenlijst in te vullen. Dit zal ongeveer 10 minuten duren. Achteraf krijgt u ook de mogelijkheid om aan te geven of ik u later kan benaderen voor een opvolg interview en/of een testprocedure van mijn uiteindelijke product. Wees zo open als u wilt zijn in het beantwoorden van deze vragen, het gaat om uw perspectief in deze situatie.

De inhoud van de vragenlijst zal vertrouwelijk worden behandeld en alleen worden ingezien door het onderzoeksteam van de Universiteit Twente. Informatie zal altijd anoniem worden verwerkt en niet terug te leiden zijn tot individuele personen. Contactgegevens van het onderzoeksteam en de Ethische Commissie staan hieronder en aan het eind van de vragenlijst.

There was a total of 37 responses. All participants gave permission for their answers to be used for this research.

What is your gender?

Male → 1 (2.7%)

Female → 36 (97.3%)

Prefer not to say → 0%

What is your age?

Answers range from 26 to 48, with an average and a median of 35 years old, and a modus of 32 years old.

How would you grade your life?

Answers range from 6 to 9, with an average of 7.8, and a median and modus of 8.

To what extent did the following factors lead to stress in your life? (1 = not at all)

Family

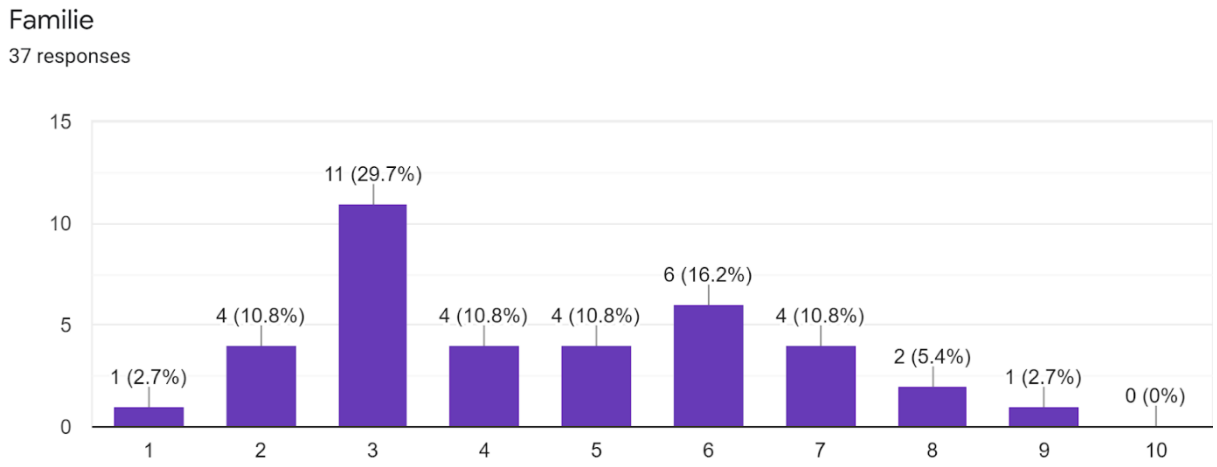


Figure D1. *Graph showing to what extent family leads to stress in the respondents' lives.*

An average of 4.5/10

Reasons: worries about the COVID-19 pandemic, (mental) health worries regarding (grand)parents, having young children, having relationship problems with a spouse or family member.

Family composition

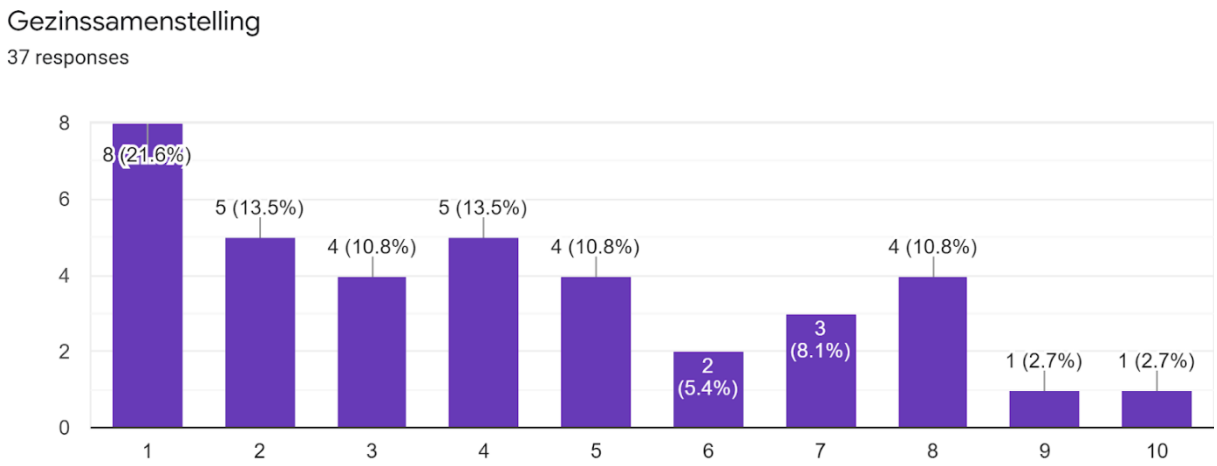


Figure D2. *Graph showing to what extent family composition leads to stress in the respondents' lives.*

An average of 4.2/10

Reasons: having young children, sometimes with (behavioural) problems, the influence of the COVID-19 pandemic on this, relationship issues or divorce.

Home

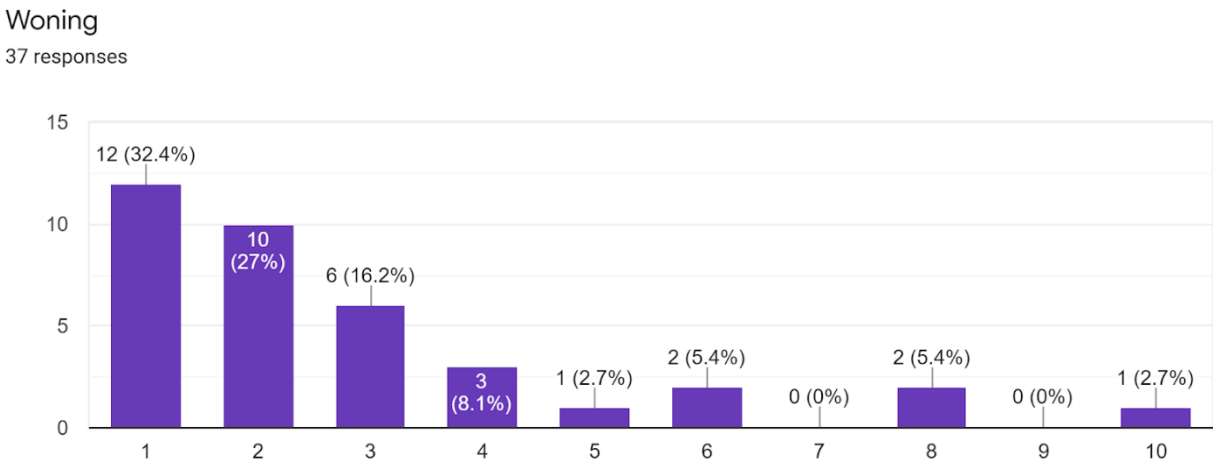


Figure D3. *Graph showing to what extent housing leads to stress in the respondents' lives.*

An average of 2.8/10

Reasons: generally being content with the location and size of the house, some are lacking space, however, and some families are renovating the house or have moved houses.

Work

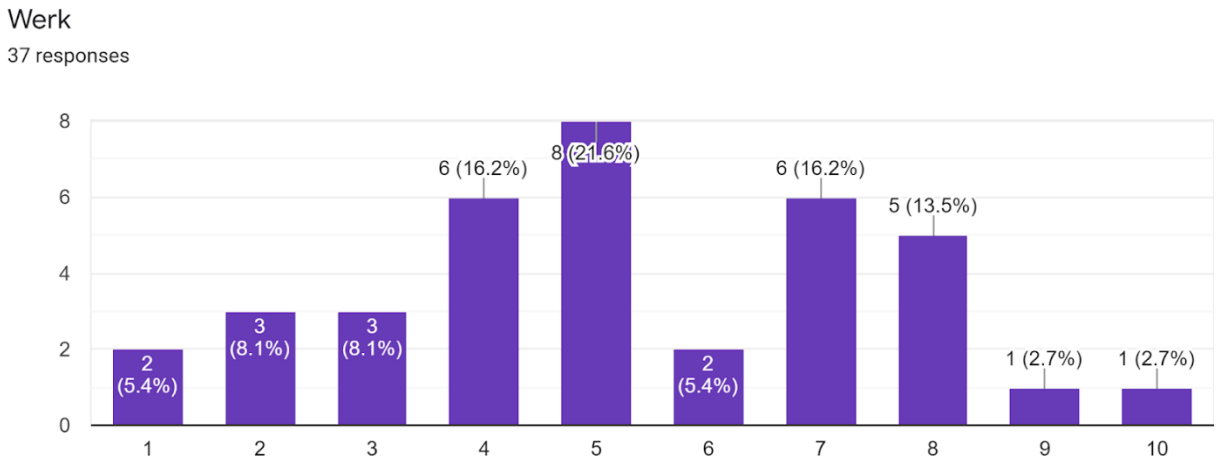


Figure D4. *Graph showing to what extent work leads to stress in the respondents' lives.*

An average of 5.2/10

Reasons: the influence of COVID-19 on the intensity and location of work (working at home with young children), unstable work situations (changing jobs, self-employed).

Financial situation

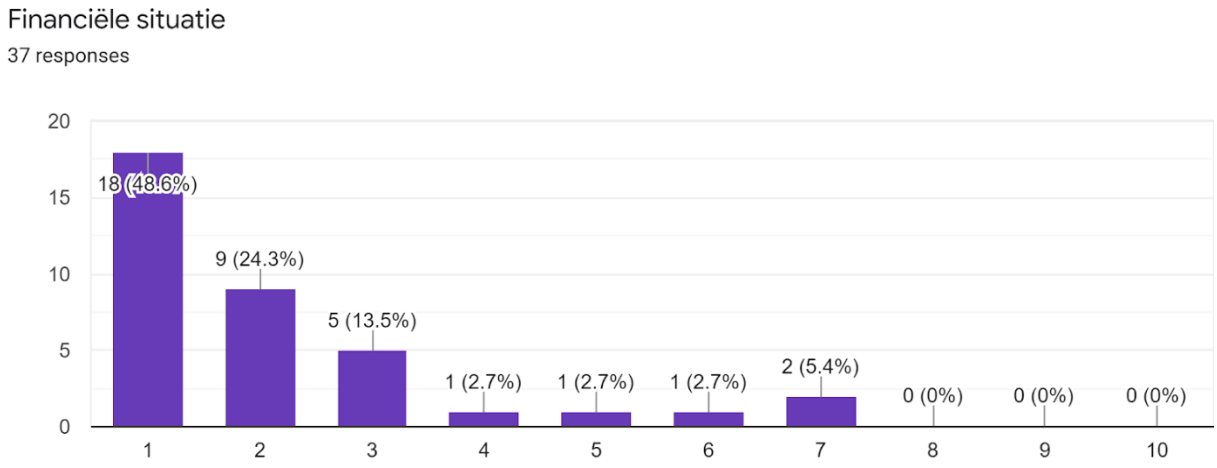


Figure D5. *Graph showing to what extent their financial situation leads to stress in the respondents' lives.*

An average of 2.2/10

Reasons: their income is generally steady and sufficient, some families have had financial challenges because of renovations in the house, pregnancies, partial joblessness, or divorce.

Mental health

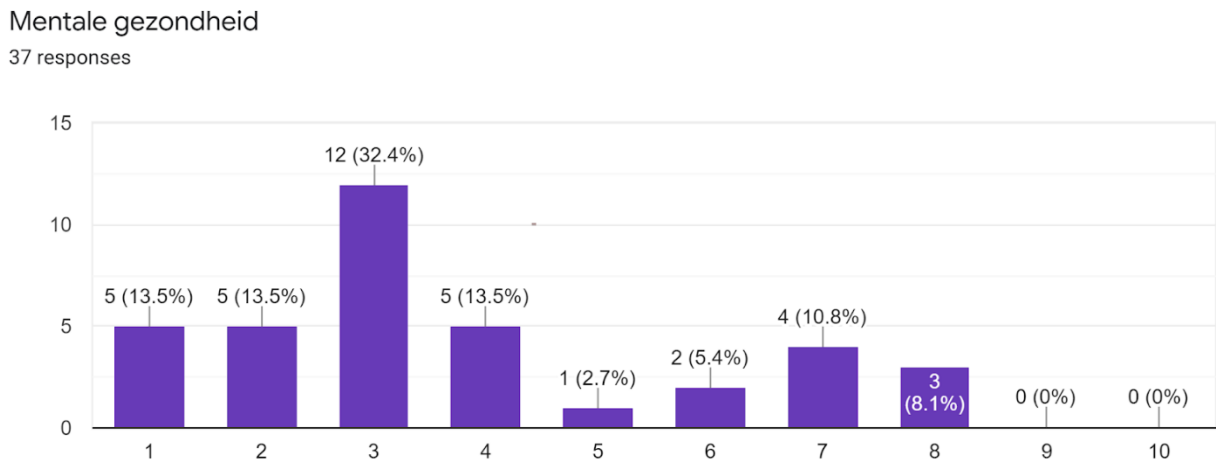


Figure D6. *Graph showing to what extent mental health leads to stress in the respondents' lives.*

An average of 3.6/10

Reasons: wanting to do everything perfectly or feeling like failing, finding the balance between work and living (working at home), recovery from pregnancy issues, anxiety, or PTSD, exhaustion, stress.

Physical health

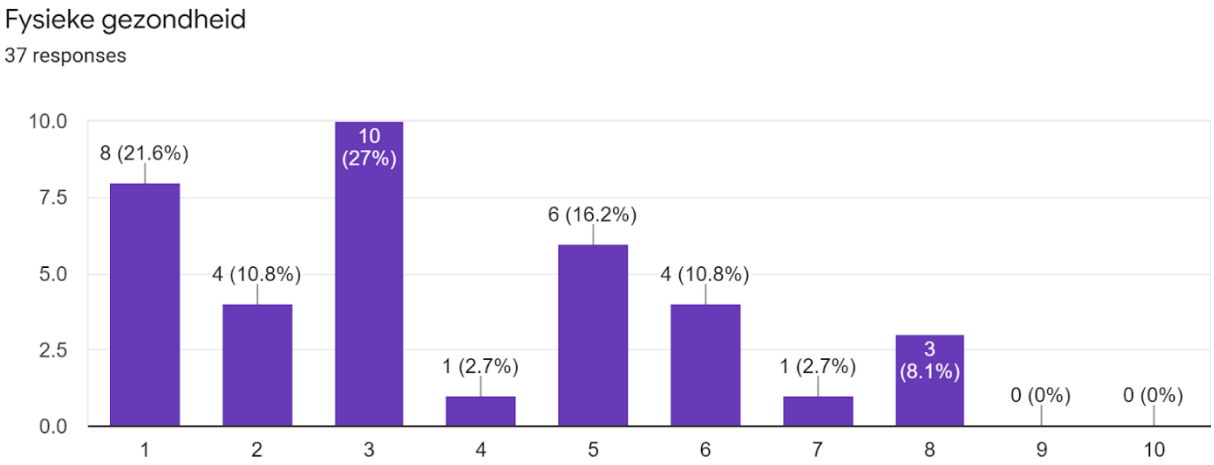


Figure D7. *Graph showing to what extent physical health leads to stress in the respondents' lives.*

An average of 3.6/10

Reasons: pregnancy issues, lack of physical exercise, migraines/headaches, worries about getting sick; whereas a positive reaction focused on being healthy and having a healthy environment

Other…

Youthcare, threats, abusive behaviour, relation with the spouse, worries about the world situation (COVID-19, Trump, BLM, sustainability).

How many children do you have?

Ranging from 1-4, with an average of 2 (51.4%).

What is the gender of your child(ren)?

Boy: 52%

Girl: 48%

What is the age of your child(ren)? (of all respondents, multiple options were possible)

<1 year old: 46%

1-2 years old: 40.5%

3-4 years old: 24.3%

>4 years old: 45.9%

Do you think (one of) your child(ren) is or has been stressed?

Yes, I noticed that myself (48.6%)

Yes, a professional told me (2.7%)

No (45.9%)

Other…: I hope not (2.7%)

→ In case of "Yes, I noticed that myself" (18 responses)

How did you find out?

Behavioural cues like anger, being upset, crying, being scared, clinginess, rebellious, being tense and easily agitated, intense feelings

Sleeping problems and nightmares, not wanting to sleep alone

Acting like a baby

Child indicated it

→ In case of "Yes, a professional told me" (1 response)

How did you get into contact with the professional?

Child suffered from anxiety.

What was their function?

Play therapist

How did the professional indicate that your child was stressed?

During the intake session.

→ In case of “No” (17 responses)

How did you get to that conclusion?

Behavioural cues like being happy, relaxed, energetic. No tension nor feelings of stress.

Sleeping and eating well, not crying too much, peeing and pooping well

Being caring as a parent towards their children, asking for help when needed

Having no developmental or physical issues, children are developing well

Getting a positive confirmation from their environment (e.g. grandparents)

→ In case of “Other… → I hope not” (1 response)

Can you elaborate on this?

It might be possible that they have noticed that we (parents) are really busy and sometimes tense. Although they are an easy child, it is known that babies can be sensitive to such feelings.

Do you sometimes worry about the stress of your child(ren)?

Yes (54.1%)

No (45.9%)

→ In case of “Yes”

How do you experience that?

Wanting to explain or solve the problem that the child is experiencing, which does not always work; feeling tense, powerless, and insecure. Wanting to help.

Having mood swings, worrying about what the child notices about the tension between their parents, or how they feel about the pressure to perform well (kindergarten and primary school).

Projecting their own stress on their children, not wanting their children to see the parent stressed, worrying about the child's future because of the child's current stress.

Being worried, but not supported in this feeling, making it hard to find help.

How do you cope with these worries?

Trying to be as caring, safe and comforting as possible to the child, especially during the pandemic. Describe to the child or spouse what the parent is seeing and feeling. Paying extra attention to the child.

Trying out a lot of possible solutions, to see if it would help or to see if the cause is found. Asking for professional help.

Trying to let go and get rest, looking for distractions.

Would you make use of a product that would monitor stress?

Yes (45.9%)

No (21.6%)

Other…

Maybe (8.1%)

Depending on the product (5.4%)

Not for my child, but as a professional I would like to use it (5.4%)

I don't know yet (2.7%)

Only if the paediatrician would refer me to it, or if it would be a standard screening procedure. (2.7%)

If we (parents) can't find a solution on our own. (2.7%)

Maybe during day-care. (2.7%)

If I suspect my child is stressed, yes. (2.7%)

Comments:

Being aware of the impact of stress on a child's development, they would like to decrease this impact as much as possible.

It is sometimes hard to know what is going on with their child (what is normal behaviour), especially if they cannot talk. A tool would help in understanding them better.

It would be useful if it does not require too much effort, would still let parents be involved.

Some respondents are not sure whether the product would actually decrease or increase stress (in the parent at least); one suspects it could work the other way around (justifying bad parent behaviour).

It feels weak to use a product, it should be the parent's job to know what is going on. Their observations should be sufficient. However, it would be nice to use as a supportive tool if the parent has no other option to think of. Other respondents indicated that they would use anything if it would help their child.

The product would also be useful to indicate to others that there is a problem, hopefully leading to better insights into what is necessary.

19 respondents indicated that I could contact them for interviews.

16 indicated that I could contact them for the testing phase or additional information.

Appendix E – Full-Size Sketches Of The Eight Ideas

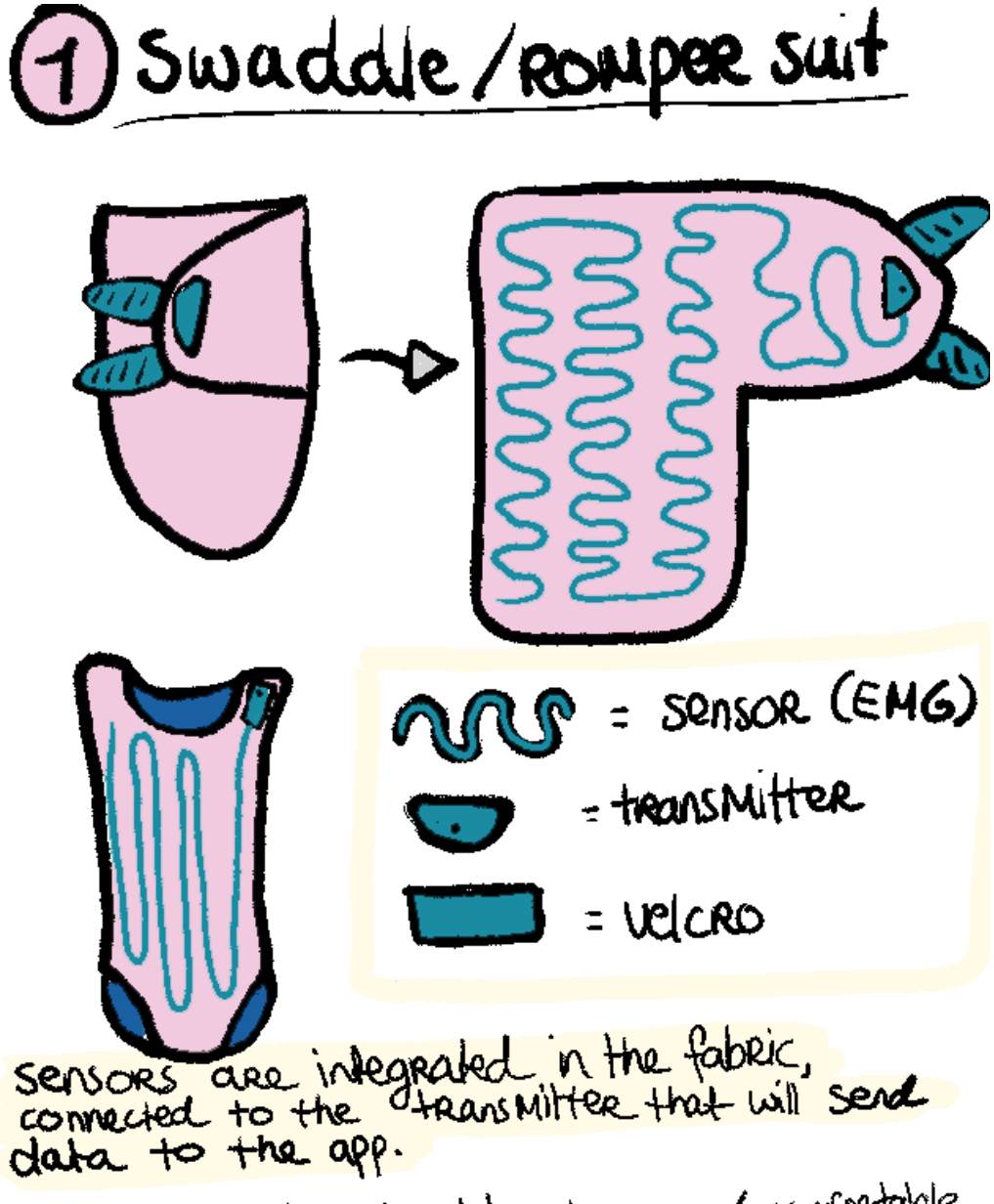


Figure E1. *Full-size image of the swaddle/romper suit idea.*

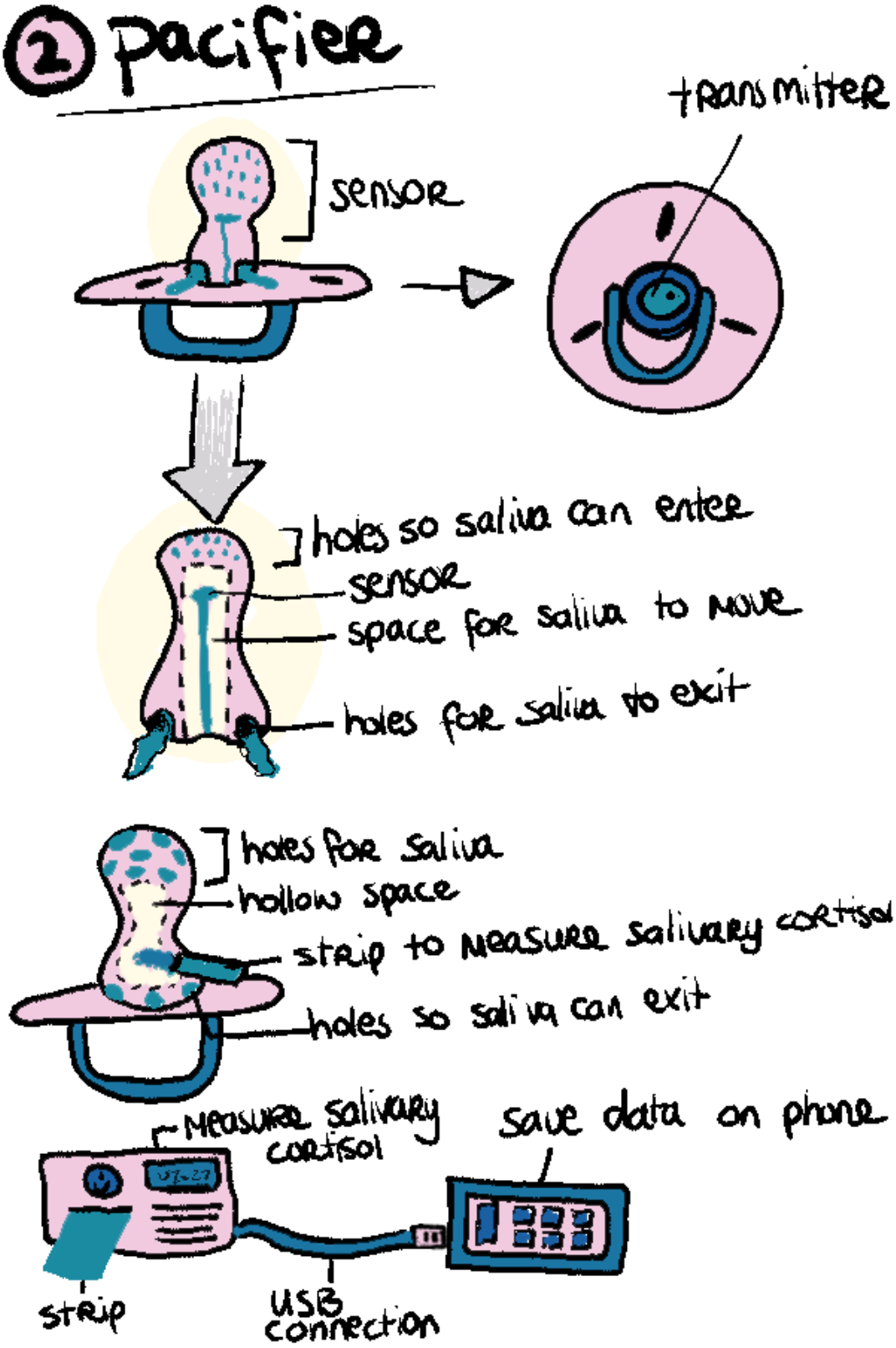


Figure E2. *Full-size image of the pacifier idea.*

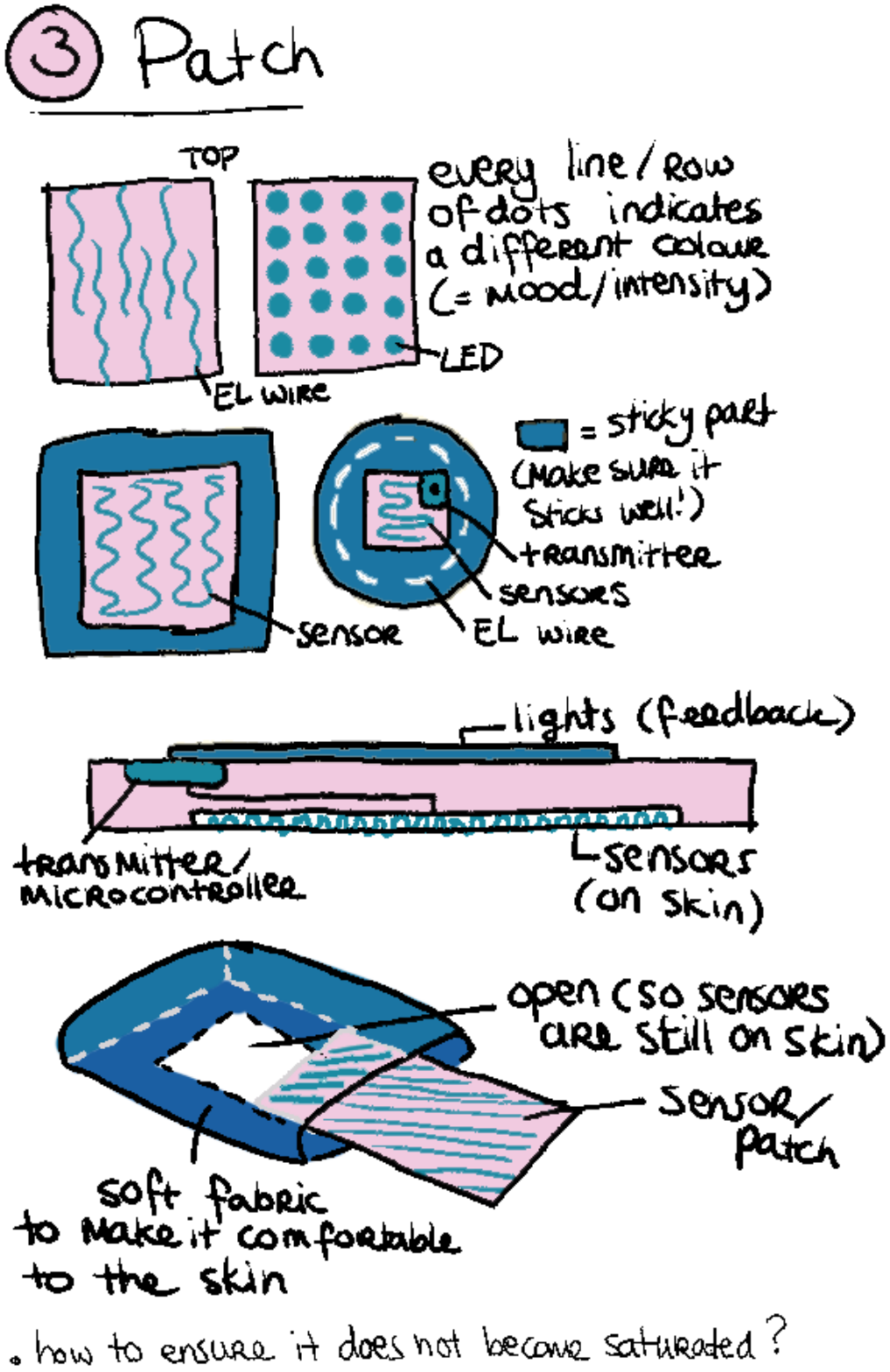


Figure E3. *Full-size image of the patch idea.*

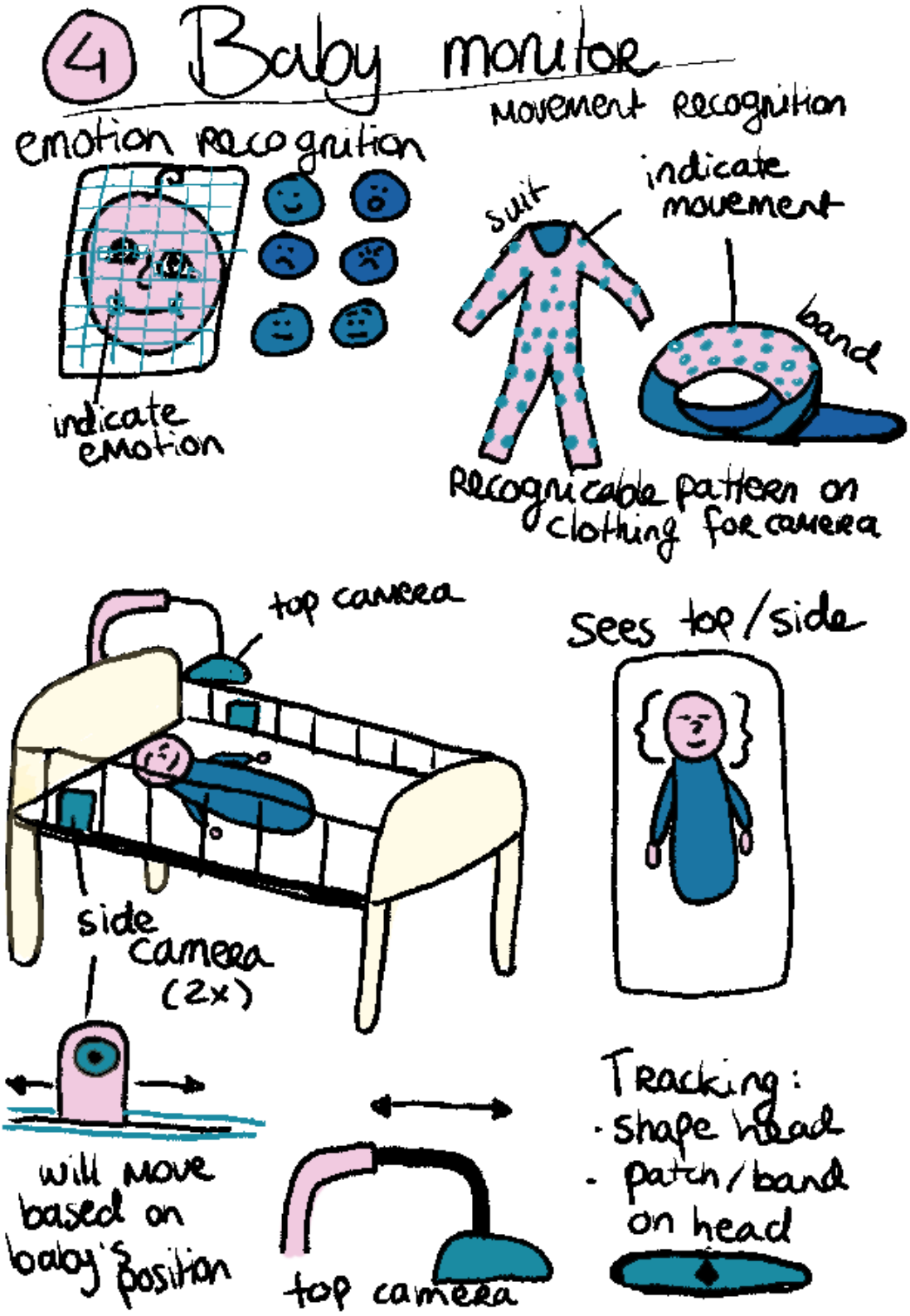


Figure E4. *Full-size image of the baby monitor idea.*

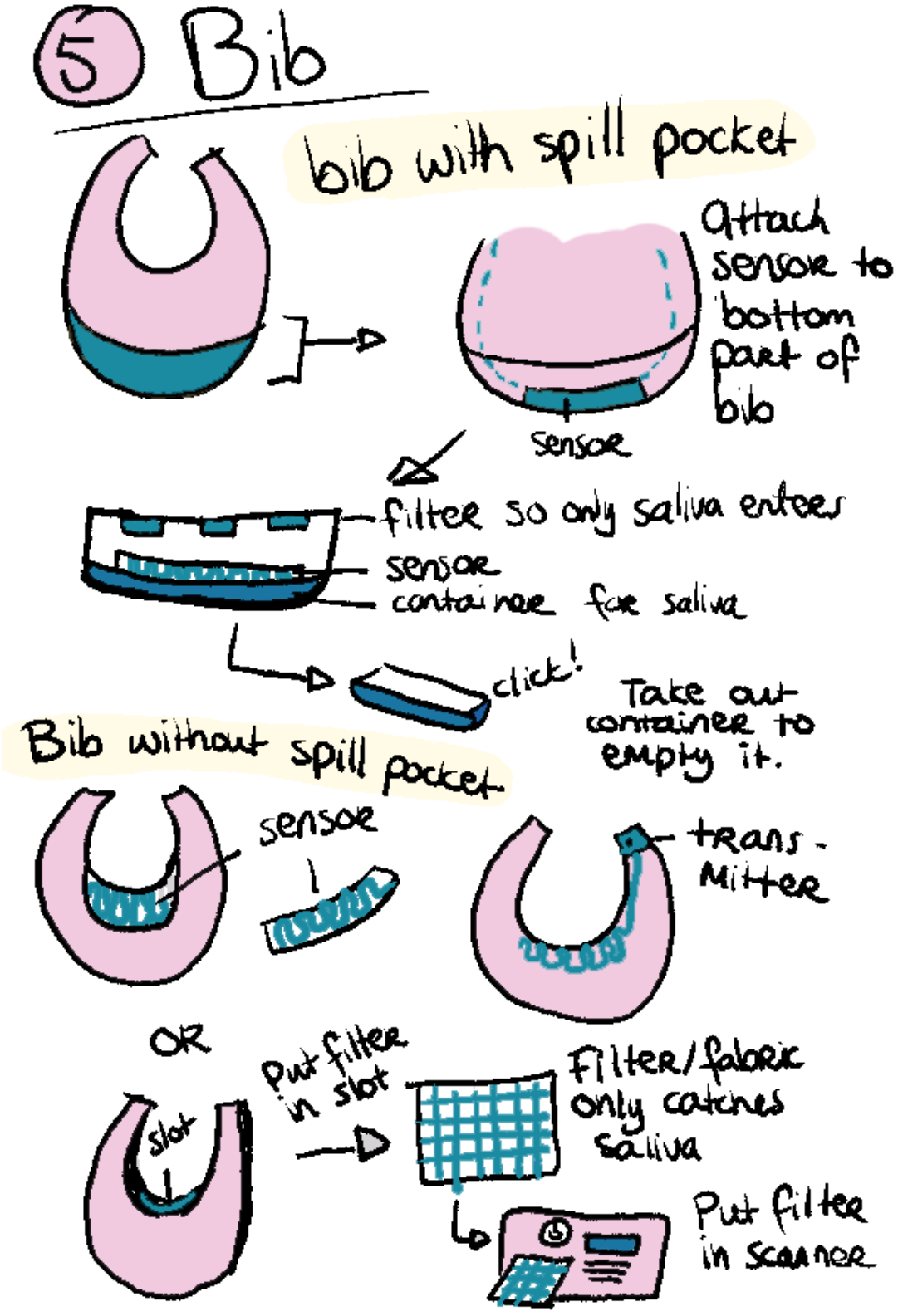


Figure E5. *Full-size image of the bib idea.*

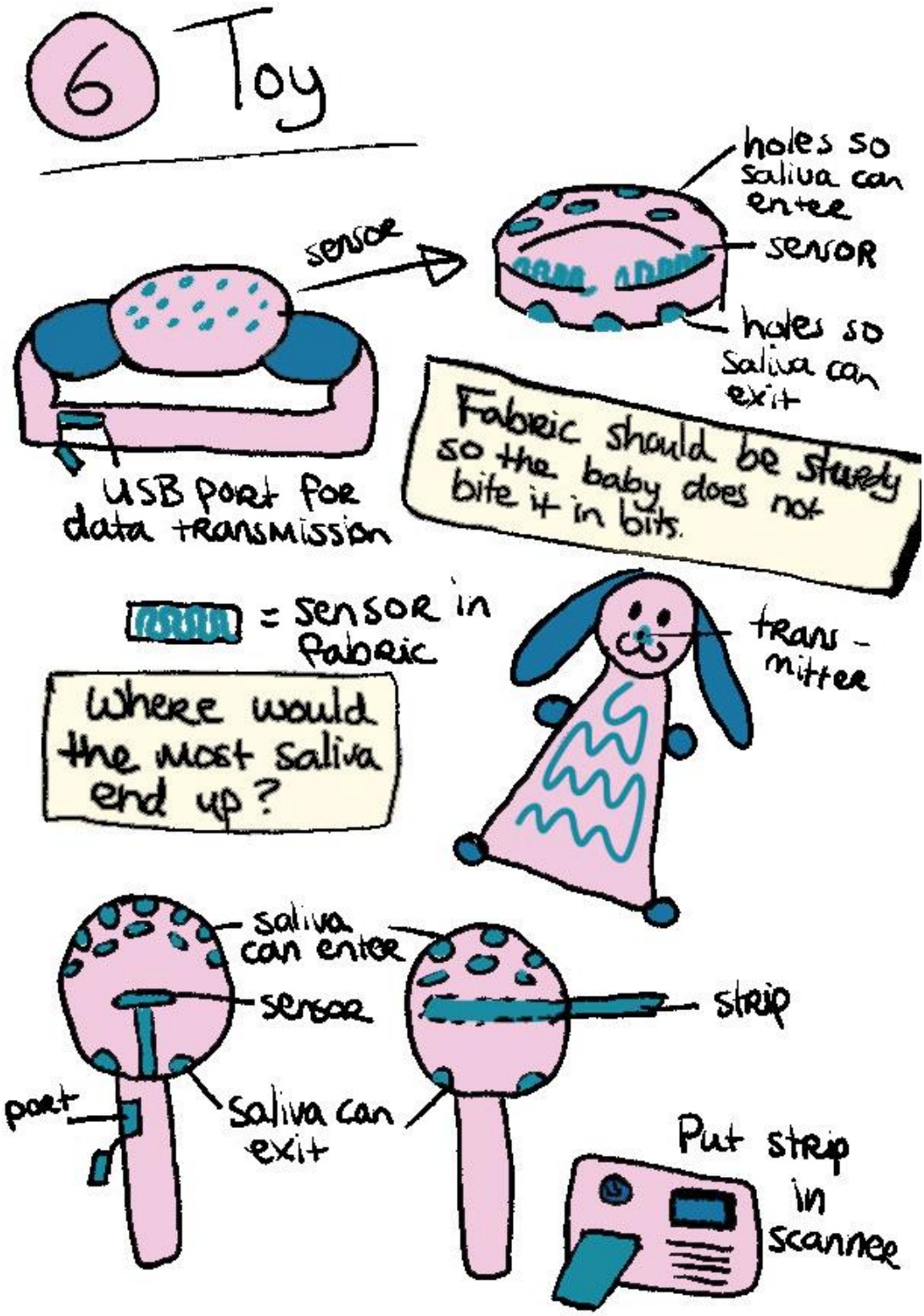


Figure E6. *Full-size image of the toy idea.*

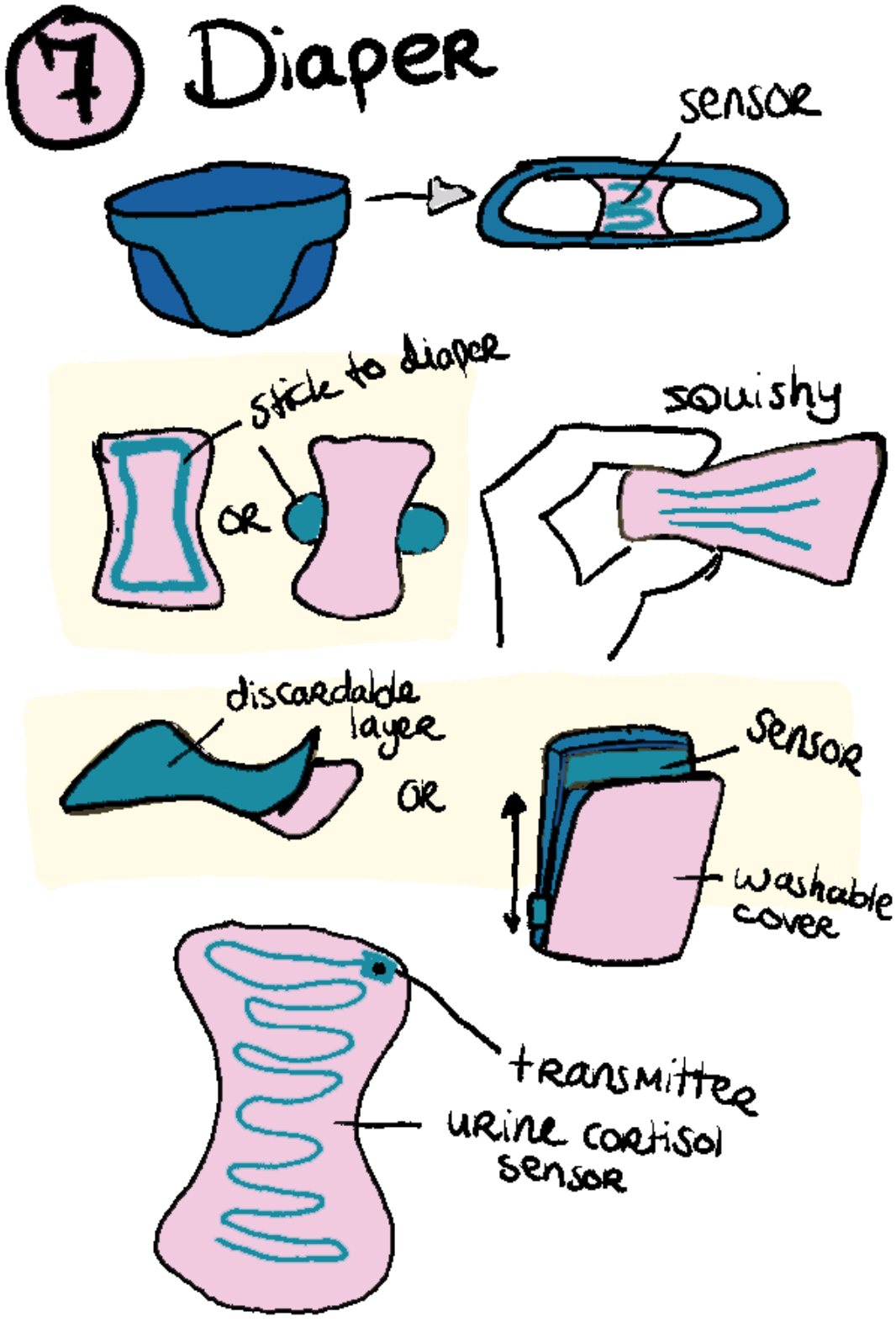


Figure E7. *Full-size image of the diaper idea.*

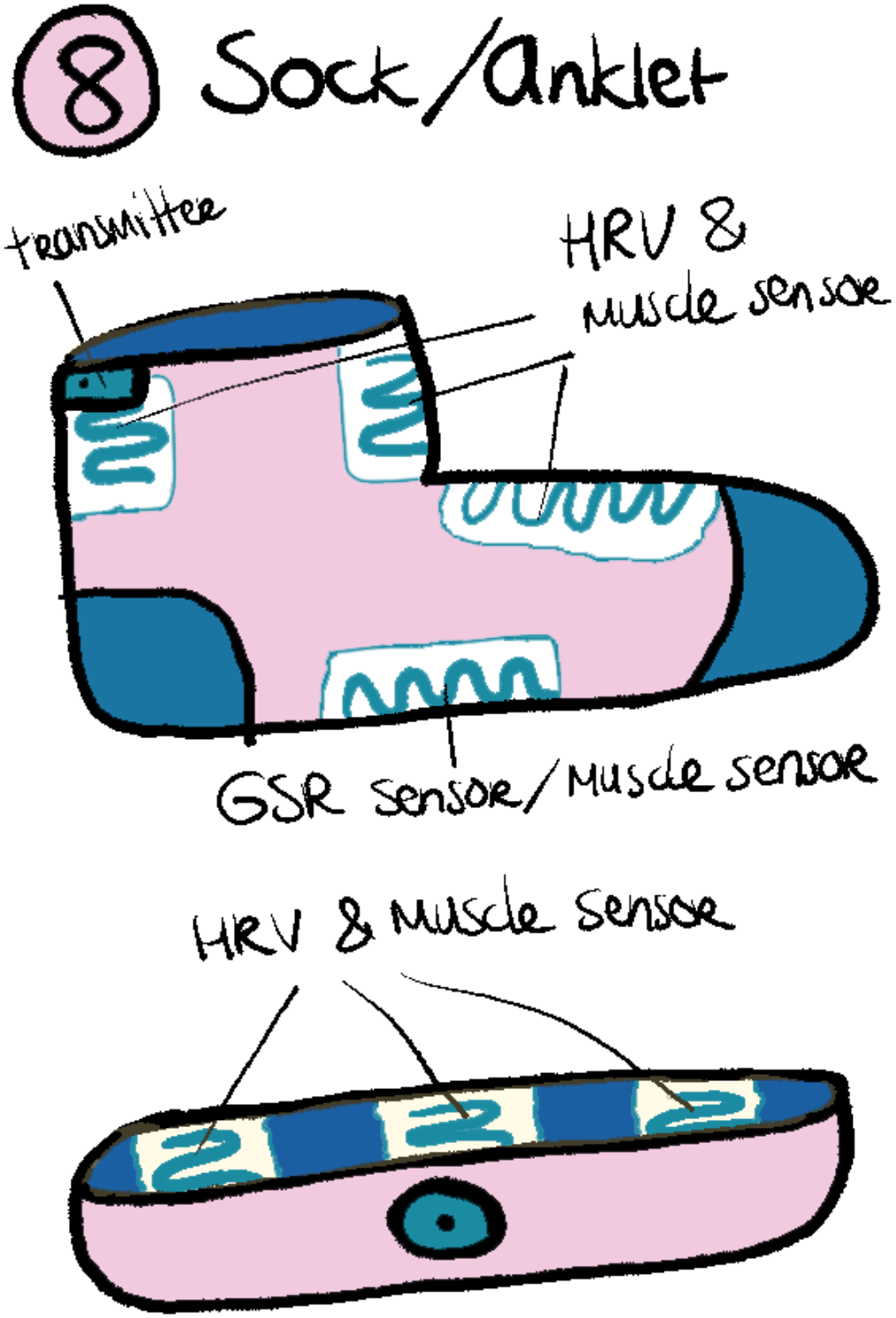


Figure E8. Full-size image of the sock idea.

Appendix F – Dutch Overview As Shown To Parents

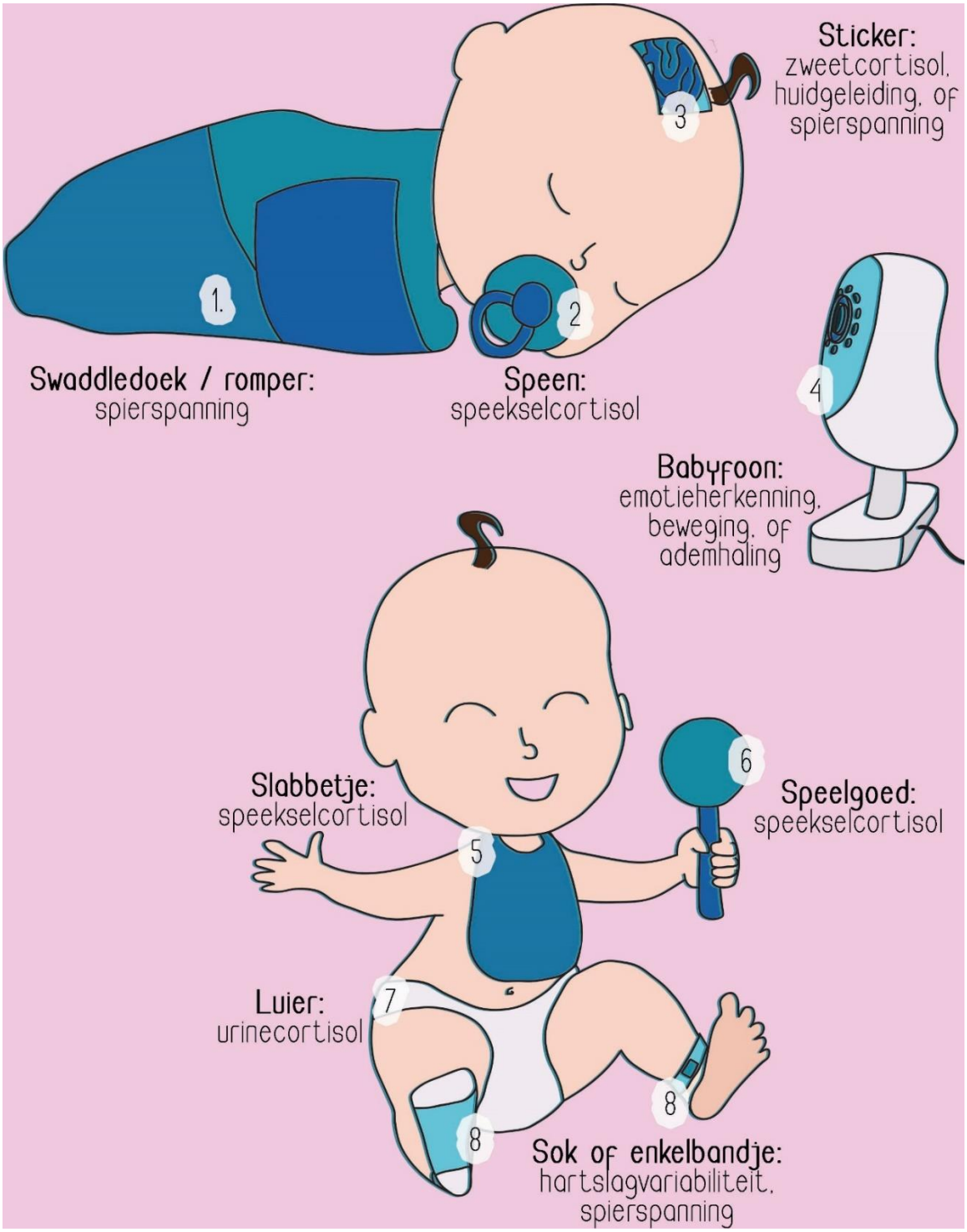


Figure F1. *Summarized drawing of the concept ideas as shown to target users.*

Nummer	Product	Omschrijving	Gebruik
1	Swaddle/romper	Bevat sensoren die de spierspanning van de baby kunnen meten, en een zendertje om informatie te sturen.	Aantrekken bij de baby en aanzetten.
2	Speen		
a	Inwendige sensor	Vangt speeksel op en leest via de sensor in de speen af of de baby stress ervaart. Stuurt via het zendertje de informatie op.	Aan baby geven, aanzetten.
b	Strip	Vangt speeksel op op een strip, die je uit de speen kunt halen om in een kastje te stoppen en zo ook de stress af te lezen. Het kastje kan aangesloten worden op apparaten om de informatie te delen.	Aan baby geven, strips in een kastje stoppen en aflezen, aansluiten op een apparaat.
3	Sticker	Bevat sensoren die verschillende lichaamsfuncties aflezen en de informatie via de zender doorsturen. De kleur van de sticker geeft aan de ouder weer of het een positieve of negatieve emotie/gevoel is.	Op baby plakken en aanzetten.
4	Babyfoon		
a	Emotie	Herken emotie door de camera op het gezicht van de baby te richten. Deze kan dan, door te letten op bepaalde plekken van het gezicht, emoties onderscheiden.	Camera monteren, positioneren, aanzetten.
b	Beweging/adem	Herken stressvol beweeggedrag (overstrekking) of stressvolle ademhaling (onregelmatig) door de baby kleding aan te doen met een patroontje dat de camera kan aflezen.	Camera monteren, positioneren, aanzetten. Baby kleding aan doen met het patroontje.
5	Slabbetje		
a	Plaatsbare sensor	Een object dat je in het opvangstukje van het slabbetje kunt plaatsen, welke speeksel filtert en afleest en deze informatie via het zendertje opstuurt.	Omdoen bij baby, plaatsen in het slabbetje.
b	Inwendige sensor	Sensoren aan de bovenkant van het slabbetje die speeksel aflezen en de informatie via het zendertje doorsturen.	Omdoen bij baby, aanzetten.
6	Speelgoed	Vangt speeksel op en leest dit af. Het speelgoed kan worden verbonden met een apparaat via een afdekbare poort om zo de informatie af te lezen.	Aan baby geven, inpluggen.
7	Luier	Een maandverband-achtige sensor met een beschermend laagje die je op de luier kunt plakken welke urine kan analyseren. Bij het verschonen van de luier kan de sensor er afgehaald worden, het beschermende laagje vervangen worden, en de sensor in een andere luier opnieuw gebruikt worden.	In luier stoppen, beschermend laagje vervangen.
8	Sok/enkelband	De sok of enkelband bevat sensoren die via de voetrug of enkel o.a. hartslag en spierspanning meten. Via het zendertje wordt de informatie doorgestuurd.	Aantrekken bij baby, aanzetten.

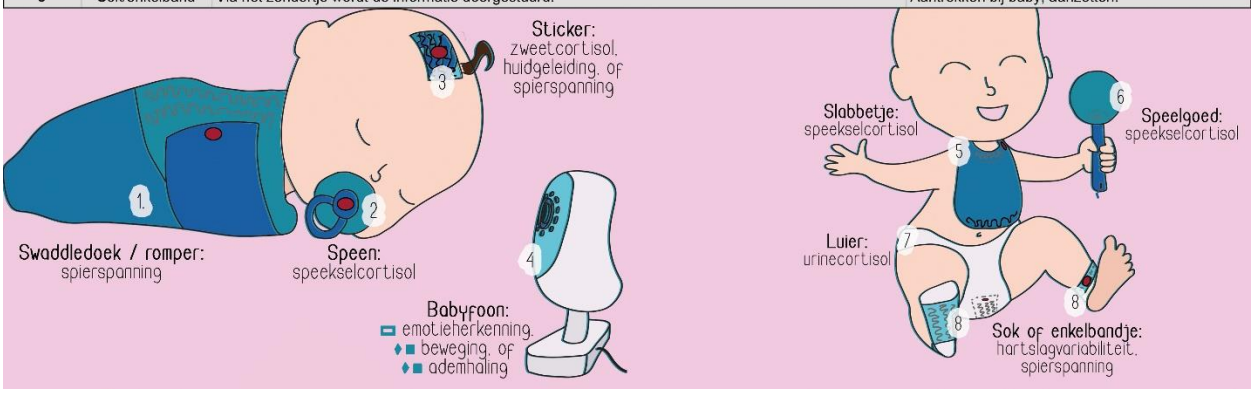


Figure F2. *Complete overview of drawings as well as descriptions of the ideas as shown to target users.*

Appendix G – Interview Questions (Translated)

Introduction

- Are there still questions about the information brochure?

We will cover three topics today: your answers in the survey, your experience about being in contact with a professional, and my concept ideas regarding a product that can monitor stress levels in infants. At any moment, you are free to withdraw from this interview. You are also completely free to say you do not want to answer a question. If you want to ask me a question, that is of course also possible.

Interview

5 min: Survey

These questions were different per interview and phrased based on their survey answers. They are, therefore, not included in this appendix.

5 min: Contact Professional

Now, I would like to ask you some questions about your experience with a professional (e.g. a doctor). This would be about appointments you and your child have had, for example, visits to the paediatrician.

- Did you ever get advice from a professional during such an appointment?
    - What kind of advice?
        - Specifically aimed at the child
    - How did you experience getting such advice?
- Did you ever try out products or tools because a professional suggested it?
    - What kind of products/tools?
    - Why?
    - How was this proposed?
    - Did you also understand why it was necessary or useful to use this product/tool?

I am asking you this because my goal is to develop a product that can monitor stress levels in infants, which can be referred to by a doctor or therapist. The idea would be that during an appointment, they could point you to the product which you could then use at home so it would

monitor the child in a normal environment. During another appointment with the doctor or therapist, you would then be able to discuss the results.

- What would, in your eyes, be the best way to get such a product?

20 min: Product

Now we will take a look at the product itself. I have worked out a couple of ideas, but first I would like to ask you to describe for yourself what you would like to see.

- What kind of product or effect would you need to effectively monitor stress in your child?
    - What would it look like?
    - Where would it be?
    - What would it do?
    - How would you use it?
    - How often would you use it?
    - How long would you need to use it?
    - When would you want to use it? (e.g. only when the child is crying, only when I don't know what to do)
    - What would be the most important element of such a product?

Thank you for the descriptions. Now we will take a look at the ideas that I have worked out. These concept ideas function in a similar way like smartwatches in the sense that they measure bodily functions in a safely embedded and subtle way. So while the product consists of sensors, it is not a new technology that is being used. The ways in which stress is monitored differ per idea, but will all communicate their measurements to another location or device. Please let me know if an idea is unclear.

- **[Show image without sensors]** *This image will show you all ideas and where they would be worn on the infant's body.*
- **[Show image with overview and sensors]** *This image will show you how these ideas would work.*
- What are your first thoughts? Feel free to say anything that comes to mind.
- What would be the pros and cons of each idea?
    - Swaddle/romper suit
    - Pacifier

    - Patch
    - Baby monitor
    - Bib
    - Toy
    - Diaper
    - Sock/anklet
- Do you have pen and paper, then we can continue in a somewhat interactive way. I would like to ask you to rank the ideas based on a feature that I will name. Take as much time as you need. One would be the most positive, eight the most negative.
    - Comfortable for your child.
    - Comfortable for you.
    - Easy to use.
    - Clear to use.
    - Added value.
    - Subtle functioning.

  We want to make sure the product functions as much as possible in a background role, so it does not influence you or your child's emotional state.
    - General attractiveness.

Together with the product, we want to develop an app as well. This app can be used to store all measurement data, but also to write down your observations and provide tips.

- What do you think about this idea?
- How would you like to use such an app?
- What kind of features would you like to see?
    - Write down observations
    - Give tips
    - Give insights
- (How) Would you like to share this information with a doctor or therapist? (e.g. share online, upload through a cable, show screen)

Now you should have a bit of an idea about the options that are still available. Based on these interviews, the ideas can still be changed with regards to the use, location of sensors, size, etc.

- What would, for you, be essential or most important to include in the product?
- What would be good features to add to the product?

Test Participants

As stated before in the survey, I am going to develop a prototype that has to be tested. The focus will be put on user experience and intuitive use, so it will not focus on reliability.

- I cannot test on infants, so my current idea is to let you test the prototype while keeping your child in mind.
- In the survey, you have indicated that you would be willing to participate in the testing phase. Is that still the case?

Comments

- Do you have any comments or questions?

Appendix H – Summary Of Interviews

Stress Signals

Factors that parents see as signs of stress (ranked in occurrence)

Crying a lot (4x), sleeping problems (4x), not being able to find a rhythm (3x), being tense physically and mentally (2x), restless (2x), being sensitive (2x), being overstimulated (2x), clinginess (2x), a developmental delay (1x), eating problems (1x), not getting calmed by their parents (1x), being in a bad mood (1x), being really uncomfortable (1x), reacting abnormally to things (1x), getting scared (1x), tantrums (1x), being withdrawn (1x), nightmares (1x), being scared to do things (1x), regressive behaviour (1x).

A parent indicated that short moments of stress are normal. Babies do not yet have the emotional regulation that adults have, so they'll easily cry if something is wrong.

Experience Professional

Positive experiences when getting advice

Parents all described different aspects, focusing mostly on the inclusion of the parent in the process. They appreciate it when the doctor thinks along, so parents can do it in their way. Getting rest and finding a solution that can be understood, in which the professional makes sure it is clear what is wrong is also liked. Parents want the professional to look at and involve both the child and the parent and want them and the professional to have a common understanding of the problem and what is necessary.

Using products to monitor/cope with stress

Most participants indicated that they found and tried out products themselves (which often did not really work), such as swaddles, training, specific types of food, bottled food. Half of the parents have also used products such as melatonin or sab simplex because a professional advised or prescribed it, as a result of a specific experience or problem (sleeping and eating problems, etc.). They stated that this (getting advised) would be better than looking for a solution on their own, but it would still be nice to be able to access it independently as well.

"The first three years of life are so important, such a product

could have an enormous impact on the child." - Parent 1

The parents indicated that "they would try anything if it would help their child", but also "want to trust their intuition and parent's instinct". As the impact of stress on such a young age can be huge, it is important to be able to see when their child is stressed, maybe using it preemptively (use in maternity week or at the children's healthcare centre). Although their child did not seem stressed, a parent described, it is still hard to know for sure. Some parents

also have a hard time knowing what their child is feeling or distinguishing normal behaviour from stressful behaviour (how to interpret signs). A product that could guide them with this would be nice, especially in unstable families.

Lastly, a parent indicated that the product should be completely objective, so the results cannot be influenced by the parent's subjective view, but it also shouldn't put additional pressure on the child.

Concept Ideas And Comments

General

Overall, several parents stated that the concept ideas were kid-friendly, unobtrusive, clear, modern, and objective. Parents could also see the added value of measuring stress at home since professionals cannot see that part (capabilities of parents, their interaction, atmosphere).

- Although having an objective tool to monitor stress is very well-appreciated because it helps put experiences in perspective, parents stated the importance of being able to discuss the results with a professional. For example, if a product says the child is not stressed but the parent disagrees, there should still be room for a discussion about this with the professional.
    - To put experiences in perspective, a parent suggested timing signs and activities (e.g. how long does the baby actually cry).
- Several parents suggested also measuring stress levels at parents, as they are often also the result of stress in their child. As the interaction between parents and children is very important, so involving both of them this way would be nice and effective.

"The concepts seem really kid-friendly, you wouldn't burden a child with this." - Parent 4

"These kinds of products are the future, really nice." - Parent 5

While describing their own vision, a parent said it would be nice to look at heart rhythm or breathing. Several parents thought a survey or some way of inclusion for the parent would be helpful; trying to find a connection between stressors and the child's behaviour while customizing these stressors mentioned in the survey on the parent.

- Looking at the concept ideas, some parents suggested combining some products, so they would measure cortisol levels as well as muscle tension or heart rate to get a broad overview of their child's stress levels. In general, parents prefer measuring multiple things simultaneously as it is associated with more reliable measurements.

"I would say, keep it safe!" - Parent 1

Parents indicate that children put a lot of things in their mouth, and, once their teeth start coming in, they bite on things as well. Therefore, the product should be sturdy and safe so

they cannot be accidentally electrocuted or swallow a sensor. Additionally, a parent expressed their worry about radiation near their child, stating that it should be as little as possible.

- A suggestion for this is to develop a product per "age stage" (e.g. a product for 2-months old babies and a product for 8-months old babies) to adjust the features of the product to their typical behaviour.
- Another suggestion is to let the product be worn on the torso so the baby cannot easily access it.

They stated that they would use the product if they don't know what to do themselves anymore, as the basis should be intuition. It would be ideal if the product was somewhere at home so they could easily grab it. Additionally, in a stressful situation, parents do not really have the time and mind space to actively use a product. Therefore, it would be best if the product requires little effort and is possibly multifunctional. If the stress-monitoring tool has an additional use that is needed anyway (e.g. clothing), it does not require a lot of extra time to use.

- Another moment to use the product would be in a situation where the child is alone and not under supervision (e.g. at night) since they might feel scared or alone.

In the end, parents state that - although they have preferences - they are willing to try anything, as long as it works.

"I don't have an aversion to any concept, so if a doctor would recommend

any of these concepts, I would use them." - Parent 4

Swaddle

A parent said that swaddles are not recommended to use as children can't lose their heat well enough. Parents commented that this product is only used in the early months of a child's life, and it is not always used. Additionally, the way a parent swaddles their child differs a lot per person, so there need to be specific guidelines. Furthermore, a child's response to being swaddled is also very diverse. Overall, it is not seen as the most comfortable and practical tool to use.

There were also some concerns regarding the safety of the product (because of sensors and other electronics), and whether it could be washed or not.

Romper suit

This suit is worn more often and more continuously than swaddles, and it is also suitable for older babies as well. There were still some concerns regarding the safety of the product (because of sensors and other electronics), and whether it could be washed or not.

Pacifier

Two main points came up when discussing the pacifier; not all parents see this product as very safe, and not all babies use pacifiers.

- Most parents feared that their baby might accidentally swallow or bite on components of the sensor - especially if they have teeth already. Parents feel an aversion towards putting such technology in a child's mouth. A parent suggested using strips to read the cortisol levels as that would be safer, but pointed out it would also increase the parent's effort needed.
- If a child does not naturally use a pacifier, it would not use the product or it would be less comfortable to use. Additionally, the parent will have to put more effort into the tool actually being used.

On a more positive note, parents did point out that the pacifier would work better than the other tools that focus on measuring salivary cortisol. Its use would be easier, more practical and (to one parent) safer than the other tools.

Patch

The feelings about this tool were fairly mixed. Parents liked how easy it was to use and the diverse and informative measurements it would result in. However, they also suspected that attaching and removing the patch would be uncomfortable, cause irritation on the skin or be painful - which the child would not always be able to clearly indicate.

- If the patch could be worn for multiple days simultaneously, that might be doable - but then hygiene would be a concern.

The sketch showed the patch located on the head, resulting in concerns about the reliability of the patch if the child had hair. Additionally, they suspected it would not attach well. An alternative location of the patch that would be better would be on the belly or back with clothes covering it, so it would be less uncomfortable, more subtle, and the baby would not be able to reach it. However, some parents felt an overall aversion to sticking a patch to the child's body.

"Do not stick things to my child's body." - Parent 5

"Well, no, I don't think so!" - Parent 3

Baby monitor

As this tool was the only one that did not have direct contact with the baby, it was seen as a very safe and non-invasive tool. Parents liked how it requires little to no effort to use it, and it can be used for a longer time. Most parents saw it as the most comfortable tool for both the child and the parent (although some parents could be conscious about the camera being there), however, some parents expressed their worries about their child's privacy and the tool's reliability. What would happen with the video recordings? And what happens if the child moves away from the monitor? Isn't it too far away from the baby?

Some other remarks that parents made were: not all parents use baby monitors, it differs per parent how often they would like to check the baby monitor (and if they would also get more stressed about having something to check), and it might become very pricy (which influences the parent's willingness to use this product). Lastly, a parent commented that it would be very helpful if the baby monitor would be able to sense emotion, as it could then teach parents how to recognize their baby's emotions.

Bib

Compared with the pacifier, the bib was not seen as the most effective way of measuring stress through salivary cortisol. Parents suspected that other fluids, food, or dust would interfere with the measurements. A parent questioned how this product would be washed, and what happens if their child does not drool so much. Lastly, parents stated that it is less useful as it would not be used throughout the day and night.

- A suggestion to result in more continuous use would be to make a tank top instead of a bib, so it can also be safely worn at night.

Toy

Although parents liked the idea, they feared that the baby would not sufficiently put the toy in their mouth or prefer using a different toy. This would then either result in irregular measurements or the parent having to put a lot of effort into making the baby use the toy without forcing them. Additionally, babies cannot hold toys from day one, meaning that the product would only be useful once the child is around four months old.

- A parent suggested making a teether since that product is designed to be in the mouth.
- A parent suggested designing the toy so that it would be more attractive to use than other toys.

Diaper

Most parents liked the diaper because it has to be used anyways ("every child pees"), is changed quite a lot (so would result in regular measurements), and cannot be accessed by the baby. They also see this as a reliable tool because it focuses on cortisol. There were, however, some question marks considering the measurement method; parents suspected it was not very practical and would result in a lot of extra effort from the parent's side (has to be cleaned every time).

- A parent suggested using the "old-fashioned" strip to decrease the amount of effort needed.
- One parent stated the location of the tool is too intimate to use.

"No, no, this is too intimate." - Parent 3

Sock

Parents were very positive about the sock. It was seen as easy to use, has to be used anyway, and is comfortable. Additionally, parents liked that it measures multiple things. The greatest downside mentioned was the fact that it could be easily taken off by the baby, and that it is not always worn.

- A parent suggested using cotton to make sure the product is comfortable.
- A parent suggested designing the sock in a gender-neutral way (e.g. use mint green colours) to increase accessibility.

Anklet

Parents were fairly positive about the anklet as well. Similarly to the sock, parents stated it would be easy to use and would measure multiple things. Additionally, the baby would not be able to take it off accidentally, and it can be worn regardless of the situation (weather, time of day). Three concerns regarding the anklet were: it has to be attached well so it can require a bit more effort from the parent, it might not measure well if it is not attached correctly, and an anklet itself is often associated with criminals. Although parents indicated that it is not bothersome, they stated that this should be taken into consideration when designing the product.

Ranking The Concepts

Parents were also asked to rank the concept ideas based on a specific property, so we can get more indicative input from the target users and get a more based decision-making process. The properties have been formulated based on requirements as specified by the experts and as indicated through research. These rankings have been processed and the complete overview can be seen in Table . For example: if the toy has been ranked as most comfortable, and patch as least comfortable, the first would get 1 point and the latter 8 points. So a low score means a high ranking, and the three concepts in each category with the lowest scores have been coloured green. That means that the best ideas in the category "Comfort (child)" are the baby monitor, sock/anklet, and pacifier.

As can be seen, the sock and anklet, baby monitor, and diaper have been indicated as the most popular concept ideas overall – looking at the sum of all categories. Simultaneously, the top-3 in the category of "General Preference" is the same, meaning that there is no significant difference between the parents and the categories regarding the ranking of these three concepts. The diaper is in the top three in five out of seven categories, and the baby monitor is only missing in one category. Since the sock and anklet are in the top three in all categories and have no polarised/extreme comments as can be seen in the interview notes, this will be the most ideal concept to focus on.

Table H1. Overview of concept ideas ranked based on several criteria.

Product \ Category	Comfort (child)	Comfort (parent)	Easy to use	Clear in use	Added value	Subtle functioning	General preference	Sum
1: Swaddle/romper suit	31	20	22	19	21	25	32	170
2: Pacifier	22	21	23	25	27	24	34	176
3: Patch	42	35	22	21	18	26	35	199
4: Baby monitor	10	17	16	25	13	21	25	127
5: Bib	28	28	26	24	21	23	40	190
6: Toy	28	28	29	24	24	25	40	198
7: Diaper	24	30	17	19	16	13	24	143
8: Sock/anklet	16	13	14	13	12	19	12	99

Involvement Of An App

Most parents indicated that they would like to use an app as a supportive and informative tool besides the wearable technology, some weren't certain yet. All parents were in favour of sharing the data of the products with a professional during appointments.

"Don't give too much feedback […] otherwise we could let technology raise our child." - Parent 5

Time investment

As a parent, you are lived by the rhythm of your baby (feeding, cleaning, etc.), so the product should not be very time consuming and high-effort. Additionally, a parent should learn to rely on their gut feeling.

- Parents suggested to avoid using text boxes in the app, so there is no need for (time-consuming) typing. This also makes it easier to use the app without thinking a lot.
- Some parents stated that the app should be simple, not have too many possibilities (otherwise it could be distracting), and give limited feedback regarding the measurements (so parents do not focus on the app too much). Getting insights into their own notes and observations would be helpful, however.
- A parent suggested using the products (app + wearable) intensively at least twice a day for a week while keeping the focus on the wearable.
- A parent indicated that a maximum of 5 minutes should be needed to use the app.
- Lastly, a parent stated that it should also not be obligatory to use the app, it should merely be a supportive tool.

Observations

When explaining the functionality of registering the parent's perspective in the app as well, the participants had some wishes and concerns.

- As mentioned earlier, the use of the app should be as effortless as possible, so parents indicated it would be nice to be able to use colours, checkboxes, scales, or multiple-choice questions to quickly fill in their observations.

- Parents expressed their wish to be able to write down observations for specific moments or activities, so you can see patterns and know where stress might be coming from.
- Some parents also described their desire to be able to connect the observations with stressful moments as measured by the tool, so patterns and causes can be recognized even better.
- Suggestions for factors to look at when registering were:
    - Is specific behaviour occurring more/less than normal?
    - Is there abnormal behaviour?
    - How often do negative signs occur? (muscle tension, stress, crying)
    - How often do more positive signs occur? (being awake, being happy)

Overview

Parents would like to see data visualizations of their observations, and some would also like to get such insights in the measurements.

- Using colours, they would be able to see how severe the stress is that their child is experiencing. Connecting this to their calendars, or a schedule in general, would help identify the cause of this stress.
- Using graphs, so you can see the change of stress over time (per day, per week)

A parent questioned whether it would be best to show the measurement results in real-time, or if it would be better to show them afterwards (e.g. during an appointment with the professional).

- Direct results would enable parents to give more specific input and get specific insights, but their behaviour and their own stress levels could also be influenced by that. They might check the app a lot just to check whether their child is alright, or get stressed because they do not find out why their child feels bad.
- Results afterwards would enable parents to let go of these measurements and would result in more realistic measurements as parents do not adjust their behaviour to the insights they get. That way, it can effectively be discussed with the professional.
    - A suggestion made was to use the product for a week (together with the registration option, so the parent's perspective is included), then discuss the results with the professional so they can also give tips, and then try again with the product.
    - By comparing this with a weight-loss process, the participant clearly described their point of view.
- Several other parents agreed with this thought process and concluded that it would be better to discuss the results afterwards with a professional.
    - That way, the risk of parents acting badly out of stress or agitation is also decreased.

Additional features

- Parents suggested providing tips and suggestions so parents can learn from the product and know what to do in a certain situation. However, the way this suggestion is phrased should be adjusted based on the parent (more straightforward vs. more considerate).

- It was suggested to implement a way to chat or contact the professional that referred the product to the parent, so the professionals are more approachable. It was pointed out that this could result in more stress as well.

Lastly, a parent brought up that not all parents might use or understand the use of smartphones, so would there be an alternative?

Appendix I – Muscle Sensor Code

```
/*  AnalogReadSerial
  Reads an analog input on pin 0, prints the result to the Serial Monitor.
  Graphical representation is available using Serial Plotter (Tools > Serial Plotter menu).
  Attach the center pin of a potentiometer to pin A0, and the outside pins to +5V and ground.

  This example code is in the public domain.
  http://www.arduino.cc/en/Tutorial/AnalogReadSerial
*/

// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // print out the value you read:
  Serial.println(sensorValue);
  delay(5);        // delay in between reads for stability
}
```

Appendix J – App Icons

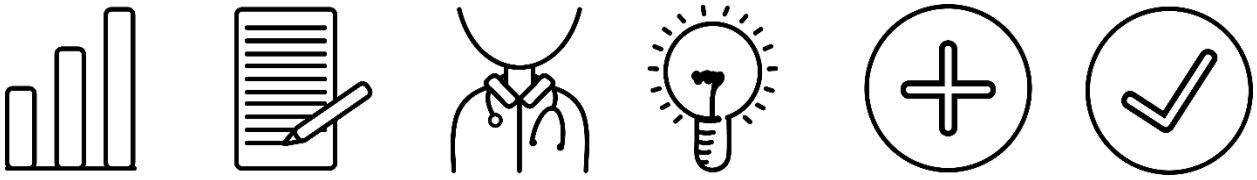


Figure J1. *Icons for the navigation bar. From left to right: statistics, overview entries (main page), professional, tips, new entry, finish entry. Made in Adobe Illustrator.*

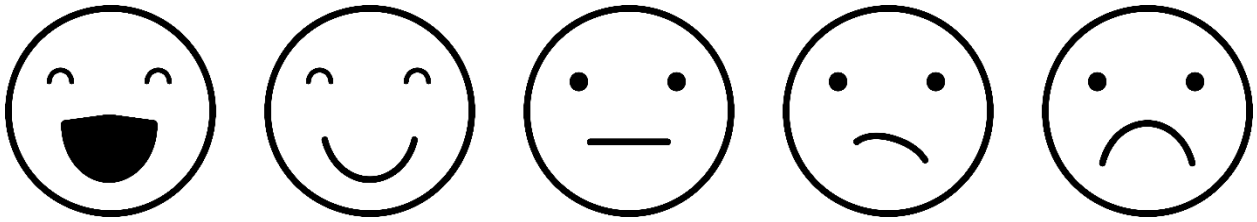


Figure J2. *Icons used to indicate one's mood. Visible in the main page, new entry page, and statistics page. Made in Adobe Illustrator.*

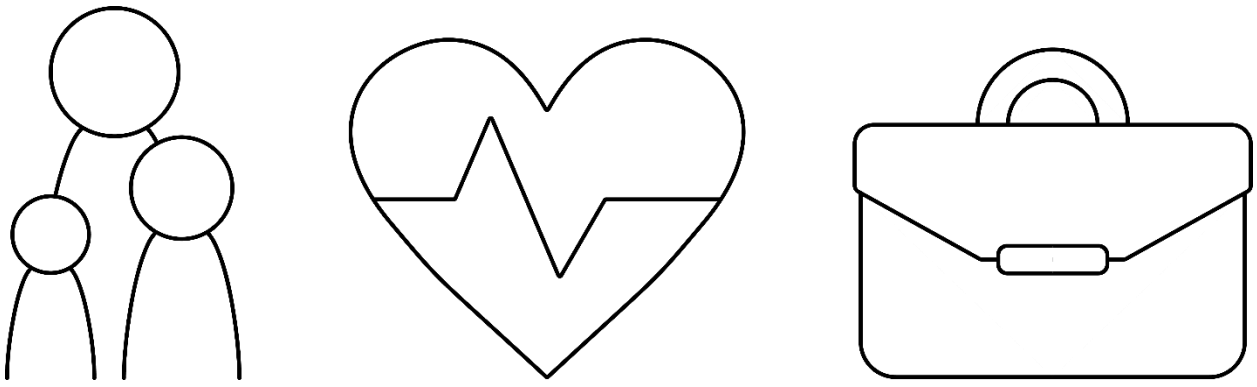


Figure J3. *Icons used to indicate factors that can influence stress levels, which are used in the entries and statistics. From left to right: family, health, work. Made in Adobe Illustrator.*

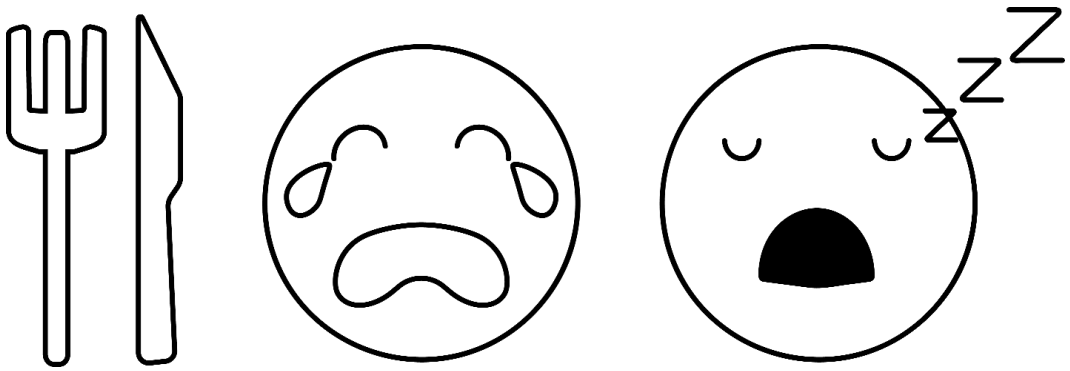


Figure J4. *Icons used to indicate behavioural cues that are often signs of stress in infants, which are used in the entries and statistics. From left to right: eating problems, excessive crying, sleeping problems. Made in Adobe Illustrator.*

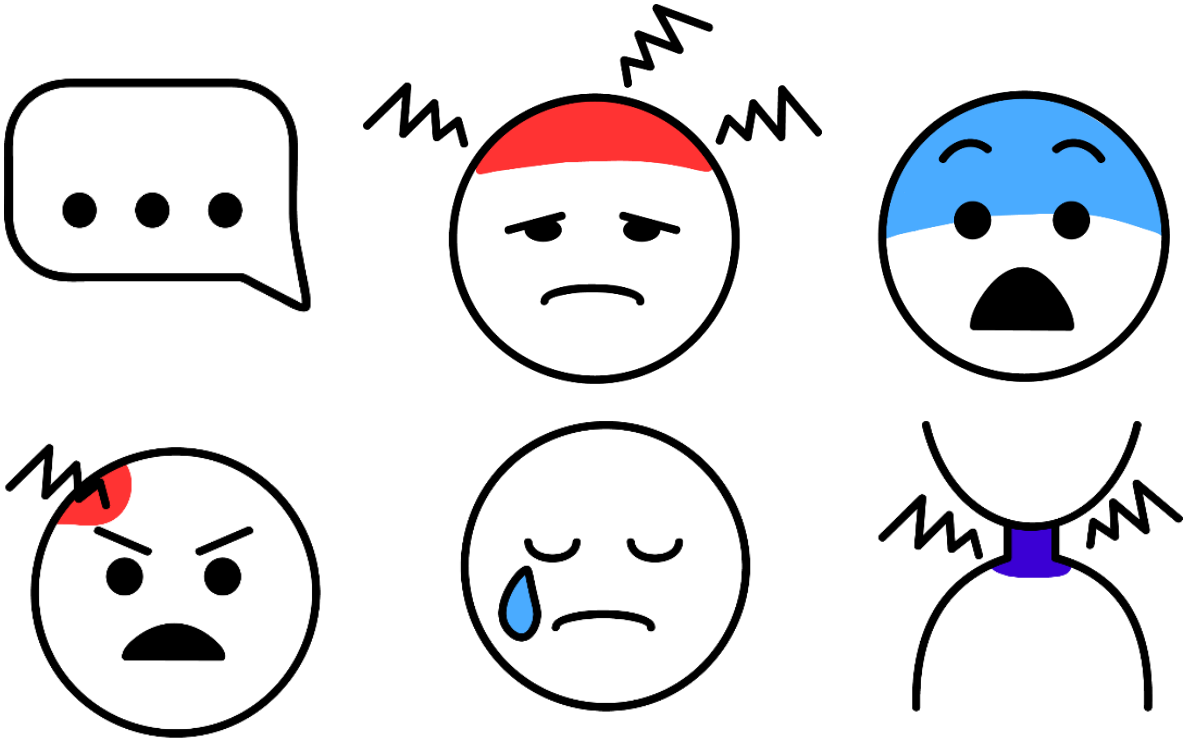


Figure J5. *Icons used to indicate symptoms of stress, which are used in the expandable version of the entry summary. From top to bottom, left to right: being very silent/passive (infant), having headaches (parent), being scared (infant), having tantrums (infant), feeling depressed (parent), and having a stiff neck (parent). Made in Adobe Illustrator.*

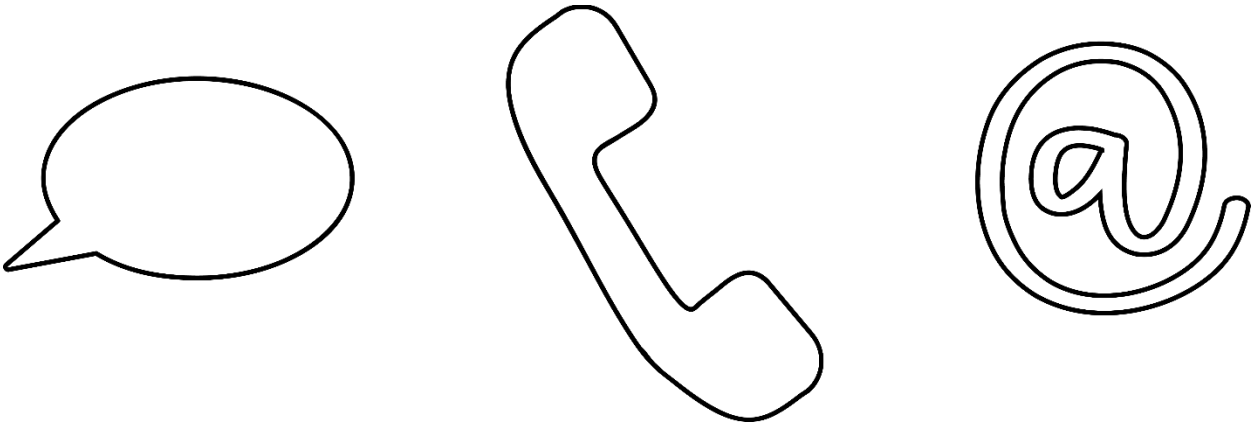


Figure J6. *Icons made to illustrate ways to contact a professional, visible on the professional page. From left to right: start a chat, call them, email them. Made in Adobe Illustrator.*

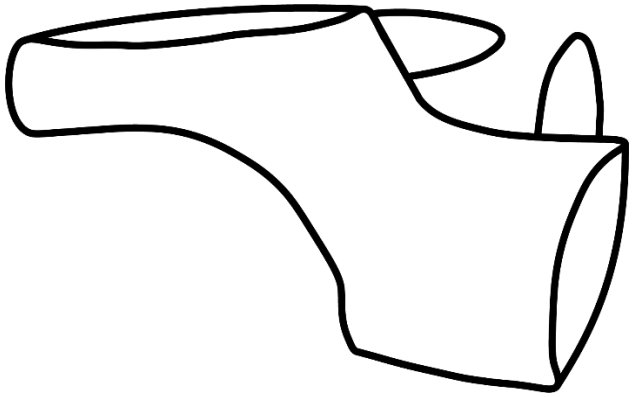


Figure J7. *Icon used when connecting the wearable sock to the app. Made in Adobe Illustrator.*

Appendix K – Full-Sized App Pages

K.1 Log-in Page

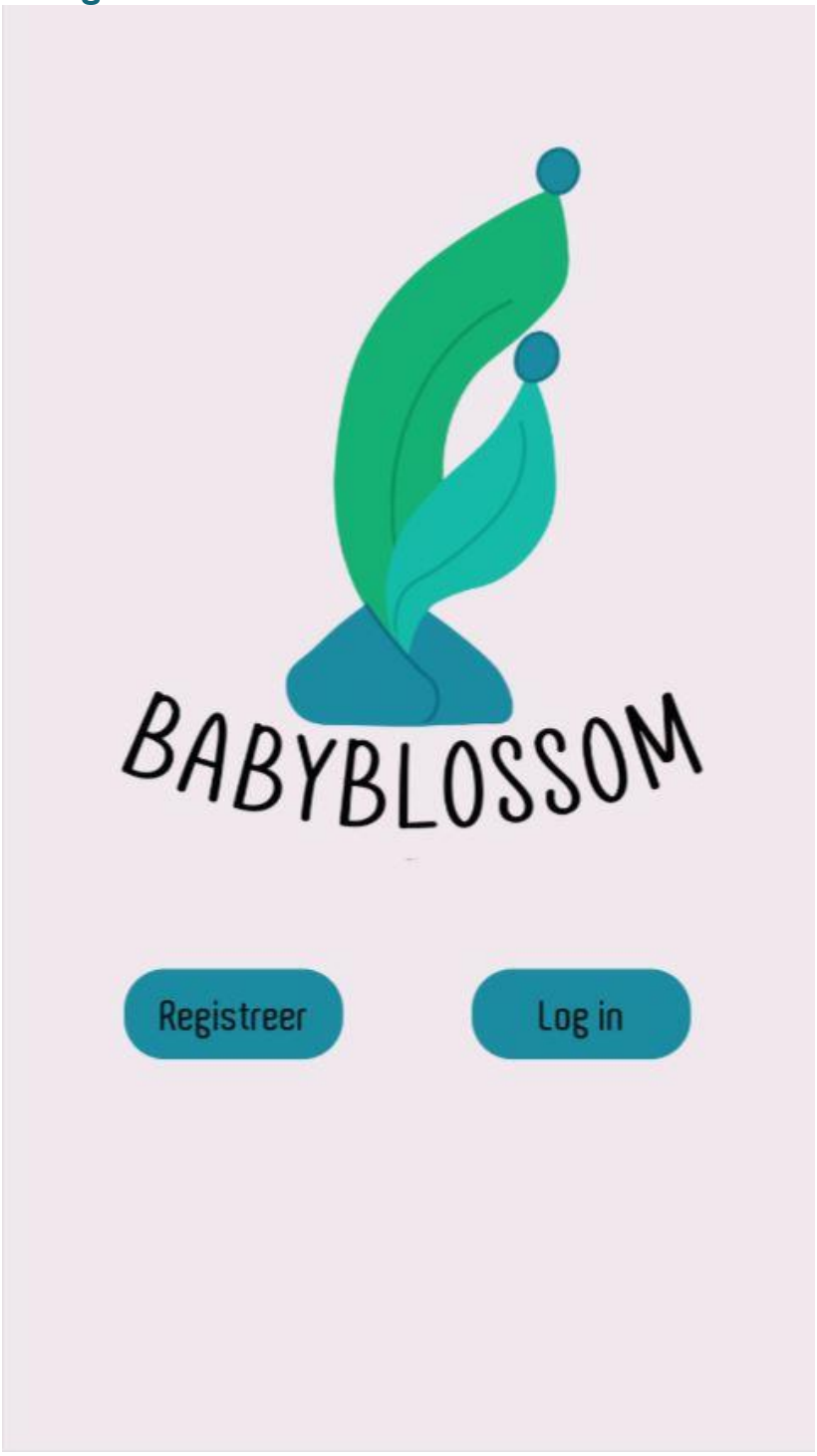


Figure K1. *First page to see, the log-in page.*

Figure K2. *Actual log-in page after clicking "Log in".*

Figure K3. *Transitional page when logging in.*

K.2 Main Page

Figure K4. *Main page you see when opening the app.*

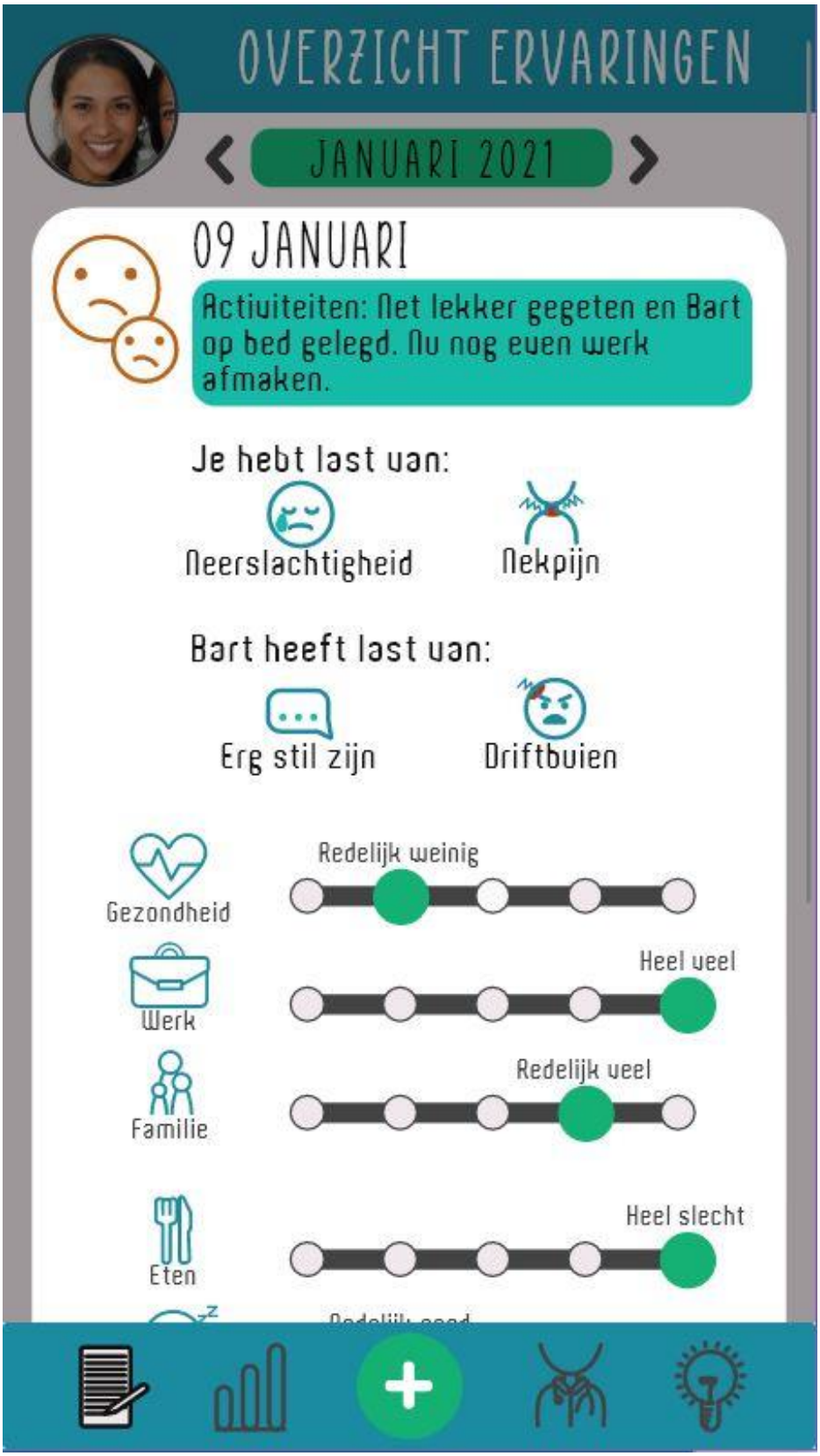


Figure K5. *Tapping on an entry will give an expanded version.*

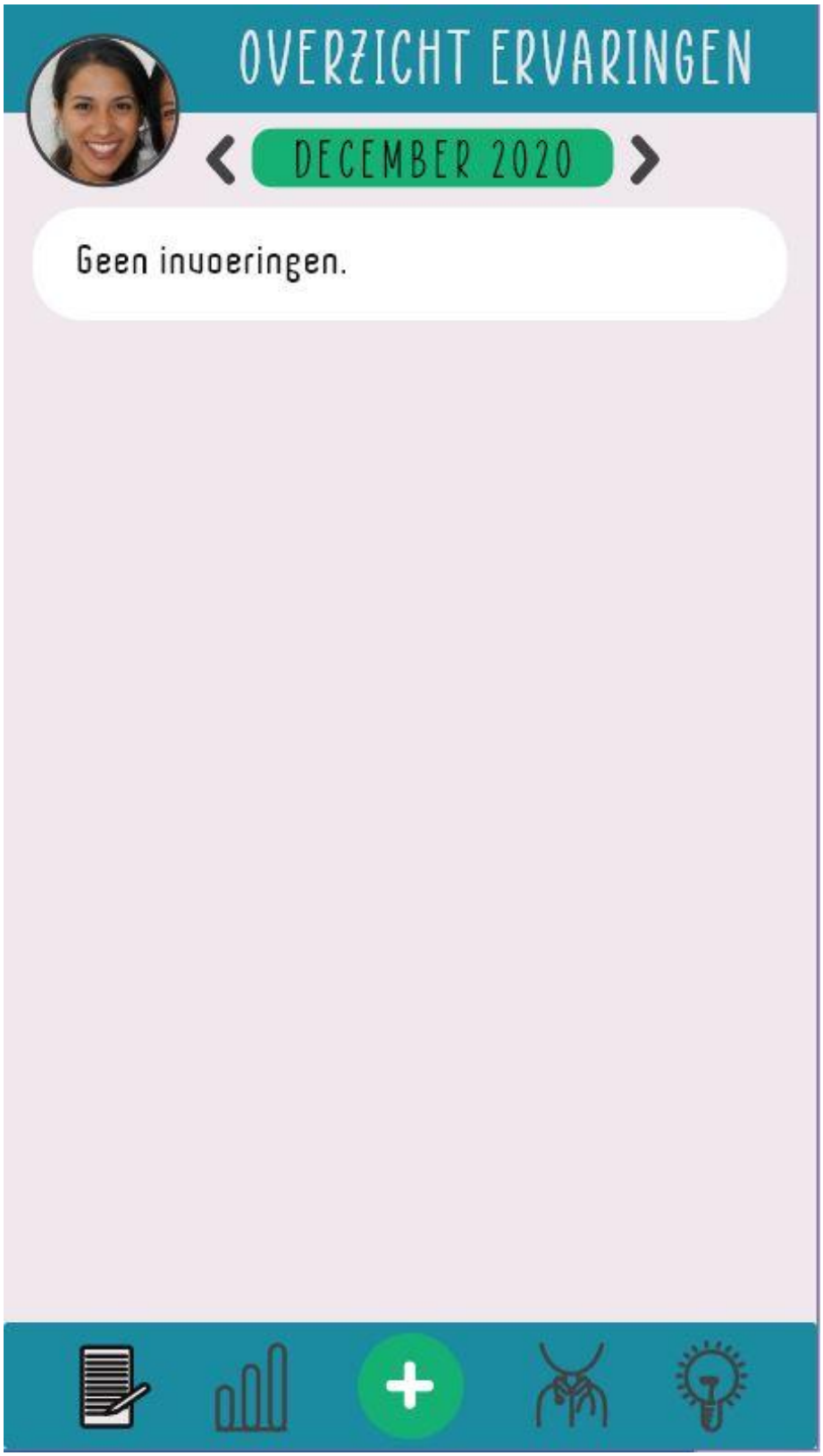


Figure K6. *Swipe to the left to go back in time.*

Figure K7. *Swipe to the right to go forward in time.*

K.3 Statistics

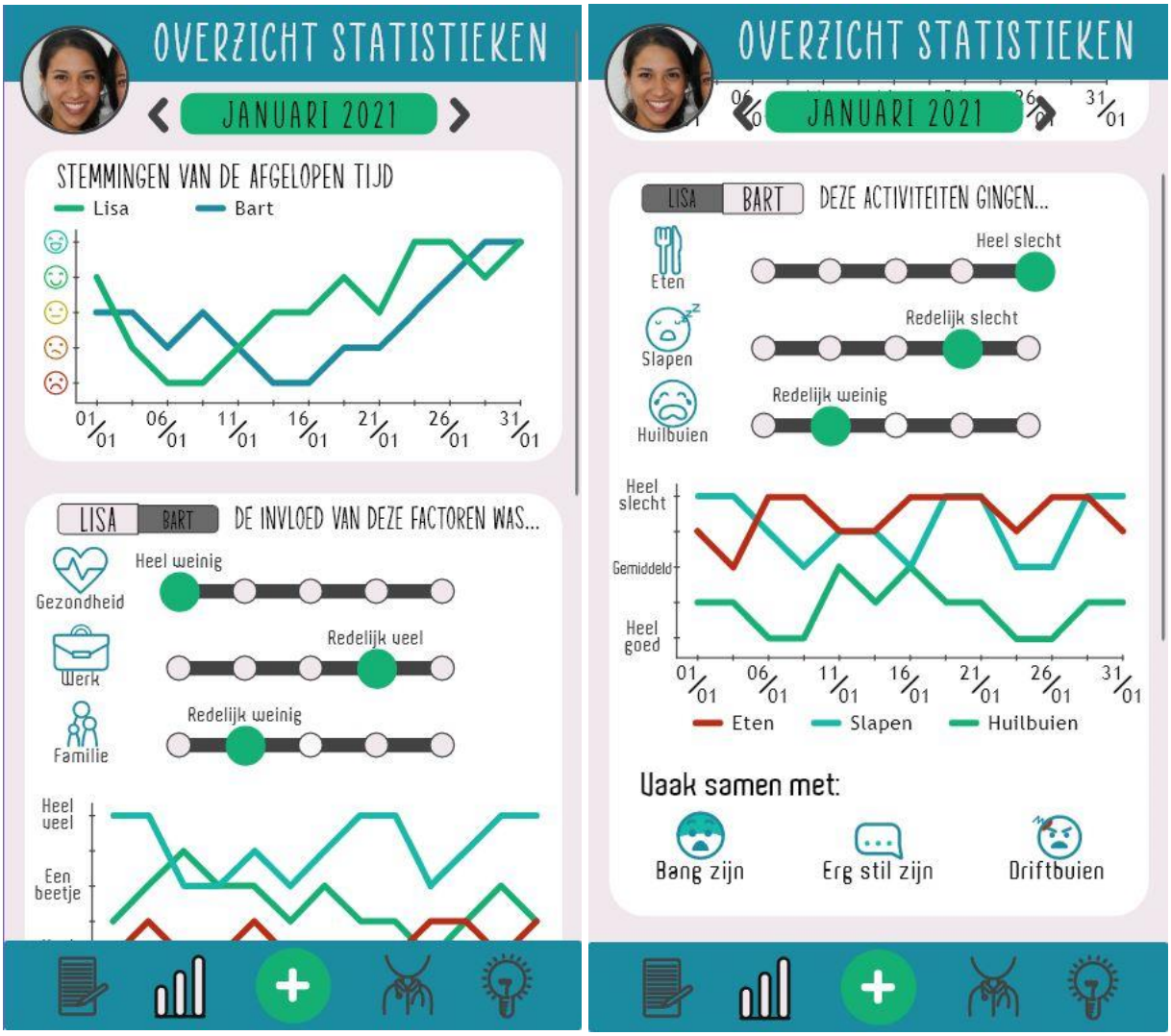


Figure K8. *Gain insights in the statistics page.*

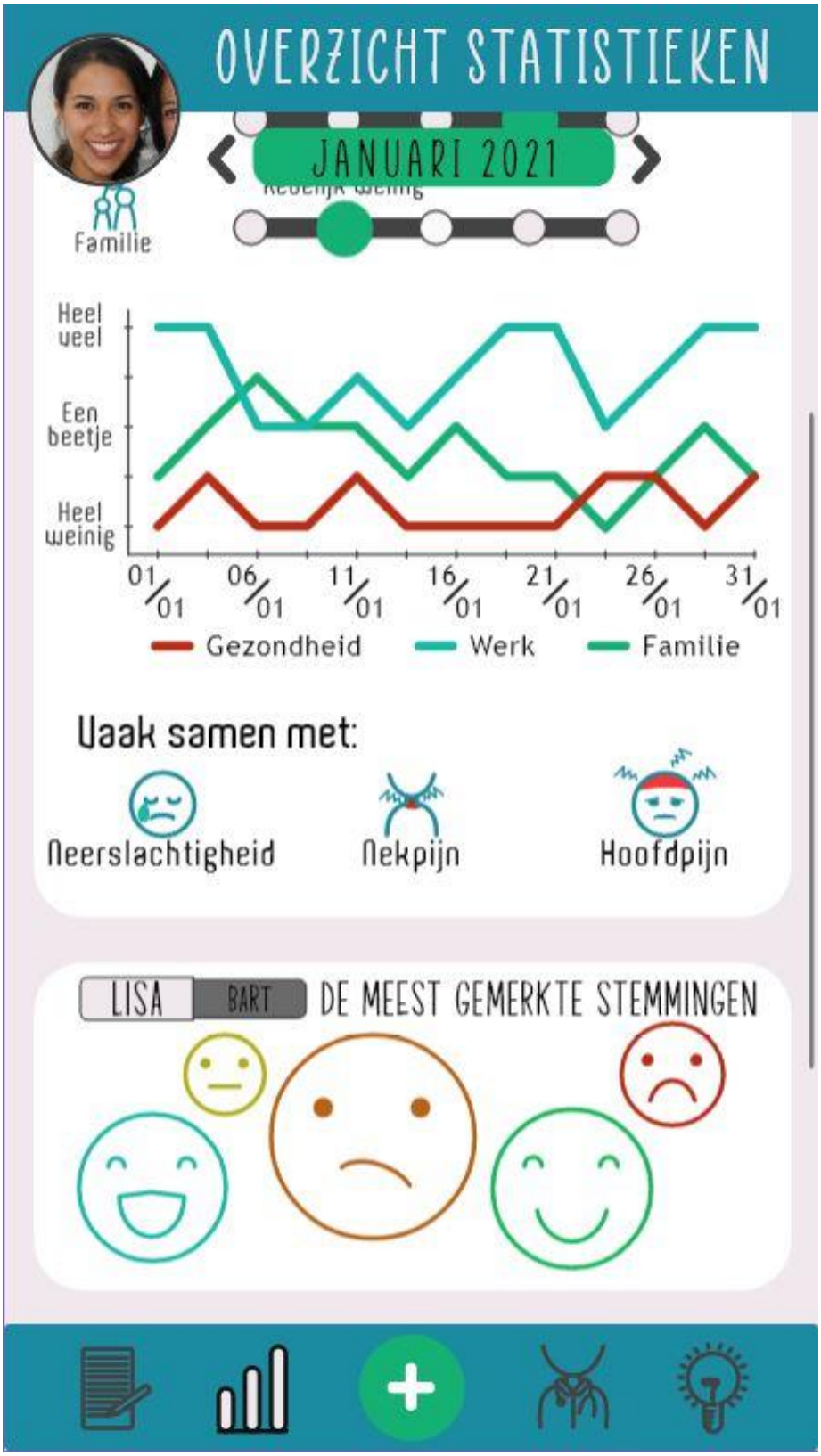


Figure K9. *View the most prevalent emotions.*

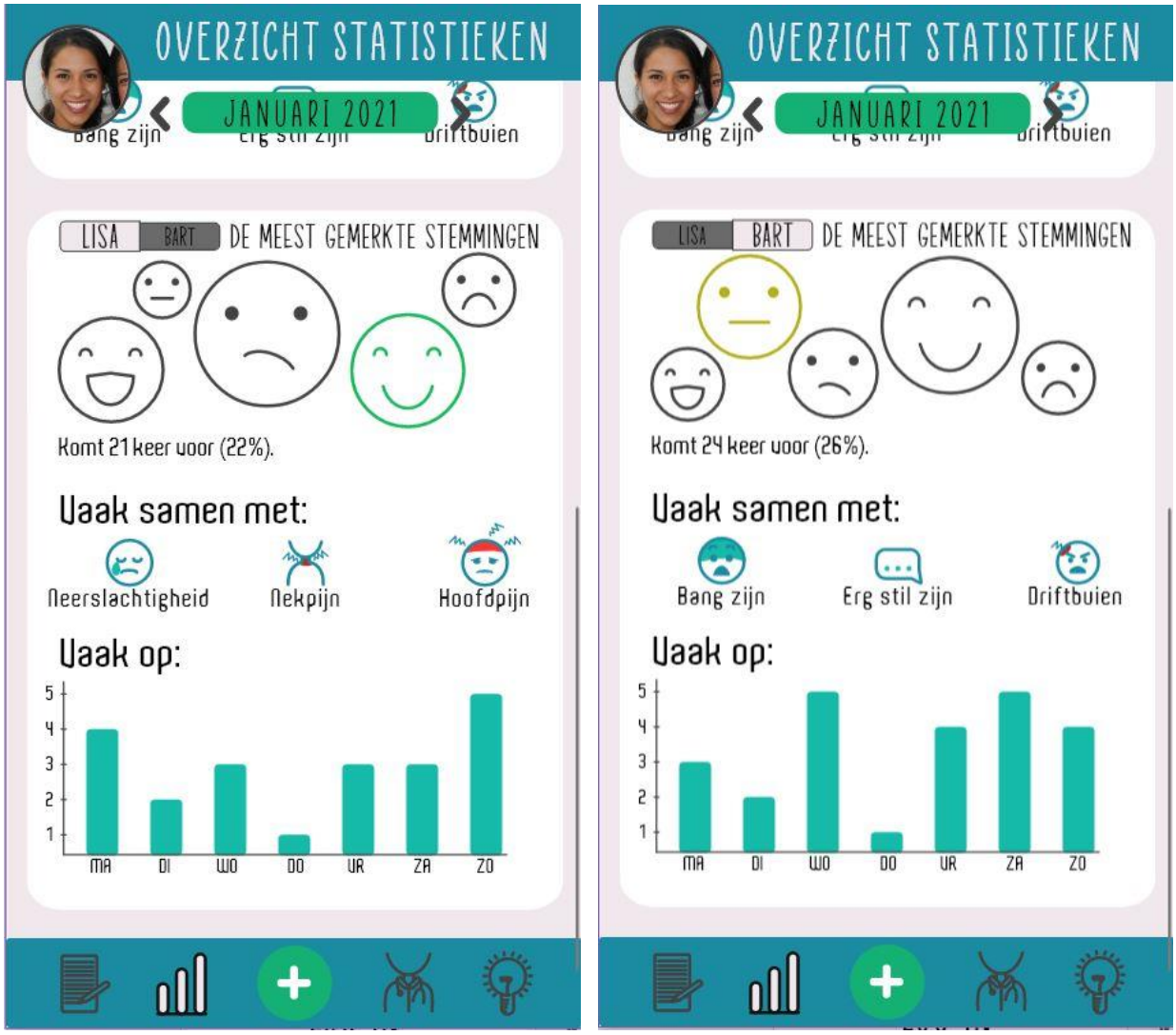


Figure K10. *Choose to see more information on your more prevalent emotions.*

K.4 New Entry

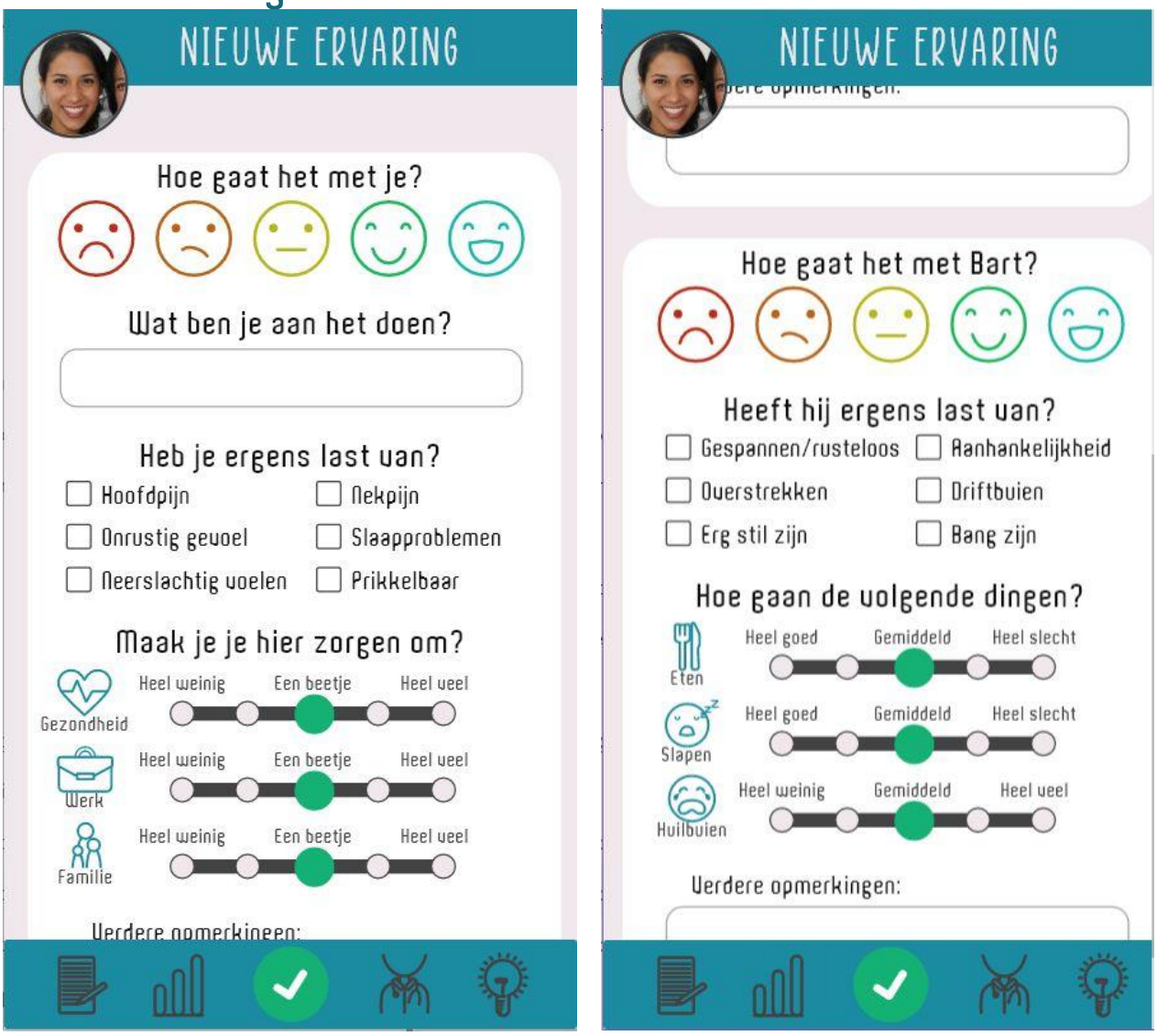


Figure K11. *Fill in how you and your child are doing.*

K.5 Contact A Professional

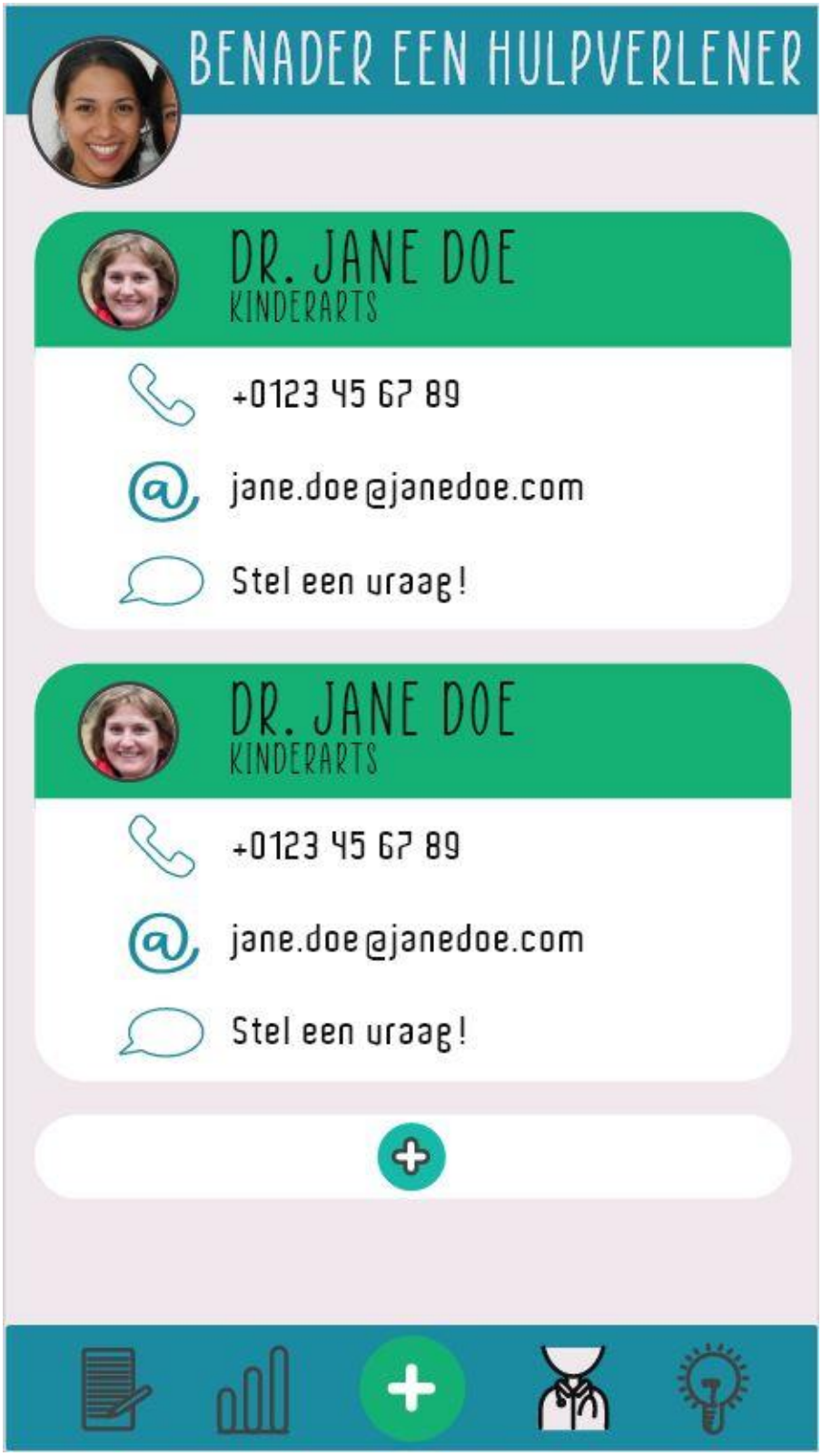


Figure K12. *Contact a professional by calling, emailing or chatting with them.*

K.6 Tips

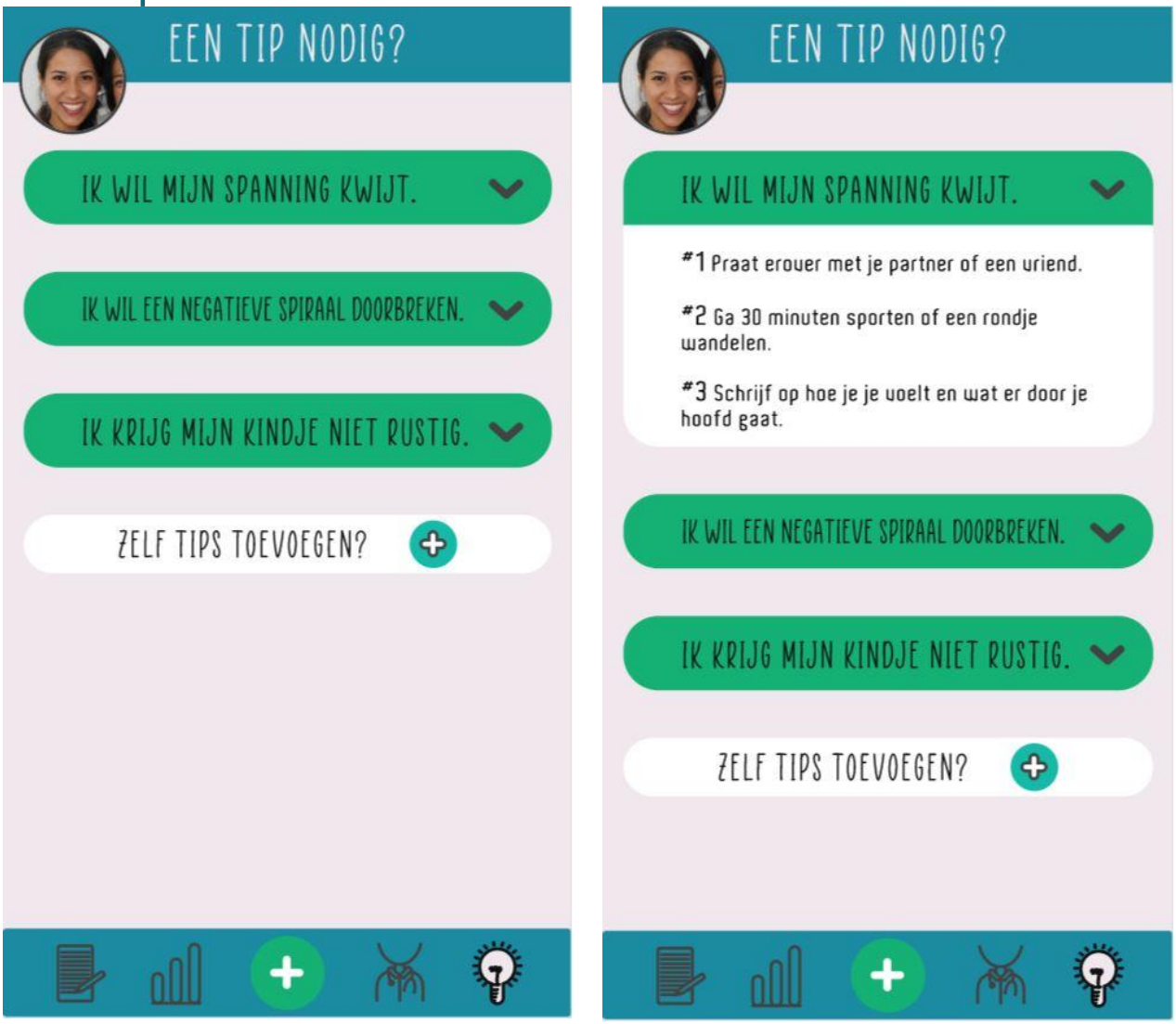


Figure K13. *Tap on a green bubble to expand it and get tips.*

K.7 Settings

Figure K14. *Tap on the profile icon to see all options.*

K.8 My Products

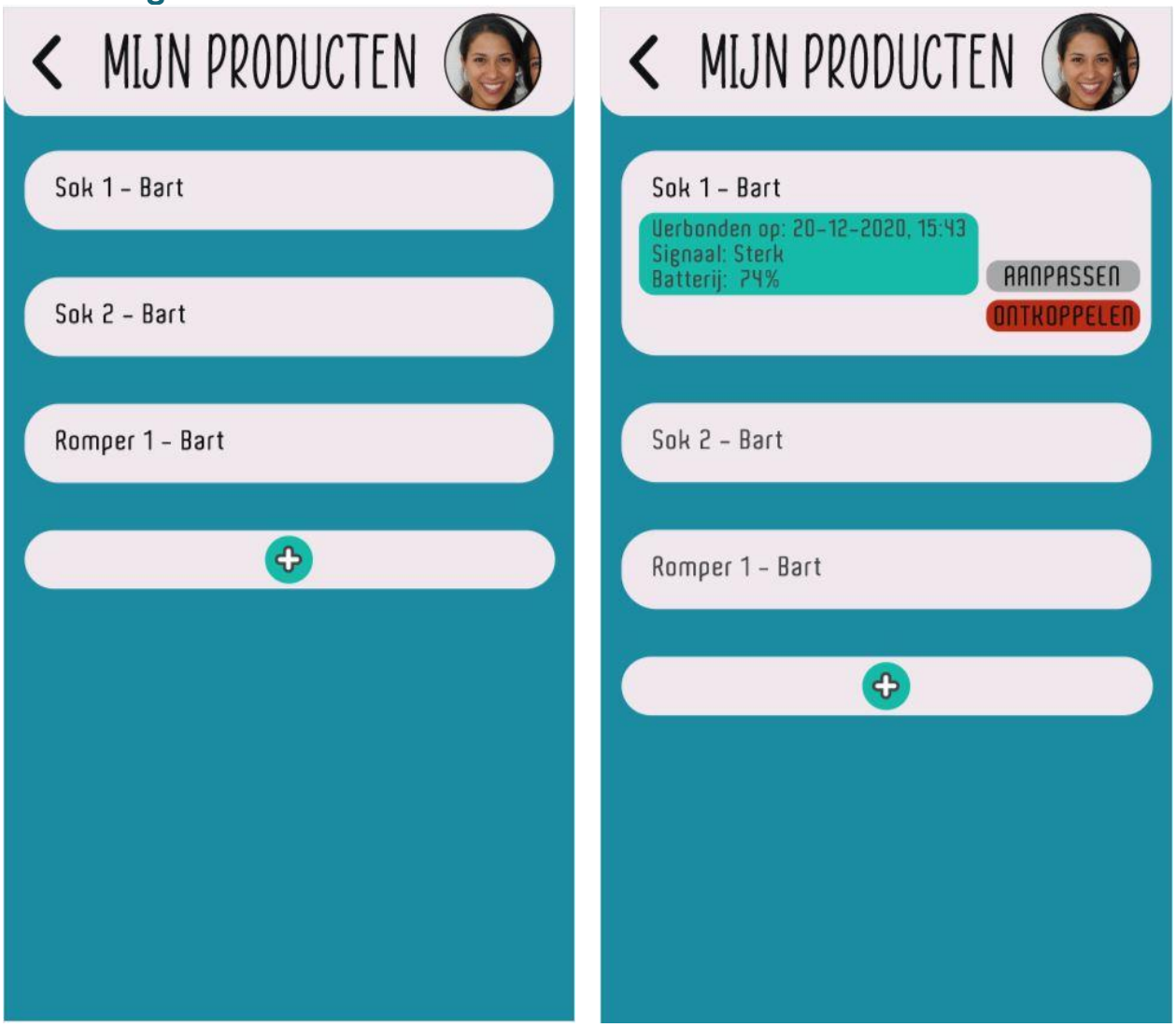


Figure K15. *View your connected products and their properties.*

Figure K16. *Tapping on "Ontkoppelen" will ask the user for a confirmation.*

Figure K16. *Tapping on "Ontkoppelen" will ask the user for a confirmation.*

Figure K17. *After pressing "Proceed" the device will disconnect.*

Figure N1. *Empatica E4 measurement data of test one. Blue is sitting, yellow is standing, and red is running.***Figure K17.** *After pressing "Proceed" the device will disconnect.*

K.9 Connect A New Product

Figure K18. *View all devices that can be connected.*

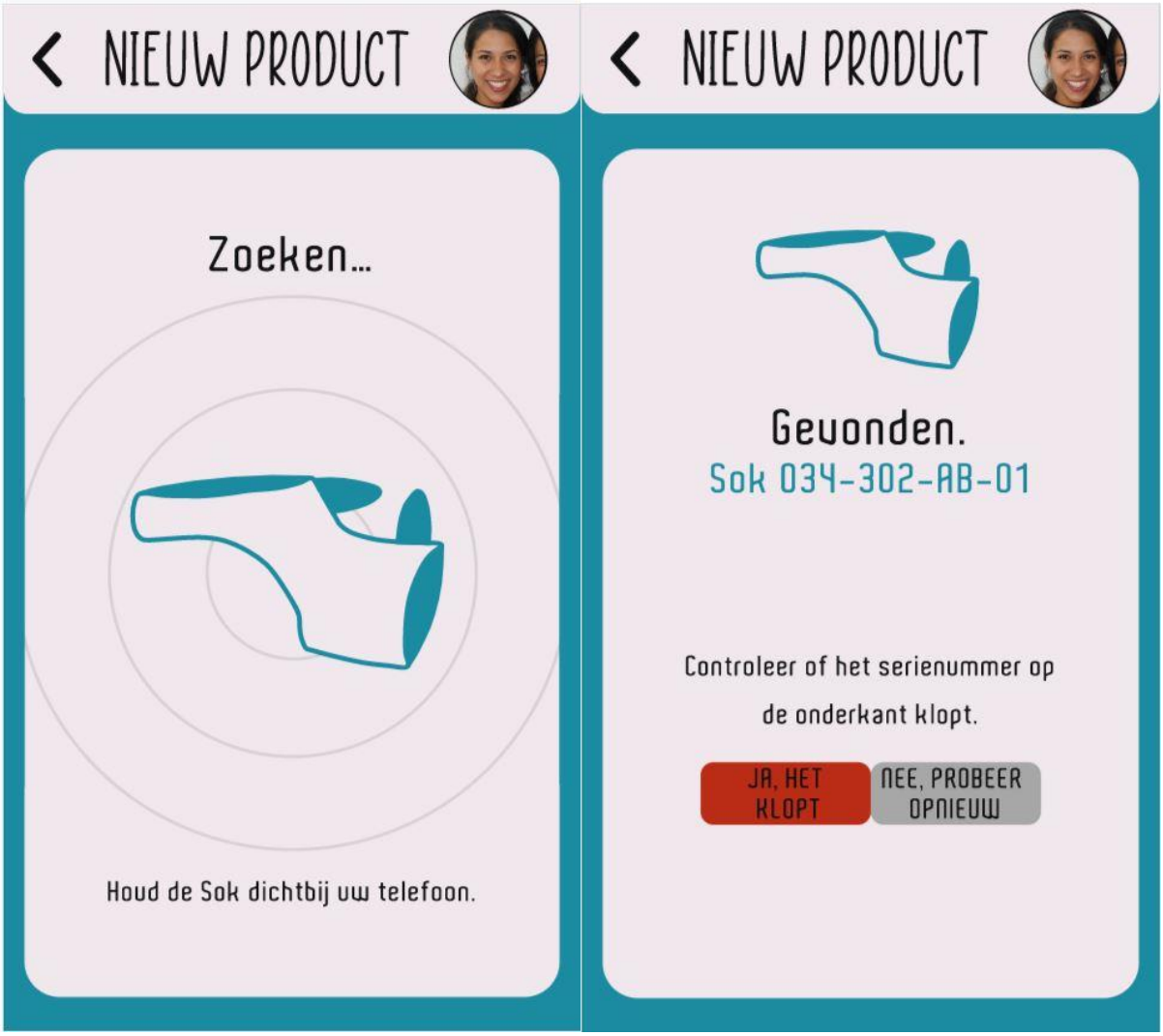


Figure K19. *Search for the sock and then confirm that it is the right one.*

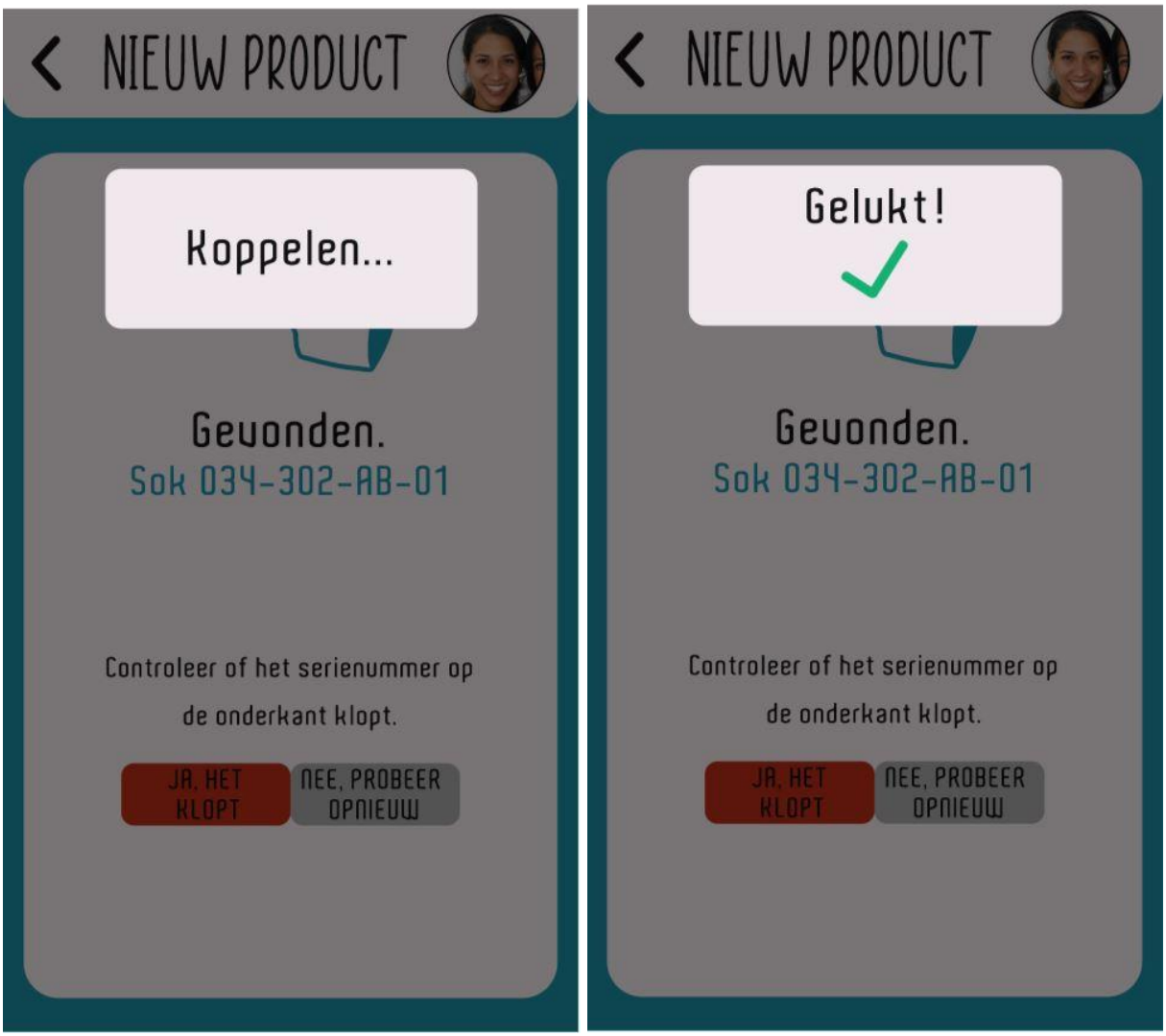


Figure K20. *Confirm that the device found is the once you want, and connect it.*

Appendix L – Test Procedure Physical Testing

1. Geef informatiebrochure + toestemmingsformulier. [5 min]

- Terwijl de deelnemer aan het lezen is, alle objecten desinfecteren.
- Sensoren met alcohol desinfecteren, electrodes met alcohol desinfecteren.

2. Lees de stappen van de het testproces voor: [1 min]

- Eerst zal ik de sensoren aan u bevestigen op de juiste plek. Geef het vooral aan als dingen te strak zitten, maar het moet goed tegen de huid. [3 min]
- Daarna zal ik u vragen een aantal taken uit te voeren. Dit zijn taken als “Zit rustig”, “Sta rustig”, “Ren op je plek”, “Beweeg je voet”. Ik geef aan wanneer u daar mee mag stoppen, maar het zal niet langer dan een paar minuten duren.
- Daarna zal ik nog een aantal vragen stellen.
- Daarna is er ruimte voor u om mij vragen te stellen.
- Heeft u nu nog vragen over deze testprocedure?

3. Voer de test uit: [20 min]

- Zet de (video)opname aan. [2 min]
    - Als het mag, de video op de voet op het moment dat er bewogen wordt (EMG).
- Zet de notitie ruimte klaar. [1 min]
- Zet de E4 aan en connect deze met de mobiel. Log in op de Empatica website zodat de metingen achteraf aan de testpersoon kunnen worden laten zien. [1 min]
- Bevestig de sensoren: [3 min]
    - Empatica E4 aan de rechter enkel, met het dikke/grote gedeelte aan de rechteronderkant. Zo strak mogelijk in voet-op-knie-positie.
    - Muscle sensor aan bovenkant/onderkant voet?
    - Checken of het zo goed zit, kunnen ze hun voet ronddraaien?
    - Maak een foto van de voet (if permission).
- Connect de muscle sensor met de laptop, upload de code en run de serial monitor. [1 min]
- Voer de taken uit: [10 min]
    - Zit in een rustige houding (voet op andere knie). [1 min]
    - Sta in een rustige houding (rechtop staan). [1 min]

    - Ren op je plek. [30s]
    - Sta in een rustige houding (rechtop staan). [1 min]
    - Ren op je plek. [30s]
    - Zit in een rustige houding (voet op andere knie). [1 min]
    - Beweeg je voet naar boven en houd vast. [10 sec]
    - Ontspan je voet. [10 sec]
    - Beweeg je voet naar beneden en houd vast. [10 sec]
    - Ontspan je voet. [10 sec]
    - Beweeg je voet naar boven en houd vast. [10 sec]
    - Ontspan je voet. [10 sec]
- Dat was het test gedeelte, bedankt!
- Haal de sensoren van de testpersoon af. [2 min]

4. Stel vragen. [10 min]

- Wat is je leeftijd?
- Wat studeer je?
- Hoe was het om dit te dragen? Algemene ervaring?
    - Hoe voelde het om zo sensoren te dragen?
    - Hoe comfortabel voelden de sensoren?
    - Wat vind je het belangrijkste als het gaat om een slimme sok/enkelband?
    - Wat zou er anders kunnen?
        - Locatie
        - Stof
        - Subtieler
        - Etc.
- [Laat metingen zien] Dit is wat er uit de gegevens is gekomen. Wat vind je er van?
- Het idee is dat deze drie gegevens samen kunnen bepalen of iemand gestresst is.
    - Wat zou jij zelf inschatten als je deze gegevens ziet?
    - Zou je direct willen weten of je gestresst zou kunnen zijn?
    - Waarom wel/niet?
- In het uiteindelijke idee zouden deze sensoren subtieler geïntegreerd zijn in een soort sok (laat foto zien) die een baby kan dragen om continue waardes te meten.
    - Wat vind je van dit idee?

    - Van een schaal van 1-10, zou je dit product gebruiken mocht je een kind hebben?
- Deze waardes worden naar een app gestuurd en opgeslagen. Bij die app kunnen de ouders ook hun eigen observaties en gevoelens noteren, zodat er niet alleen meetdata maar ook contextuele data wordt verzameld. Het idee is dan dat alle gegevens samen bij een professional (een arts of psycholoog o.i.d.) worden ingezien en besproken, zodat er duidelijk en betrouwbaar kan worden gezien of de baby lijdt aan stress.
    - Wat vind je van dit idee?
    - Van een schaal van 1-10, zou je dit product gebruiken mocht je een kind hebben?

5. Rond de test af: [1 min]

- De meetdata en je antwoorden op deze vragen gebruik ik om in de afronding van mijn bacheloropdracht te kunnen bespreken:
    - Of de locatie van de sensoren (op de enkel/voet) gewenst is.
    - Of de locatie van de sensoren (op de enkel/voet) stabiel genoeg is om alle data te verzamelen.
    - Of er aanbevelingen of wensen zijn die meegenomen kunnen worden in toekomstig onderzoek.
- Dit zal compleet anoniem verwerkt worden in een algemene samenvatting. Indien anders aangegeven op het toestemmingsformulier is je naam of andere persoonlijke informatie waarmee je geïdentificeerd zou kunnen worden dus niet terug te vinden in mijn verslag of presentatie.
- Heb jij nog vragen?

6. Geef ze een bedankje voor de moeite.

Appendix M – Summary Physical Testing

Demographics

Five participants, all between the 19 and 22 years old. They are all students doing a technical study within the range of mathematics, computer science, and electrical engineering.

These participants were recruited face-to-face as they are housemates.

After a short explanation of the procedure, the sensors were attached to the participants' ankle and the test would begin.

Tasks

The participants were asked to perform specific tasks to see how that would influence the measurement data.

- Sit in a relaxed position, putting your foot (with sensors) on your other knee. (1 minute)
- Stand in a relaxed position without moving. (1 minute)
- Run in your spot. (30 seconds)
- Stand in a relaxed position without moving. (1 minute)
- Run in your spot. (30 seconds)
- Sit in a relaxed position, putting your foot (with sensors) on your other knee. (1 minute)
- Move the toes of your foot (with sensors) up and keep that position. (10 seconds)
- Relax your foot. (10 seconds)
- Move the toes of your foot (with sensors) down and keep that position. (10 seconds)
- Relax your foot. (10 seconds)
- Move the toes of your foot (with sensors) up and keep that position. (10 seconds)
- Wiggle your foot to the sides. (10 seconds)

The graphs of these movements can be found in Appendix N - Measurement Results Physical Testing.

Wearing The Sensors

General experience:

- Overall, participants said that it was fine to wear the sensors, although the band was quite tight. It was seen as a non-invasive tool.

- One participant felt quite nervous during the experiment because of the information about a possible shock. They stated that, had this not been explained to them, they would feel a lot more comfortable.
- A participant joked that he felt a bit like a criminal wearing this anklet.
- The location of the sensors on the ankle, however, was mostly experienced as a good place since it would be a more difficult place for the baby to access (and therefore it would be harder to take off). However, it would be difficult to know whether the baby was having pain or experiencing other negative sensations because of the sock.

Wearing sensors:

- A participant indicated that it did not really feel nice to wear sensors like this, it made them think of experimental things in hospitals. However, they said that this was only because of the prototype; if the sensors were integrated into the fabric it would be completely fine.
    - Another participant compared the use of this product to scans in a hospital, the latter of which required much more effort and posed small risks as well.

"It is cool that you can know what your body is doing. Especially if you don't have to do any scans for this, so you don't have to go to the hospital for this and it poses no health risks through radiation." - Participant 3

- The sensors were tight, but not in a negative way. However, some participants indicated that their ankles did feel a bit limited in movement and might require some extra effort to move well.
    - One participant did experience some discomfort from the Empatica E4 (a bit prickly), especially when moving the foot up and down at the end.
- One participant stated that they did not notice the sensors at all, which they thought was nice.
- A participant indicated that it might worry people if they wear the sock and they feel their foot get warmer, even though it might be completely unrelated to the sock.
- One participant argued that it feels quite normal to wear sensors since he has other devices that do similar things as well.

"I am also using my phone and there are also smartwatches that do similar things, so it is not really weird to wear sensors." - Participant 5

Most important element:

- Make sure it is safe (both on a technical side, as well as a mental/physical side (no side effects)).
- Ensure that the data that is acquired and processed is done well. It is the most impactful part of the product.
- The baby should not notice that they are wearing a special kind of sock.
- People should not have to be extra careful when wearing the sock. It should be sturdy and tight enough so parents do not have to worry about it.
- The sock should not be too expensive.
- The data collected should be accurate, and if not, then it should be known how inaccurate it can be to avoid worries.

Suggestions:

- The Socklet should be stretchy, as the thickness of the ankle can change based on the movement of the wearer (and also differs per person).
- The real product should be wireless.
- One participant doubted whether an anklet/sock would be the best option regarding reliability, but they also wouldn't know what else to go for. Looking at user-friendliness, it was seen as the best option.
    - A participant suggested using a romper suit instead since babies wear that as well.
- They expressed their wish for a complete sock rather than a half sock since it would be annoying to have to wear two socks at once.

"A complete sock would also make it feel more normal." - Participant 4

- It was suggested to look at other ways to tighten a sock (for example tight spots similar to sport socks), rather than Velcro as that might be a bit painful. There should be a balance between tightness for reliability and comfort.

Measurement Data

The measurement data from the Empatica E4 was shown to the participants and explained a bit.

Measurement data:

- Participants liked seeing the data but indicated that without the explanation it would be quite useless to see - as it is hard to interpret. It needs to be processed so it is understandable to people.

"Cool! It is epic that I can see my data this way." - Participant 2

"It is alright, but for most things, you do not know what it means. With an explanation is a bit better, but still vague." - Participant 4

- It was visible that not all data was measured correctly, which the participants noticed but also thought it was a shame.
- There was no consensus on the dilemma of giving direct feedback to parents or not; some stated it would be nice to see so they could check their (or their baby's) health. Some thought it might make parents scared or stressed, causing them to Google symptoms.
    - It was also indicated that it would highly depend on the reliability of the data; if it can show that a baby is stressed then it might be of use - although parents can often be the cause of this stress.

"No, don't give direct feedback. Parents are stress tornadoes, maximally." - Participant 5

Grade: Would you use it if it were referred to you?

Participant 1: depends on the state of the product, but a seven. If it is effective it can add a lot to the life of a baby, but in an experimental state, it could also give false positives.

Participant 2: a ten, no doubt. It is very interesting and cool, I am also curious about what the results would be in a general way - not necessarily focused on stress. It is also interesting to see whether the possible impact of parents' stress on their child would be noticed this way.

Participant 3: an eight, as long as it works. The combination with the app makes the concept even more appealing.

Participant 4: a ten, if it is referred I would follow it.

Participant 5: looks nice and if it is referred then a ten, but I would prefer only looking at the child when filling in data.

Questions/Remarks

- A participant raised their concern about involving parents in the stress-monitoring process as they might be able to play down the severity of their child's stress if they know they are the cause.

"The cause of stress (parents) would then influence the conclusion or information of the stress-monitoring process." - Participant 1

Appendix N – Measurement Results Physical Testing

N.1 Participant One

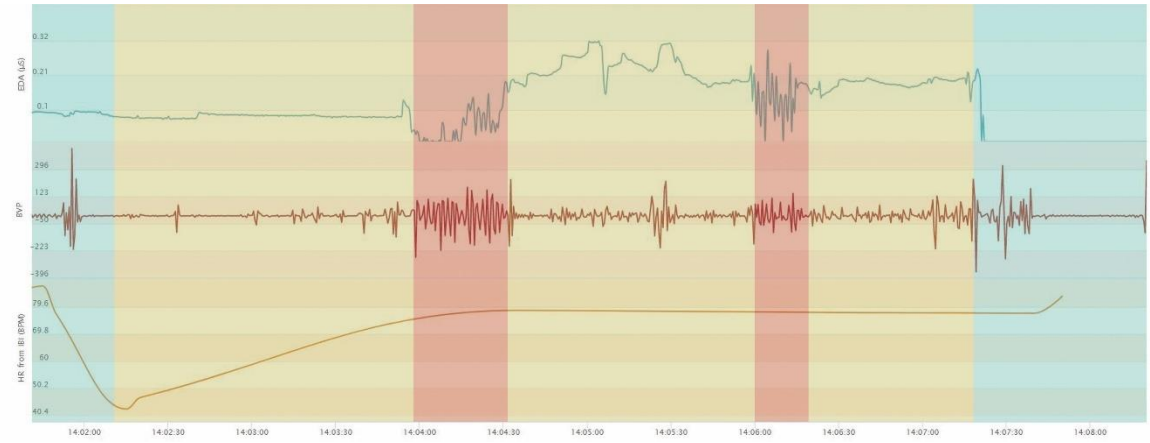


Figure N1. *Empatica E4 measurement data of test one. Blue is sitting, yellow is standing, and red is running.*

Figure N2. *MyoWare Muscle Sensor measurement data of test one. Blue is sitting, yellow is standing, and red is running.***Figure N1.** *Empatica E4 measurement data of test one. Blue is sitting, yellow is standing, and red is running.*

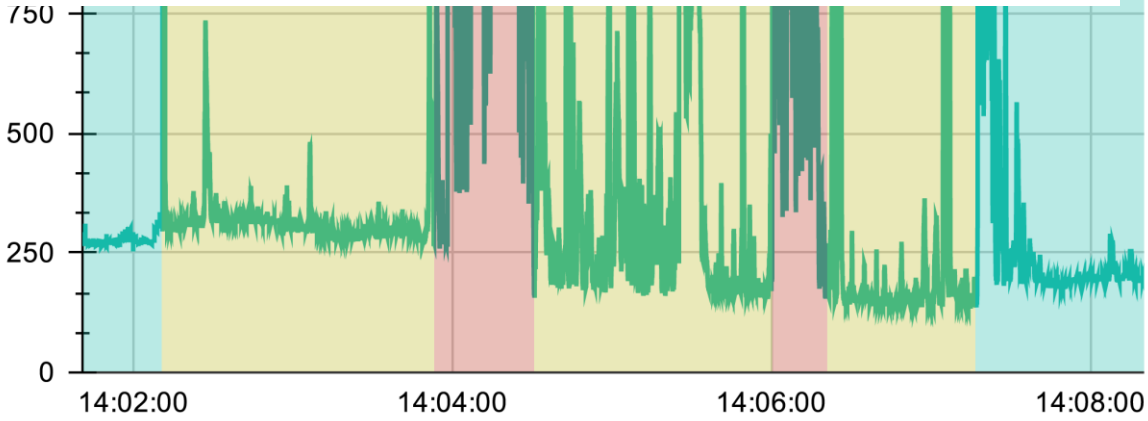


Figure N2. *MyoWare Muscle Sensor measurement data of test one. Blue is sitting, yellow is standing, and red is running.*

Figure N2. *MyoWare Muscle Sensor measurement data of test one. Blue is sitting, yellow is standing, and red is running.*

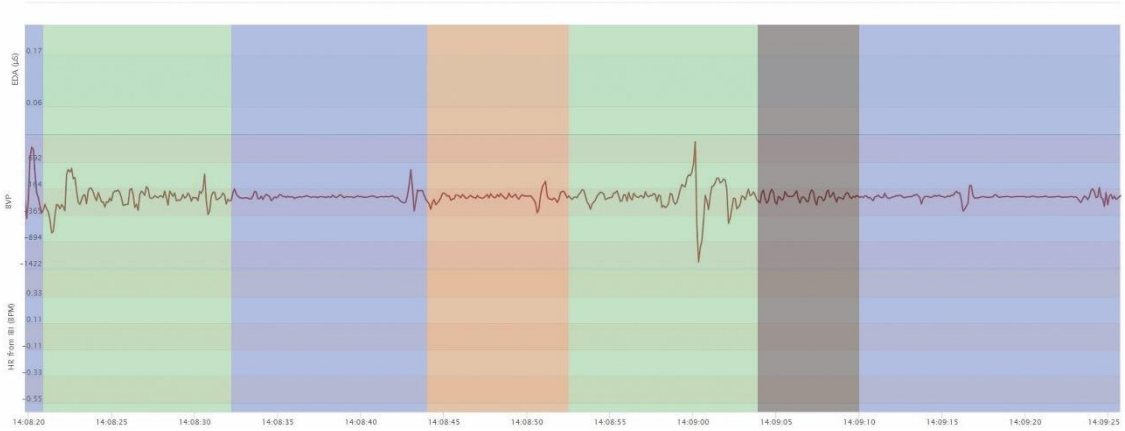


Figure N3. *Empatica E4 measurement data of test one. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N3. *Empatica E4 measurement data of test one. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

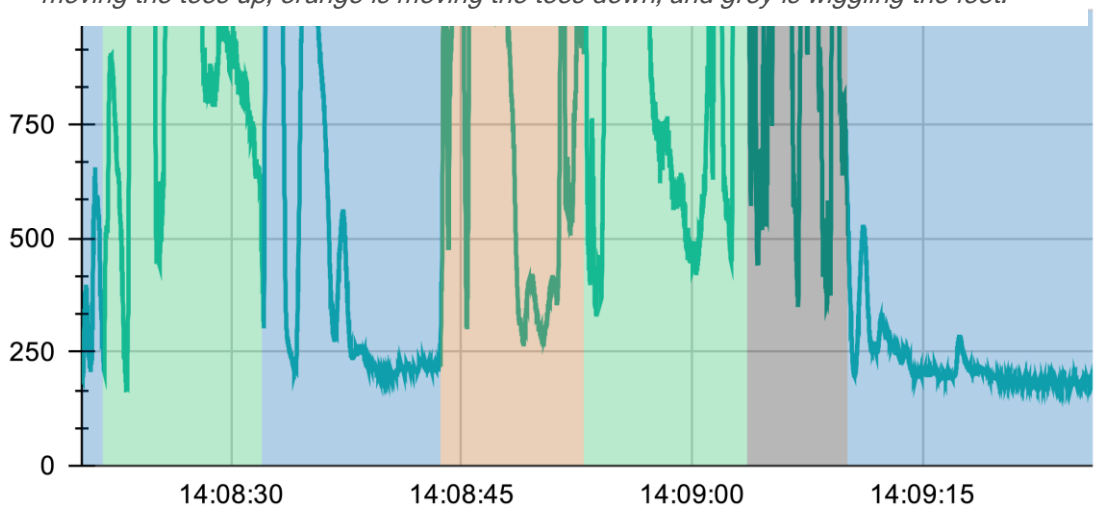


Figure N4. *MyoWare Muscle Sensor measurement data of test one. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N4. *MyoWare Muscle Sensor measurement data of test one. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

N.2 Participant Two

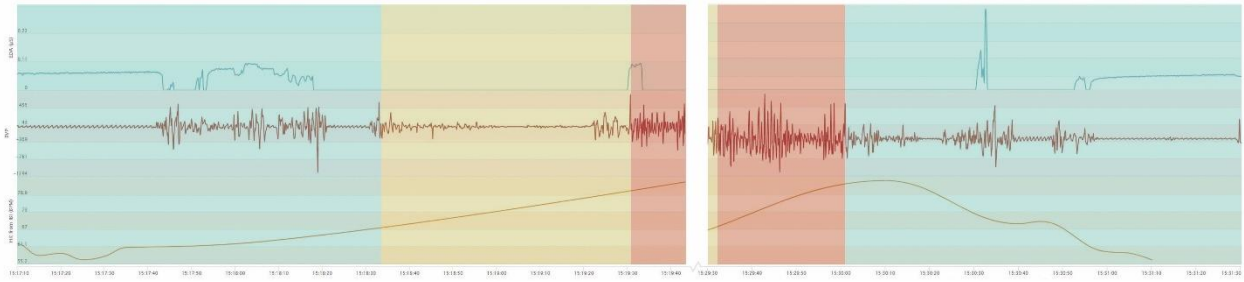


Figure N5. *Empatica E4 measurement data of test two. Blue is sitting, yellow is standing, and red is running.*

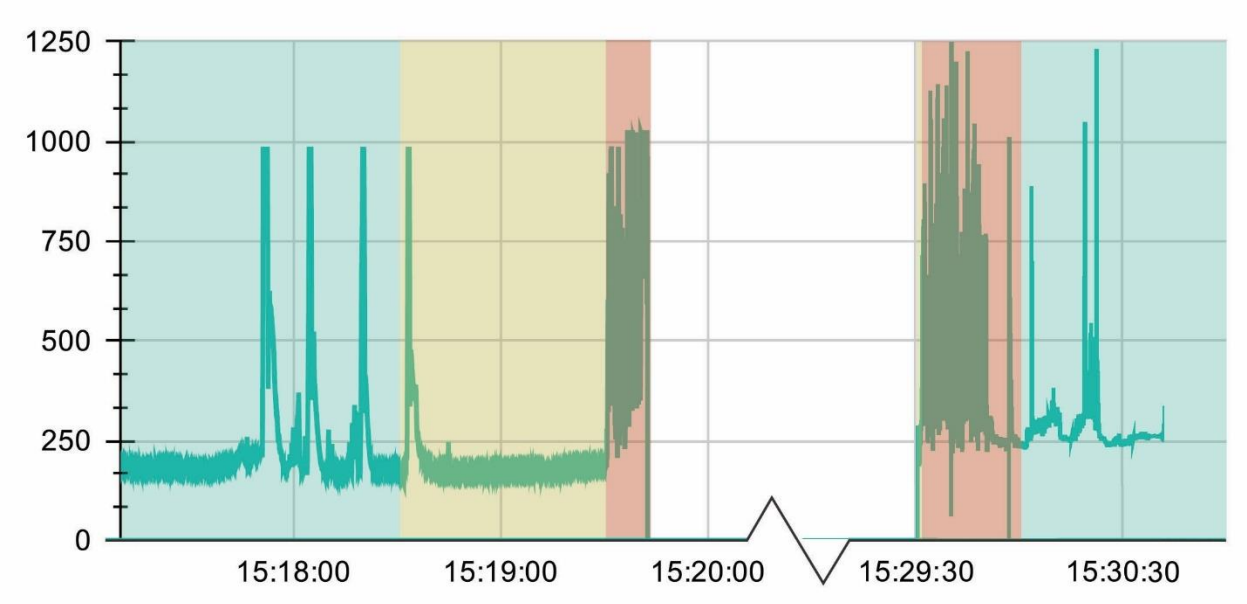


Figure N6. *MyoWare Muscle Sensor measurement data of test two. Blue is sitting, yellow is standing, and red is running.*

Figure N6. *MyoWare Muscle Sensor measurement data of test two. Blue is sitting, yellow is standing, and red is running.*

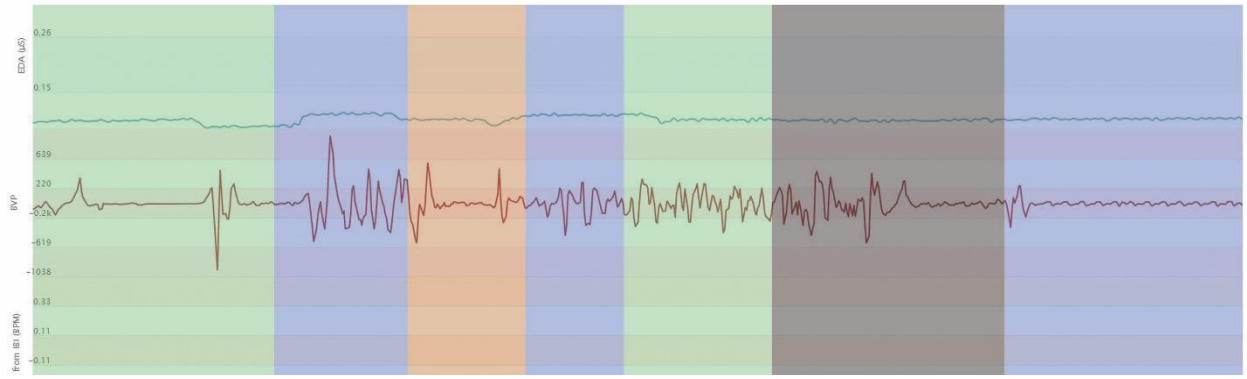


Figure N7. *Empatica E4 measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N7. *Empatica E4 measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

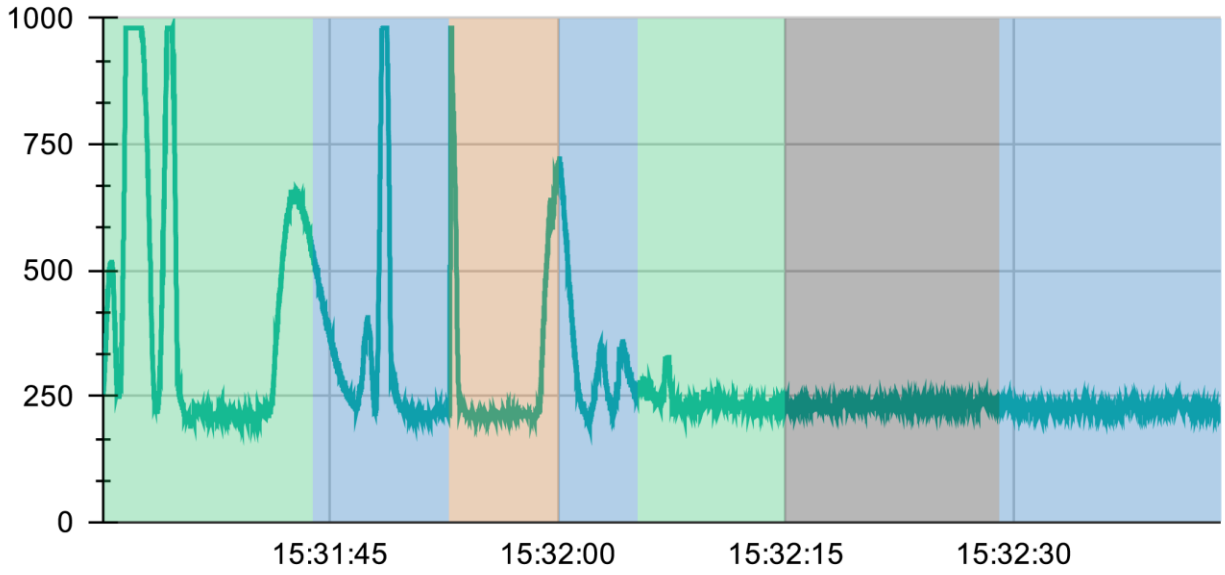


Figure N8. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N8. *MyoWare Muscle Sensor measurement data of test two. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

N.3 Participant Three

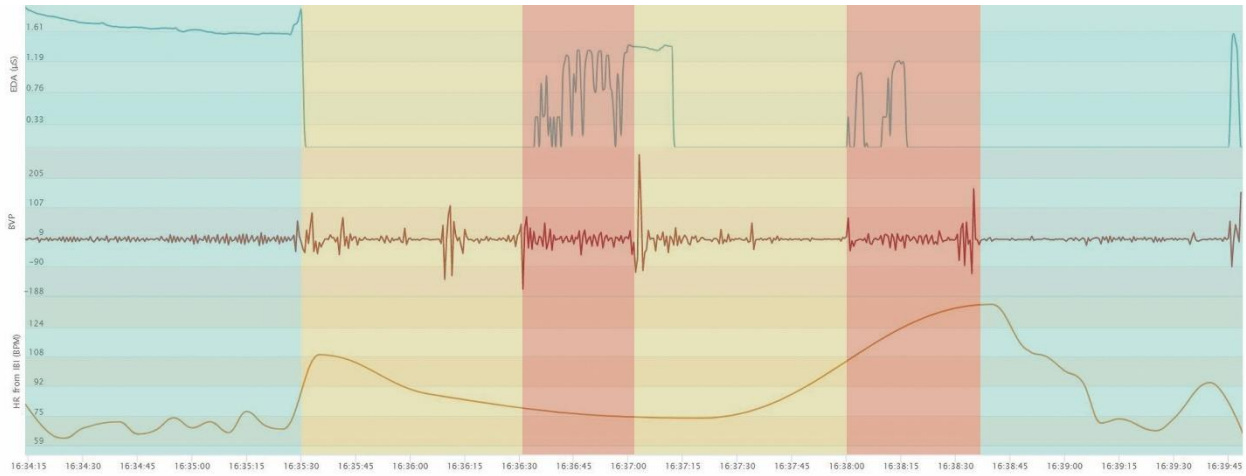


Figure N9. *Empatica E4 measurement data of test three. Blue is sitting, yellow is standing, and red is running.*

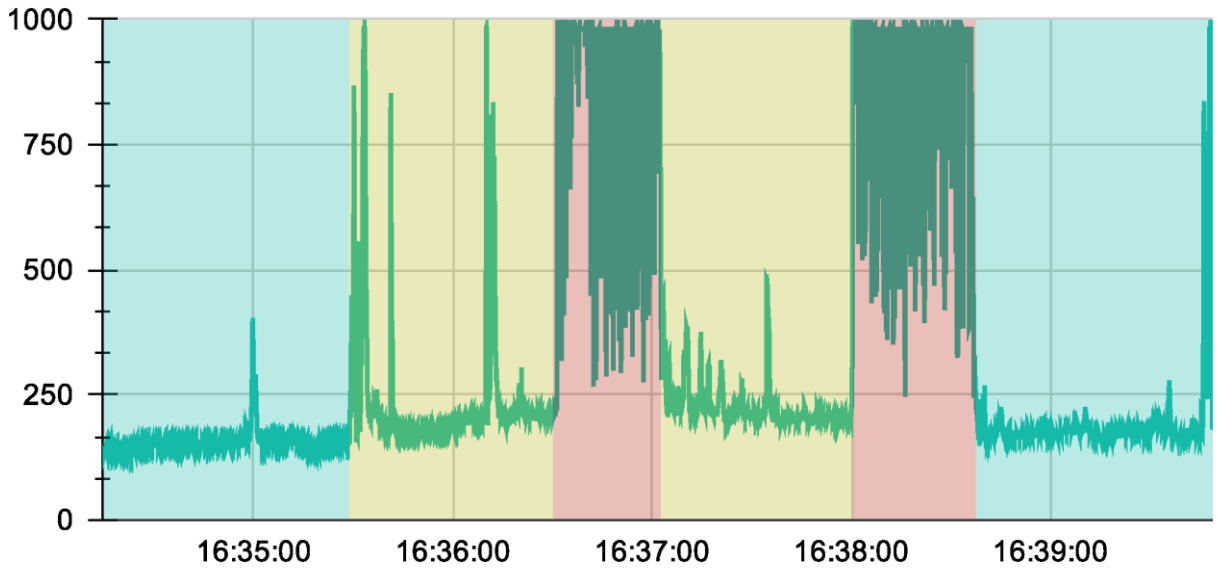


Figure N10. *MyoWare Muscle Sensor measurement data of test three. Blue is sitting, yellow is standing, and red is running.*

Figure N10. *MyoWare Muscle Sensor measurement data of test three. Blue is sitting, yellow is standing, and red is running.*

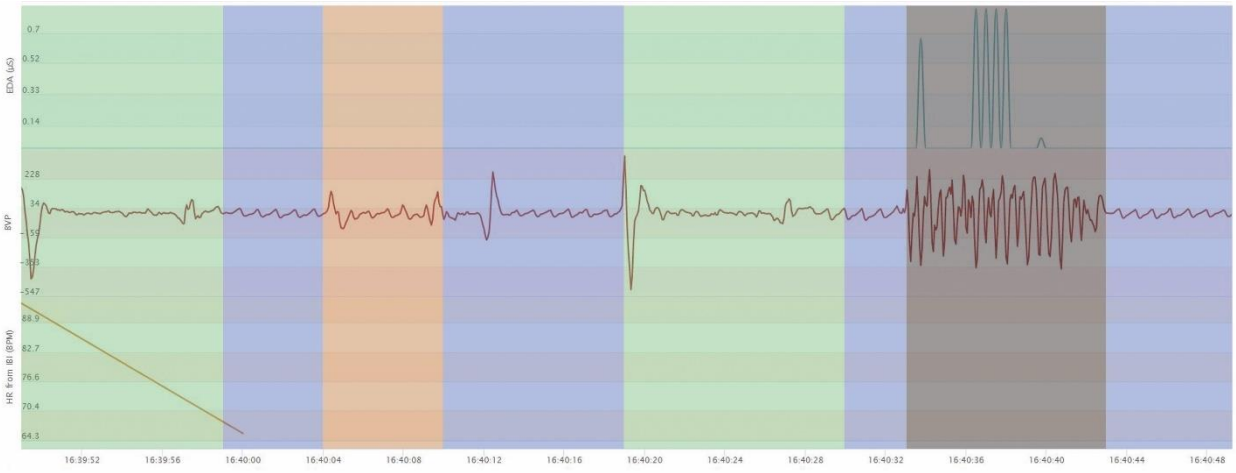


Figure N11. *Empatica E4 measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

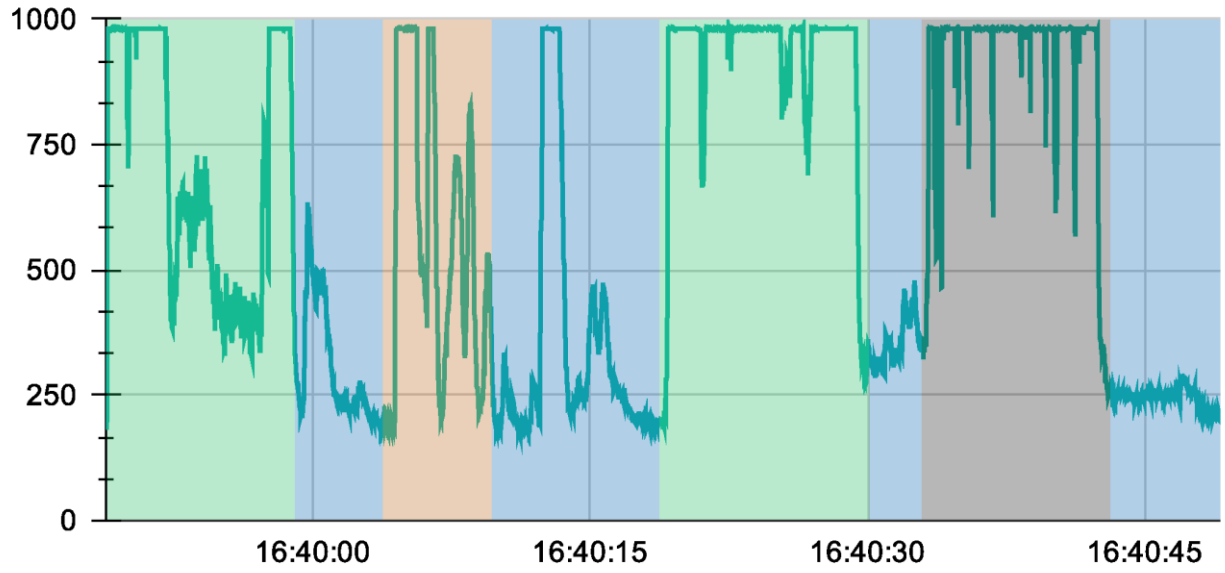


Figure N12. *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N12. *MyoWare Muscle Sensor measurement data of test three. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

N.4 Participant Four

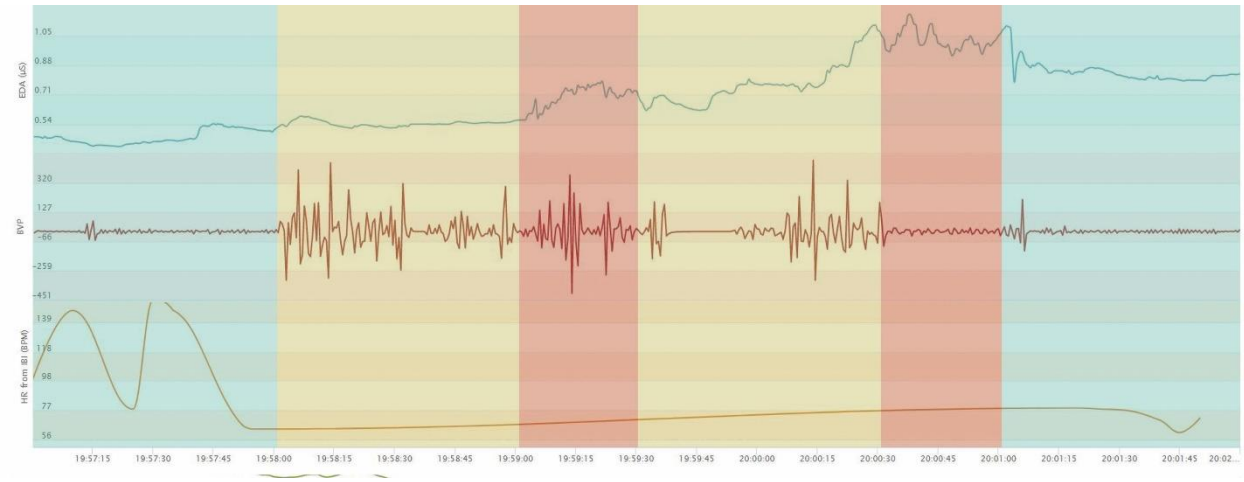


Figure N13. *Empatica E4 measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

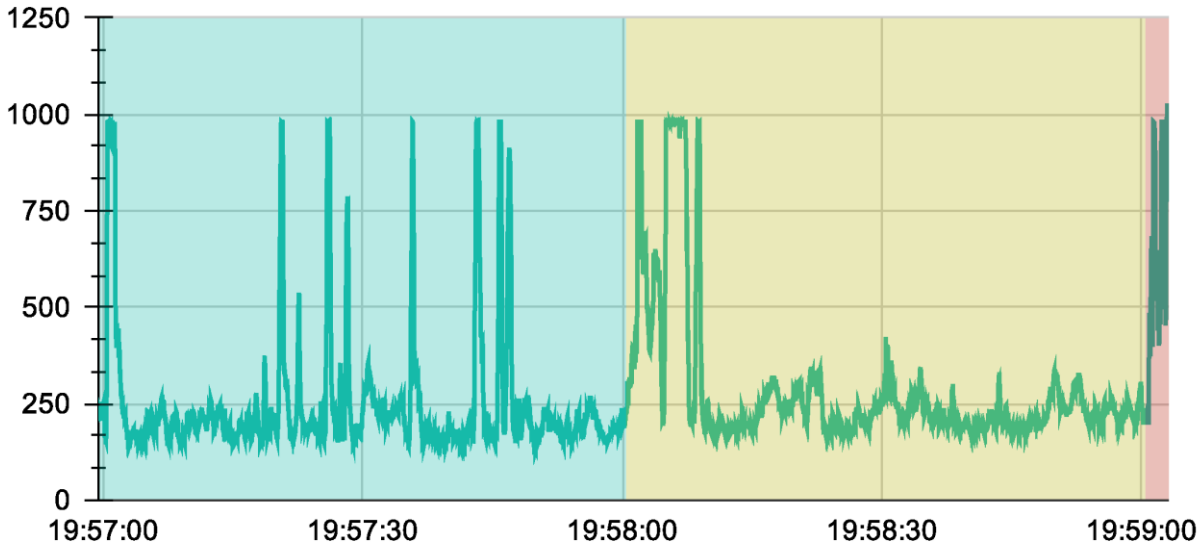


Figure N14. *MyoWare Muscle Sensor measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

Figure N14. *MyoWare Muscle Sensor measurement data of test four. Blue is sitting, yellow is standing, and red is running.*

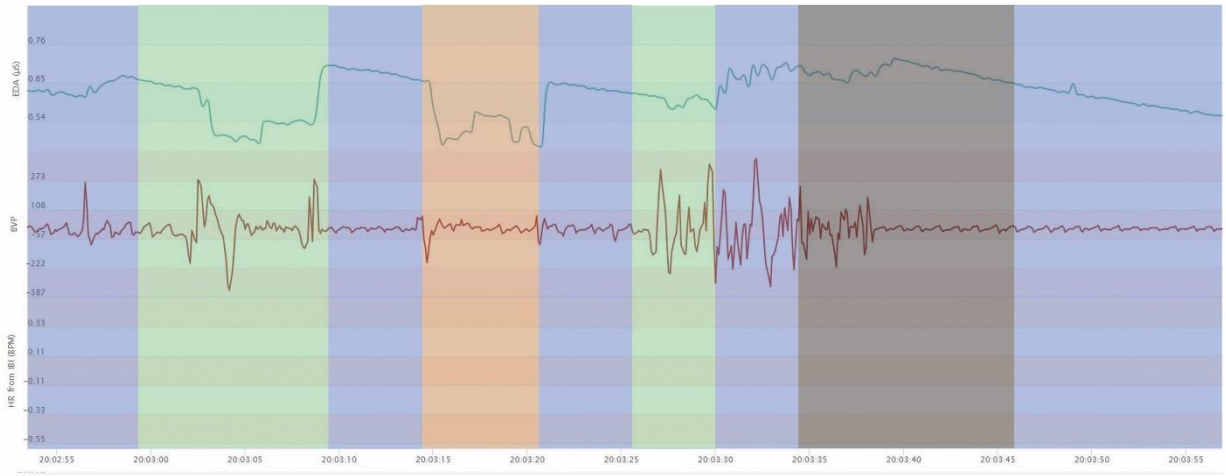


Figure N15. *MyoWare Muscle Sensor measurement data of test four. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N15. *MyoWare Muscle Sensor measurement data of test four. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

N.5 Participant Five

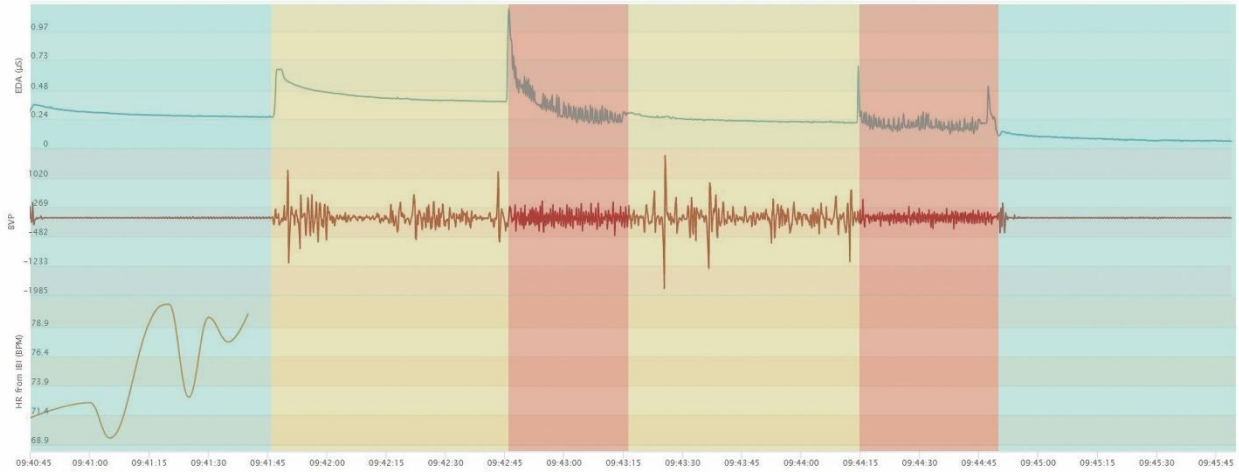


Figure N16. *Empatica E4 measurement data of test five. Blue is sitting, yellow is standing, and red is running.*

Figure N16. *Empatica E4 measurement data of test five. Blue is sitting, yellow is standing, and red is running.*

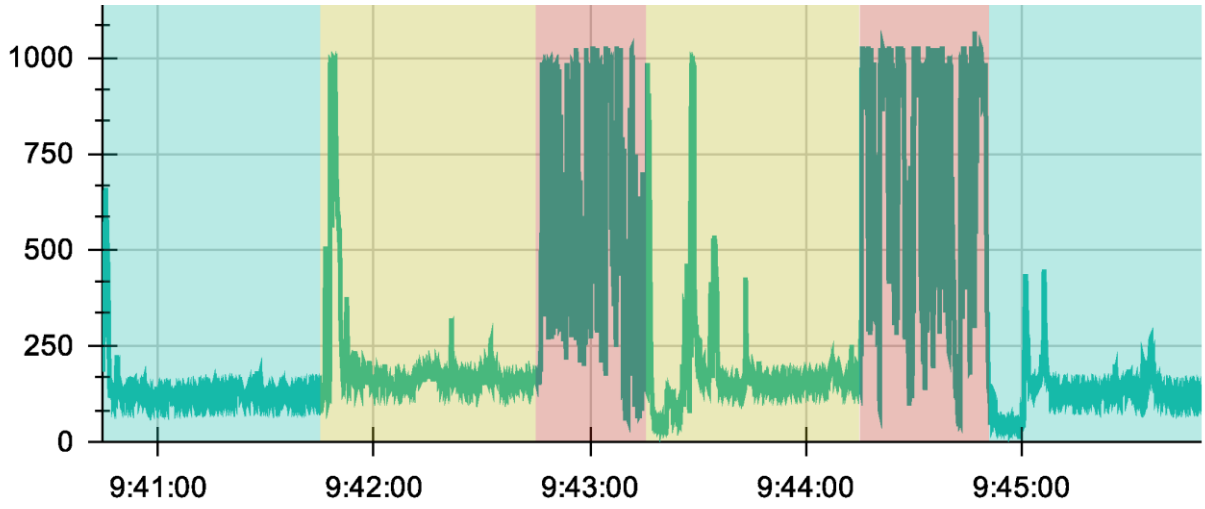


Figure N17. *MyoWare Muscle Sensor measurement data of test five. Blue is sitting, yellow is standing, and red is running.*

Figure N17. *MyoWare Muscle Sensor measurement data of test five. Blue is sitting, yellow is standing, and red is running.*

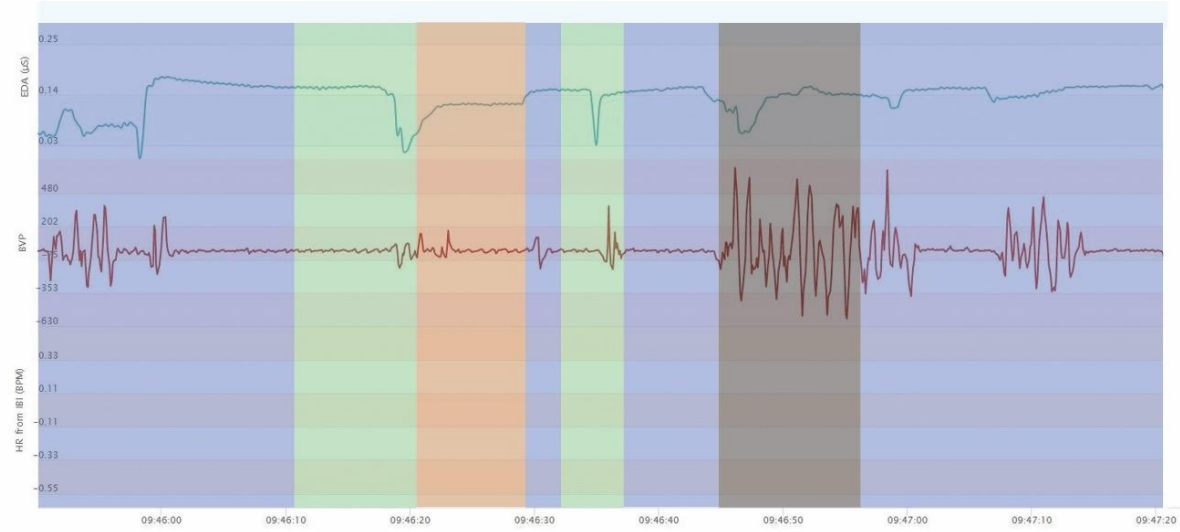


Figure N18. *Empatica E4 measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N18. *Empatica E4 measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

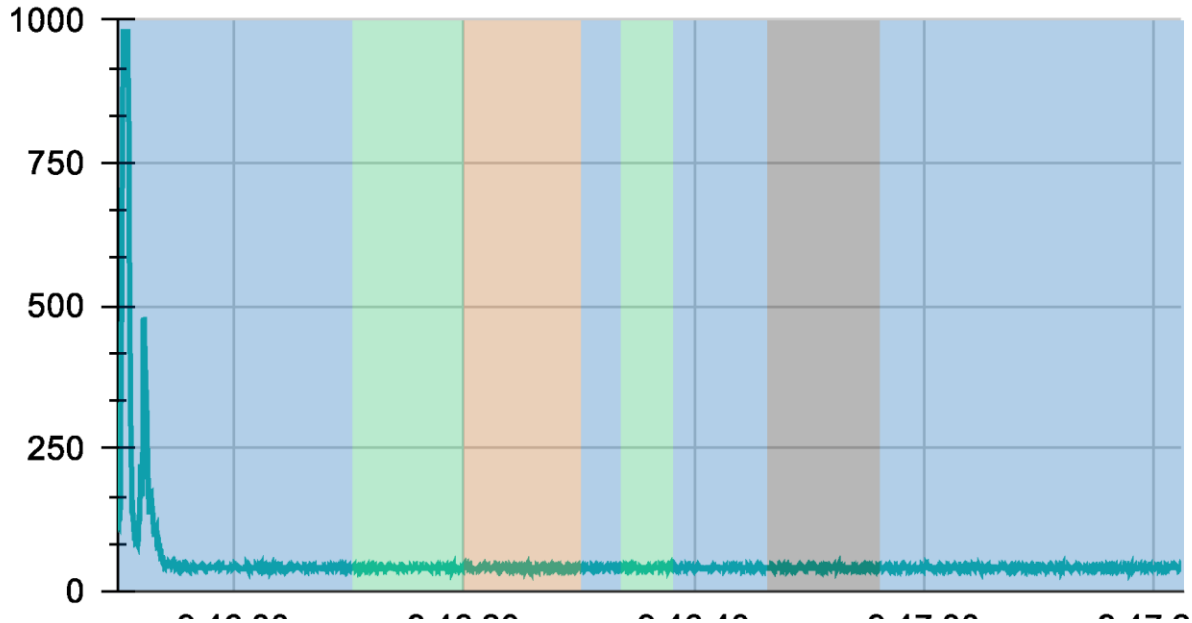


Figure N19. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Figure N19. *MyoWare Muscle Sensor measurement data of test five. Blue is relaxing the foot, green is moving the toes up, orange is moving the toes down, and grey is wiggling the foot.*

Appendix O – Test Procedure Digital Testing

1. Geef informatiebrochure + toestemmingsformulier. [5 min]

- Terwijl de deelnemer aan het lezen is, de Adobe XD applicatie klaarzetten.

2. Lees de stappen van de het testproces voor: [3 min]

- Ik zal u een link sturen voor een app. Deze kunt u op uw computer openen, en het zou fijn zijn als u uw scherm zou kunnen delen. Op die manier kan ik meekijken waar u bent, en als u ergens vragen over hebt kan ik daar makkelijker antwoord op geven.
- De app is bedoeld om naast de sok gebruikt te kunnen worden. De sensoren in de sok meten de harstlag, spierspanning, en huidgeleiding van de baby en kunnen op deze manier stress herkennen. In de app willen we zorgen dat ouders hun beeld maar ook hun gevoelens kunnen opschrijven zodat ook contextuele gegevens meegenomen worden.
- De app is niet helemaal werkend; het is niet mogelijk om dingen te typen en niet alle functionaliteiten zullen werken. Als u dus ergens op klikt en er gebeurt niks, dan ligt dat niet aan u. De focus ligt vandaag op een beperkt aantal pagina's, dus daar kunt u doorheen navigeren.
- Tijdens deze test vraag ik u om uw gedachten hardop uit te spreken. Wees niet bang met wat u zegt. Het draait om uw mening en ervaring, dus die wil ik graag zo goed mogelijk meekrijgen.
- Ik zal u eerst een tijdje door de app heen laten klikken zodat u er een beetje aan gewend bent. Daarna zal ik een aantal situaties schetsen en taken voorlezen om uit te voeren. Hierbij gaat het niet om snelheid, maar om natuurlijk gebruik. Doe het dus vooral op uw eigen tempo. :)
- Nadat die taken zijn uitgevoerd heb ik nog een aantal vragen voor u.
- Daarna is er ruimte voor u om mij vragen te stellen.
- Heeft u nu nog vragen over deze testprocedure?

3. Voer de test uit: [13 min]

- Begin met opnemen. [1 min]
- Zet de notitie ruimte klaar. [1 min]
- Stuur de link. [1 min]
- Je hebt net de app gedownload. Zorg dat je kunt inloggen op de app.

    - De deelnemer kan nu rustig door de app heen gaan. [3 min]
- Lees taken voor: [10 min]
    - Buiten de app heeft u ook de sok die uw kindje draagt. Verbind de sok met de app (doe alsof u de sok bij zich heeft).
    - Vandaag is al weer een tijdje bezig, en u heeft net een notificatie gekregen. Vul in hoe u en uw kindje zich voelen.
    - U bent benieuwd naar wat u twee weken terug hebt ingevuld.
    - U wilt ook zien hoe het eerder daarvoor was.
    - Afgelopen maand was best hectisch. Hoe zag dat er uit volgens deze app?
    - U wilt meer informatie over uw meest voorkomende emotie.
    - Een vraag komt op over uw observaties. Kunt u die ergens kwijt?
    - U loopt vast en weet niet zo goed wat u moet doen. Kan de app u ergens mee helpen?

4. Stel vragen. [10-15 min]

- Sommige informatie heb ik al vanuit de survey. Ik ben alleen nog wel benieuwd naar uw professionele achtergrond. Dan kan ik beter inschatten hoeveel kennis u over dit onderwerp heeft.
- Wat is uw algemene indruk van de app?
    - Design
    - Duidelijkheid
    - Logische opbouw
    - Compleet qua gebruikswensen
    - Voldoende? Niet te afleidend?
- Nu gaan we even door de specifieke onderdelen van de app heen:
    - De hoofdpagina: hoe vond u dat?
        - Design
        - Duidelijk
        - Goede samenvatting
        - Optie met uitklappen begrijpelijk of liever alles zonder te tikken?
        - Maand vs. dag of week overzicht?
    - Het invoeren van uw gevoel: hoe vond u dat?
        - Onderdelen logisch

        - Duidelijke termen
        - Kind en ouder samen
        - Hoeveelheid moeite
        - Missende dingen
        - Zou u dit liever op uw eigen initiatief willen doen wanneer u dat nodig acht, of zou u liever regelmatige notificaties krijgen? Of op een andere manier herinnerd worden aan de observaties noteren.
    - Het bekijken van de statistieken: hoe vond u dat?
        - Informatie logisch
        - Overzichtelijk
        - Nuttig
        - Toegevoegde waarde
        - Statistieken missen
    - De mogelijkheid om een expert te benaderen: hoe vond u dat?
        - Toegevoegde waarde?
    - De mogelijkheid om tips te bekijken: hoe vond u dat?
- Het idee is dat samen deze informatie van de app, samen met de informatie van de sok, ervoor zorgt dat in overleg met een professional (een arts of psycholoog o.i.d.) er beter en sneller kan worden gesteld of een baby lijdt aan stress.
    - Wat vindt u van dit idee?
    - Van een schaal van 1-10, zou u dit product gebruiken dit nodig zijn?
- Heeft u nog vragen of opmerkingen over dit product?

5. Rond de test af: [1 min]

- Uw opmerkingen en aanbevelingen zullen worden gebruikt om verbeterpunten voor dit idee te formuleren en zullen in een samengevatte en geanonimiseerde vorm terugkomen in mijn eindverslag. Uiteindelijk zal er in toekomstig onderzoek op verder gebouwd worden.
- Heeft u nog vragen?

6. Geef ze een bedankje voor de moeite.

Appendix P – Summary Digital Testing

Demographics

Six participants, all between the ages of 32-36. They are all mothers, with an average of 2 children. Most mothers have a background that is closely related to this subject, as (child)psychologists, in an educational role, or as a coordinator for family support. Some parents did notice how their children were stressed, pointing out the factors that might contribute to this (instability in life, sleeping problems, clinginess). Others explained why their children were not stressed at all, focusing on their child's smooth development and lack of sleeping or eating problems but also on their own problem-management. All mothers were aware of how they might influence their child and how they could notice stress signals in their child.

The participants were recruited through the social media accounts of the clients (ZGT and IMH Nederland) as well as within the personal network.

After an explanation about the app and its goal, the participants were given a few minutes to familiarize themselves with the app. As this app will be used for a longer period, it is important to see how the constant use of the app would be experienced - not necessarily the first few minutes of the app. Through the Thinking Aloud method, valuable information was gathered in this section about the intuitiveness and general design of the app.

Tasks

All participants were asked to perform certain tasks, to see what they would intuitively look for in such situations that would be common as a regular user of the app. They have been written descriptively to make it more realistic to empathize.

1. In addition to the app, you also have a smart sock that your baby will be wearing. Connect the sock with the app.

Nearly all participants first overlooked the clickable profile picture and therefore have a hard time finding this page. After a hint, they do find it rather easily. But before that, they look at the New Entry button and the Statistics page, then try out the remaining pages.

"I would want to find such a thing on the first screen you see, the main page." - Wies

2. Today has been quite a day and you just received a notification from the app. Fill in how you and your child are doing.

Participants know where to go to and have no trouble filling in the entries.

3. You want to get more information on the data you filled in two weeks ago.

Some participants visited the main page for this, whereas some participants went straight to the statistics page.

4. You are also curious about your entries the month before that.

Some participants visited the main page for this, whereas some participants went straight to the statistics page.

5. The previous month has been quite a chaotic month. What did it look like, according to the app?

Participants immediately go to the statistics page for this. They know what to find on this page.

6. You want to get more information about your most prevalent emotion.

Not all participants immediately see that they can click on the emotions to get more information, but they do go to the "most prevalent emotions" graph.

When they see the information, it is described as clear.

7. A question arises based on one of your registrations. What would you do?

Participants first go to the Tips page and then to the Contact page, pointing at the "Ask a question" option.

Some participants directly go to the Contact page.

*"First go to the tips, but if that is not sufficient because *dramatic voice* YOU TRIED EVERYTHING ALREADY, then it is useful to call the professional." - Wies*

8. You get stuck in your doing and don't know what to. What would you do?

Some participants go to the Tips page directly. Others stated they would navigate to the "Help" or "About the app" option on the Profile Options page if it were a technical problem.

One participant described that if it was a problem related to the notifications, she would visit that page via the Profile Options, and then she would go to the Tips page first before contacting a professional.

General

After the tasks, some questions were asked about the general design of the app - focusing on several aspects (design, user-friendliness, the number of features).

Design:

- The app is seen as aesthetically pleasing and clear. Participants liked the colour palette, font, and the logo and described the app as friendly and calm.
- The button and icon designs were experienced as logical, showing the user what they can expect.
- It was also appreciated that there was some personal touch in the app (e.g. profile picture, addressing the mother and the child).
- A participant pointed out some elements that were consistent throughout the design (e.g. only questions in the New Entry page, five emotions to choose from and five elements in the scale.

"The app works well intuitively, the structure and design are clear. Visually it is very strong, containing good and clear icons." - Participant 2

- Participants liked that there was not a lot of text, making it easy to quickly gain insights from.
- One participant indicated that the phrasing of the scale labels could be more nuanced; using "difficult" instead of "bad".

"Personally, I don't like using the word "bad" as it is super negative. Maybe "difficult" is better." - Participant 6

Intuitive use

- Generally, the app was experienced as insightful and clear.
- Finding the "Add Product" option was not straightforward if it is not known that one can click on the profile photo. Once this is known, it becomes very easy.
- Not all participants noticed that pages were scrollable.

- A participant indicated that the scales on the “New Entry” and “Statistics” page were not intuitive in the sense that the positive labels were on the left and the negative ones on the right. She suggested switching these.
- This was also seen at other participants who intuitively hovered their mouse to the right side when wanting to fill in positive things.

Features

- The number of features is seen as balanced, not being distracting but still being very useful. There are still some suggestions for additional features, however.
- It is seen as a good thing that this app would collect a lot of information, as it would also result in a lot of insights for the parents and the professional.
    - A participant indicated that she was also curious about the measurement data and would like to see the graphs about these next to the observational data. However, she then brought up that not all parents might be able to handle the data it would show (getting scared) and that they might also influence the “natural” results of this process by trying out new parenting strategies based on these graphs.
        - It might be useful when the products are available for more general use, and not integrated with a monitoring procedure through a health care professional.
- A participant noticed that a big focus was put on more negative things (e.g. stress symptoms and stressors). She suggested that involving more positive things that are important when bonding with children would be more motivating and might also result in more realistic input. She assumed that parents might end up in a negative downward spiral because of the focus on negativity, so they might exaggerate the severity of a stressor or the role that a stress symptom played in their life.

“From the perspective of positive psychology, that is something you should always do: finish the day on a positive note.” - Participant 5

- Suggestions for more positive things were: affection, being outside, eye contact with the child, hugging the child, laughing, being relaxed
- Focusing more on the relationship between the child and the parent would also help with that.

Suggested features

- Including a forum, so you can discuss matters with “peers”. Another suggestion would be to be able to add people to your app - like creating a network. The participant does realize that it might also result in useless information being spread around.
- A participant suggested implementing a zoom-in function on the Statistics page so you would be able to look more specifically at the graphs/values and the relationship between some days or weeks. Lastly, an export function for all collected data would be nice to have - especially when discussing the results with the professional.
- A participant noticed that you would not be able to fill in everything at every moment of the day; e.g. when the child would be at daycare they would not know how they feel. Therefore, it would be nice to be able to leave everything empty so you do not ruin the data.
- It might also be an idea to include information about the development of young children, so it can be informative and reassuring if there are worries. Suggested sources were “Ouders van Nu” and “Oei Ik Groei”.

“When my kid cried a lot, we were confused and didn’t know what to do. But then we read that it might be because of teething which reassured us.” - Participant 4

- Regarding the measurement data, a participant suggested to include such data as separate graphs in the statistics page. Discussing the idea of giving parents direct feedback or not because it might cause extra stress, she brought up that instead, the professional getting the measurement data could contact the parents if there were consistent bad readings. That way, parents would not get stressed by data that might be hard to interpret, but would still get informed about their baby’s measurement data.
- A participant suggested customizing the stress symptoms for the child so that they can be adapted to the age of the baby (in months). For example, in the beginning, vomiting and the diapers are a big part of a baby’s life but later on other factors are (being scared).
    - It might also be good to be more specific about the factors. When does the baby sleep well? Is that if they sleep throughout the whole night? Or when they fall asleep quickly? Or when they are relaxed?
    - However, that is also something that could be discussed with the professional.

- A suggestion was made to be able to close the Profile Options page again by touching on the profile picture.
- It was also brought up that parents, as proud as they are of their children, might like to share small accomplishments (e.g their child liking a new type of food, or eating their first new meal) either through text or photo. A participant said that it would be a nice addition to the app, also increasing the positive elements it contained.

Grade: Would you use it if it were referred to you?

Participant 1: an eight, I would use it but I am uncertain whether I would use it consistently every day. However, it does really help that this is a useful app.

Participant 2: a ten, you have already taken the step to ask help - which is often a big step. Then it is only logical that you first analyse the situation.

Participant 3: an eight or nine, no ten because I wouldn't be too thrilled about filling in the app multiple times a day. The sock wouldn't be that much effort, but the app would require quite some attention from the parents.

Participant 4: a ten, the sock is kid-friendly and the app works well. If it is in the best interest of the child, I would do it.

Participant 5: ten. However, I would register more things such as drinking times and diaper quality. It might be good to look at the MyMedela app, so these can be combined into one.

Participant 6: difficult. I wouldn't use the app myself because I trust my gut and know that I have a lot of experience in this field (>15 years). However, I would use it in my work, to refer other parents to it. Especially when it's their first child.

Pages

Then, the pages were discussed using similar aspects. Most of this information was also retrieved during the "exploratory" part of the test so this part was used to provide additional room to give comments or elaborate on previously commented parts.

Overview

- This page was experienced as clear and aesthetically pleasing, with clear icons showing the moods of the parent and the child in an easy way.

- The name “Overview Page” was not always understood well, a participant thought that it belonged to the statistics page.
- The diary-like style of this page was also appreciated, and the fake data that was put there was easily empathized with.

*“Oh, yeah *laughs* the 9th of January is very relatable!” - Participant 1*

- The popup entry was also seen as attractive and insightful; it did not include too much text - instead using icons to make it easy to see what information is in there. Its value compared to the Statistics page was also acknowledged - as it provided more in-depth information on one specific day whereas the Statistics page looked at periods of time. However, it was not always immediately found.
- One participant initially missed the link between the “Activities” and “What are you doing” option on the New Entry page, but after a while she noticed it. She explained that she would probably immediately see the link if she had filled in the data herself.
    - Another participant suggested to only show the smileys and the Activities, and include remarks in the popup.
- A participant liked how the entries were categorized based on months.

Statistics

- Participants immediately started to analyse the information the graphs provided, especially the first one; noticing a possible relationship between the parent’s and the infant’s mood. It was, however, indicated that more graphs like these (combining a parent’s and child’s mood in one graph) would not be needed. The reason for this would be the personal and sensitive nature of such information, which might make parents insecure and might therefore be better suitable during the appointment with the professional.
- Participants related to several factors and stress symptoms shown in the overviews.
- The number of graphs and insights one could get from this page was seen as proportionate; and good that it would be discussed with a professional as well.
- Several participants also indicated that the “Influence of factors” label was not clear, as she did not know whether the factors were influenced by something or influencing something.
- At the graphs which also show “Often seen with:” icons, it is clear that these symptoms are related to specific moods or stress factors. However, as a participant indicated, it does

not say anything about the relationship between these symptoms. Some textual explanation would be nice. Furthermore, it seems illogical to put the negative stress symptoms in relation to positive emotions felt (in the "Most prevalent emotion"-graph). Positive elements are expected there, or less negative ones. Maybe even keep it empty.

- A participant suggested implementing a zoom-in function so you would be able to look more specifically at the graphs/values and the relationship between some days or weeks.
- It was appreciated that both your and your child's statistics are visible.
- The "Most apparent moods" was also seen as very clear. It was suggested to only show the percentage when describing how often the emotion is noted, and to think of the way the "Often on…" graph would convey its information. It is nice but could also feel heavier than it is.

"Looking at the days of the week is nice because then you can see which days went well and which didn't. You could then relate this to your own activities." - Participant 6

"The days of the week can be very insightful, but also be tough to see for parents. They might think that every Monday or Tuesday is bad, while it might not be that bad." - Participant 5

- A participant suggested moving the "Most prevalent emotion"-graph up so the emotion-related graphs would be grouped. Additionally, she stated that in "Influence of factors", maybe both the graph and the averages would be a bit too much. These could be combined into one graph.
- The green and blue lines in the second graph were quite similar so hard to tell apart. Also considering people with colour blindness it is good to look at that, participants suggested. Another participant noticed that the red line in this graph did not fit within the general style of the app and might attract too much attention because of its signal colour. Maybe purple or yellow would be better.
- It was noted that especially the second graph might be harder to interpret by parents with less affinity with such data visualisations and data. This was also pointed out about the date labels of the first graph, she suggested to change 01-01 to 01 Jan etcetera. There were some other changes mentioned:
    - Using "gevoel" (feeling) instead of "stemming" (mood)
    - Using "gezin" (household) instead of "family" (familie)

"Often such research is focused on people who are a bit stronger verbally, but often the people that have trouble expressing themselves are the people that need a problem to be solved." - Participant 5

New Entry

- All participants indicated that they would prefer receiving notifications on specific moments of the day over deciding for themselves when they would use the app. They stated that it would result in more reliable and stable data input, and also explained that a parent would not think of using the app themselves in a stressful situation - although that might be the moment you would like to get an entry. Participants did say that the notifications should not be too much in the foreground, as it is not always the right moment. Additionally, some participants wondered whether they would just close the notification and forget about it.

*[talking about a loud notification on the app] "I had just put my child to bed, and I just succeeded, *sarcastically* thanks guys." - Wies*

- Some participants noted that it would be nice to be able to add more specific stress symptoms themselves, so it would be more fitting to the parents using the app. It was suggested to have a longer list of symptoms in a page at the Profile Options, of which a selection can be made that would be visible on the "New Entry" page.
- The diary-like functionality of this overview was well-appreciated; participants all stated that it is good to keep track of feelings. Also looking at factors like work, health, and family is seen as good. A participant also suggested providing the option to add such factors manually as well.
- A participant suggested to flip the labels of the scales so the negative labels would be on the left, and the positive ones would be on the right, as that would be more intuitive.
- One participant indicated that the plus icon for the New Entry might not be the most logical; as it can also be interpreted as adding new things for the other respective pages (e.g. graphs).
- It was also suggested to rephrase the "What are you doing" question to "What have you been doing in the past X hours?" so it would be more clear that the question is looking at a description of activities. Examples of activities might also help with that.

"It is actually quite particular that the plus leads you to fill in a new experience, and that the note block leads you to the overview. It seems that clicking the plus button while on the Statistics page would lead you to a different page." – Participant 2

- A participant also suggested providing some way of confirmation towards the parents after they have filled in the New Entry page; e.g. by showing a pop-up message with "Your experience has been saved.".
    - Another participant indicated that she was not completely sure that the checkmark meant "Save entry" because she did not get a confirmation. However, this might also be so because the overview page is not updated.
- A participant pointed out that the user was able to quickly fill in a New Entry but also be more elaborate if they wished.
- It was also suggested that it might be nice to be able to choose a factor to focus on for a while, only filling in that specific one (if, for example, a parent notices sleeping problems, they can look at the sleeping factor).
- A participant doubted whether it would be best to ask the same questions all the time, especially if these questions focus on worries. They could better be asked once a day.
- Another stressor that could be added to the parent's side was the parent's night's sleep, and housework (huishouden). For the baby's side, suggestions were made about adding pooping and peeing.
- A participant suggested to change the phrasing of the questions here as well, so they would be more neutral/optimistic.

Contact

- This page was appreciated and seen as a good and unique addition to the app. It would make it more accessible when needing to contact a professional, like for example the children's healthcare centre or a PJG (Passie voor Jeugd en Gezin [106]) employee.
- A participant pointed out that, to make it more accessible, it might be better to rephrase the page title to something along the lines of "Do you have a question, then contact someone".

"The children's healthcare centre also says "You can always contact me", but it is still quite a high bar to approach. Integrated into this app would be a much easier way." - Participant 1

- Participants indicated that this page was of great value.
- There was some variety in the wishes regarding who to put here as a contact person. Some participants indicated that they would like to have all kinds of professionals in there so it is all in one spot, whereas others would only like to have the professional in here that was also involved in this stress-monitoring process.

"You won't use the app for a long time, so it won't be the first place to look when you need help. Or maybe it will, but then only for the professional that is doing this procedure with you." - Wies

- One participant noted that the chat option could be titled differently; using "Start a conversation" instead of "Ask a question" to make it more clear that it is about chatting.
- A participant stated that it was highly dependent on the kind of professional that would be connected whether it would be a useful page or not. She indicated that a known professional would be fine, but an internet doctor would be more difficult and less approachable.
    - Another participant pointed out how a paediatrician would focus on more physical well-being and practical things, whereas a specialist in bonding would be focusing more on the relationship between the parent and child.
- It was also noticed that this page would not be the most-visited page and it was therefore suggested to be moved to the Profile Options. Perhaps the "My Products" option could then be added to the navigation bar.

Tips

- This page was experienced as very good in combination with the Contact page. If you cannot find a tip very quickly, you can contact an expert. But the other way around, it also provides the user with the possibility to find information first before asking a professional.
- A participant also indicated that she would really like to see the tips focusing on calming down your child, she stated it would be valuable as it would also relate to how the parent was feeling.

- One participant suggested only incorporating tips that would be provided by institutes so you know they are legit. Additionally, she brought up that a reference to these institutes might be useful - providing users with the possibility to find more (reliable) information.
    - Another participant suggested a similar thing, preferring to have some more information.
- Being able to add your own tips might also be useful when it comes to getting more personal tips and information. A participant suggested that the user could add the tips received through a coaching session which they thought were the most applicable to them.
- To neutralize the undertone of the sentence, a participant suggested rephrasing the tips to more optimistic sentences. Avoid using “not” or negative words.

My Products

- When exploring the app, participants do not notice that the profile picture is clickable and are therefore first unable to navigate to “My Products”. After giving a hint about this, the page is easily found and is experienced as clear.
- It was suggested to add this page to the navigation bar instead or show the Profile Options immediately when you log in.

Questions/Remarks

- Some participants indicated that, from a professional perspective, they would also see themselves referring parents to using this app (even though they are not part of the “medical circuit”) since she sees it as a very useful tool.
- It was not clear to all participants that they did not need to provide credentials to log in. (That is not relevant to the structure of this app, rather some feedback regarding the test setup)
- A participant asked whether the app would need to be used every day. After an explanation about using it for a limited amount of time, she concluded that although it would be quite some work it would be fine since it is not used forever.
- A participant described how she had used multiple baby apps before, especially when her children were just born (the first few months). She stated that it was required to keep track of what they drink and that an app was much more useful to her than pen and paper as it helped her gain insights about their (daily) routines. She also liked the option to share such notes as it increased communication speed.

- One participant commented that the entries would be quite subjective, although that is a property of such diary-like entries.
- A participant suggested that it might be nice to also include salivary cortisol sensors in the sock so, in case the sock is taken off and put in the mouth by the baby, there are still valuable measurements.
- A discussion occurred about the ethical aspects of this report, debating what should be done in case child abuse is noticed, or how to ensure parents are sufficiently stable to use these informative tools. What would happen if the research has concluded, but two months later the child has injuries that might lead to the discovery of child abuse. Would you still be able to do anything with the data collected in this research? And should you let parents fill in their experiences without helping them so the data acquired is as realistic as possible, or do you want to make sure they do not "suffer" needlessly? If a family is unstable then it might also be good to involve another professional in the process to make sure no bad things happen in the heat of the moment.
    - Similarly to the children's healthcare centre, ask parents to fill in a quick form in which they can indicate their mental wellbeing. That way, you can assess their stability.
    - Additionally, she stated that it should also be normalized a bit more that it is normal to feel bad sometimes and that it is logical after a pregnancy.

    "As a mom, your child is your biggest vulnerability." - Participant 5

- Participants were positive about the impact and effectiveness the app would have on the stress-monitoring process, stating that it would also help parents gain insights in their feelings and how they would be influenced by external factors such as work.
- It was pointed out that a distorted picture would be presented if only one parent would fill in the app. Therefore, it would be of high importance if all caregivers were involved in this.