Enhancing emotional communication between autistic and non-autistic individuals through assistive Information Technology

Mina Abouei

Uppsala University

Recognising people's emotions is a promising research area in human-computer interaction as emotional communication plays a crucial role in humans' lives. One of the main reasons for ineffective emotional communication is a deficit in understanding emotional signals such as facial expressions and body posture.
There is a bidirectional challenge between autistic and non-autistic individuals since they display their emotional signals differently. This thesis discovers differences in emotional signals, in particular facial expressions, body posture, and physiological signals. Based on the interviews and questionnaires conducted in this thesis, the need to design an aid tool to assist autistic and non-autistic participants during their emotional communication is identified. Therefore, Emognition, a smartwatch, and its mobile application is designed to blur these differences and enhance the emotional communication between them. Furthermore, Emognition's user evaluation indicates that the smartwatch could successfully detect non-autistic participants' sadness and happiness. Also, they found the mobile application useful and aesthetically motivating to interact with. Even though we could not evaluate how well the Emognition recognises autistic participants' sadness and happiness, it is promising to measure their emotions successfully by accurate sensors and, more importantly, by finding their autonomic response patterns to different emotions and enhance emotional communication between autistic and non-autistic people by Emognition.

Additional Keywords and Phrases: Human-Computer Interaction (HCI), Assistive Technology (AT), Autism Spectrum Disorder (ASD), Recognising emotions, Emotional communication, Physiological signals, Heart rate (HR), Skin Conductance Level (SCL).

ACM Reference Format:
This work was submitted in partial fulfilment for a master's degree in Human – Computer Interaction at Uppsala University, Sweden, on 15 June, 2021.

1. INTRODUCTION

We all as humans need to have effective communication and interaction with each other in order to stay mentally and even physically healthy. Emotional communication is one of the most crucial interactions which keeps us healthy. Therefore, difficulties with the cognitive processing of emotions cause noticeable problems in identifying or even describing our emotions, linked with a high rate of depression in our societies (Honkalampi et al., 2000).

Emotional communication requires understanding different emotional signals such as facial expressions, tone of voice, body postures. Situations trigger emotions, and most children understand these emotional signals from an early age. For instance, newborns can imitate their parent's facial expressions, and when they

become a two-month-old child, they can respond to the emotional signals (Tanguay, 1990). By the age of three, they can distinguish their various feelings and use different emotional terms. For example, they make a happy face when they are happy (Stein et al., 1989). Thus, their emotional communication skills develop little by little while they are growing up.

Earlier studies show that people diagnosed with Autism Spectrum Disorder (ASD) cannot understand their own and other people's emotions from an early age like non-autistic individuals (Hill et al., 2004). Thus, there is a lack of emotional recognition in autistic people formulated as a characteristic of ASD that leads to having social interaction difficulties in everyday situations. However, they ignored the fact that there should be a two-way interaction between people. It is also essential to think about how well non-autistic people recognise autistic people's emotions. Some argue that there is evidence of deficits in autistic people's facial, gestural and vocal expression of emotions (Hobson, 1989); therefore, it is challenging for non-autistic people to interpret autistic people's facial expressions and bodily movements.

According to Hill et al. (2004), after investigation of 111 participants (35 normal adults, 27 high-functioning autistic adults, and 49 relatives of autistic individuals), 6.4 percent of the relatives and none of the normal adults fell into the category of clinical depression, but 22.2 percent of the autistic individuals needed clinical treatment for their depression. Besides depression, autistic individuals also suffer from other emotional themes, such as a sense of alienation, a sense of frustration, and a pervasive sense of fear/apprehension (Jones et al., 2001).

Therefore, the research questions are why autistic and non-autistic people struggle to recognise each others' emotions? Moreover, how to enhance emotional communication between them to reduce depression?

1.1. Research Goal

This thesis focuses on understanding the differences in emotional signals sent by autistic and non-autistic individuals, particularly facial expressions, body posture, and physiological signals. Understanding these differences is crucial to get a clearer idea about the main reasons behind this bidirectional challenge in their emotional communications that likely leads to a high rate of depression, specifically in autistic people. The main goal of this study is to design an aid tool to blur these differences as much as possible and enhance emotional communication between autistic and non-autistic individuals.

1.2. Paper overview

This paper will discuss differences between autistic and non-autistic individuals' facial expressions, body posture, and physiological signals. Moreover, we go through some related works to find out what others have done to enhance emotional communication. Then, the methods we applied, the challenges these people face, and what they need are presented. Furthermore, the design process of the Emognition smartwatch and its mobile application, their implementations, and evaluations are reported. To conclude, the thesis discusses Emognition's limitations and future work.

2. BACKGROUND

Later studies focus more on how these two groups recognise each other's emotions. In contrast, recent studies suggest that non-autistic and autistic individuals are less divergent in recognising emotions than expressing them. Below we will argue these differences in their emotional signals. Furthermore, we will review

some related works that cover recognising people's emotions by novel technologies to discover ways to enhance emotional communication.

2.1. Facial Expression

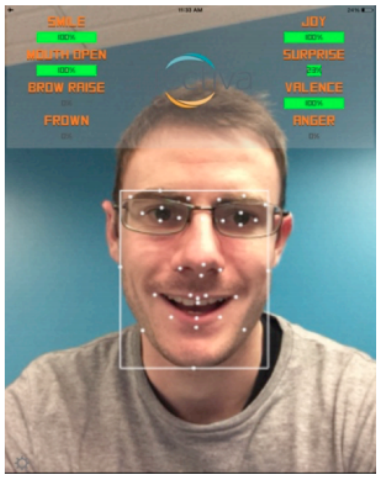
There has not been much experimental research on emotional expression differences in autistic individuals (Begeer et al., 2008). Some of the previous evidence gathered in naturalistic settings indicates that autistic individuals use nonverbal emotional expressions atypically. (Bieberich et al., 2004; Stagg et al., 2014). For instance, during experimental research about autistic children, fewer facial muscle movements occurred while playing (Czapinski & Bryson, 2003). Also, they displayed atypical facial expressions of emotion during describing an emotional story (Grossman et al., 2013). Another observational evidence is that they struggled to communicate happiness through facial expressions (Langdell, 1981). More recently, Volker et al. (2009) found in a larger sample of children that non-autistic raters could not recognise expressions of sadness produced by autistic children, and their expressions were odd. The same as Langdell's (1981) findings, Faso et al. (2014) found that NT raters hardly recognise the expression of happiness in autistic than non-autistic people. Based on their results, non-autistic raters perceived the facial expressions of autistic adults to be less natural and more intense than non-autistic individuals. However, emotional expressions of anger in autistic people were surprisingly better recognised.

According to Czappinski et al. (2003), most of the time, during natural social interactions, autistic individuals show facial expressions for a shorter amount of time, less frequent than non-autistic individuals. Moreover, they may display expressions that are visually different. For instance, using another part of their face, and those expressions may be socially incongruous or even lower in quality (Czapinski et al., 2003; Faso et al., 2014; Wiley Online Library, (n.d.)). However, they display the same intensities of expression as non-autistic people. Also, few studies investigated that differences in their emotional production are not due to a physical inability. It is likely because of their atypical spontaneous productions. They can produce facial expressions that others recognise (Wiley Online Library (n.d.)).

Latter evidence argues that Alexithymia linked with atypical facial recognition (Swart et al., 2009) is responsible for emotion recognition deficits in autistic individuals (Cook et al., 2013). Alexithymia is highly common in ASD (approximately 50 percent of them have severe levels of alexithymia) (Berthoz & Hill, 2005), which makes emotion recognition challenging for them. Thus, most autistic individuals suffer from a deficit of facial emotion recognition, which leads to social interaction difficulties. Autistic people may have difficulties reading the facial expressions of non-autistic people, but non-autistic individuals probably are impaired at reading autistic people emotional expressions as well. During a successful interaction, both sides rely on each other's common representations of emotions. Therefore, a mismatch between a sender and a receiver or vice versa could lead to a failure in emotional communication. It is also possible that autistic individuals may be better at reading other autistic people's emotional expressions since previous experiments on emotional recognition of autistic individuals used only non-autistic facial expressions, which might have a noticeable effect on the results.

AFFDEX, a real-time facial expressions recognition toolkit, can automatically code the expressions of people. Based on users' facial expressions, it offers novel interfaces responding to their emotions. One of the advantages of this toolkit is that it is available on different platforms such as Windows, Android, and iOS. Thus, various users with different preferences can get it and interact with it. It is trained on the world's largest

dataset of facial expressions with few false detections. They used a web-based framework and collected videos of hundreds of thousands of individuals. Then these videos were coded by expert Facial Action Coding



System (FACS) coders to provide a rich dataset of facial expressions examples. They also trained state-of-the-art facial action and emotion classifiers using this data (McDuff et al., 2016).

Figure 1: Screenshot of the iOS SDK demo application (McDuff et al., 2016).

Facial expressions have numerous advantages as a method for measuring people's emotion since they are the most traditional and also remain one of the best methods for measuring emotions in the matter of their reliability and widespread usage in various studies that is in contrast with most of the other newly developed methods (Calvo et al., 2010). Moreover, this method can be analysed right after an experiment using human coders or in real-time by software programs such as FaceReader (Craig et al., 2008).

The disadvantage of using facial expressions as the method of measuring emotions is that it is very labor-intensive if done by trained human coders instead of software. According to Calvo et al. (2010), facial expressions research is best suited to examining basic emotions using automatic facial recognition programs. Thus, most of the facial expressions coding schemes count on the FACS used to detect the six basic emotions. Furthermore, examining non-basic emotions requires broad cross-method validation to connect facial expressions configurations measuring emotions (Harley, 2015).

2.2. Body Posture

Apart from facial expressions differences, studies argue that these two groups also show different body movements. Understanding these body movements and body postures are also crucial for effective emotional communication (Halberstadt, 2001), especially when facial expressions are unavailable to observers in everyday situations.

Hubert et al. (2007) argue that even though autistic individuals performed very well, similar to non-autistic participants in recognising object manipulations and straightforward actions, they had difficulties recognising emotions from point-light display compared with non-autistic participants. Therefore, emotional perception difficulties in autism are not restricted to facial emotional expressions but also influence bodily emotional expression. Later, Hadjikhani et al. (2009) examined the behaviour and brain activation in autistic and non-

autistic individuals. The purpose of their study was to evaluate and compare emotional body expressions, in particular fear, with emotionally neutral bodies engaged in everyday actions. In contrast to non-autistic people, they showed emotion, expressed by the whole body while excluding facial expressions, is likely to fail in activating ventral visual areas and Mirror Neuron System (MNS) in ASD. Therefore, their data show a clear difference between autistic and non-autistic participants during the body's perception of fear.

These findings help us consider two possibilities if an autistic individual shows atypical emotional representations. Firstly, they probably have their own idiosyncratic emotional representations, which are different from other autistic individuals. Secondly, they may share common but atypical emotional expressions that are varying from non-autistic individuals. Thus, if the second possibility is true, autistic people can recognise the emotional signals of other autistic people. Still, they cannot understand non-autistic people emotional expressions. The consistent use of non-autistic raters in previous studies may have placed autistic individuals at a disadvantage. However, according to Edey et al. (2016), autistic individuals show different bodily movements from non-autistic individuals and other autistic people. Therefore, non-verbal emotional communication between autistic-autistic pairs cannot be more understandable and successful than non-autistic-autistic pairs.

Wrnch company built a prototype to identify human behaviours with AI (Wrnch, 2018). This tool can detect body movements, for instance, the wavy movement of hands. Then, it correlates the movement as a specific behaviour to an emoji. Although this prototype aimed to detect human behaviours through body movements, it may also be possible to detect emotions by connecting the prototype to another data set that gathered specifically body postures as emotional signals to detect various emotions.

The advantage of reading body posture is that their data is non-invasive and online to collect (Rodrigo & Baker, 2011). This approach is less resource-intensive than human coding and provides real-time emotion classification data because of automatic classification methods.

The major disadvantage of measuring body posture is that it is a nascent method of measuring emotions compared to facial expressions. Therefore, less empirical work has been done to outline its validity. Some also suggest posture is an emotional measurement method within multi-sensor research sets (Burleson, 2011; Grafsgaard, et al., 2014) and part of a coding scheme that includes facial expressions (Rodrigo & Baker, 2011). Based on studies in multi-method evaluations, postural coding has had mixed results regarding its additive contribution to classifying emotions when combined with other methods like facial expressions (D'Mello & Graesser, 2010; Grafsgaard et al., 2014).

In summary, a large enough corpus of research cannot assess the additive value of postural methods as a means for measuring emotions confidently. Therefore, research to date does not support its use over other methods such as automatic facial recognition software.

2.3. Physiological Signals

As mentioned earlier, people display their emotions through facial expressions, body gestures, and physiological signals. Many researchers suggest that using physiological signals is beneficial since they are not controllable by people. For example, people may control their facial expressions to hide their emotions, but physiological signals cannot be controlled (Wioleta, 2013). So, emotions can be recognized based on various changes in our body parameters, such as heart rate variability and the galvanic skin response. Although autistic people can display different physiological signals than non-autistic people, studies argue that

physiological signals are linked with different emotions. By measuring them, we can gain an overall accuracy of almost 90 percent in recognising people's different emotional states (Shu et al., 2018). Jansen et al. (2006) argue that autistic adults can display a decreased heart rate in response to psychosocial stressors than non-autistic adults. Also, autistic people show increased cardiovascular arousal even without a stressor's apparent presence (Groden et al., 2005). Liu et al. (2008) applied pattern analysis to dozens of physiological signals to separate various emotions such as anxiety, liking, and engagement in autistic children while interacting with a robot. Based on their experiment, physiological signals can be useful for patients with autism who cannot explicitly express their emotions. It is also helpful for their parents since they are more likely to understand the emotional state of their autistic child (Krupa et al., 2016).

The MIT Media Laboratory has recently been working on various projects to discover new technologies for people with communication difficulties to improve their abilities to have effective emotional communication. However, it is not an easy problem to solve. One of the projects they worked on is an emotion detection device working with wireless signals (MIT CSAIL, 2016). According to Adib et al. (2015), signal reflections can be used without body contact to measure people's average heart rate and breathing. Thus, the device can measure the interaction of physiological signals and emotions, while users are not required to wear any sensors on their body (Zhao et al., 2016).

Physiological patterns are becoming popular for measuring emotions as they can be used for non-invasive and non-labor intensive online measurements of people's emotional states. For example, tools that measure galvanic skin response to emotions have evolved from gloves (Woolf et al., 2009) to wrist bracelets (Burleson, 2011). Moreover, more affordable devices have become available, such as Affectiva, which reduces costs and increases the use of these technologies.

There are some challenges in using physiological devices. In addition to cost, training and human expertise are required to use these devices (e.g., accurate analysis of the results, signal processing for feature extraction, and analysis to create meaningful emotional information labels).

In summary, physiological sensors offer promising directions for real-time and online measurement of emotions. Although human expertise and cost affect the widespread use of this method until cheaper hardware becomes available, not to mention that many physiological sensors, such as those that measure heart rate and skin conductance, are becoming more affordable, less invasive, and consequently increasingly used to collect emotions data (Arroyo et al., 2009).

2.4. Important Consideration

When classification algorithms are not available to identify emotional labels, context is likely crucial since it can provide extra information. For instance, the researcher may need the use of assumptions and may assume that the spike is because of anxiety. However, it is also possible that the participant is excited to move on to content she perceives as more enjoyable.

3. METHOD

In this section, we will discuss methods applied in the project for collecting qualitative data, analysing data, and the design process. Moreover, there are some concerns regarding the ethical issues related to the data collection phase that we will explain more further.

3.1. Data Collection Methods

One of the main methods applied in this thesis project is a literature review. According to Hart (2018), the reasons why literature review is essential are that *"without it you will not acquire an understanding of your topic, of what has already been done on it, how it has been researched, and what the key issues are."* Thus, we applied the literature review to create a firm foundation for advancing knowledge and facilitating theory development.

According to Benyon (2014), one of the best ways to collect qualitative data and understand target groups' needs is to talk to them and ask them questions. It is a meeting in which the interviewer is provided with pre-prepared questions but can also explore new topics as they arise during the interview by asking spontaneous and appropriate open-ended questions. As an interviewer, it allows us to discuss the topic with the interviewee rather than straightforward questions and answers. Thus, we planned to conduct semi-structured interviews (Appendix 1 and 2) over the phone with ten autistic individuals and ten non-autistic caregivers with the goal of acquiring interviewees from different locations, various age groups and both gender. However, only two caregivers (one mother and one certified caregiver) from two different countries and three autistic individuals (two female and one male), aged 21-35 years old from varied locations participated in the interviews. We found out many autistic people get too nervous talking over the phone, so we gave them an option to chat over Facebook messenger instead. Since the number of participants was not fulfilled with our study plan, we studied similar interviews conducted in other research (e.g., Robledo et al., 2012).

Another data collection method utilised in this project is online questionnaires. They help gather qualitative data and provide statistical information on specific issues since we receive responses on a larger scale. However, creating a workable questionnaire is time-consuming and challenging. We made two questionnaires with the same goal as interviews (e.g., acquiring participants from different locations); Questionnaire A establishes autistic people's background and their challenges of communicating emotions. Questionnaire B targets the close connections of autistic people (e.g., parents and siblings), and the difficulties they face in communicating emotions. These questionnaires, A and B (Appendix 3 and 4),were shared in various ASD community groups (24 groups with an average of 7658 members) on Facebook, and participants were selected based on availability and willingness to take part in the questionnaires. In the end, we could gather 58 responses in total (28 autistic individuals and 30 non-autistic parents and relatives).

3.1.1. Ethical Consideration.

There were some ethical issues related to collecting data from vulnerable groups of people with cognitive impairments since we wanted to gather confidential data related to autistic and non-autistic people's emotions. According to some studies, many interviews concern sensitive issues that make the interview sessions emotionally intense for both interviewers and interviewees (Borbasi et al., 2005; Cohn et al., 2003; Peled et al., 2002). One of the ethical issues might be the risk of unanticipated harm. Therefore, at the beginning of the interview session, interviewers informed interviewees about the research topic, the potential distress and asked them to sign consent forms (Appendix 5). When the interviewer listens and encourages the interviewee to speak about the topic, interviewees may unexpectedly talk about their personal information, express their intense feelings on prior experience that may be painful for them, and become uncomfortable after completing the interviews. As a result, the process probably develops unanticipated harm to the interviewee; thus, we provided them some information about their right to withdraw from participating at any

time. Another ethical issue is about the privacy of the interviewees. Therefore, in this study, participants could decide whether to use their real names or participate as anonymous.

As we wanted to discover particular emotional communication issues between people linked together, an ethical issue that needed to be considered was protecting participants' privacy. Privacy and confidentiality may be threatened when participant A prefers to keep some information private, but the other participant linked to participant A reveals the personal details. (Forbat et al., 2003) Therefore, to protect the participants' privacy, we let them fill out the online surveys anonymously.

3.2. Data Analysis Methods

Analysing the data of questionnaires[1] was based on statistical analysis while we did the qualitative analysis on the interviews' data. We asked interviewees to give us consent to record their voices during the interview. Thus, we could generate recording transcriptions by the Amber Script application. After that, we applied Thematic Content Analysis (TCA), a reliable qualitative data analysing method.

3.3. Design Methods

This project followed a Human-centered design approach to develop possible solutions to enhance emotional communication between autistic and non-autistic individuals by involving the human perspective in every step. Human involvement occurs while observing the problem within the context, brainstorming, conceptualising, developing, and implementing the solution. We used brainstorming and sketching to discover the best design solution. According to Benyon (2014), brainstorming is one of the best ways of expanding our design space. It is important to stay creative and brainstorm about the various solutions that could work instead of sticking to one solution.

4. DATA COLLECTION FINDINGS

We collected responses through questionnaire A from 28 autistic individuals (17 female, 11 male), aged 18-68 years old, from varied locations. Also, 30 non-autistic parents and relatives (30 female and no male), aged 25-66 years old from various locations, contributed to questionnaire B.

While 17 out of 30 non-autistic participants thought they had difficulties in their emotional communication with autistic people, 5 out of 30 non-participants had no or minor problems, especially when they are in a place with other people (Figure 2).

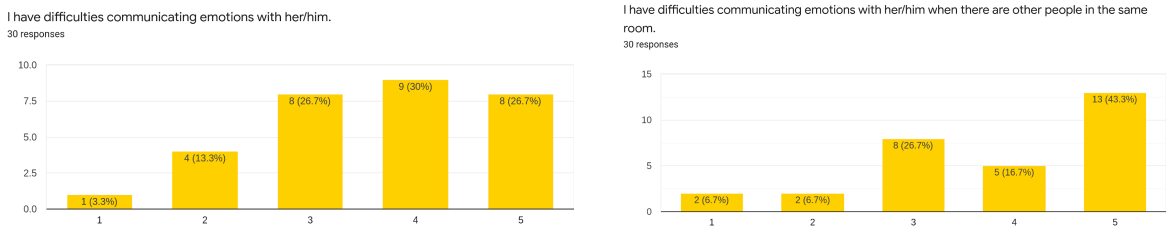


Figure 2. Questionnaire B shows most participants have difficulties in emotional communication with autistic people.

[1] Data of questionnaires A and B can be found here.

Data from questionnaire A show, autistic participants believe that it is challenging for them to recognise fear, disgust, and surprise in others. In contrast, they can easily understand other people's happiness, sadness, and anger. However, the data from questionnaire B show that autistic people can not understand sadness and anger successfully (Figure 3). One of the autistic participants also said in the interview,

> *"The problem with this is how does someone who isn't good at recognising emotions know when they get it right or wrong? I might think I'm good at knowing when someone feels happy or sad but get it wrong."*

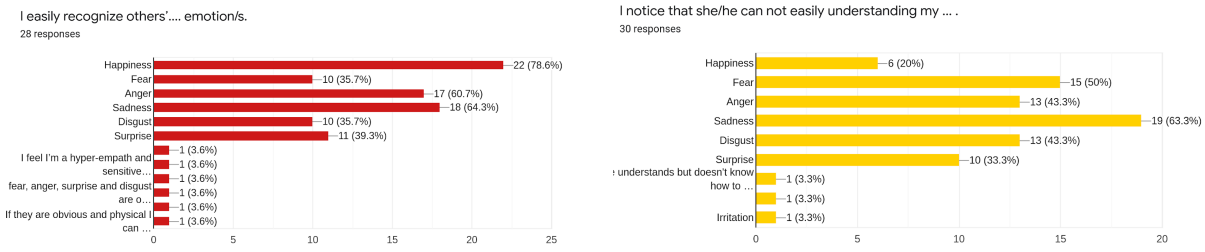


Figure 3. Questionnaire A and B, asking about emotions that autistic people can and cannot recognise easily.

Thus, based on the data, there is evidence that bidirectional challenges exist between most autistic and non-autistic people in understanding each other's emotions, and, they often have inefficient emotional communication.

21 out of 28 autistic participants told us they have few close relationships (Figure 4), and most of them thought they probably had more close relationships if they could communicate their emotions effectively. However, almost 39% of them were neutral.

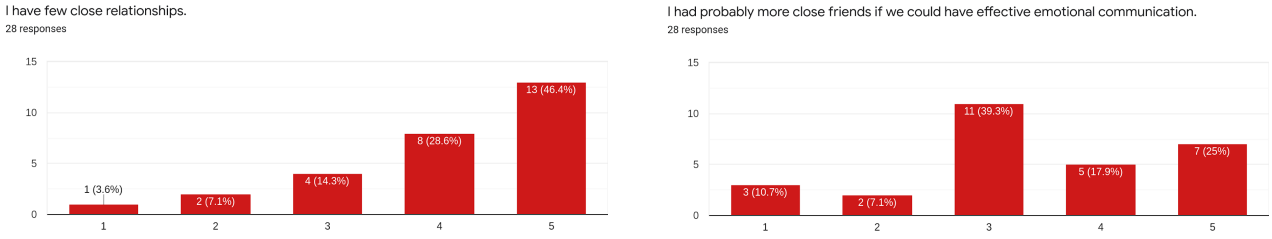


Figure 4. Questionnaire A shows autistic participants have few close relationships.

On the other hand, participants of questionnaire B, who were chiefly mothers of autistic children, also believed that autistic people have few friends due to a lack of effective emotional communication, and they were worried about autistic people's relationships (Figure 5). We can argue that emotional communication is essential to intimate relationships. As such, enhancing their emotional communication may help autistic people to have more close relationships.

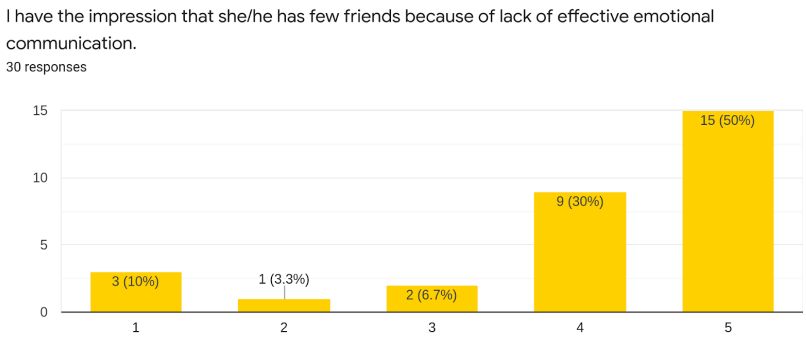


Figure 5. Questionnaire B, autistic people have few friends due to a lack of effective emotional communication.

Based on the data, most autistic participants feel relieved when people have understood their emotions. However, they rarely express their emotions because of a lack of confidence in expressing their feelings, as most of the time, people cannot understand their emotions (Figure 6). Therefore, this is likely one of the main reasons for the high rate of depression in autistic people. One of the non-autistic mothers told us,

> *"It's often very difficult to understand what my autistic child is going through. They try to explain it to the best of their ability, but it's like someone having an extra appendage, trying to explain how that extra appendage feels to someone that only has the normal amount."*

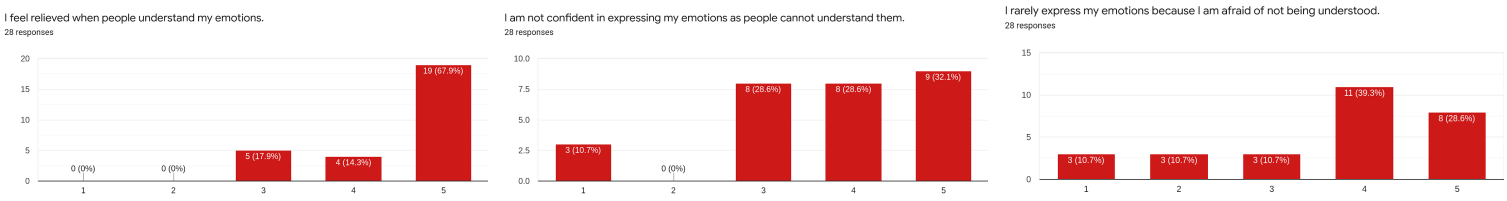


Figure 6. Questionnaire A, autistic participants rarely express their emotions due to lack of confidence.

Furthermore, she added, although she got better at recognising her child's emotions, there are still challenges. She also explained,

> *"When they show emotion, it's pretty apparent which emotion it is. Then again, we've known them since birth, so maybe it's easier for us to recognise. Other people won't know what's going on."*

Another striking finding is that nearly 50% of participants believed they do not get depressed when autistic people cannot understand their emotions, while almost 36% found it depressing (Figure 7). It is also possible that these participants are not aware of its negative effect on their mood.

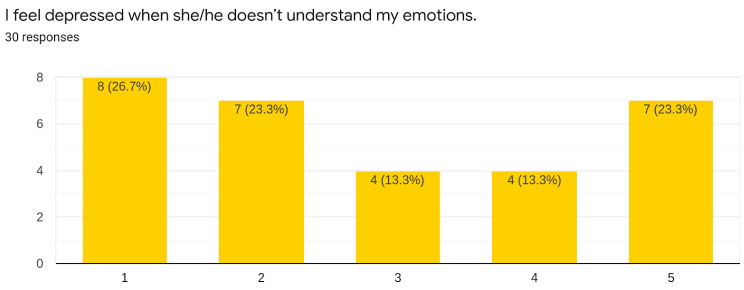


Figure 7. Questionnaire B, participants believed they do not get depressed when autistic people cannot understand their emotions.

However, 57% of non-autistic participants believed they get more depressed when they do not know what autistic people feel (Figure 8). Hence, it can affect their mood negatively when they have ineffective emotional communication. One non-autistic caregiver explained that when he cannot understand autistic people's emotions, it negatively affects him. He said,

> *"It is not only part of my job responsibilities, but also it makes me feel good when I comfort someone sad and make them happy again. At the end of a working day, I feel relieved and satisfied because I was a useful person."*

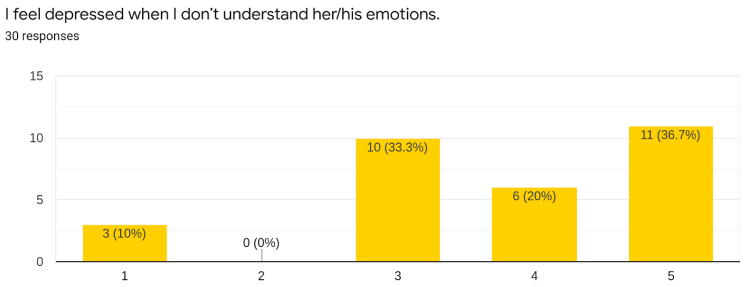


Figure 8. Questionnaire B shows most participants were negatively affected by difficulties in understanding autistic people's emotions.

A non-autistic mother described the situation when they could not understand their autistic child's emotions as follows,

> *"We get upset, but we try not to show it. We get exasperated but try not to show it. It's an exhausting process."*

Based on the data, these difficulties in understanding autistic people's emotions put non-autistic relatives at risk of depression. By enhancing emotional communication between them, the rate of depression will probably decrease in both groups.

According to data (Figure 9), sometimes controlling emotions is difficult for most autistic participants, especially in stressful situations. Therefore, they may need to help them control their emotions better. Barbara mentioned,

> *"I try to stay out of a situation where I am stressed. Otherwise, there is no controlling my emotions."* (Robledo et al., 2012)

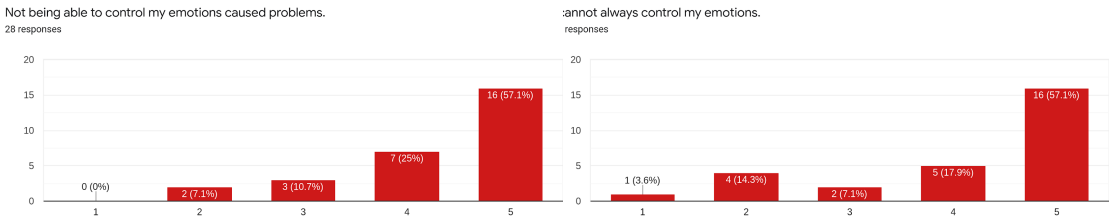


Figure 9. Questionnaire A, autistic participants need to control their emotions better.

The non-autistic mother also shared her concerns about the moment her autistic child has emergencies. She said,

> *"I had asked them if they thought it was possible to use a chat program or a very simple app to load in a blanket statement so that they could hand it to someone in the case of emergencies. Basically, with them, it's a toggle switch. Either they can communicate (and they do it well), or they are unable to communicate and would be unable to function enough to use a program. They are typically very loquacious. However, they will lock up completely and become both non-verbal and incapable of moving if under extreme stress or anxiety."*

According to the interview data, autistic people may become non-verbal and cannot move when stressed out; therefore, it would be helpful to design something to inform their parents or close relatives in case of emergencies.

Another fascinating piece of data is that although about 47% of participants thought most autistic people express emotions that are not adequate to the context, almost 30% disagreed with the statement (Figure 10).

One of the autistic participants explained her emotions as follows,

> *"They're not always what people seem to expect, or sometimes even what I know they should be. Under intense pressure, I have occasionally laughed or smiled when I was feeling terrible (sad or guilty), no idea why and it seems impossible to control. I'd usually cover my face with my hands if I'm aware that my reaction is not congruent with what I'm feeling or what is expected."*

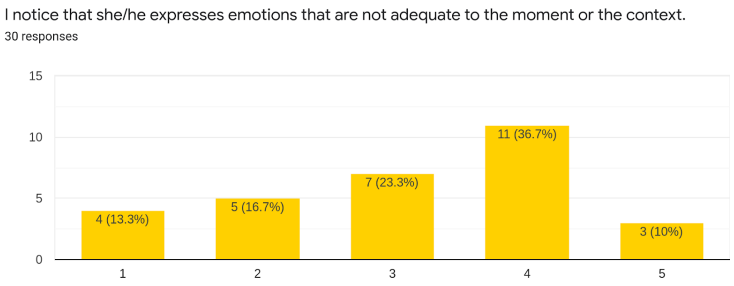


Figure 10. Questionnaire B, most autistic people show emotions that are not adequate to the context.

We became more aware of the importance of context to recognise emotions after this study as the autistic participant also told us the context is crucial when she wants to understand others' emotions:

> *"I have learned to read clues and context, and some emotions are obvious in certain circumstances - like happiness when someone wins a contest or sadness at a funeral."*

Thus, we thought it should be necessary to add various contexts for more accurate emotion recognition in our design.

Even though most autistic participants need help for their emotional communication (Figure 11), only a few of them use aid tools or get support from, for example, therapists. In addition, there should be other significant reasons except for lack of interest since most of them would like to have something or someone to guide them through their emotional communication (Figure 12), especially when they would understand what other people are feeling.

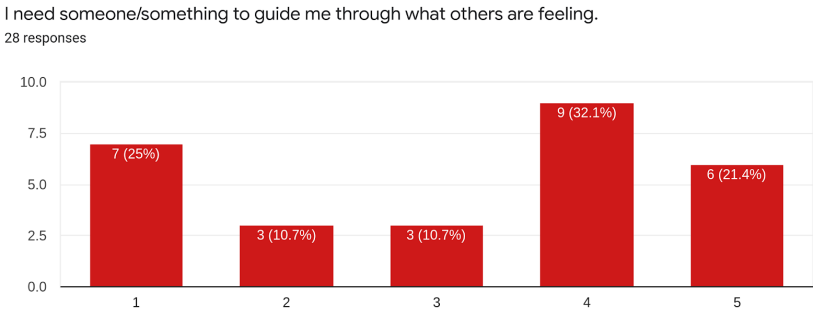


Figure 11. Questionnaire A, most autistic participants need help for their emotional communication.

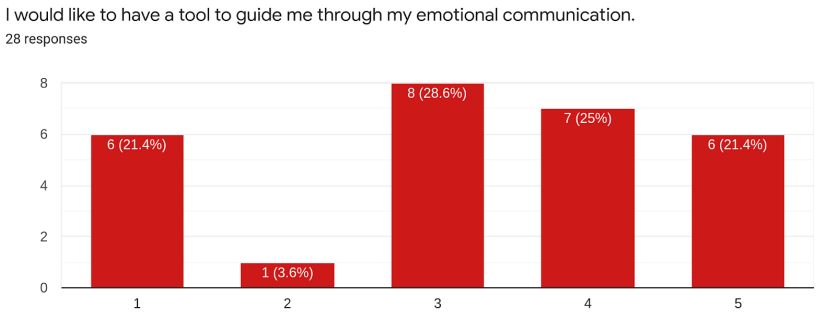


Figure 12. Questionnaire A, most autistic participants would like to have emotional communication support.

The final finding is that 76% of non-autistic participants, and 46% of autistic individuals, were interested in having an aid tool to make emotional communication more effective, while about 21% of autistic participants were not interested (Figure 13).

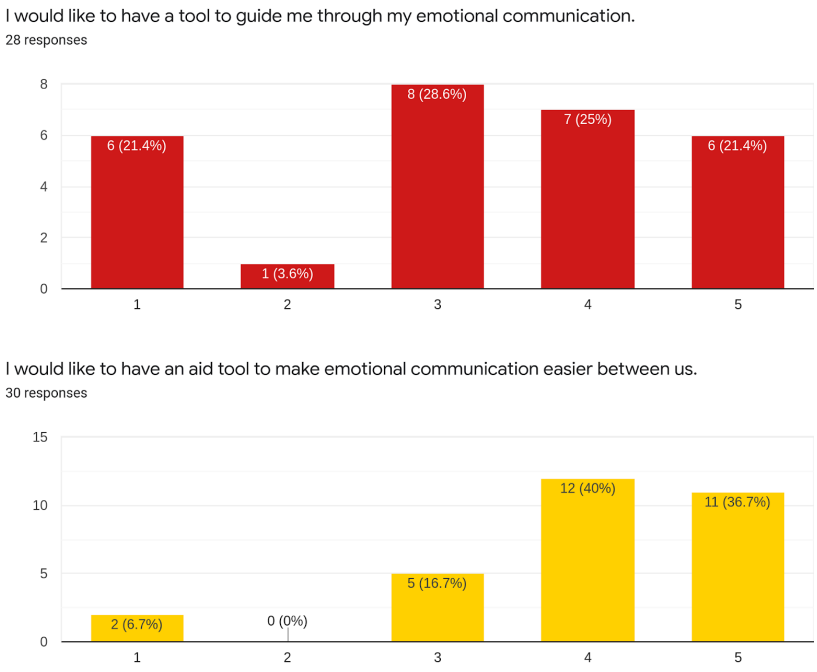


Figure 13. Questionnaire A and B, most participants interested in using an aid tool.

5. THE EMOGNITION'S DESIGN PROCESS

After analysing the interviews and questionnaires, we argue that most of the findings were similar to the other studies that we mentioned earlier in this thesis. There are bidirectional challenges between autistic and non-autistic participants in recognising each other's emotions. Thus, they have ineffective emotional communication, which is linked with depression in both groups. Also, due to ineffective emotional communication, autistic participants have few close relationships.

Since most participants were interested in having an aid tool, we decided to design a tool to enhance emotional communication and reduce depression. Also, hopefully, to help them have more close relationships after using the tool and control their emotions better as most of the time, autistic participants have difficulties controlling their emotions. To achieve that, we made two personas (one for autistic and the other for a non-autistic person) based on participants' needs and frustrations (Figure 14).

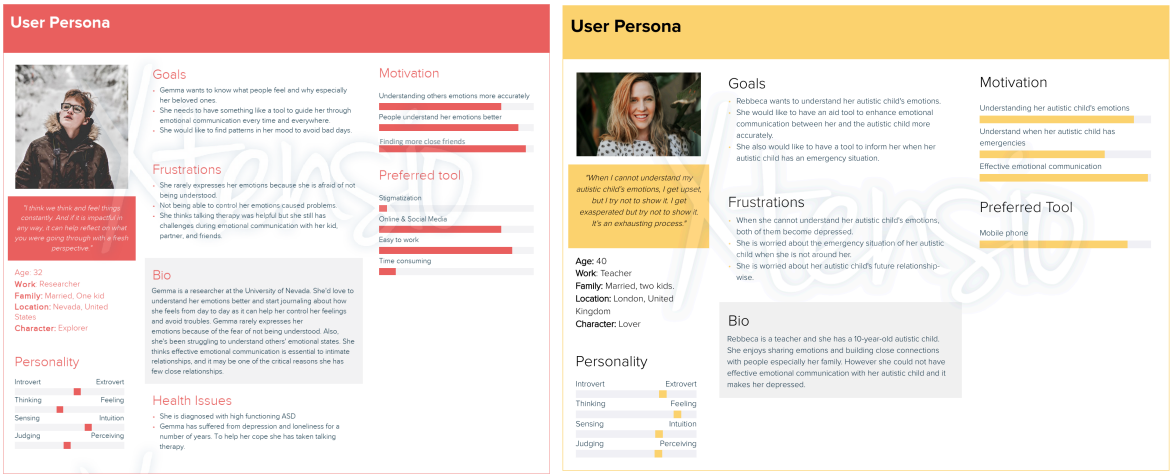


Figure 14. User personas, autistic user persona on the left and non-autistic user persona on the right.

The autistic user persona indicates her needs to understand what people feel exactly or vice versa, increase their confidence in sharing emotions through effective emotional communication, find more close friends, control their emotions better, and find patterns in their mood to avoid negative feelings.

On the other hand, the non-autistic persona highlights the primary needs and frustration of autistic people's close connection, for instance, a non-autistic mother who needs to understand her autistic child's emotions or vice versa, learn to manage her negative emotions like worry, and have a tool to get informed about her autistic child emergencies.

We started sketching to meet the users' needs as much as possible in an appropriate way (Figure 15 and 16). After that, we started building hi-fi prototypes in an iterative design process (the repetitive process of prototyping, testing, analysing, and refining).

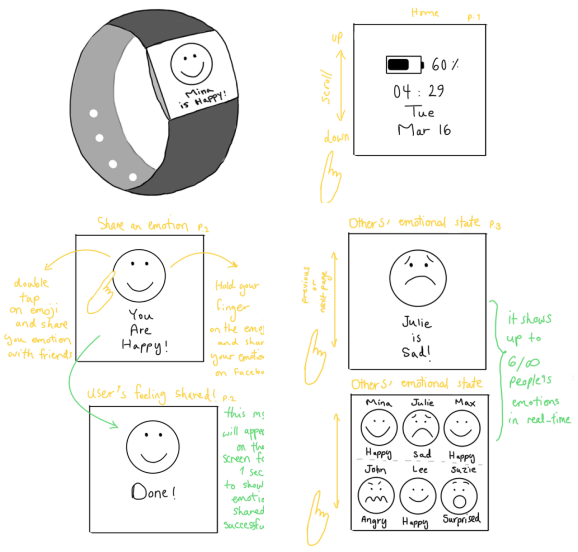


Figure 15. Sketches of a smartwatch measuring various physiological signals.

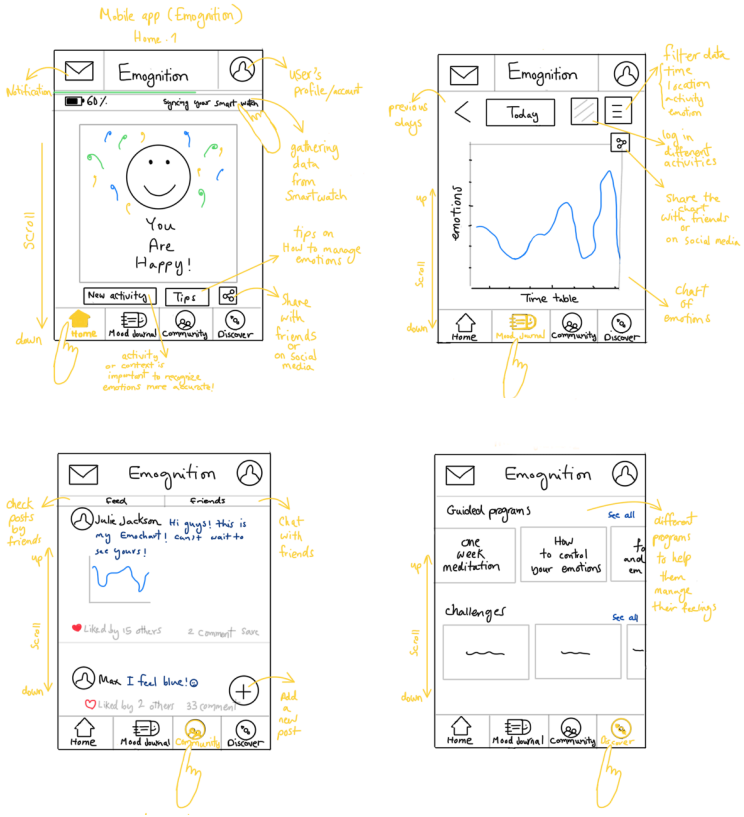


Figure 16. Sketches of a a mobile phone application.

Although we did the literature review on how to measure six basic emotions through facial expressions, body posture, and physiological signals, we finally focused on recognising two basic emotions (Sadness and Happiness) by measuring physiological signals such as Heart Rate (HR) and Skin Conductance Level (SCL). Based on the studies, measuring autistic individuals' facial expressions and body posture is more challenging than measuring physiological signals since each autistic person often uses reduced and different expressions. For instance, they often show neutral facial expressions and use other parts of their face that may affect their facial expressions to be lower in quality (Sherer et al., 2005; Yirmiya et al., 1989; Czapinski et al., 2003). Moreover, their expressive body postures are lacking as their body movements are often limited (Fournier et al., 2010). In contrast, Picard et al. (2009) argue that most of the time, autistic individuals experience an extreme emotional state internally, which is not apparent externally (e.g., although they may seem calm, they have a high heart rate due to being nervous). Moreover, Allen et al. (2013) suggest, physiological signals are functional in autistic people while experiencing an emotion, and they display standard SCL patterns to neutral, pleasant, and unpleasant pictures.

5.1. Implementation

We designed a smartwatch and a mobile phone application under the name of “Emognition”. One of the main goals in designing the Emognition smartwatch was to avoid stigmatising autistic people from the other. Most users with impairments appreciate designs that do not bring particular attention to their disability and exclude them from other people. Thus, they might even abandon Assistive Technologies (AT) as its usage causes stigmatisation. As strategies to de-stigmatise AT, Bispo and Branco (2008; 2009) suggest, designers need to design based on the context of use, cover AT and use symbols to alter stereotypical indicators of disability. So we designed the Emognition smartwatch that autistic and non-autistic people could wear on their wrists with a similar design to other smartwatches to avoid stigmatising the users.

The Emognition smartwatch performs three main tasks: (1) detection of users’ emotions and possible outbursts situations, (2) display emotions, and (3) share emotions.

In terms of explicit interaction, the Emognition smartwatch has a small screen to display emotions. It is tactile, and the interaction is through touch (short or long), tap (one or double), and slide (vertically and horizontally).

The Emognition smartwatch gathers HR and SCL data through sensors (Figure 17), recognises the possible users’ emotions, and matches those data with happy, neutral, and sad emojis.

At first, gathering data from sensors was not easy. During our iterative process of building the smartwatch, we faced many challenges. It was difficult to measure emotions by the sensors, and the results were too inaccurate. There were too many errors and randomness involved, which made the result irrelevant to the context. We found out most of them were due to the practical issues with the Arduino breadboard and loose wires. So, after soldering all the wires and sensors, we could gather more accurate data.

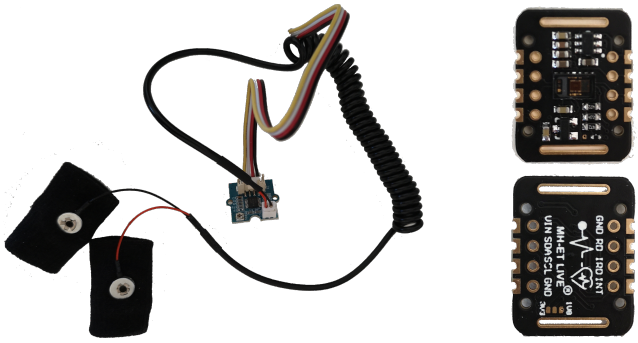


Figure 17. Grove GSR Sensor and MAX30102 Heart Rate Sensor.

In order to recognise emotions, we developed an algorithm to map HR and SCL data to one specific emotion. Kreibig (2010) made a table based on a summary of findings of non-autistic people's autonomic emotion responses reported in studies. The table highlights HR and SCL increase while experiencing happiness and decrease while experiencing non-crying sadness. We used these patterns to define sadness and happiness in our prototype (Table 1). Although some studies focused on the effects of stress on the Autonomic Emotion Responses (AER) in autistic people, there was insufficient data about other emotions like happiness and sadness on AER. Hence, we planned to run workshops with autistic individuals to find these patterns. However, due to the COVID-19 pandemic, we were not able to accomplish our goal. Thus, the present report is limited to findings from detecting emotions in non-autistic people.

Physiological Responses	Happiness	Sadness
HR	↑	↓
SCL	↑ or --	↓

Table 1. Modal response patterns for happiness and sadness emotion. Arrows indicate increased (↑), decreased (↓), or no change (- -).

In our algorithm, we use HR and SCL as input to discover users' emotions. For HR data, three zones (sadness, neutral, happiness) are defined (Figure 18). The happy and Sad zones represent happy and sad emotions, respectively, while the Neutral zone represents the normal state of users. The HR sensor measures users' heart rates as Beats Per Minutes (BPM) and maps it to a zone. Moreover, the SCL sensor measures skin conductance. Happiness triggers a 10% increase in a user's normal skin conductance, while sadness leads to a 10% decrease. The exact definition of zones is user-specific. Thus the smartwatch calibrates the zones specifically for each user based on their individual parameters and general factors such as age, gender, autistic and non-autistic.

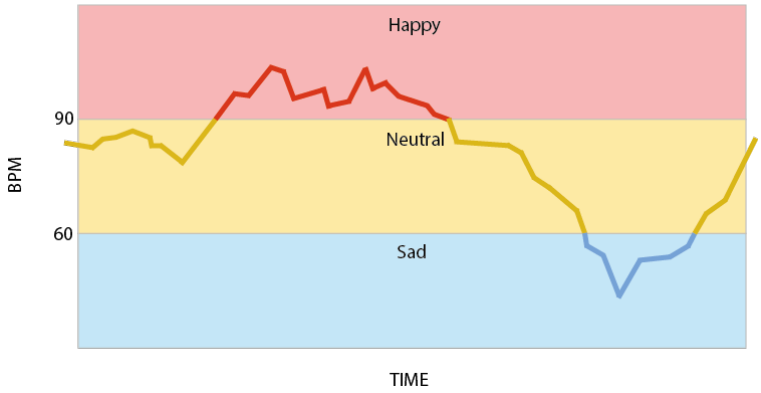


Figure 18. Sadness, neutral, and happiness zones defined based on HR data.

Whenever the smartwatch detects an emotion, users could share it (Figure 16) with whomever they wish. For instance, they could share emotions with family and friends who also have Emognition connected to Bluetooth or even share it on social media.

The Emognition application prototype is built in Adobe XD. For its design, we considered one of the crucial aspects of the interface design: consistency. According to Somberg (2000), *"'Consistency' allows the user to develop expectations about how an application operates and to use this knowledge to reduce errors."* Therefore, we used icons and patterns that users are familiar with while interacting with the application to clarify cognitive dissonance. The other important aspect of the design is considering the users' mental models. We will use the following definition of the term "mental model":

"The user's model provides an integrated package of knowledge that allows the user to predict what the system will do if certain commands are executed, to predict the state of the system after the commands are executed, to plan methods for novel tasks, and to deal with odd error situations (by characterising the system's state according to the model, then choosing operations necessary to leave that state" (Garnham et al., 2013).

Based on the previous statement, we needed to be cognisant of different user mental models and users' expectations. Therefore, we designed the application similar to those mental models to avoid accruing too many errors. We also applied Affordance, which is one of the essential design fundamentals. Affordance in design means that, for instance, user interfaces need to be designed in an appropriate way so that different interface objects are immediately apparent to the users. Door handles, for example, may "pull" Affordance to a handle that invites you to pull the door towards you (Kaptelinin, 2014).

Emognition mobile application and the smartwatch are connected through an API, so they have the same features. However, some other crucial users' needs are covered in the Emognition mobile application. For instance, there are helpful tips, programs, and challenges to help users control and manage their emotions better. Also, Emognition could send an emergency notification to their emergency contact (e.g., when they become non-verbal under extreme anxiety). It has a mood journal to allow users to add and track triggers of their emotions, learn new things about themselves, and find out the reasons behind experiencing various emotions to assist them to avoid bad days (Figure 19) hopefully. Emognition also uses this data to calibrate its algorithm for each user.

Figure 19. Emognition mobile application hi-fi prototype.

6. USER EVALUATION

Before conducting the actual user evaluation, we designed a pilot test (Figure 20). We followed our final test plan to determine if the prototypes work well and finalise our test materials (e.g., short videos). Although the prototypes worked well as we predicted, we found out one of the chosen videos was not the best choice to evoke happiness. Thus, we used another video in the actual user evaluation.

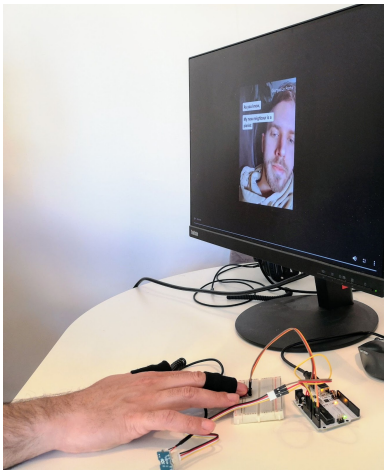


Figure 20. Pilot test.

Conducting the testing sessions with both target groups (autistic and non-autistic participants) was challenging due to the pandemic situation, so we had to limit the user evaluation scope and test the prototype with some non-autistic participants. Therefore, six non-autistic participants (three female and three male; age

range between 30 - 45) took part in the user evaluation. Each testing session was divided into two parts (testing the Emognition smartwatch and mobile application) and lasted approximately twenty minutes in total.

6.1. The Materials and Procedure

The testing sessions took place under pandemic restrictions, which had some implications on the testing environment since we could not use any lab facilities. The experiments were conducted in a private apartment setting under the observation of distance regulations and similar constraints. It is estimated that this did not affect the outcome to any significant degree.

The moderator asked each participant to sign a consent form (Appendix 6). Then, she helped the participants to wear the Emognition smartwatch on their wrists. The moderator's laptop was connected to the smartwatch to read the participant's HR and SCL data on the screens. At this stage, the prototype cannot calibrate its algorithm for each user; as such, the moderator had to do it manually. Initially, the neutral zone had to be defined by getting an average number from the participants' HR and SCL data in a minute. Based on those data, the moderator could calibrate the other zones (e.g., defining the happiness zone by increasing ten percent of the neutral zone data and sadness zone by decreasing ten percent of neutral zone data).

The participants watched short emotionally evocative videos[2] (two approximately four-minute videos) to induce specific emotions such as happiness and sadness for emotion elicitation (Figure 21).

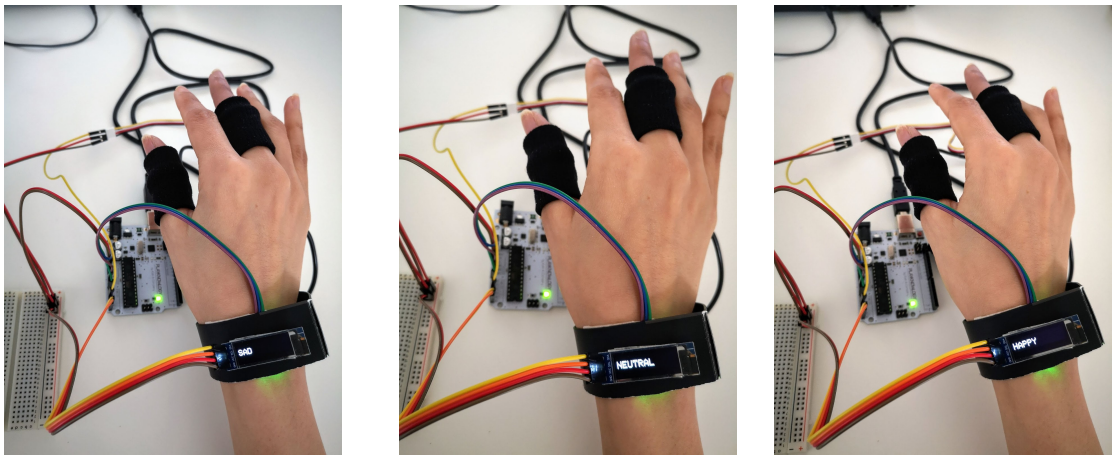


Figure 21. Participants are wearing the Emognition smartwatch prototype while watching the videos.

Since the primary goal of the evaluation was to understand if the Emognition smartwatch could recognise participants' emotions correctly, after the test, we asked participants some questions regarding their interpretation of their emotions while watching the videos to compare the answers with the results of the smartwatch.

Four questions were asked for each video. The first question was whether participants had seen the videos before. The second one was regarding the emotion they experienced while watching the videos, and we asked them to check one of the seven options (sadness, anger, happiness, disgust, fear, surprise, and

[2] Links to the videos are here: The first and second video.

others). If the participants checked “others”, they should specify which emotion they experienced. The third question was to rate the intensity of the emotion they experienced on a five-point scale, and the final question inquired whether they experienced any other emotions at the same intensity or higher and, if so, to specify what that emotion was.

We also evaluated the Emognition application prototype[3] with the participants (Figure 22). The main goal of the evaluation was to examine the usability aspect of the application. According to the ISO 9241–11:2018 (Ergonomics of human-system interaction), usability means *“the extent to which a product can be used by specified users to achieve the specified goals, with effectiveness, efficiency, and satisfaction in a specified user context.”*

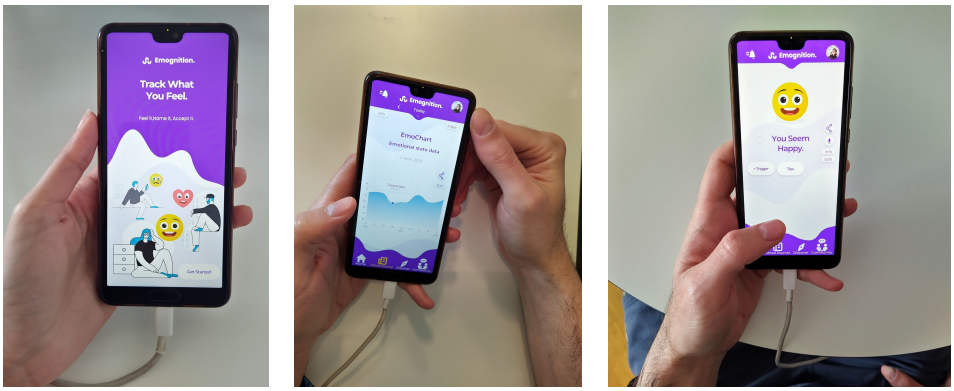


Figure 22. A participant interacting with the Emognition mobile application.

We asked participants to complete ten quick tasks (Appendix 7) to examine their interaction with the application. After that, we asked them to complete a usability post-test questionnaire (Appendix 8). During the test, participants were asked to use Think Aloud, an observational method, and let them describe their brain’s cognitive process through a verbal protocol (Benyon, 2014) to better understand the challenges they face and what they like and dislike. However, for some participants, it was not easy to think out loud and, at the same time, interact with the prototype. Benyon (2014) also argues that it is difficult for some people to describe an activity in words. Therefore, we let them complete the tasks, and we observed how they behaved or felt. We also measured each participant’s task completion time by a timer.

7. RESULT

7.1. Emognition Smartwatch Evaluation

None of the participants had watched the drama video before. However, one of them had watched the happy video. The following, Figure 23, shows the triggered emotions in each participant based on their responses.

[3] Link to Emognition application prototype is here.

All the participants experienced happiness by watching the first video while four participants experienced sadness and two participants became calm after watching the second video.

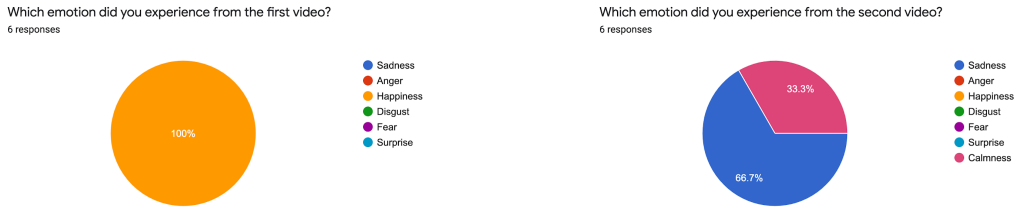


Figure 23. Triggered emotions in each participant based on their own responses.

Table 2 shows the HR and SCL patterns gathered by the Emognition smartwatch while participants were watching the videos. Most of these patterns are similar to the patterns presented in Table 1. For instance, according to Table 1, non-autistic people experience decreased HR and SCL when they are sad; similarly, Table 2 shows participants had decreased HR and SCL when watching the drama video.

Participant	Sensor	Sadness	Neutral	Happiness
No 1	HR	↓ 48	63	↑ 71
	SCL	↓ 278	356	↑ 389
No 2	HR	↓ 59	68	↑ 79
	SCL	↓ 365	378	↑ 398
No 3	HR	↓ 67	70	↑ 76
	SCL	↓ 387	398	↑ 410
No 4	HR	↓ 54	73	↑ 80
	SCL	↓ 358	389	-- 389
No 5	HR	↓ 54	74	↑ 85
	SCL	↓ 330	401	-- 401
No 6	HR	↑ 75	68	↑ 71
	SCL	-- 352	352	↑ 364

Table 2. HR and SCL patterns for sadness, neutral and happiness in participants. Arrows indicate increased (↑), decreased (↓), or no change (- -).

Since the Emognition smartwatch could gather similar patterns to Table 1, we can argue that it is promising to recognise sadness and happiness successfully by Emognition smartwatch. To ensure how well it recognised participants' emotions, we compared the smartwatch patterns with the participants' answers.

We discovered notable similarities between most patterns (Table 2) and what participants perceived as their emotional states (Figure 23). Therefore, the smartwatch worked successfully.

It was fascinating that the calm participants had similar HR and SCL patterns to sad participants but felt differently. Thus, we found out emotions are interleaved and relative to various factors. Also, triggers of emotions work differently from person to person, and the way we interpret our emotions is tricky. In addition, it might be the case that sadness and calmness may be signalling the same part of the spectrum. This kind of more detailed interaction between the emotional patterns will have to be explored in a further study.

The intensity of emotions was also different in participants. Based on the data (Figure 24), two participants cried due to the sad ending and rated five out of five on the scale, while another participant did not rate high (one on the five-point scale). So, we can argue, different people feel different intensities of emotions, and again it depends on various factors.

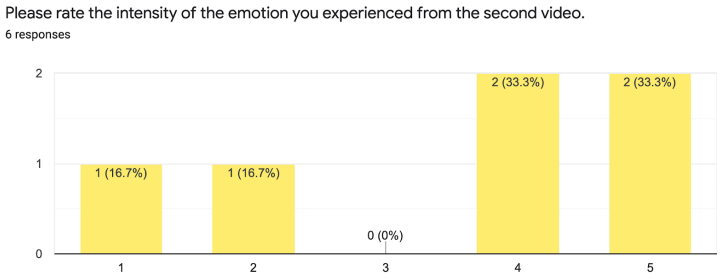


Figure 24. Participants rated the intensity of the emotion they experienced from the drama video.

Another interesting observation was that the measured intensity of happiness (Figure 25) was lower than the intensity of sadness (Figure 24) even though we could not find the report about the effect.

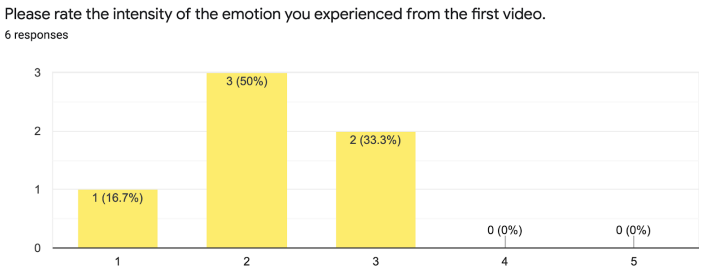


Figure 25. The highest rate for the happy video was three out of five.

7.2. Emognition Mobile Application Evaluation

The purpose of evaluating the mobile application was to examine its usability aspect in terms of efficiency, usefulness, ease of use, ease of learning, and satisfaction.

The task completion time was different for each participant. Nevertheless, most of them completed the tasks in approximately five minutes. Since five minutes is not a long time to complete ten tasks, we can argue that the mobile application works efficiently.

Half of the participants believed it is helpful to become more aware of their emotions (Figure 26). Also, most participants said the Emognition application does what they expect it to do. Based on the results, we conclude that the Emognition application prototype is useful.

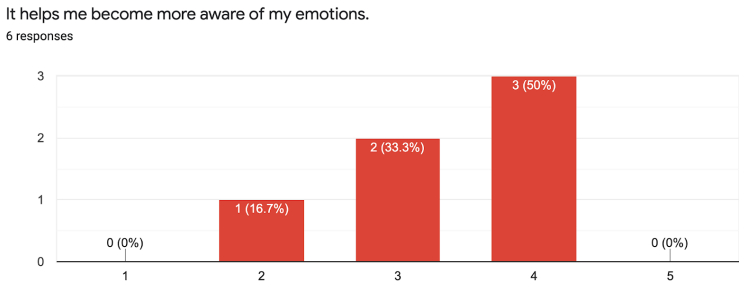


Figure 26. Half participants rated four out of five for the usefulness of the Emognition mobile application.

They all thought the Emognition application is easy to use, and there were no errors or difficulties while completing the tasks. Moreover, in terms of ease of learning, almost 80% of participants learned to use it very quickly (Figure 27).

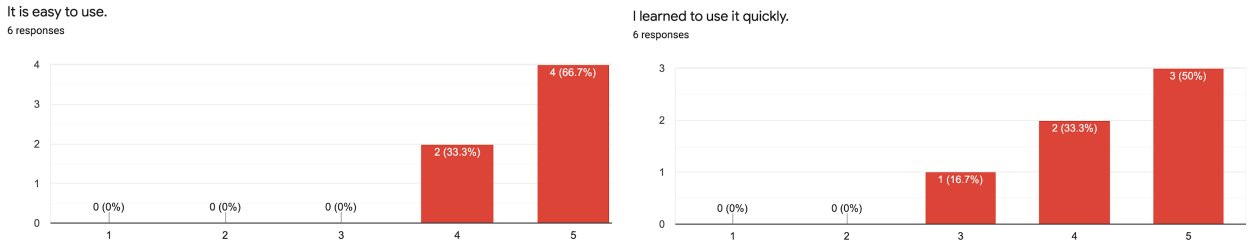


Figure 27. On the left participants rated the Emognition mobile application in terms of ease of use, on the right participants rated based on ease of learning.

The mobile application user interface was pretty appealing to the participants, and two of them mentioned it has nice colours and shapes that motivate them to continue working with it.

Half of the participants were satisfied with the application, and they would recommend it to their friends, while the other half were neutral (Figure 28).

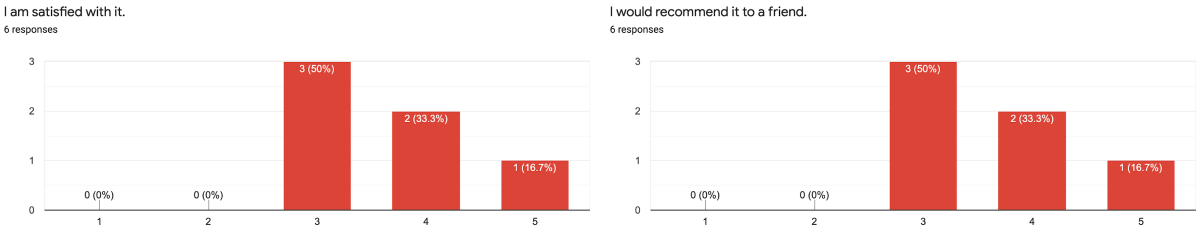


Figure 28. Participants rated the Emognition mobile application in terms of satisfaction.

Although we got interesting results from the interaction between non-autistic participants and the Emognition prototypes, we do not have results indicating how well the smartwatch prototype recognises autistic participants' emotions and how they would interact with the mobile application. Therefore, more research and evaluation sessions with both target groups need to be done to demonstrate that the Emognition prototype can overcome the gap and enhance emotional communication between them.

8. DISCUSSION

Based on what is known after literature review, interviews and questionnaires, there is evidence that bidirectional challenges exist between autistic and non-autistic individuals in reading each other's facial expressions and body posture. That is why they struggle to recognise each other's emotions. For instance, when an autistic person is sad, she shows a facial expression that a non-autistic person would not show when feeling the same emotion. Therefore, the non-autistic person gets confused and vice versa. Moreover, these two groups show different body movements that make emotional communication even more challenging. However, physiological signals are likely to work similarly in both groups when they experience emotion.

We also found out that autistic participants have few close relationships due to ineffective emotional communication, and they often cannot control their emotions. Furthermore, under stressful situations, they become, for example, non-verbal, which makes the close connections of autistic people worried about their emergencies.

In order to answer the second research question, which is mainly discovering ways to enhance emotional communication and then coming up with a design solution, initially, we tried to understand how we can measure emotions by novel technologies. Therefore, some emotion measurement methods were discovered after reviewing related works, each with its disadvantages and advantages. Indeed, more research needs to be done about which methods are the most accurate in measuring emotions. Nevertheless, it is promising that there is an increasing number of ways to measure emotions more accurately in the future. What is clear about measuring emotions is that each emotional signal has its unique impact on effective emotional

communication, and they work together more accurately. Their various weaknesses or strengths complete each other. For instance, a facial expression detector is useless when a subject's face is covered.

Another striking insight is the importance of the context in recognising emotions with almost all the measurement methods, so we considered adding different contexts to our design solution to recognise emotions more accurately.

After that, we started discovering various design possibilities. We focused on recognising sadness and happiness by measuring heart rate and skin conductance level since, according to studies, measuring autistic individuals' facial expressions and body posture are less effective than measuring physiological signals.

We planed to measure both autistic and non-autistic participants' sadness and happiness emotions, then blur the differences in their emotional signals and bridge the gap by displaying their emotions in an understandable way for both target groups through the Emognition prototype. However, due to pandemic restrictions and the lack of data in other studies regarding the effects of sadness and happiness on autistic people's HR and SCL patterns, we could not accomplish our goals. Thus, we had to limit the scope of the thesis in measuring non-autistic participants' sadness and happiness by Emognition prototype.

After Emognition smartwatch evaluation, we got impressive results. We can argue that the Emognition smartwatch could successfully recognise non-autistic participants' sadness and happiness as most of the participants' answers regarding their interpretations of their emotions were similar to what the Emognition smartwatch recognised. Also, participants found the mobile application useful, well-designed, and aesthetically attractive, that motivates some of them to continue working with the Emognition prototype.

Unfortunately, limiting the scope of the thesis to recognising non-autistic participants' emotions affected responding to the second research question. Hence, we do not have results if measuring autistic participants' sadness and happiness could be as successful as measuring non-autistic participants' sadness and happiness by the Emognition prototype to bridge the gap. However, we believe it is promising to successfully measure autistic individuals' sadness and happiness if we find accurate HR and SCL patterns as this is the main challenge of emotion recognition by the Emognition prototype.

We believe the scope of the user evaluation was insufficient to get the final accurate results. We need to test on more people from both target groups besides covering more emotions (e.g., calmness) and the interaction between the emotional patterns.

9. CONCLUSION

This thesis project discovered that differences in emotional signals lead to ineffective emotional communication between autistic and non-autistic people. We also reviewed some emotion measurement methods with their advantages and disadvantages to find good ways to measure autistic and non-autistic people's emotions through novel technology. Therefore, we found that measuring emotions by physiological signals is functional in both groups. Based on the results of the literature review on measuring emotions by physiological signals (heart rate and skin conductance level sensors), unstructured interviews, and online questionnaires answered by autistic and non-autistic participants, the Emognition prototype's concept was developed. We presented a prototype as Emognition smartwatch and its mobile application for the two target groups to enhance emotional communication.

Even though measuring non-autistic participants' emotions by physiological signals such as heart rate and skin conductance level was challenging, we got interesting results in the end. The smartwatch could

successfully recognise non-autistic participants' sadness and happiness, but we do not have sufficient data regarding how well the Emognition prototype could recognise autistic participants' sadness and happiness to bridge this gap. However, it is promising to measure autistic people's emotions successfully by accurate sensors and, more importantly, by finding their autonomic response patterns to different emotions. Therefore, the current result is indicative, and confirmation in a considerably more extensive and more representative sample is advised to draw a definite conclusion if the Emognition prototype can successfully bridge this gap and enhance emotional communication between autistic and non-autistic people.

9.1. Future Work

For future work, we need to cover recognising autistic people's emotions by running various workshops to find their autonomic response patterns while experiencing different emotions such as sadness and happiness. These patterns will also help us to recognise autistic people's emotions by the Emognition smartwatch. If emotion recognition happens successfully on both sides of the interaction (between the autistic and non-autistic people) through the Emognition prototype, we will hopefully bridge this gap.

Moreover, we will cover recognising more emotions from both target groups and discover the interaction between different emotional patterns. Analysing the interaction between different emotional patterns (e.g., calmness and sadness HR patterns) will lead to having a more accurate emotion recognition.

Furthermore, the prototypes need to be fully developed to evaluate the interaction between the smartwatch and the mobile application. It is also essential to see how well these prototypes interact with each other.

We will plan to test the prototypes on more autistic and non-autistic participants with diverse backgrounds to get a more accurate result, obtain more in-depth perception, and gather more reflection about the Emognition prototype from various viewpoints.

Another interesting future work would be adding more sensors to the Emognition prototype, like respiratory sensors, to measure the effect of various emotions on autistic and non-autistic people breathing. Each autonomic response may have different patterns while we are experiencing various emotions. Therefore, as an add-on accessory (e.g., a necklace), it applies respiratory data to the Emognition prototype to increase emotion recognition accuracy.

ACKNOWLEDGMENTS

First, I would like to thank my supervisor at Uppsala University, **Lars Oestreicheror**, for helping me to get started and for his advice that made problems easier for me to manage my thesis.

Lastly, and most importantly, I wish to give special thanks to my parents **Azar** and **Majid**, my sister **Maryam** and my beloved husband **Mazdak Rajabi Nasab**, who have always supported me. To them, I dedicate this thesis.

REFERENCES

Adib, F., Mao, H., Kabelac, Z., Katabi, D., & Miller, R. C. (2015). Smart Homes that Monitor Breathing and Heart Rate. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (pp. 837–846). Association for Computing Machinery. https://doi.org/10.1145/2702123.2702200

Allen, R., Davis, R., & Hill, E. (2013). The Effects of Autism and Alexithymia on Physiological and Verbal Responsiveness to Music. *Journal of Autism and Developmental Disorders*, *43*(2), 432–444. http://dx.doi.org.ezproxy.its.uu.se/10.1007/s10803-012-1587-8

Arroyo, I., Cooper, D. G., Burlesonb, A. W., Woolf, B. P., Muldner. (2009). Emotion sensors go to school. In V. Dimitrova, R. Mizoguchi, B. du

Boulay, & A. Graesser (Eds.), *Proceedings of the International Conference on Artificial Intelligence in Education* (pp. 17-24). Amsterdam, Netherlands: IOS Press. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.724.6879&rep=rep1&type=pdf

Begeer, S., Koot, H. M., Rieffe, C., Meerum Terwogt, M., & Stegge, H. (2008). Emotional competence in children with autism: Diagnostic criteria and empirical evidence. *Developmental Review*, *28*(3), 342–369. https://doi.org/10.1016/j.dr.2007.09.001

Benyon, D. (2014). Designing Interactive Systems: A comprehensive guide to HCI, UX and interaction design, 3/E. 5.

Berthoz, S., & Hill, E. L. (2005). The validity of using self-reports to assess emotion regulation abilities in adults with autism spectrum disorder. European Psychiatry, 20(3), 291–298. https://doi.org/10.1016/j.eurpsy.2004.06.013

Bieberich, A., & Morgan, S. (2004). Self-Regulation and Affective Expression During Play in Children with Autism or Down Syndrome: A Short-Term Longitudinal Study. *Journal of Autism and Developmental Disorders*, *34*, 439–448. https://doi.org/10.1023/B:JADD.0000037420.16169.28

Bispo, R., & Branco, V. (2008). Designing out stigma—The role of objects in the construction of disabled people´s identity. 5.

Bispo, R., & Branco, V. (2009). Designing out stigma – The potential of contradictory symbolic imagery. 6.

Borbasi, S., Jackson, D., & Wilkes, L. (2005). Fieldwork in nursing research: Positionality, practicalities and predicaments. Journal of Advanced Nursing, 51(5), 493–501. https://doi.org/10.1111/j.1365-2648.2005.03523.x

Burleson, W. (2011). Advancing a Multimodal Real-Time Affective Sensing Research Platform. In R. A. Calvo & S. K. D'Mello (Eds.), *New Perspectives on Affect and Learning Technologies* (pp. 97–112). Springer. https://doi.org/10.1007/978-1-4419-9625-1_8

Calvo, R. A., & D'Mello, S. (2010). Affect Detection: An Interdisciplinary Review of Models, Methods, and Their Applications. *IEEE Transactions on Affective Computing*, *1*(1), 18–37. https://doi.org/10.1109/T-AFFC.2010.1

Cohn, E. S., & Lyons, K. D. (2003). The Perils of Power in Interpretive Research. American Journal of Occupational Therapy, 57(1), 40–48. https://doi.org/10.5014/ajot.57.1.40

Cook, R., Brewer, R., Shah, P., & Bird, G. (2013). Alexithymia, Not Autism, Predicts Poor Recognition of Emotional Facial Expressions. *Psychological Science*, *24*(5), 723–732. https://doi.org/10.1177/0956797612463582

Craig, S. D., D'Mello, S., Witherspoon, A., & Graesser, A. (2008). Emote aloud during learning with AutoTutor: Applying the Facial Action Coding System to cognitive–affective states during learning. *Cognition & Emotion*, *22*(5), 777–788. https://doi.org/10.1080/02699930701516759

Czapinski, P., & Bryson, S. (2003). 9. Reduced facial muscle movements in Autism: Evidence for dysfunction in the neuromuscular pathway? *Brain and Cognition*, *51*(2), 177–179. https://doi.org/10.1016/S0278-2626(02)00541-9

D'Mello, S. K., & Graesser, A. (2010). Multimodal semi-automated affect detection from conversational cues, gross body language, and facial features. *User Modeling and User-Adapted Interaction*, *20*(2), 147–187. https://doi.org/10.1007/s11257-010-9074-4

Edey, R., Cook, J., Brewer, R., Johnson, M. H., Bird, G., & Press, C. (2016). Interaction takes two: Typical adults exhibit mind-blindness towards those with autism spectrum disorder. *Journal of Abnormal Psychology*, *125*(7), 879–885. https://doi.org/10.1037/abn0000199

Faso, D., Sasson, N., & Pinkham, A. (2014). Evaluating Posed and Evoked Facial Expressions of Emotion from Adults with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*. https://doi.org/10.1007/s10803-014-2194-7

Forbat, L., & Henderson, J. (2003). "Stuck in the Middle with You": The Ethics and Process of Qualitative Research the Two People in an Intimate Relationship. Qualitative Health Research, 13(10), 1453–1462. https://doi.org/10.1177/1049732303255836

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor Coordination in Autism Spectrum Disorders: A Synthesis and Meta-Analysis. *J Autism Dev Disord*, 14.

Garnham, A., & Oakhill, J. (2013). Mental Models In Cognitive Science: Essays In Honour Of Phil Johnson-Laird. Psychology Press.

Grafsgaard, J. F., Wiggins, B., Boyer, K., Wiebe, E., Lester, J. (2014). Predicting Learning and Affect from Multimodal Data Streams in Task-Oriented Tutorial Dialogue. 8.

Groden, J., Goodwin, M. S., Baron, M. G., Groden, G., Velicer, W. F., Lipsitt, L. P., Hofmann, S. G., & Plummer, B. (2005). Assessing Cardiovascular Responses to Stressors in Individuals With Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, *20*(4), 244–252. https://doi.org/10.1177/10883576050200040601

Grossman, R., Edelson, L., Tager-Flusberg, H. (2013). Emotional Facial and Vocal Expressions During Story Retelling by Children and Adolescents With High-Functioning Autism | Journal of Speech, Language, and Hearing Research. (n.d.). Retrieved January 10, 2021. https://pubs.asha.org/doi/full/10.1044/1092-4388%282012/12-0067%29?casa_token=r7nlWts9CAwAAAAA:c3BbO09eHh69ikFzTU1Gy51hzl86OyV09aND2Ds1roXslLFLqdo822SW00KO5mqsKwUTMLG_W2Xtsgs

Hadjikhani, N., Joseph, R. M., Manoach, D. S., Naik, P., Snyder, J., Dominick, K., Hoge, R., Van den Stock, J., Flusberg, H. T., & de Gelder, B. (2009). Body expressions of emotion do not trigger fear contagion in autism spectrum disorder. *Social Cognitive and Affective Neuroscience*, *4*(1), 70–78. https://doi.org/10.1093/scan/nsn038

Halberstadt, A. G., Denham, S. A., & Dunsmore, J. C. (2001). Affective Social Competence. *Social Development*, *10*(1), 79–119. https://doi.org/10.1111/1467-9507.00150

Harley, J. (2015). Measuring Emotions: A Survey of Cutting-Edge Methodologies Used in Computer-Based Learning Environment Research (pp. 89–114).

Hart, C. (2018). Doing a literature review: Releasing the research imagination. *Evaluation & Research in Education*, *24*(4), 303–304.

Hill, E., Berthoz, S., & Frith, U. (2004). Brief report: Cognitive processing of own emotions in individuals with autistic spectrum disorder and in

their relatives. J Autism Dev Disord. 34:229–235.

Hobson, P.R. (1989) 'Beyond Cognition', in G. DAWSON (ed.) *Autism: Nature, Diagnosis and Treatment.* New York: Guilford.

Honkalampi, K., Hintikka, J., Tanskanen, A., Lehtonen, J., & Viinamäki, H. (2000). Depression is strongly associated with alexithymia in the general population. *Journal of Psychosomatic Research*, *48*(1), 99–104. https://doi.org/10.1016/S0022-3999(99)00083-5

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Fonséca, D. D., & Deruelle, C. (2007). Brief Report: Recognition of Emotional and Non-emotional Biological Motion in Individuals with Autistic Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *37*(7), 1386–1392. https://doi.org/10.1007/s10803-006-0275-y

ISO 9241-11:2018. ISO. Retrieved May 15, 2021, from https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/35/63500.html

Jansen, L. M. C., Gispen-de Wied, C. C., Wiegant, V. M., Westenberg, H. G. M., Lahuis, B. E., & van Engeland, H. (2006). Autonomic and Neuroendocrine Responses to a Psychosocial Stressor in Adults with Autistic Spectrum Disorder. *Journal of Autism and Developmental Disorders*, *36*(7), 891–899. https://doi.org/10.1007/s10803-006-0124-z

Jones, R. S. P., Zahl, A., & Huws, J. C. (2001). First-hand Accounts of Emotional Experiences in Autism: A qualitative analysis. *Disability & Society*, *16*(3), 393–401. https://doi.org/10.1080/09687590120045950

Kaptelinin, V. (2014). Affordances and design. Denmark: Interaction Design Foundation.

Kreibig, S. D. (2010). Autonomic nervous system activity in emotion: A review. Biological Psychology, 84(3), 394–421. https://doi.org/10.1016/j.biopsycho.2010.03.010

Krupa, N., Anantharam, K., Sanker, M., Datta, S., & Sagar, J. V. (2016). Recognition of emotions in autistic children using physiological signals. *Health and Technology*, *6*(2), 137–147. https://doi.org/10.1007/s12553-016-0129-3

Langdell, T. (1981). *Face perception: An approach to the study of autism* [Ph.D., University of London]. https://discovery.ucl.ac.uk/id/eprint/1317720/

Liu, C., Conn, K., Sarkar, N., & Stone, W. (2008). Physiology-based affect recognition for computer-assisted intervention of children with Autism Spectrum Disorder. *International Journal of Human-Computer Studies*, *66*(9), 662–677. https://doi.org/10.1016/j.ijhsc.2008.04.003

McDuff, D., Mahmoud, A., Mavadati, M., Amr, M., Turcot, J., & Kaliouby, R. el. (2016). AFFDEX SDK: A Cross-Platform Real-Time Multi-Face Expression Recognition Toolkit. *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, 3723–3726. https://doi.org/10.1145/2851581.2890247

MITCSAIL. (2016). *EQ-Radio: Emotion Recognition using Wireless Signals*. https://www.youtube.com/watch?v=nmcDnEhZTJM&feature=emb_title

Peled, E., & Leichtentritt, R. (2002). The Ethics of Qualitative Social Work Research. Qualitative Social Work, 1(2), 145–169. https://doi.org/10.1177/147332500200100203

Picard, R. W. (2009). Future affective technology for autism and emotion communication. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1535), 3575–3584. https://doi.org/10.1098/rstb.2009.0143

Robledo, J., Donnellan, A. M., & Strandt-Conroy, K. (2012). An exploration of sensory and movement differences from the perspective of individuals with autism. Frontiers in Integrative Neuroscience, 6. https://doi.org/10.3389/fnint.2012.00107

Rodrigo, Ma. M. T., & Baker, R. S. J. d. (2011). Comparing the Incidence and Persistence of Learners' Affect During Interactions with Different Educational Software Packages. In R. A. Calvo & S. K. D'Mello (Eds.), *New Perspectives on Affect and Learning Technologies* (pp. 183–200). Springer. https://doi.org/10.1007/978-1-4419-9625-1_14

Sherer, M.R., Schreibman, L. (2005). Individual behavioral profiles and predictors of treatment effectiveness for children with autism. J. Consult. Clin. Psychol. 2005, 73, 525, doi:10.1037/0022-006X.73.3.525.

Shu, L., Xie, J., Yang, M., Li, Z., Li, Z., Liao, D., Xu, X., & Yang, X. (2018). A Review of Emotion Recognition Using Physiological Signals. *Sensors*, *18*(7), 2074. https://doi.org/10.3390/s18072074

Somberg, B. L. (2000). Procedural Consistency in the User Interface. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 44(2), 307–310. https://doi.org/10.1177/154193120004400203

Stagg, S. D., Slavny, R., Hand, C., Cardoso, A., & Smith, P. (2014). Does facial expressivity count? How typically developing children respond initially to children with autism. *Autism*, *18*(6), 704–711. https://doi.org/10.1177/1362361313492392

Stein, N. L., & Levine, L. J. (1989). The Causal Organisation of Emotional Knowledge: A Developmental Study. *Cognition and Emotion*, *3*(4), 343–378. https://doi.org/10.1080/02699938908412712

Swart, M., Kortekaas, R., & Aleman, A. (2009). Dealing with Feelings: Characterization of Trait Alexithymia on Emotion Regulation Strategies and Cognitive-Emotional Processing. *PLOS ONE*, *4*(6), e5751. https://doi.org/10.1371/journal.pone.0005751

Tanguay, P. E. (1990). Early infantile autism: What have we learned in the past 50 years? *Brain Dysfunction*, *3*(5–6), 197–207.

Calvo, R. A., & D'Mello, S. (2010). Affect Detection: An Interdisciplinary Review of Models, Methods, and Their Applications. *IEEE Transactions on Affective Computing*, *1*(1), 18–37. https://doi.org/10.1109/T-AFFC.2010.1

Volker, M. A., Lopata, C., Smith, D. A., & Thomeer, M. L. (2009). Facial Encoding of Children with High-Functioning Autism Spectrum Disorders. *Focus on Autism and Other Developmental Disabilities*, *24*(4), 195–204. https://doi.org/10.1177/1088357609347325

Wiley Online Library. (n.d.), Retrieved January 6, 2021. Facial Expression Production in Autism: A Meta-Analysis—Trevisan—2018—Autism Research. from https://onlinelibrary.wiley.com/doi/abs/10.1002/aur.2037

Wioleta, S. (2013). Using physiological signals for emotion recognition. *2013 6th International Conference on Human System Interactions (HSI)*, 556–561. https://doi.org/10.1109/HSI.2013.6577880

Woolf, B., Burleson, W., Arroyo, I., Dragon, T., Cooper, D., & Picard, R. (2009). Affect-aware tutors: Recognising and responding to student affect. *International Journal of Learning Technology*, *4*(3/4), 129. https://doi.org/10.1504/IJLT.2009.028804

Wrnch. (2018, June 16). *Frictionless Behaviour Capture*. https://www.youtube.com/watch?v=pzylMhlhRY4 https://wrnch.ai/

Yirmiya, N., Kasari, C., Sigman, M., & Mundy, P. (1989). Facial Expressions of Affect in Autistic, Mentally Retarded and Normal Children. *Journal of Child Psychology and Psychiatry*, *30*(5), 725–735. https://doi.org/10.1111/j.1469-7610.1989.tb00785.x

Zhao, M., Adib, F., & Katabi, D. (2016). Emotion recognition using wireless signals. Proceedings of the 22nd Annual International Conference on Mobile Computing and Networking,95–108. https://doi.org/10.1145/2973750.2973762

APPENDIX 1

Interview questions to establish caregivers' background and the challenges they face while communicating emotions with autistic individuals.

1. What is your name?
2. What is your age?
3. What is your job title?
4. How many years of experience do you have as a caregiver?
5. How do you usually communicate emotions with autistic people?
6. Is it usually verbal or nonverbal emotional communication? Why?
7. Have you ever struggled to understand what autistic people feel? If so, what were the reasons?
8. Do they express their basic emotions(e.g., happiness, fear, anger) differently from TD (typically developing) individuals? If so, give an example.
9. How do they express/show their basic emotions(e.g., happiness, fear, anger)?
10. Do you still have the challenge to understand their feelings after all these years of experience?
11. Why do you think it is still challenging?
12. Are there emotional communication barriers? If so, what are they?
13. When you cannot understand how they feel, do they act differently? Do they show unusual behaviour/aggression?
14. When you cannot understand how they feel, how do you feel? Does it negatively affect your mood?
15. When you can understand their emotions correctly, how do they react? How do you feel afterward?
16. Do they usually understand what you feel without saying it? (by your body language, tone of voice and etc)
17. Do they need special help with their emotional communication?
18. Do they use any aid tools? What is its name? Are there any pros and cons?
19. How do you help them to have effective emotional communication with you?
20. Do you provide any aid tools for them? If so, what is its name? Are there any pros and cons?

APPENDIX 2

Interview questions to establish autistic individuals' background and the challenges they face while communicating emotions with their caregivers.

1. What is your name?
2. What is your age?

3. What is your level of ASD? (Level 1 ASD: Requiring Support, Level 2 ASD: Requiring Substantial Support, Level 3 ASD: Requiring Very Substantial Support)
4. At what age have you been diagnosed with ASD?
5. How do you usually communicate emotions with people? Is it usually verbal or nonverbal emotional communication? Why?
6. Do you prefer nonverbal emotional communication?
7. Have you ever struggled to understand what non-autistic people feel? If so, what were the reasons?
8. Do they express their basic emotions(e.g., happiness, fear, anger) differently from how you express your emotions? If so, give an example.
9. When you cannot understand how they feel, what do they do?
10. When you cannot understand how they feel, how do you feel? Does it negatively affect your mood?
11. When you can understand their emotions correctly, how do you feel?
12. Do they usually understand what you feel without saying it? (by your body language, tone of voice and etc)
13. Do you need special help with your emotional communication?
14. Do you use any aid tools? If so, what is its name? Are there any pros and cons?
15. If a tool helps you to understand people's/your emotions, do you use it?

APPENDIX 3

Questionnaire questions to establish autistic people's background and the challenges they face while communicating emotions with their family and close friends.

Demographic Questions:

- What is your age?
- What is your gender?
- Where do you live?
- What is your level of ASD?
- What is your relationship status?

1. I am not comfortable with expressing .... emotion/s. (select your choices)
    1. Happiness
    2. Fear
    3. Anger
    4. Sadness
    5. Disgust
    6. Surprise
2. When asked which emotion I'm feeling, I frequently don't know the answer.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree

3. I'm unsure of which words to use when describing my feelings.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
4. I usually do not understand how others feel.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
5. I am not comfortable with understanding others'.... emotion/s. (select your choices)
    1. Happiness
    2. Fear
    3. Anger
    4. Sadness
    5. Disgust
    6. Surprise
6. I easily recognise others'.... emotion/s. (select your choices)
    1. Happiness
    2. Fear
    3. Anger
    4. Sadness
    5. Disgust
    6. Surprise
7. I do not care about the others' emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
8. I do not care about my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
9. When people do not understand my emotions I feel lonely.
    1. Strongly disagree
    2. Somewhat disagree

3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

10. I do not have close relationships because we cannot communicate our emotions effectively.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
11. I do not have any friends to talk about my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
12. I probably had more close friends if we could have effective emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
13. I do not care if I do not have close friends.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
14. I do not want anyone to understand my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
15. I do not want to understand anyone's emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
16. I would rather understand people's emotions whenever I want.
    1. Strongly disagree

2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

17. I prefer to share my emotions whenever I like.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
18. I express my happiness by … (open answer)
19. I express my Fear by … (open answer)
20. I express my Anger by … (open answer)
21. I express my Sadness by … (open answer)
22. I express my Disgust by … (open answer)
23. I express my Surprise by … (open answer)
24. Emotional communication is essential for intimate relationships.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
25. I do not need emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
26. I am not confident in expressing my emotions as people cannot understand them.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
27. I rarely express my emotions because I am afraid of not being understood.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
28. I prefer people to understand what I am feeling without verbal communication.

1. Strongly disagree
2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

29. I prefer verbal emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
30. I always talk about my emotions with people.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
31. I feel relieved when people understand my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
32. I always cannot control my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
33. Not being able to control my emotions caused problems.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
34. I need to control my emotions better.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree

35. I control my emotions surprisingly well.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
36. I usually experience a rollercoaster of emotions that causes ambiguity in what I am feeling exactly.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
37. I can have a better emotional expression in special places or conditions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
38. Most of the time, people ignore my emotions because they cannot understand what I am feeling.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
39. I feel happy when … (open answer)
40. I feel Fearful when … (open answer)
41. I feel Angry when … (open answer)
42. I feel Sad when … (open answer)
43. I feel Disgusted when … (open answer)
44. I feel Surprised when … (open answer)
45. When I am happy, I can easily laugh.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
46. When I am sad, I can easily cry.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree

5. Strongly agree

47. What do you do when you are happy? (open answer)
48. What do you do when you are fearful? (open answer)
49. What do you do when you are angry? (open answer)
50. What do you do when you are sad? (open answer)
51. What do you do when you are disgusted? (open answer)
52. What do you do when you are Surprised? (open answer)
53. I always experience strong/intense emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
54. When I am sad, I cannot change my mood, and I become depressed.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
55. My emotions can be easily changed from intense happiness to intense depression.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
56. I use methods/tools to help me understand what emotion I feel.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
57. I need someone to guide me on what I am feeling.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
58. I need someone to guide me through what others are feeling.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree

    4. Somewhat agree
    5. Strongly agree

59. I would like to have a tool to guide me through my emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
60. If you already use any aid tools for your emotional communication, what is its name? (open answer)
61. If you already use any aid tools for your emotional communication, what is its pros and cons? (open answer)

APPENDIX 4

Questionnaire questions to establish autistic people's family or close friends background and the challenges they face while communicating emotions with their autistic children or friends.

Demographic Questions:

- What is your age?
- What is your gender?
- Where do you live?
- What is your child/ren level of ASD?
- What is your relationship status?

1. I notice that my son/daughter is not comfortable with understanding my.... emotion/s.
    1. Happiness
    2. Fear
    3. Anger
    4. Sadness
    5. Disgust
    6. Surprise
2. Most of the time I have difficulties understanding what my son/daughter feels.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
3. I have difficulties communicating emotions with my son/daughter.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
4. I have difficulties communicating emotions with my son/daughter when there are just the two of us.

1. Strongly disagree
2. Somewhat disagree
3. Neither agree nor disagree
4. Somewhat agree
5. Strongly agree

5. I have difficulties communicating emotions with my son/daughter when there are other persons in the same room.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
6. I feel depressed when my son/daughter doesn't understand my emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
7. I feel depressed when I don't understand my son's/daughter's emotions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
8. I get upset when I notice my son/daughter doesn't initiate emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
9. Most of the time I feel that I do not understand my son's/daughter's emotional expressions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
10. I feel that my son/daughter does not understand my emotional expressions.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree

5. Strongly agree

11. I notice that some people make fun of my son/daughter when he/she tries to express emotions.
    1. Strongly disagree
    6. Somewhat disagree
    7. Neither agree nor disagree
    8. Somewhat agree
    9. Strongly agree
12. I always communicate my emotions to my son/daughter even if he/she doesn't share their emotions to me.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
13. I notice that my son/daughter express emotions that are not adequate to the moment or the context.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
14. I have the impression that my son/daughter has few friends because of lack of effective emotional communication.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
15. I worry about my son/daughter staying single.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
16. I would like to have an aid tool to make emotional communication easier between me and my child.
    1. Strongly disagree
    2. Somewhat disagree
    3. Neither agree nor disagree
    4. Somewhat agree
    5. Strongly agree
17. If you already use any aid tools for your emotional communication, what is its name? (open answer)

18. If you already use any aid tools for your emotional communication, what is its pros and cons? (open answer)

APPENDIX 5

The online consent form was created in Google forms, filled out by participants before the interviews.

Please fill the form after keenly going through the instructions.
This master thesis project is conducted by one of the students studying HCI at Uppsala University. This study aims to measure the satisfaction of emotional communication between people with ASD and typically developing individuals and enhance the emotional communication between them.
You are invited to participate in this study because you are a fit candidate. Your participation is voluntary. If you decide not to participate, or you decide to withdraw from participating at any time contact mina.abouei.7164@student.uu.se.
We will do our best to keep your information confidential to keep in compliance with GDPR. Your answers will be collected through an over-the-phone interview, and we will record your voice. All the data will be stored in a password-protected electronic format. For protecting you confidentially, we will not share any information for identifying you. The results will only be used for scholarly purposes and may be shared with the Uppsala University teacher.

Sign yourself if you agree with the following statements:
1. You are at least 18 years old.
2. You have agreed with the above information.
3. You voluntarily agree to participate.

Consent:*
Yes
No

Full name:*
Would you like to be anonymous?*
Yes
No

Date:*

APPENDIX 6

The online consent form was created in Google forms, filled out by participants before the usability evaluation sessions.

Please fill the form after keenly going through the instructions.

This master thesis project is conducted by one of the students studying HCI at Uppsala University. This study aims to measure the satisfaction of emotional communication between autistic and non-autistic individuals and enhance the emotional communication between them.
Your participation is voluntary. If you decide not to participate, or you decide to withdraw from participating at any time contact mina.abouei.7164@student.uu.se.
We will do our best to keep your information confidential to keep in compliance with GDPR. We will record some of your physiological signals such as heart rate and galvanic skin response through sensors. All the data will be stored in a password-protected electronic format. For protecting you confidentially, we will not share any information for identifying you. The results will only be used for scholarly purposes and may be shared with the Uppsala University teacher.

Sign yourself if you agree with the following statements:
1. You are at least 18 years old.
2. You have agreed with the above information.
3. You voluntarily agree to participate.

Consent:*
Yes
No

Full name:*
Would you like to be anonymous?*
Yes
No
Date:*

APPENDIX 7

Participants completed these tasks while interacting with the Emognition mobile application during usability evaluation sessions.

1. Create your account.
2. Check your current emotional state.
3. Share your emotion on Facebook.
4. Check “Tips” about your current emotion.
5. Add a “Trigger” that you are going to watch a drama video.
6. Add a “Trigger” by voice that you are going to watch a happy video.
7. Open “Mood Journal” and check your today’s EmoChart.
8. Check out yesterday’s EmoChart.
9. Discover new programs and challenges.
10. Open “Community” and find the chat with “Emergency contact”.

APPENDIX 8

Emognition Mobile Application post-test questionnaire. Participants rated their agreement from 1 (Strongly disagree) to 5 (Strongly agree).

Usefulness:

1. It is useful.
2. It helps me become more aware of my emotions.
3. It has many errors and/or crashed.
4. It does everything I would expect it to do.

Ease of use:

1. It is easy to use.
2. It is user friendly.
3. Using it is effortless.
4. I can use it successfully every time.

Ease of learning:

1. I learned to use it quickly.
2. I quickly became skilful with it.

Satisfaction:

1. I am satisfied with it.
2. I would recommend it to a friend.
3. It is fun to use.