UNIVERSITY OF TWENTE.

Faculty of Behavioural, Management, and Social Sciences

The intra-individual relationship between core affect and skin conductance in daily life – An experience-sampling study

Lena Franke

B.Sc. Thesis

June 2019

Supervisors:

1st Dr. M. L. Noordzij

2nd Dr. M. Radstaak

Faculty of Behavioural, Management and Social Sciences

Department of Psychology, Health, and Technology

Objective. In the last few years, there has been an increasing interest in how physiological signals, such as skin conductance, are related to emotions and in whether wearable technology can be used to benefit from this relationship. Although a coherence between the two constructs is often postulated, earlier studies found inconsistent results. Importantly, almost none of them focused on emotions in a daily life setting and on the individual level. Based on that, the current study investigated the relationship between skin conductance and self-reported core affect – as a means to measure emotions – on an intra-individual level and in an everyday context.
Method. In total 23 subjects, mainly German and Dutch, with an age ranging between 19 and 70 participated. Their level of SC, measured with the E4 wearable by Empatica, as well as their self-reported core affect, measured with a smartphone application, were captured for 7 days through the method of experience sampling. The correlations were applied for each individual separately.
Results. In contrast to most inter-individual studies, no clear relationship was found between the core affect dimensions and skin conductance. Most individuals did show no or very weak associations. Regarding the arousal dimension the average intra-individual correlation was -.065 (SD = .29) with 95% CI [-.193, .064]. The mean of the intra-individual correlation regarding the valence dimension was .032 (SD = .238) with 95% CI [-.08, .126].
Discussion. On the individual level, the postulated coherence between physiological signals and emotions was not substantiated which challenges the findings from earlier research. The current study addressed the previous methodological difficulties to increase the generalizability to the individual level and to an everyday context. It is suggested to compare healthy individuals with individuals suffering from emotion recognition difficulties and to investigate other factors that might be of higher importance, such as personality traits or interoceptive awareness.

Table of Content

Introduction

In the last few years there has been increasing interest in the relationship between physiological signals and everyday human feelings and in how technology, particularly wearable bio-sensors, can help to benefit from this relationship (Bonato, 2003, Fletcher, Ming-Zher Poh, & Eydgahi, 2010; Peira, Pourtois, & Fredrikson, 2013; Ragot, Martin, Pallamin, & Diverrez, 2017). Since wearable sensors are measuring the body's nervous system activity, they are said to provide an opportunity to measure psychological phenomena that are related to this activity and thus, also help to understand human feelings. Two of the physiological signals used to measure the activity of the nervous system are heart rate (HR) and skin conductance (SC) (Kreibig, 2010). Fluctuations in these signals are often operationalized to some form of psychological experience.

Investigating the relationship between emotional experiences and physiological signals has several benefits within the field of Psychophysiology and Mental Health. Many people have difficulties to be aware of, to recognize, and to regulate their emotions, particularly individuals suffering from mental disorders related to stress and anxiety as well as borderline personality disorder and Autism (Derks, Visser, Bohlmeijer, & Noordzij, 2017; Fletcher et al. 2010; Picard, 2009). Hence, developing methods that operationalize physiological signals to emotions could be an immense help for sufferers as well as for relatives and health care workers.

There are already different studies that researched the relationship between physiological signals and emotional experiences. Many of those studies were measuring physiological signals in the laboratory and investigated emotions that were experimentally induced through film clips or affective sounds (Aboulafia-Brakha et al., 2016; Fernández et al., 2012; Khezri et al., 2015; Kreibig, 2010; Stephens, Christie, and Friedman, 2010). For example, Khezri et al. (2015) were able to predict different emotions by measuring different physiological signals in the laboratory with an accuracy of 80 percent. This provides evidence for a strong relationship between the nervous system activity and emotions on the aggregated group level. However, few of the earlier studies focused on wearable sensors that can be used outside laboratories and enable to measure physiological activity and emotions in everyday life and in the moment in which the emotions are activated. This is said to have several advantages in terms of generalizability to daily life and will be considered by the current study. (Conner & Feldman Barrett, 2012; Loeffler, Myrtek, & Peper, 2013; Myrtek & Brügner, 1996; Myrtek, Aschenbrenner, & Brügner, 2005).

Further, little research has focused on the intra-individual level between emotions and bodily signals but applied inter-individual research designs (Aboulafia-Brakha, Allain, & Ptak, 2016; Fernández, Pascual, Soler, Elices, Portella, & Fernández-Abascal, 2012; Kreibig, 2010). This means that conclusions were based on group averages which were then generalized to the individual level. However, due to the fluctuating nature and high variance of emotional experiences as well as of physiological signals, the validity of the results derived by inter-individual methods is questionable (Fisher, Medaglia, & Jeronimus, 2018; Molenaar & Campbell, 2009; Van Geert & Van Dijk, 2002). Since wrong conclusions based on group averages could have detrimental effects, the focus of the current study lies on the individual level. Besides, attention is paid to the benefits of wearable biosensors in capturing everyday physiological signals and emotions. Therefore, the aim of the current study is to investigate the relationship between physiological signals and emotions on an intra-individual level and in an everyday context.

Definitions and understanding of emotions and core affect

In everyday life, an emotion is defined as "a strong feeling deriving from one's circumstances, mood, or relationships with others" such as fear, anger, sadness, and happiness (Oxford Dictionary). However, among researchers, there is little consensus on what emotions are, what they entail, and how they are elicited. The same accounts for the relationship between nervous system activity and emotions (Barrett, 2009; Desmet, 2008; Levonson, 2014; Stephens, Christie, & Friedman, 2010). One concept related to emotions is Core Affect which describes a neurophysiological state with two dimensions which combined result in a continuous affective state (Russell, 2009). Specifically, Core Affect is an umbrella term for all subjective experiences that are valanced and also entail some form of physiological arousal. Accordingly, the first dimension of Russell's two-dimensional model (Russel, 2003), valence, ranges from displeasure to pleasure and the second dimension is related to the level of arousal and ranges from deactivation to activation (Desmet, 2008; Russel, 2009). Importantly, Core Affect is always present in some state as it continuously responds to internal stimuli, such as hormonal changes and nutritional deficiencies, and to external stimuli, such as events, people, objects, and weather (Desmet, 2008; Russel, 2009).

Since the two-dimensional model of Core Affect includes all affective reactions, it allows measuring a wide range of emotions as they can be placed onto the two dimensions. For example, a high level of arousal and pleasure could result in a feeling of ecstasy (Desmet, 2008; Russel, 2009). This has the advantage that emotions are captured regardless of their kind with only one or two questions. It ensures that there is sufficient and varying data for each individual. In contrast, when focusing on a few specific emotions, such as anger, it is not likely that there is high variance within one individual during one day. For these reasons, the current study will focus on the concept of Core Affect in order to be able to capture all kinds of emotional states.

Autonomic nervous system activity and its relation to emotions

The autonomic nervous system (ANS) is responsible for the monitoring and regulation of our organism and regulates the organism's adjustments to internal as well as to external demands (Levenson, 2014). It monitors and coordinates the different signals from a network of nerves, organs, and other biological sensors and communicates between those. Based on these signals, the ANS is eliciting all responses in the organism in order to react appropriately to the internal and external cues (Levenson, 2014). Thereby the ANS is either increasing (sympathetic nervous system) or decreasing (parasympathetic nervous system) the physiological activity in the organism. Thus, the ANS functions as a regulator, activator, coordinator, and communicator (Levenson, 2014). Regarding emotions, it is important to consider that the ANS does not only regulate the activity in the target organs but also sends signals from the organs' conditions to the brain. Hence, the organs' states, such as the activity of efferent nerves in the skin, are important feedback for the brain to make interpretations of, for example, emotional arousal (Levenson, 2014). Accordingly, measuring the state of the target organs is an indicator for ANS activity and the ANS activity might, in turn, be related to cognitive and emotional arousal.

The definition and role of skin conductance

Most studies in the field of ANS focused on the level of skin conductance (SC) and heart rate (variability) (HR(V)) as physiological measures for ANS activity (Fernández et al., 2012; Kreibig, 2010). SC is an indicator for sympathetic (increasing) nervous system activity and HR(V) for both sympathetic and parasympathetic (decreasing) activity. Electrodermal Activity (EDA), indicated by the level of SC, is also one of the most frequently used forms of physiological recording in psychophysiology (Boucsein, 2012; Kreibig, 2010). The term was first referred to and defined by Johnson and Lubin (1966). According to them, the term includes all electrical reactions that happen in the skin, one of which is the activity of the sweat glands that are conducting sweat through the layers of the skin to its surface (Boucsein, 2012; Johnson & Lubin, 1966). Thus, autonomic stimulation of the sweat glands is reflected in changes in the level of SC whereof the glands on the palms of the hands and feet are held to be associated with emotion-evoked sweating (Boucsein, 2012; Critchley, 2002; Dawson, Schell, & Fillion, 2002). The level of the skin's electrical conductance depends on external as well as on physiological and psychological conditions and reflects changes in the autonomic sympathetic arousal which is said to be related to emotional and cognitive states (Critchley, 2002). This is why it can be argued that measuring the level of SC is a suitable method for estimating emotional arousal.

Emotions, core affect and the relation to skin conductance and other physiological signals

As stated above, different studies investigated the relationship between emotions and physiological signals. In her systematic review, Kreibig (2010) concluded that ANS activity is seen as a major component of emotions in most modern theories. She compared different studies that focused on the various emotions, ranging from positive, such as happiness, amusement, and affection, to negative, such as fear, anger, and sadness. Specifically, most negative emotions are accompanied by an activation of the sympathetic nervous system which was represented by an increased HR and level of SC (Kreibig, 2010). A similar pattern, although less consistent with regard to the direction of activation, was found for positive emotions.

In line with the review of Kreibig (2010), are the studies of Aboulafia-Brakha et al. (2016), Fernández et al. (2012), and Stephens, Christie, and Friedman (2010). These studies focused mainly on the emotion anger and found that sympathetic arousal, in terms of the level of SC, increases when observing anger-inducing film clips as well as when recalling a past anger-inducing event. Additionally, the study of Aboulafia-Brakha et al. (2016) compared the emotion-physiology relationship of patients suffering from emotional regulation and recognition problems with a healthy control group. The former participants were reporting less perceived anger and at the same time lower levels of SC than the control group which is a further indication for a relationship between SC and emotions.

Further, a quadrant similar to the core affect quadrant by Russel (1989) was used by Nardelli, Valenza, Greco, Lantana, and Scilingo (2015) who aimed to estimate emotional states by means of ANS activity. To establish an emotion categorization system, four different levels of arousal and two different levels of valence were used. Thereby, they found that HRV fluctuated significantly on both, the arousal and valence dimension, and ultimately achieved an emotion recognition accuracy of 84.72% on the valence and of 84.26% on the arousal dimension (Nardelli et al., 2015). First, this indicates that the core affect dimensions are a sufficient measure for several emotions. Second, it is a further sign for a correlation between ANS signals and emotions or core affect. Whether this pattern can be replicated by focusing on the level of SC rather than HRV will be shown by the current study. Similar studies are those of Okada et al. (2018) and Ragot et al. (2017) who were able to use physiological measures to classify emotions as well which further supports the findings of Nardelli et al. (2015).

In the study of Fernández et al. (2012) the authors measured the participants' emotional response on three different dimensions, two of which seem to be similar to the dimensions of core affect, namely valence, from unhappy to happy, and arousal, from relaxed to excited. The results showed that fluctuations in the level of SC were significantly correlated with the arousal dimension. The correlation between SC and the valence dimension did, however, not reach significance which differs from the study of Nardelli et al. (2015) (Fernández et al., 2012). Still, all of the earlier studies applied an inter-individual design. This is why investigations on an intra-individual level are necessary, to see whether the relationship between the level of skin conductance and emotions show a similar pattern on an individual level.

Although the above studies seem to indicate a relationship between ANS-related physiological signals and emotions, there are several studies that challenge those findings. For example, the study of Evers, Gross, Fischer, Manstead, and Mauss (2014) suggests two response systems one of which is automatic, such as the physiological response and emotion accessibility, and the other is reflective, such as the experienced emotion and instrumental behaviour. Interestingly, they did find coherence within the two systems but not between the two systems. This indicates that there might not be a relationship between the level of SC, belonging to the automatic system, and self-perceived core affect, belonging to the reflective system. Instead, SC would rather be related to response components that also belong to the automatic system and self-perceived core affect would be related to factors that are part of the reflective system. This stands in contrast with the seemingly high coherence between the physiological and the experienced response of emotions that is suggested by the other studies. Similarly, the studies of Myrtek & Brügner (1996) and Myrtek et al. (2005) concluded that in everyday life, emotions are not necessarily linked to physiological activation but rather to other factors. For instance, cognitive schemata and personality dimensions have shown to be of higher importance than physiological signals.

The current study

In conclusion, the above studies provide inconsistent evidence regarding the relationship between ANS-related physiological signals and emotions. Some studies found significant correlations between one specific physiological signal and emotions. However, all studies had a different approach and focus. For example, the study of Fernández et al. (2012) found a significant correlation between the level of SC and the arousal dimension but not for the valence dimension. On the contrary, the study of Nardelli et al. (2015) found a correlation between both dimensions and HR. Evers et al. (2014) did not find evidence for a relationship between the physiological response and experienced emotions. In addition, none of the studies used an intra-individual study design and at the same time, focused on the level of SC and the core affect dimensions by Russel (2003) in an everyday context. The inter-individual methods of the earlier studies do not provide sufficient evidence that can be generalized to the individual level (Fisher et al., 2018; Van Geert & Van Dijk, 2002). Therefore, the current study will explore to what extent an individual's level of skin conductance is related to the valence and to the arousal dimensions of core affect on an intra-individual level and in an everyday context.

Methods

Design

For the current study, a longitudinal interval-based experience-sampling method with a within-subject and repeated-measures design was applied. Experience-sampling is a self-report diary technique which allows insight into the subjective experience of each individual's emotions in an everyday context and thereby captures its variability over time (Myin-Germeys, Kasanova, Vaessen, et al., 2018). Therefore, it is an optimal method for measuring the participants' emotions in the context of the current study. The study investigated the relationship between the self-reported valence, self-reported arousal and the level of SC within each individual and in an everyday context. The Ethical Committee of the University of Twente granted ethical approval at the 9th of April 2019.

Participants

Participants were recruited by using the method of convenience sampling. To be able to take part in the study each person needed a phone with sufficient storage and a working computer with USB slots and internet connection. In case the participants were students of the University of Twente, they were able to subscribe to the study on SONA systems where they received 5 study points, after their participation. The other participants received no reward. Once a person agreed to participate, an appointment for a preparation meeting was made where all participants signed the informed consent (see Appendix A).

From the original sample ($N = 27$), four participants had to be excluded because they had less than 10 measurement points for the level of SC, arousal, and valence. In total, the data of 23 participants were used from which 13 were taken from a previous measurement round. The previous sample included 11 males and 5 females with an age ranging from 21 to 70 (M = 30.63, SD = 12.96). The new sample consisted of 3 males and 7 females with a mean age of 28.2 (SD = 14.2) ranging from 19 to 55. In both samples, most of the participants were known to the researchers and belonged either to their family or to their circle of friends. Therefore, most participants were German and four were Dutch.

Materials

The E4 wristband, E4 manager, and E4 connect

To measure the participants' level of skin conductance the E4 wristband and accompanying software by Empatica Inc. are used. The E4 wristband is a wearable biosensor that captures various physiological signals in an everyday environment and in real time. Specifically, it measures blood volume pulse, acceleration, heart rate, temperature, and EDA. The EDA sensor of the E4 measures the fluctuating changes in electrical properties of the skin with electrodes located on the wrist. The E4 computes the level of SC as an average over longer intervals and uses microSiemens (μS) as units of measurement (Empatica Inc., 2019; van Lier, Pieterse, Garde, et al., in press). The data is synchronized by the E4 manager, version 2.0.3., which automatically transfers the sessions into the Empatica cloud platform called E4 connect. From the online cloud, the stored sessions can be downloaded in zipped CSV format which allows for further processing, such as in the IBM SPSS software platform for advanced statistical analysis.

Since the E4 wristband continuously measures fluctuations in ANS signals it is a suitable device that can be used along with other continuous and ambulatory assessments and thus, can be applied in experience sampling (van Lier, Oberhagemann, Stroes, et al., 2017; van Lier, Pieterse, Garde, et al., in press). However, the completeness of the data depends on the participants' ability and motivation to use the E4 correctly as well as on the technical functioning of the wristbands. At the same time, the SC data is only useful when it overlaps with the core affect assessment because the relationship between the two variables is of interest. Therefore, missing values are likely to occur. In the current study, the E4 wristbands are used alongside the Incredible Intervention Machine (TiiM), version 1.3.7., to measure self-reported valence and arousal.

The Incredible Intervention Machine

TiiM is a mobile device application developed by the BMS Lab of the University of Twente and was created to collect data for psychological research. TiiM sends questions to the participants on a determined moment and notifies the participants when new questions are available. The flexible and mobile application makes TiiM a suitable platform for the method of experience sampling since the participants can be easily asked in their everyday context. For the current study, the questions were available in German, English, and Dutch.

To measure the two dimensions, valence and arousal, of Core Affect a picture of a coordinate system was used (Figure 1), based on the one developed by Russel (1989). The x-axis represented the valence dimension ranging from unpleasant to pleasant and the y-axis is regarded as the arousal dimension ranging from low arousal to high arousal. To answer the core affect questions the participants had to mark a position in the quadrant that best corresponded to their emotions. This was done by placing the yellow button at the appropriate position in the core affect quadrant. The first item questioned the participants about their feelings in the past minute and the second item about their feelings in the past two hours. The more energized the participant felt the higher the button had to be placed. When feeling drained or low on energy the button had to be placed low. The more they experienced their feeling as being pleasant the more they had to put the button to the right. In case their feelings were neither pleasant nor unpleasant the button had to be put more at the middle of the quadrant, indicating a neutral feeling.

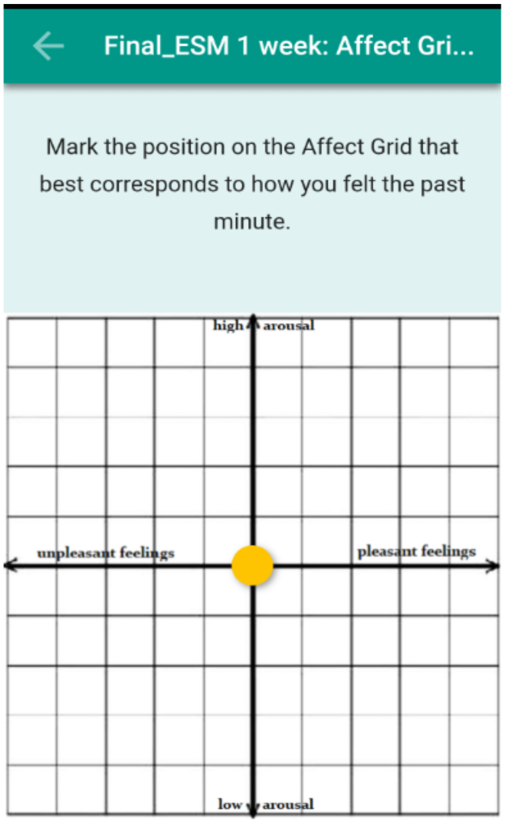

Figure 1. The affect grid question as it was displayed on the participants' mobile devices.

Procedure

Once a person agreed to participate, they received an email (see Appendix B) in which all required links and documents were attached that were required for the installation of the E4 software and the TiiM app. Each preparation meeting took approximately 45 to 60 minutes and started by giving the participants a broad overview of the study and its purpose. When they still agreed to participate, they were asked to sign the informed consent. After that, the researchers installed the E4 manager and created an E4 connect account for the participant. The participants were asked to use the link for the TiiM app to register as well as to download the TiiM app on their mobile phones. In order to be able to communicate in case of questions or problems, the participants received the mobile phone numbers of the researchers.

Each participant started on the agreed upon date and participated in the study for the following 7 days. Firstly, to measure the participants level of SC, they had to wear the E4 wristband from the moment at which they woke up until they went to bed. Each evening the participants had to synchronize the data by connecting the wristband with the E4 manager app and they had to charge the E4 wristband overnight. Secondly, to measure the participants' self-reported emotions, they had to answer the two core affect questions every two hours. The questions run non-stop, although it was made clear that they do only have to answer the questions during their waking hours, parallel to wearing the E4 wristband. In this way, the study could be adapted to each participant's individual waking hours. In case the participant did not answer the questions, they received one silent notification 15 minutes after each set time point. After 30 minutes the questions were skipped without any further notification. To keep the pressure as low as possible participants were reassured that they do not have to worry when they cannot answer all questions. Still, they were asked to answer them as often as possible.

The participant and the researchers met again after the 7 days to collect the wristband from the participant, to reassure that everything went well, and to thank them for their participation. After the last meeting the researchers downloaded the E4 sessions by logging into the participants' E4 connect accounts and gave each participant a number for the anonymization of the data. The data was shared with the other researchers of the study in the data cloud of the University of Twente for the processing in SPSS. The data was collected in April and May 2019.

Data Analysis

The skin conductance data was pre-processed using the EDA explorer (implemented in Pyhton; Taylor et al., 2015)). The Through-to-Peak analysis utilized a minimum SCR amplitude of .001 µSiemens. Subsequently, the timestamps of SC level, SCR peaks and amplitudes were synchronized (with Python) with the timestamps of the self-reported values from TiiM to create mean SCL and summed peak and amplitude scores per 1 minute and 2-hour intervals.

All further analyses were performed with SPSS, Statistical Package for the Social Sciences, version 25. During all analyses two-tailed tests were utilized, using an alpha of .05. Descriptive statistics provided the important means and standard deviations of the level of SC, the level of self-reported valence and arousal, as well as for the demographic variables gender and age. Boxplots were used to display the mean level of SC as well as valence and arousal for the past two hours for each individual. To test whether the variables are normally distributed a Shapiro-Wilk test was used and supported by histograms and scatterplots. Based on the distribution of the data, to test whether the level of SC is related to the level of self-reported valence and arousal, it was chosen between the Pearson or the nonparametric Spearman correlation. The correlations were run for each individual separately. Hereby a correlation below .3 was considered as weak, between .3 and .7 as moderate, and above .7 as strong (Cohen, 1988).

To have more insight into the spread of the correlation histograms of the intra-individual correlations were used.

Results

Descriptives and normality testing for all variables concerning the past two hours

The following figures and descriptives illustrate the data concerning the past two hours. The sample showed an average level of SC of 1.1µS (SD = 5.84) ranging from .00 to 107.21. The median of the level of SC is .26µS which shows that the participants mostly had a level of SC lower than the sample mean. This was supported by a histogram that illustrates that the overall level of SC is positively skewed and is heavier in the right flank. This indicates that the subjects mostly had a low level of SC and a few extreme scores. The values of the level of SC for each subject are displayed in figure 2.

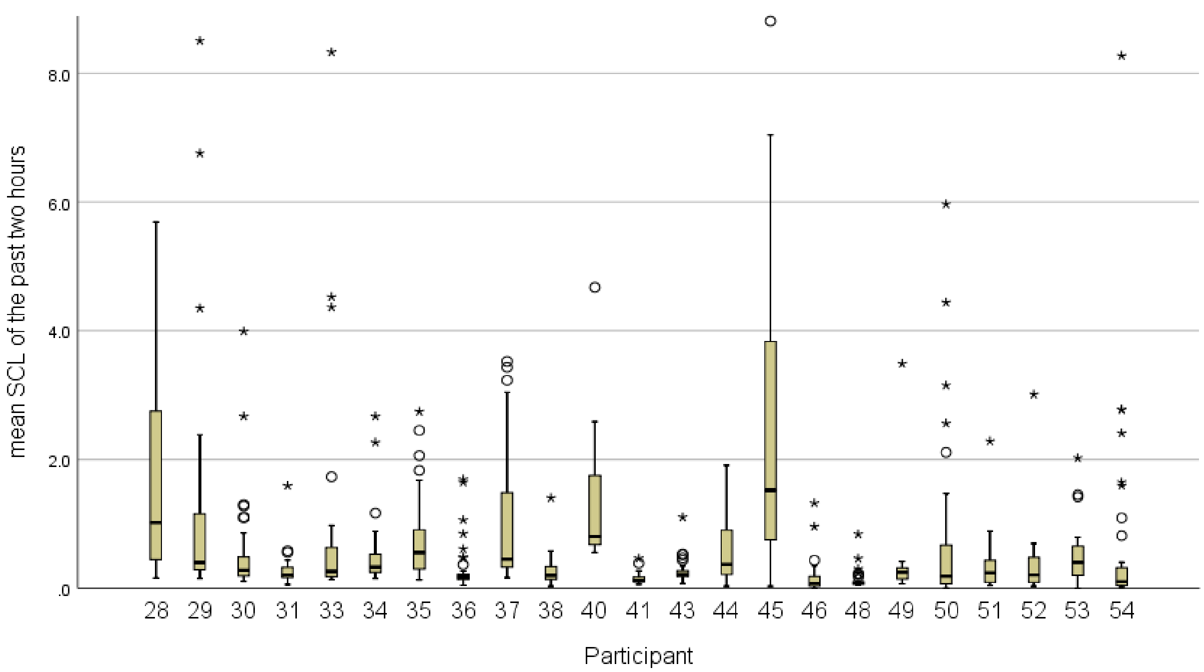

Figure 2. The average level of SC of each participant for the past two hours. Most participants' level of SC seemed to be positively skewed since the lower whisker is shorter than the upper whisker which is spread more widely. This supports that most participants had low levels of SC and high scores were rare.

The subjects had an average arousal level of -3.12 (SD = 46.57) with a minimum level of arousal of -96 and a maximum of 100. Figure 3 illustrates the self-reported level of arousal for each subject. The average level of self-reported valence is 2.95 (SD = 43.55) ranging from -100 to 99. The average levels of valence per subject are displayed in figure 4. Histograms and Scatterplots of the variables showed that the variables are not normally distributed wherefore nonparametric tests were chosen for all further analyses.

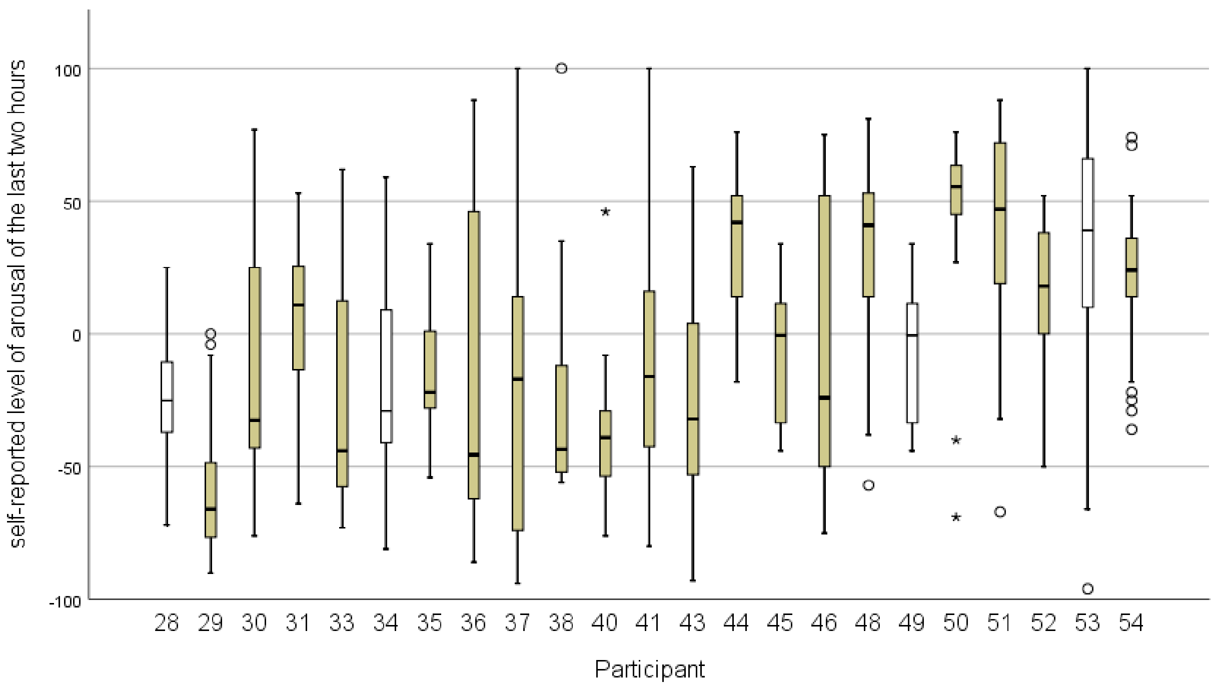

Figure 3. The level of self-reported arousal of the last two hours per participant. Most participants have a high variance of their self-reported arousal over the 7 days. Participants 29 and 40 reported only negative arousal scores indicating low levels of arousal. Participant 50 reported a mostly high level of arousal. The white boxplots mark the participants that showed significant correlations, which will be further elaborated on below.

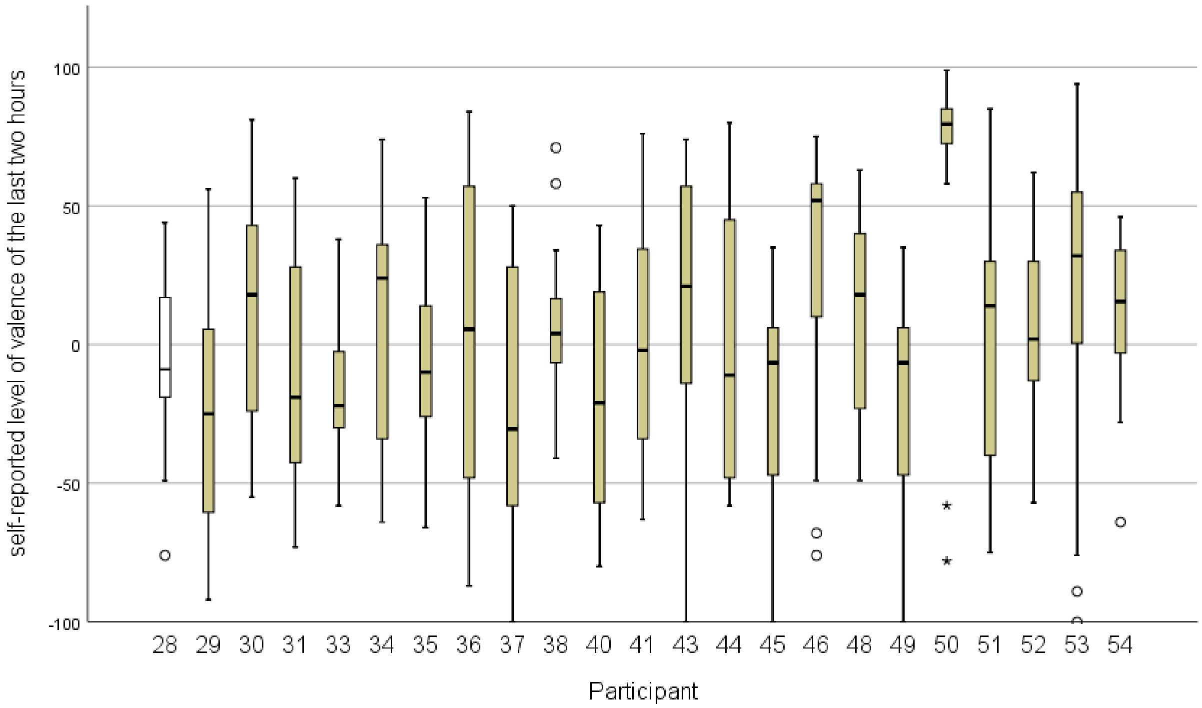

Figure 4. The level of self-reported valence of the last two hours for each participant. Apart from participant 50 most participants had varying levels of valence during the 7 day period. They reported pleasant, more neutral and unpleasant feelings. Participant 50 only indicated highly pleasant feelings with 2 exceptions that are placed in the unpleasant end. The white boxplot marks the participant that showed a significant correlation, which is further explained below.

The intra-individual relationship between the SCL and self-reported arousal and valence

As presented in figure 3, on the intra-individual level there were four participants that had a significant correlation between the level of SC and arousal considering the past two hours. Three of the four correlations indicated a moderate negative relationship and one a strong negative relationship, with the Spearman correlation coefficient ranging from -.41 to -.78. When looking at the distribution of the arousal scores (figure 3) no difference becomes apparent between those subjects that showed a significant correlation and those that did not. Those participants that had an association had no specific pattern in the distribution of their arousal scores. Thus, there is no cluster in the distribution of the arousal scores that could explain the difference between the individuals.

Regarding the self-reported valence, the Spearman correlation revealed one significant moderate negative correlation between the level of SC and valence ($r = .39$, $p = .022$) for the past two hours (see figure 4). Since only one subject (participant 28) showed an association no conclusions can be drawn from visually comparing that subject with the others. Participant 28 mostly reported valence scores from -50 to 50. This did not differ from several other participants that did not show associations. Thus, a difference in the distribution of the valence scores does not seem to explain why this particular subject showed a significant correlation.

The spread of the intra-individual correlations

Overall, the mean of the intra-individual correlations between the SCL and arousal regarding the past two hours was -.065 (SD = .29) with 95% CI [-.193, .064]. The mean of the intra-individual correlation between the SCL and valence regarding the past two hours was .032 (SD = .238) with 95% CI [-.08, .126]. This shows that on an intra-individual level participants are likely to have weak to no correlations between the level of SC and self-reported arousal and self-reported valence. The spread of the intra-individual correlations for all variables are displayed in the histograms below (see figure 5). The histograms show that the intra-individual correlations are spread around zero, where most individuals are likely to have weak correlations and moderate correlations are less likely to occur. It is noticeable that, on an intra-individual level, correlations are both negative and positive, and thus there is no clear direction visible.

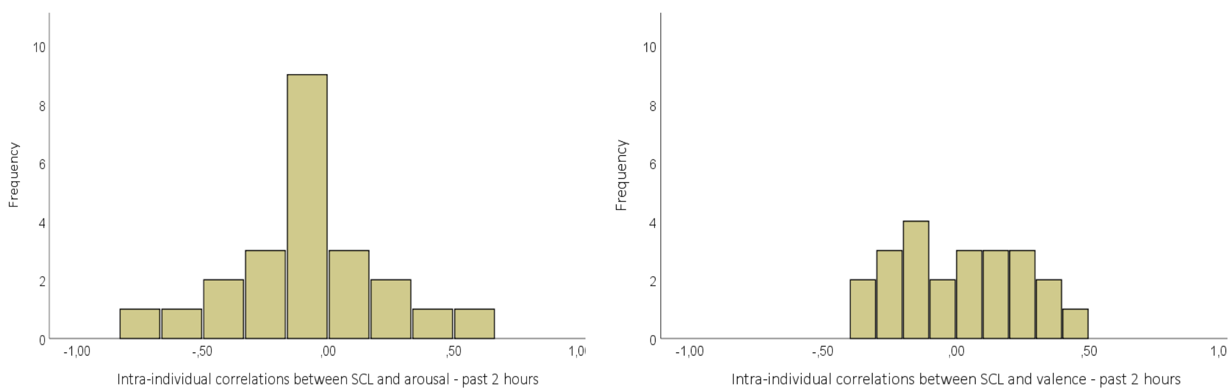

Figure 5. Frequency distributions of the intra-individual correlations. The left histogram shows the intra-individual correlations between the level of SC and arousal. The right histogram displays the intra-individual correlations between the level of SC and valence.

Discussion

This study was one of the first that explored the extent to which bodily signals are related to emotions on an intra-individual level and in an everyday context. Specifically, the study investigated the relationship between the level of SC, as an indicator of the body's ANS activity, and the level of self-reported valence and arousal, which are the two dimensions of core affect as defined by Russel (2003). The current findings provide mixed evidence for an intra-individual relationship between the level of SC and the core affect dimensions, but mostly indicate weak to no associations. Although the relationship tended to be a weak negative one, some participants also had weak positive correlations. Thus, there was no clear direction in the relation between the level of SC, arousal, and valence on an intra-individual level. Interestingly, more individuals showed an association between the level of SC and arousal compared to the valence dimension. Still, since there were mostly non-significant associations, the level of SC does not seem to cohere with self-reported core affect in an everyday life, which is an important insight for the mental health sector (Derks et al., 2017; Picard, 2009). Importantly, earlier studies applied inter-individual methods and investigated experimentally induced emotions which makes it difficult to generalize these findings to the individual level (Fisher et al., 2018; Molenaar & Campbell, 2009) and to a daily life context (Myrtek & Brügner, 1996; Myrtek et al., 2005). In the present study these difficulties were addressed by focusing on the individual and on daily life.

Reflection of the current findings in the light of previous research

Generally, in the debate regarding the physiology-emotion relationship, it is often postulated that there is a response coherence between the physiological response and the perceived emotional response. The evidence of the current study, however, does not substantiate this coherence, since most individuals did not show an association between the level of SC and core affect. In line with this is the dual response framework by Ever et al. (2014). Their framework suggests two independent response systems, one automatic and one reflective system. The automatic system entails, for example, physiological signals and emotions accessibility. The reflective response system includes emotion-experiences and instrumental behaviours. They concluded that the response systems are rather independent and thus one might expect coherence within one system but rather little coherence between the two systems (Evers et al., 2014). When linking this to the current study it becomes apparent that the level of SC and self-reported core affect might not belong to the same system. Instead, SC seems to belong to the automatic system and core affect more to the reflective system which explains the weak to no associations between the two concepts. Accordingly, the level of SC and the self-reported core affect belong to separate systems and are thus, relatively independent from each other. Still, their results stand in contrast with several experimental studies that did find a relationship, wherefore the results must be interpreted with caution and their framework needs to be tested on an individual level.

Most of the findings that indicate a relationship between physiological signals and emotions, and thus are not in line with the current finding, were derived from experimental settings. The current study, however, was implemented in a daily life setting which might account for the discrepancy between the current and most earlier findings (Aboulafia-Brakha et al., 2016; Boucsein, 2012; Critchley, 2002; Fernandez et al., 2012; Fletcher et al., 2010; Kreibig, 2010). A major difference is the different level of awareness between experimental settings and an everyday context. According to Myrtec et al. (2015) and Myrtec and Brügener (1996), emotional events often do not reach peoples' perception in an everyday setting. Mostly, only those events leading to extreme emotional arousal are likely to be perceived and reported by individuals (Boucsein, 2012). In the laboratory, physiological signals are measured right before being exposed to an emotion-inducing cue, which is then compared to the physiological level right after they were shown video clips which aim to induce specific emotions (Aboulafia-Brakha et al., 2016; Fernandez et al., 2012). Therefore, the contrast between the calm situation beforehand and the sudden emotional cue is more extreme than in daily life and the relationship between physiological signals and emotions might be created by the experimental setting. Next to that, the subjects in an experimental setting know that they are going to be put in a special situation wherefore all attention is drawn to the emotions, and participants already have some hypothesis in mind which, altogether, lead to a rather artificially induced relationship (Myrtec et al., 2005). In contrast, in the everyday context of the current study, individuals have higher competition between internal and external sensory data than in the laboratory, wherefore emotional cues must compete with external stimuli. This might impair the emotional awareness wherefore physiological signals might not be of such high importance for self-perceived core affect in daily life than indicated by the results of the experimental settings, which is in line with the low associations found in the current study (Myrtec et al. 2015; Myrtek & Brügener, 1996).

Still, in contrast to the present findings, Kreibig (2010) concluded that ANS activity is a major component of emotions. Mostly, the level of SC and HR increased when individuals reported negative emotions. In the current study, the negative emotions are represented with the negative side of the valence dimension. Yet, feeling unpleasant might differ from emotions such as anger and fear, in that it might be a more subtle and rather continuous condition (Russel, 2003). Thus, differences in the kinds of emotions that were investigated in the current and in earlier studies might explain the ambiguous findings. This difference might be emphasized by the fact that many of those earlier studies focused on anger and fear (Kreibig, 2010), which might be especially different from the core affect measure used in the current study and their level of awareness. Namely, anger and fear are likely to be followed by a strong behavioural response which might, in turn, be accompanied by a strong ANS activity (Fernandez et al., 2012; Kreibig, 2010) and require a higher level of awareness. Feelings, apart from anger and fear, are likely to be followed by more subtle and communicative responses which require a less strong activity of the sympathetic nervous system (Boucsein, 2012; Fernandez et al., 2012). This indicates that there might be a difference regarding the extent to which varying emotions are related to physiological signals which might explain why the current findings differ from previous findings. Accordingly, emotions apart from anger and fear, are less aware to individuals and are not necessarily linked to physiological changes in an everyday context (Myrtec et al., 2005; Myrtec & Brügener, 1996).

A further methodological difference that might account for the deviations between the present and the previous findings is the way in which subjects were asked about their emotions. In this study, interval-based experience sampling was used, wherefore the participants were asked every two hours to pinpoint an average feeling of the past two hours. This might hide strong emotions and physiological responses because subjects might think that these emotions are not representative for the past two hours or they simply forget about such emotions when they happened already an hour ago. In the laboratory settings of the previous studies, those difficulties were prevented since participants were asked about their emotions immediately after they were exposed to the emotional stimuli (Kreibig, 2010; Nardelli et al., 2015). Thus, one might argue that the interval-based method of the current study accounts for the non-evident relationship between core affect and the level of SC. Still, Myrtec and Brügener (2005) found that event-based physiological feedback does not show higher correlations with self-reported emotions than random feedback, which might relativize the difference between the event- and interval-based experience sampling method.

Further, individuals generally differ to the extent to which they are sensitive to their emotions as well as in estimating how they are feeling (Aboulafia-Brakha et al., 2016; Boden & Thompson, 2015). This might account for the differences found in the current study between individuals, namely that some individuals showed stronger associations than others as well as that those associations differed in their direction. Therefore, for some individuals the associations were negative whereas others showed positive correlations. Earlier studies did not report such individual differences because they applied inter-individual study designs and thus, based their findings on the aggregated group level (Boucsein, 2012; Critchley, 2002; Fletcher et al., 2010; Nardelli et al., 2015). However, conclusions based on aggregated group levels propose a serious threat to the generalizability of those findings to the individual level (Fisher et al., 2018; Molenaar & Campbell, 2009). Specifically, Fisher et al. (2018) concluded that correlations within individuals exhibit at least twice as much variation as those found within groups. Since core affect and emotions, as well as physiological signals, are not normally distributed and fluctuate strongly throughout the day, the generalizability of the previous findings to the individual level is questionable (Fisher et al., 2018; Molenaar & Campbell, 2009). This major difference between the current and earlier studies makes it difficult to compare the evidence. This is supported by the findings of Barrett (2009) and Barrett et al. (2007) which point out that an emotion label, such as fear, is associated with a wide variety of different mental states that do not look alike on a neurophysiological level and do not feel alike. Even when stimulating the same brain side different emotions were reported by the individuals which might have been caused by interpretations that were made based on the context. These notions emphasize the high variance physiological patterns of emotions and therefore stress the importance of investigating the individual level. Therefore, the current study constitutes an important advantage compared to earlier studies and offers a new perspective on the way in which the relationship between physiological signals and emotions can be investigated.

Strengths and Limitations

The current study has several strengths that give an added value to the existing body of literature. First, the present study applied an intra-individual study design which contributes to the generalizability of the results. Almost all previous studies applied an inter-individual study design and thus, individual differences were not apparent from those studies (Fisher et al., 2018; Kreibig, 2012; Loeffler et al., 2013). Second, the use of wearable technology is in line with the current research trend in the field of psychophysiology that aims to use devices that can be worn outside laboratories (Bonato, 2003, Fletcher et al., 2010; Peira et al., 2013; Ragot et al., 2017). This has the advantage that the physiological signals can be measured exactly when the emotions occur which in turn helps to prevent memory bias (Levine & Safer, 2002). In addition, everyday instead of experimentally induced emotions can be captured. Third, the experience sampling method has several advantages compared to experimental settings that are often measuring the participants for several hours but not longitudinally. It allows to capture emotions in an everyday context and thus, at the moment in which they occur over a relatively long period (Loeffler et al., 2013; Myin-Germeys et al., 2018). Experience sampling, or ambulatory assessment in general, appears to be an optimal method to capture emotional experiences, but also other psychological and physiological signals, in an everyday context. Fourth, the longitudinal study-design is an advantage over other studies, since it increases the chance that the subjects experience a broad range of feelings. This leads to sufficient variety in feeling, which enables to make judgments about different kinds of feelings.

The current study has three limitations that can be considered by future studies. First, the present study used the level of SC as a means to measure ANS activity captured by the E4 wristband. However, on an individual level, the SC peak amplitudes were shown to be more sensitive to stressors (Brouwer et al., 2017). The level of SC, on the other hand, was shown to be only sensitive to larger stressors when measured at the wrist. One reason for that might be that there are fewer sweat glands on the wrist than on the palms of the hand and the feet (Boucsein, 2012; van Lier et al., 2019). Thus, the E4 might underestimate responses to lower levels of stressors. Second, since emotions were measured in an everyday context it was not possible to control for external factors that might influence the results. For example, the study was highly dependent on the motivation of the participants to fill in the data and it was not possible to control for movement induced SC fluctuations. Third, although the core affect quadrant by Russel is a well-established and frequently used measure (Ekkekakis, 2013; Longo, 2015; Ramos, Sendra, Sánchez, & Mena, 2017; van den Bosch, Vlaskamp, Andringa, & Ruijssenaars, 2016), the participants reported some difficulty with the core affect questions. For example, many participants reported that they found it difficult to grasp the meaning and especially the magnitude of the dimensions. They found it difficult to pinpoint an average of their feelings of the past two hours and thus, some stronger emotional events might not have been reported.

Therefore, future research might vary in the time intervals and apply shorter time intervals, so that participants have less difficulty to give an average of their feelings.

Implications for future research and practice and conclusion

First and foremost, the findings of the current study do not substantiate the common postulate that physiological signals cohere with self-reported emotions. Due to the focus on intra-individual analyses and everyday life the results constitute insights that can be generalized to the individual level and to daily life. This innovative approach offers a new perspective on how to look at the relationship between physiological signals and emotions. For future research this suggests that the relationship between physiological signals might be more complex than assumed and that there might be individual differences regarding the extent to which physiological signals are related to emotions in daily life. This, in turn, indicates that other aspects influence the relationship between physiological signals and emotions or that other factors, apart from physiological ones, might be of higher importance in predicting emotions. Hence, future research should investigate other factors such as personality and cognitive traits or interoceptive awareness (Myrtec et al., 2005). For example, variations in personality are often said to account for difference in emotion perception (Furners, Berg, Mitchell, & Paulmann, 2019). Further, the discussion of the findings showed that emotional awareness might be crucial for the physiology-emotions relationship and thus, might be in concept of interest for future studies. At the same time, more research into the validity of wearable biosensors is required to be able to conduct more accurate research outside laboratories (van Lier et al., in press). Lastly, it might also help to compare healthy individuals with individuals suffering from disorders, such as borderline personality disorder or alexithymia, which interfere with their ability to regulate and to recognize emotions (Aboulafia-Brakha et al., 2016; Derks et al., 2017). Comparing such groups could give interesting insights into the relationship between emotions and physiological signals. This is especially important since the aim of many studies in the field is to improve the treatment, health care and quality of life of those people. Ultimately, the results of the current study suggest that the relationship on an individual level is not as straightforward as often postulated. Specifically, the study does not substantiate that physiological signals are related to emotions on an intra-individual level and in everyday life.

References

Aboulafia-Brakha, T., Allain, P., & Ptak, R. (2016). Emotion regulation after traumatic brain injury: distinct patterns of sympathetic activity during anger expression and recognition. *Journal of head trauma rehabilitation*, *31*(3), E21-E31. DOI:10.1097/HTR.0000000000000171

Barrett, L. F. (2009). Variety is the spice of life: A psychological construction approach to understanding variability in emotion. *Cognition and Emotion*, *23*(7), 1284-1306. doi: 10.1080/02699930902985894

Boden, M. T., & Thompson, R. J. (2015). Facets of emotional awareness and associations with emotion regulation and depression. *Emotion*, *15*(3), 399.

Bonato, P. (2003). Wearable sensors/systems and their impact on biomedical engineering. *IEEE Engineering in Medicine and Biology Magazine*, *22*(3), 18-20.

Boucsein, W. (2012). *Electrodermal activity*. Springer Science & Business Media.

Brouwer, A. M., van Beurden, M., Nijboer, L., Derikx, L., Binsch, O., Gjaltema, C., & Noordzij, M. (2017). A comparison of different electrodermal variables in response to an acute social stressor. In *International Workshop on Symbiotic Interaction* (pp. 7-17). Springer, Cham.

Conner, T. S., & Feldman Barrett, L. (2012). Trends in ambulatory self-report: the role of momentary experience in psychosomatic medicine. *Psychosomatic medicine, 74*(4), 327. https://dx.doi.org/10.1097/PSY.0b013e3182546f18.

Critchley, H. D. (2002). Electrodermal responses: What happens in the brain. *The Neuroscientist*, *8*(2), 132-142.

Dawson, M. E., Schell, A. M., & Filion, D. L. (2000). The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology* (pp. 200-223). New York, NY, US: Cambridge University Press.

Derks, Y. P., Visser, T. D., Bohlmeijer, E. T., & Noordzij, M. L. (2017). MHealth in Mental Health: How to efficiently and scientifically create an ambulatory biofeedback e-coaching app for patients with borderline personality disorder. *International Journal of Human Factors and Ergonomics*, *5*(1), 61-92. https://doi.org/10.1504/IJHFE.2017.088418

Desmet, P. M. (2008). Product emotion. In *Product experience* (pp. 379-397). Elsevier. https://doi.org/10.1016/B978-008045089-6.50018-6

Ekkekakis, P. (2013). *The measurement of affect, mood, and emotion: A guide for health-behavioral research*. Cambridge University Press.

Empatica Inc. (2019, January 29). *What should I know to use EDA data in my experiment?*. Retrieved from https://support.empatica.com

Evers, C., Hopp, H., Gross, J. J., Fischer, A. H., Manstead, A. S. R., & Mauss, I. B. (2014). Emotion response coherence: A dual-process perspective. *Biological Psychology*, *98*(1), 43–49. https://doi.org/10.1016/j.biopsycho.2013.11.003

Fernández, C., Pascual, J. C., Soler, J., Elices, M., Portella, M. J., & Fernández-Abascal, E. (2012). Physiological responses induced by emotion-eliciting films. *Applied psychophysiology and biofeedback*, *37*(2), 73-79.

Fisher, A. J., Medaglia, J. D., & Jeronimus, B. F. (2018). Lack of group-to-individual generalizability is a threat to human subjects research. *Proceedings of the National Academy of Sciences*, *115*(27), E6106-E6115. https://doi.org/10.1073/pnas.1711978115

Fletcher, R. R., Ming-Zher Poh, R. R., & Eydgahi, H. (2010). Wearable sensors: opportunities \ and challenges for low-cost health care.

Furnes, D., Berg, H., Mitchell, R. M., & Paulmann, S. (2019). Exploring the Effects of Personality Traits on the Perception of Emotions From Prosody. *Frontiers in psychology*, *10*.

Gramann, K., & Schandry, R. (2009). *Psychophysiologie*. Retrieved from https://www.beltz.de

Khezri, M., Firoozabadi, M., & Sharafat, A. R. (2015). Reliable emotion recognition system based on dynamic adaptive fusion of forehead biopotentials and physiological signals.

Computer methods and programs in biomedicine, *122*(2), 149-164. https://doi.org/10.1016/j.cmpb.2015.07.006

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

Levenson, R. W. (2014). The autonomic nervous system and emotion. *Emotion Review*, *6*(2), 100-112.

Loeffler, S. N., Myrtek, M., & Peper, M. (2013). Mood-congruent memory in daily life: Evidence from interactive ambulatory monitoring. *Biological Psychology*, *93*(2), 308–315. https://doi.org/10.1016/j.biopsycho.2013.03.002

Longo, Y. (2015). The simple structure of positive affect. *Social Indicators Research*, *124*(1), 183-198.

Molenaar, P. C., & Campbell, C. G. (2009). The new person-specific paradigm in psychology. *Current Directions in Psychological Science, 18*(2), 112-117. https://dx.doi.org/10.1111/j.1467-8721.2009.01619.x

Myin-Germeys, I., Kasanova, Z., Vaessen, T., Vachon, H., Kirtley, O., Viechtbauer, W., & Reininghaus, U. (2018). Experience sampling methodology in mental health research: new insights and technical developments. *World Psychiatry*, *17*(2), 123-132.

Myrtek, M., Aschenbrenner, E., & Brügner, G. (2005). Emotions in everyday life: An ambulatory monitoring study with female students. *Biological Psychology*, *68*(3), 237–255. https://doi.org/10.1016/j.biopsycho.2004.06.001

Myrtek, M., & Brügner, G. (1996). Perception of emotions in everyday life: Studies with patients and normals. *Biological Psychology*, *42*(1–2), 147–164. https://doi.org/10.1016/0301-0511(95)05152-X

Nardelli, M., Valenza, G., Greco, A., Lanata, A., & Scilingo, E. P. (2015). Recognizing emotions induced by affective sounds through heart rate variability. *IEEE Transactions on Affective Computing*, *6*(4), 385-394. DOI: 10.1109/TAFFC.2015.2432810

Okada, G., Yonezawa, T., Kurita, K., & Tsumura, N. (2018). Monitoring emotion by remote measurement of physiological signals using an RGB camera. *ITE Transactions on Media Technology and Applications*, *6*(1), 131-137.

Peira, N., Pourtois, G., & Fredrikson, M. (2013). Learned cardiac control with heart rate biofeedback transfers to emotional reactions. *PloS one*, *8*(7), e70004. https://doi.org/10.1371/journal.pone.0070004

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

Ragot, M., Martin, N., Em, S., Pallamin, N., & Diverrez, J. M. (2017, July). Emotion recognition using physiological signals: laboratory vs. wearable sensors. In *International Conference on Applied Human Factors and Ergonomics* (pp. 15-22). Springer, Cham.

Ramos, J. M., Sendra, J. M., Sánchez, A., & Mena, A. (2017). Influence of core affect in the differential efficacy of a personality disorder intervention program. *The Spanish journal of psychology*, *20*. https://doi-org.ezproxy2.utwente.nl/10.1017/sjp.2017.2

Russell, J., Weiss, A., & Mendelsohn, G. (1989). Affect grid: A single-item scale of pleasure and arousal. *Journal of Personality and Social Psychology, 57*(3), 493-502. doi:10.1037/0022-3514.57.3.493

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological review*, *110*(1), 145. http://dx.doi.org/10.1037/0033-295X.110.1.145

Russell, J. A. (2009). Emotion, core affect, and psychological construction. *Cognition and Emotion*, *23*(7), 1259-1283. https://doi.org/10.1080/02699930902809375

Stephens, C. L., Christie, I. C., & Friedman, B. H. (2010). Autonomic specificity of basic emotions: Evidence from pattern classification and cluster analysis. *Biological psychology*, *84*(3), 463-473. https://doi.org/10.1016/j.biopsycho.2010.03.014

Taylor, S., Jaques, N., Chen, W., Fedor, S., Sano, A., & Picard, R. (2015). Automatic Identification of Artifacts in Electrodermal Activity Data. *Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE*, 1934–1937. https://doi.org/10.1109/EMBC.2015.7318762

van den Bosch, K. A., Vlaskamp, C., Andringa, T. C., Post, W. J., & Ruijssenaars, W. A. (2016). Examining relationships between staff attributions of soundscapes and core affect in people with severe or profound intellectual and visual disabilities. *Journal of Intellectual and Developmental Disability*, *41*(1), 21-30. https://doi.org/10.3109/13668250.2015.1114077

Van Geert, P., & Van Dijk, M. (2002). Focus on variability: New tools to study intra-individual variability in developmental data. *Infant Behavior and Development*, *25*(4), 340-374.

Van Lier, H. G., Oberhagemann, M., Stroes, J. D., Enewoldsen, N. M., Pieterse, M. E., Schraagen, J. M. C., … & Noordzij, M. L. (2017). Design decisions for a real time, alcohol craving study using physio-and psychological measures. In *International Conference on Persuasive Technology* (pp. 3-15). Springer, Cham.

van Lier, H. G., Pieterse, M. E., Garde, A., Postel, M. G., de Haan, H. A., Vollenbroek-Hutten, M. M. R., … Noordzij, M. L. (in press). A standardized validity assessment protocol for physiological signals from wearable technology: Methodological underpinnings and an application to the E4 biosensor. *Behavior Research Methods*.

Appendix A

Informed consent

Information for participants of the study on physiological signals and feelings

Dear participant,

thank you for being interested in this study. The aim is to learn more about the relationship between bodily signals and everyday feelings. Knowledge in this field is particularly valuable for individuals that experience difficulties in recognizing and regulating their feelings.

To measure your bodily signals, you will wear an E4 biosensor watch from Empatica for 7 days (from morning to evening). When taking off the watch you will have to connect the watch with your computer to synchronize the data and to charge the watch. For this purpose, it is required to download the accompanying software onto your computer.

To measure your everyday feelings, you will be asked two questions every two hours in an agreed time slot. The first questions pertain to how you felt the last minute. The second question pertains to how you felt in the past two hours. How much energy did you feel? And how pleasurable did you feel? You will answer the questions on your phone with the help of a mobile phone application.

In total the study will endure for 7 days. The more often you answer the questions on your pone the more data can be used. However, you are absolutely free to choose whether you answer the questions or not.

To be able to participate please read the informed consent below carefully. When you decide to participate you will be asked to agree to the informed consent. Be aware that participation is voluntarily, and that you may withdraw from participation at any time, also after you signed the informed consent.

Informed consent

An experience sampling study into intra-individual correlations between bodily signals and emotions

Researcher: Lena Franke

To be completed by the participant

I declare to be informed about the aim, method, and procedure of the study. I know that the data and results of the study will be treated confidentially and anonymously. I know that this study takes place in a learning environment and I am aware that therefore supervisors from the University of Twente will have access to the data. I reserve the right to withdraw from participation at any time. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I understand that taking part in the study involves *wearing the E4 watch, answering questions on my mobile device every two hours, synchronizing the data of the E4, and charging the E4 watch overnight*. If I request further information about the research, now or in the future, I may contact the researcher via email (l.franke-1@student.utwente.nl).

I have read and understood the study information dated [DD/MM/YYYY], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

Signature

______________________ ______________________ _________

Name of participant [printed]

Appendix B

The email that participants received after their oral agreement and before the prepearation meeting

Dear Participant,

thank you for being part of the study. The following links and documents are important for the installations and the registrations required for the study.
You do not have to worry about the steps. We will go through them during our introductory meeting in which I will also explain what you must do. Of course, participation is voluntarily and you can stop at any time.

TiiM:
1. link for TiiM registration
https://app.tech4people-apps.bms.utwente.nl/enrol/5AfMz
2. Download TiiM app on phone and register with log in data created in the step before

Empatica/E4

1. Go to website and register (E4 Cloud/Connect)
https://www.empatica.com/connect/login.php
2. Go to website and download E4 manager
https://www.empatica.com/empatica-manager-download
3. Log into E4 manager with the log in data created in step 1

In case the E4 does not connect

1. Open PDF attached to this email
2. Open link and download the zip file
https://drive.google.com/file/d/1OrjiSDiLZrMRjGEnfblY50z3T50rZBK0/view?usp=sharing
3. Follow steps as stated in the PDF

Thank you very much in advance and see you at the introductory meeting. At the meeting we will also discuss your exact starting point for the study. If you have any further questions do not hesitate to ask.

Kind regards