UNIVERSITY
OF TWENTE.

The intra-individual relationship between self-reported valence and heart rate in a daily life setting

Alicia Peelen
s1683543
Bachelor Thesis

Supervisors:
1st: Dr. Matthijs Noordzij, Department of Psychology, Health & Technology
2nd: Dr. Anneke Sools, Department of Psychology, Health and Technology

University of Twente
Faculty of Behavioural, Management, and Social Sciences
Department of Psychology, Health & Technology

Abstract

Objectives. There is growing interest in how feelings are related to health. Scientists claim that feelings are related to heart rate (HR) and can therefore be an influencing factor on health. Studies show that the more pleasant or unpleasant feelings are, the higher is HR. Therefore, HR is assumed to be related to feelings. Nevertheless, only a limited number of studies investigated that psychophysiological relationship intra-individually, meaning instead of drawing conclusion from the group mean data using intra-individual correlations. Therefore, the present study investigates the intra-individual relationship between HR and self-reported valence and its consistency.

Methods. In total 35 participants with an age ranging from 19 to 70 and either Dutch or German nationality participated within this study. The participants were asked to wear a biosensor measuring HR for seven days. Self-reported valence was measured with the aid of a smartphone application. For each individual intra-individual correlations were calculated. These correlations were split in two halves, the first time randomly and the second time into two time-based halves. This enables to make judgments about the consistency of the correlations.

Findings. The correlations vary in strength and consistency. Nevertheless, those are neither consistent nor significant. There is no indication for a positive or negative relationship because there are as many positive as negative correlations. The differences among the correlations of the time-based split are higher, indicating a change during study period. Contradicting previous findings, it is concluded that HR is not related to self-reported valence.

Discussion. Future studies should investigate a possible change in awareness of feelings as a possibly influencing factor to valence. The data of HR should be considered carefully as there is no correction of the effect of movement executed. Next to that, it is recommended to use event-based sampling enabling gathering specific and accurate data of HR and self-reported valence.

Keywords: Self-reported valence, heart rate, intra-individual correlation, daily life setting, real life measurement

The intra-individual relationship between self-reported valence and heart rate in a daily life setting

Introduction

Recently, Apple and other companies developed Smartwatches with the ability to measure heart rate and thereby giving the user the possibility to track his own heart rate (HR). This shows a growing interest of the population in body signals related to health. One reason for this interest is the assumption that there is a linear association between body signals and psychological phenomena for instance by intuitively thinking that HR should go up when someone is feeling agitated (Barrett, 2006). Thus, one of the phenomena that is assumed to be related to HR is feelings. The high interest in this association is not met by sufficient knowledge about it. There are only a limited number of studies that investigate this relation while the demand of these studies is high as it might be an influencing factor on health. Studies show that HR gives indications about a range of psychological and physiological processes that are linked to health (Thayer, Hansen, Saus-Rose & Johnson, 2009).

Some scientists also agree upon the fact that HR increases when individuals experience feelings (Barrett, 2006). Hence feelings, regardless of whether positive or negative, are assumed to be related to bodily reactions (Anttonen & Surakka, 2005; Levenson, 2003). Brosschot and Thayer (2003) found that HR decelerates more when experiencing negative stimuli than when experiencing positive stimuli. In addition, the deceleration of HR lasts longer after being exposed to negative stimuli than to positive stimuli. Therefore it is concluded that a high amount of certain negative mood can increase the risk of negative health related outcomes, for example heart diseases due to frequently elevated HR (James, Yee, Harshfield, Blank, & Pickering, 1986).

The previous investigations about the relationship between HR and feelings are based on the assumption that the data and conclusions derived from group averages can be applied to the individual level in order to understand such associations within individuals. However, Fisher, Medaglia and Jeronimus (2018) argue that the group level of data can only be extended to the individual level when its variance and mean are consistent over time. Based on the fact that feelings are not consistent over time, it can be concluded that the data from previous studies cannot be generalized to the individual level without an explicit test whether such a

generalization is warranted. This shows the importance of investigating the relation between psychological experiences and bodily responses with the aid of an intra-individual research design. In order to do so, the aim of this study is to investigate the assumption that there is a relationship between bodily reactions and psychological experiences by investigating the relationship between HR and pleasant and unpleasant feelings intra-individually. This correlation is chosen to be able to make judgments about the relationship between feelings and HR as a possible factor influencing health.

Psychological Experience of Feelings

Feelings are based on how the individual experiences and interprets situations. One manner to describe those feelings is using core affect. Core affect is an assessment of the current state. It is defined as a neurophysiological state that is easily accessible, highly conscious and always present in an individual. It is independent from stimuli and does not need to be labeled, interpreted or attributed to a cause (Russel, 2003). This independency from stimuli is what core affect distinguishes from affect. The state of core affect describes one's mood, emotion and emotionally charged events in terms of feeling good or bad and energized or exhausted (Zajonc, 2000). By definition core affect is characterized by two dimensions, a hedonic dimension and an arousal dimension called valence and arousal. Valence ranges from pleasure to displeasure and arousal from activation to deactivation. These two dimensions and their terminology are chosen to describe everyday feelings easily. It also enables the integration of other feeling related concepts, for example affect or mood (Russel, 2003).

Core affect is an always changing state (Zajonc, 2000). Considering the independence of valence and stimuli there a several reasons for a change in core affect. Russel (2003) names for example internal events as activation of immune cells by bacteria, drugs or external stimuli. The change occuring due to external stimuli underlies the individuals' responsiveness to stimuli and information processing. Its function is to evaluate ones current situation and the reason of one's emotional state. The more positive events remembered or encountered the higher is positive affect (Russel, 2003). Therefore, core affect is experienced differently by each individual in each moment of life.

Because this study focuses on the relationship between feelings and HR it was chosen to only use the dimension of valence. Since a range of different feelings can be categorized into the

categories of pleasant and unpleasant, using the dimension valence is a suitable manner to investigate this relationship. The definition of valence and its terminology, namely unpleasant and pleasant enables a comparison with other previous studies investigating the relationship between HR and feelings by using other concepts of feelings with the same underlying definition.

Relation Between Heart Rate and Self-Reported Valence as One Dimension of Core Affect

Studies show that psychological experiences, such as feelings are associated with HR (Levenson, 2003). This is based on the stimulation of the autonomic nervous system (ANS). The ANS regulates bodily functions and is in charge of the functions of organs. When experiencing psychological phenomena as feelings, the sympathetic nervous system (SNS), as one part of the ANS is responsible for producing physiological effects. One effect is for instance a change in the cardiovascular system, thus HR (Appehlhans & Luecken, 2006). One very specific response, called the "fight-or-flight" body response, is the physiological response to frightening situations. Increase in HR is one physiological change during the "fight-or-flight" situation (Cacioppo, Tassinary, & Berntson, 2017). As mentioned before, feelings are based on how individuals experience the current situation by interpreting external stimuli. Therefore, an increase in HR is related to the psychological experience of feelings (Schwarz, 1990; Russel, 2003).

Jacob, Thayer, Manuck, Muldoon, Tamres, Williams and Gatsonis (1999) investigated the relationship between mood and blood pressure responses as well as HR over a period of four days in everyday life. Mood is defined by the Oxford University Press (2019) as "a temporary state of mind or feeling". In addition, Russel (2003) argues that mood is a prolonged core affect without a specific cause or external stimulus required. Based on these two definitions the study of Jacob et al. (1999) gives insights and indications about the relationship between valence and HR as well. In order to investigate this relationship, Jacob et al. (1999) used the emotion theory with a circumplex model to assess mood. This model includes the two dimensions of core affect, affect and arousal. The affect dimension ranges from feeling unhappy or grouchy to feeling happy and friendly. The arousal dimension ranges from active or attentive to uninvolved or inactive. These dimensions are the same as in core affect with the dimensions of valence and arousal. The differences are among terminology while the broader meaning remains the same. This terminology and the research design with Experienced Sampling by using the interval

contingent sampling method for affect and continuous sampling for HR in everyday life makes it comparable to the present study. Jacob et al. (1999) report that the more intensive the moods are, the higher the HR. Consequently, HR increases when experiencing intensive moods. Anxiety, for instance shows the highest increase in HR, followed by happiness whereas disengagement shows a decrease in HR. Therefore, moods are related to HR. One indication of the results of this study is that HR tends to increase when experiencing unpleasant and pleasant feelings and decreases when experiencing more neutral feelings and less engagement.

Ilies, Dimotakis and Watson (2010) investigated the intra-individual relationship between mood, described in the study as positive and negative affect, and HR in a work-related environment. Positive and negative affect are comparable to pleasantness and unpleasantness by reason of its definition. Positive affect is defined as the experience of positive experiences and the individuals' interaction with the surrounding whereas negative affect is defined as the experience of negative experiences and the individuals' interaction with the surrounding. This study gives insights about the relation between feelings of pleasantness and unpleasantness and HR. To assess affect Ilies et al. (2010) used the Positive and Negative Affect Schedule (PANAS) which consist of adjectives for instance excited or upset that have to be rated on a likert scale form 1, representative for agreeing not at all to 5, representative for extremely agreeing. The study reveals a significant parabolic intra-individual correlation between HR and negative and positive affect. HR increases when positive affect increases as well as when negative affect increases. Therefore, it is concluded that there is a parabolic relationship between HR and the experience of intense feelings.

The studies of Jacob et al. (1999) and Ilies et al. (2010) give no indication about whether the correlation of HR and feelings are consistent over time. Based on the findings of literature review, it is concluded that no study has investigated the consistency of this correlation. Nevertheless it is important to know whether the correlation is consistent. Using intra-individual correlations gives indications about the correlation of one specific individual. That can be applied to other individuals but it does not guarantee that the data itself is consistent. A consistent response in self-report measures of an individual is not warranted. As Diener and Larson (1984) demonstrate individuals do not report feelings consistently over time. It is noteworthy that some individuals respond in self-report measurements more consistent than other individuals.

In addition, Kuppens, Oravecz and Tuerlinckx (2012) found evidence for instability of valence. This instability is related to low well-being, negative emotionality and self-esteem variability. Since these factors are changing in intensity over time it is concluded that self-reported valence is inconsistent in short- and long-term. These findings demonstrate the importance of analyzing consistency of correlations in studies regarding feelings. Given the individuals do not report consistent but differ in self-report about their feelings, the correlation between the self-reported feelings and HR is influenced by that. In addition, by reporting feelings constantly, the correlation between feelings and HR can be influenced by other factors, such as unexpected changes in HR based on cardiovascular diseases for instance. In order to make reliable judgments about the correlation between feelings and HR one should consider the consistency of the correlation to exclude possible influences or changes within the period of measurement.

The Present Study

In order to investigate the relationship between psychological experiences and physiological responses, an intra-individual design is chosen. This ensures the analysis of the individual's response, which is of importance based on the sensitivity of feelings. Furthermore, it avoids the error of using the findings from group level data to make judgments about each individual. To ensure more generalizability and accurate data, it has been decided to collect the data during the participants' everyday life. This method enables general conclusions based on the daily life setting in which the data is collected and therefore enhances the ecological validity. This is based on the natural occurrence of events in contrast to the artificial and steering (in terms of giving participants clues when to self report high or low levels on questionnaires) alternation of baseline and stressful events in a laboratory setting (Cacioppo et al., 2017).

The correlation between HR and valence as a dimension of core affect is investigated. HR is measured with the aid of the wearable technology. The data of valence is self-reported and collected with one item on an application for smartphones. Based on the literature review presented above it is expected that there is a linear relationship between HR and self-reported valence. Since Ilies et al. (2010) found a parabolic relationship between HR and positive and negative affect on two different scales it is expected that HR is linear related to self-reported valence in the present study. This is based on the correlation of HR and self-reported valence on

one scale instead of two. Therefore it is expected that HR increases when self-reported valence increases. To investigate that, the following research question with its sub-questions is formulated: To what extent is self-reported valence consistently correlated to heart rate intra-individually in a daily life setting?

Method

Participants

Within the present study convenience sample was used. There were two different starting points of the data collection. Within the first data collection, 19 participants (male=8, female=10, one missing data) participated with an age ranging from 19 to 45 years (*M*=22,03, *SD*=4,391). Due to an unforeseen lost in demographic data about the participants, data of one participant is missing and no nationality of the participants can be described. Since master and bachelor students executed this experiment in the same manner, the nationality is expected to be comparable to those of the participants of the second part of the data collection. Within the second part of the data collection 16 participants participated (male=11, female=5) with an age ranging from 21 to 70 (*M*=30.63, *SD*=12.96). 13 participants were German and 3 participants were Dutch. Therefore, in total 35 participants (male=19, female=15) with an age ranging from 19 to 70 participated within the present study.

There were two criteria to this study that had to be met. First, the participants needed to own a smartphone and a laptop or computer. Second, based on voluntary willingness to participate in the study, the participants had to sign the informed consent before participating. The Ethics Committee of the Behavioral Management and Social Sciences (BMS) faculty of the University of Twente approved the ethical request. As participants were recruited from the SONA test subjects pool, the participants were compensated with 5.25 SONA points for participation.

Materials

Each participant was provided with an Empatica E4 wristband in order to gather data from physiological signals, as HR. The Empatica E4 measures HR using photoplethysmography (PPG) techniques measuring the blood volume pulse (BVP) of the participant. This BVP is sampled with a sampling rate of 64 Hz. With the Empatica E4 wristband, the participants got a

user manual and a cable that enables them to connect the wristband with a laptop. To transfer the data from the wristband to the laptop, the participants were asked to install "Empatica Manager" on their laptop.

To measure the self-reported valence, the participants were asked to install the application The Incredible Intervention Machine (TIIM) version 1.3.2 on their smartphone. TIIM is an application launched by the University of Twente in 2007 and used by researchers for interventions. It is usable for Android Smartphones and Apple iPhones. TIIM sent questionnaires every two hours, asking two questions in a grid-form with the two-axis valence and arousal (Appendix A). The participants were first asked about the experienced valence and arousal of the current state and about the experienced valence and arousal of the past two hours. This method is chosen to capture important changes in feelings. Mehl and Conner (2012) argue that there should be 4 to 10 questions per day to ensure that observation of changes. Therefore it is chosen to ask the participants every two hours about their self-reported valence. In addition, a time range of two hours in between the questions is chosen to have a comparable value to the current state that has not been a long time since the participant experienced the pleasantness or unpleasantness. This ensures that the participants' long-term memory is not supposed to be very good in order to be able to remember the feelings of the past two hours.

For the present study, only the self-reported valence is of importance. The participants answered the questions with placing a dot in a two dimensional grid (Appendix A). The indicated scores range from -100 to +100, from very low to very high in both dimensions.

To be able to investigate possible changes in understanding, processing and describing emotions, the Toronto Alexithymia Scale (TAS-20) was used as a pre and posttest (Parker & Taylor, 1994). This data is beyond this study and used for further investigations by other researchers regarding other aspects of HR and valence.

Design

The chosen design for this study is a longitudinal, repeated-measures, single subject design. The data of HR is gathered by using continuous sampling in an unobtrusive manner from each participant. Using this method by wearing the Empatica E4 wristband seven times for a whole day provides data about HR of a time frame of each day (Mehl & Conner, 2012).

Since feelings are experienced individually differently, it is important to use a method that enables the participants to report the feelings themselves. Therefore it was chosen to use the Experience Sampling Method (ESM) by using the interval contingent sampling method to gather valid and reliable self-reported data (Csikszentmihalyi, & Larson, 2014; Mehl & Conner , 2012). Using interval report by asking the participants every two hours about their experienced arousal and valence with the aid of the TIIM application minimized a bias based on the participants' long-term memory. Momentary report provided reliable and specific data about the exact moment of report (Mehl & Conner , 2012).

Procedure

The study began with a debriefing meeting in which the participants were asked to fill in the informed consent and the Toronto Alexithymia Scale (TAS-20) (Bagby, Parker & Taylor, 1994). Next, the participants were given the Empatica E4 wristband, the belonging cable and manual. The researcher informed the participant verbally about how to use the Empatica E4 wristband, how to use the installed Empatica Manager and the application TIIM after it was installed. It was emphasized that the participant is asked to wear the Empatica E4 wristband continuously, except during night, when the data should be uploaded and the wristband should be charged while sleeping. Within the next seven days, the participants got push-notifications on their smartphone reminding them to fill in the questions from the TIIM application every two hours. The questions were available for 30 minutes, after those 30 minutes the questionnaire expired. This fixed schedules are minimizing the burden of the participants because the participants can schedule their day around the standardized times during the experiment (Mehl & Conner , 2012).

After the seven days, there was a debriefing meeting. The participant was asked to return the Empatica E4 wristbands and the belonging cable and manual to the researcher. In addition the participants were asked to fill in the TAS-20 again as a posttest.

Data Analysis

The provided data of the HR of each individual measured by the E4 were stored in zip files. The data about the HR of the past two hours is based on the average HR of the participant in the past two hours. By downloading the data from the TIIM webpage in comma-separated

values (CSV) access to the self-reported valence was provided. Due to a timestamp of all data it was possible to combine both, the data of the E4 about HR and the data of TIIM about self-reported valence. All data was entered in one database that enables working with the IBM SPSS software. As mentioned, some of the used data was gathered before this experimentation. The students executing the previous data collection used another Application called “mQuest” to measure self-reported valence with values ranging from 1, very low to 10, very high. Therefore, the data of the TIIM application were recoded to values from 0 till 10 instead of -100 to +100. This was done with the following calculus with **x** as the data from TIIM and **y** the recoded data:

$$\frac{x + 100}{20} = y$$

Based on missing data concerning HR participant 37 and 39 from the previous data collection and participant 32, 38, 39 and 40 from the current data collection were excluded of the measurements. The participants were renamed from 1 to 29.

The IBM SPSS software was used to make judgments about the intra-individuals correlation of HR and self-reported valence. A bivariate within-subjects Pearson's r correlation of self-reported valence and HR was executed for each of the 29 participants. Pearson's correlation coefficient is a suitable manner to investigate the relation between self-reported valence and HR since it is a measure of the linear product-moment correlation of two variables (Sedgwick, 2012). The correlation was executed for the current state and the past two hours. To estimate the time-related consistency within each individual, the data was split into time-based two halves. The first half was the data of the first three days and the second half was the data of the last four days. This was done for each individual. In addition it was chosen to do a random split of the data to evaluate the consistency of the data in general. This random split was done by IBM SPSS using approximately 50% of the available data per participant. The random split was done for each participant and the correlation of the two halves of each participant was calculated. In order to make judgments about the consistency of the data and the differences in correlations between the two halves, Fisher's Z transformation was used. With the z scores, a one sample T-Test was executed to make a 95% confidence interval to see the differences among the splits.

Results

The subjects show an average HR of 79.52 bpm *(SD*=6.14*)* with a minimum HR of 53.60 bpm and a maximum HR of 141.93 bpm. The mean HR of each subject is illustrated in Figure 1. The scores from self-reported valence range from 1 to 10. The average self-reported valence is 5.09 *(SD*=0.85*)* and is illustrated in Figure 2.

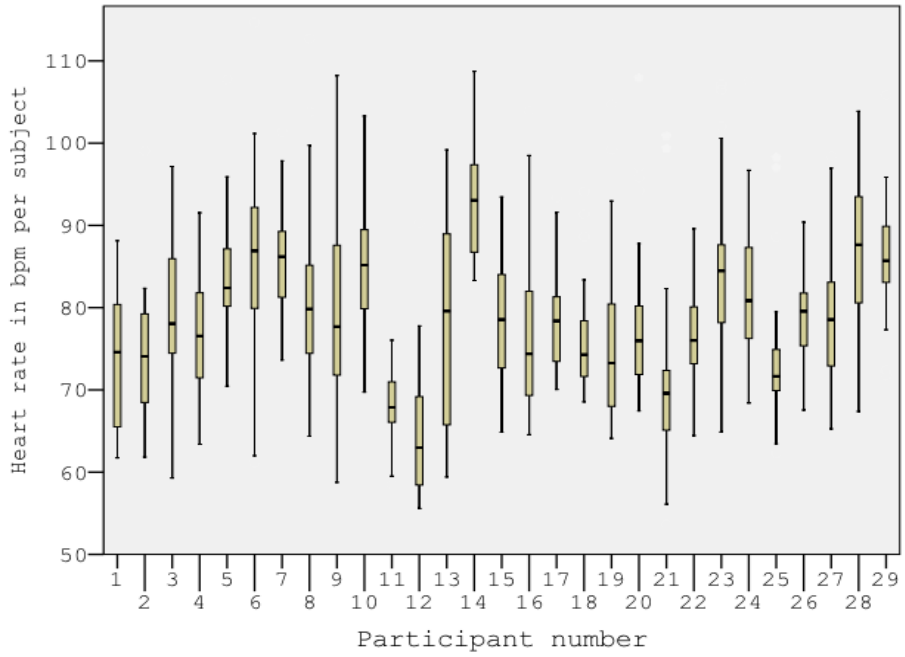


Figure 1. Average heart rate of each participant over study period

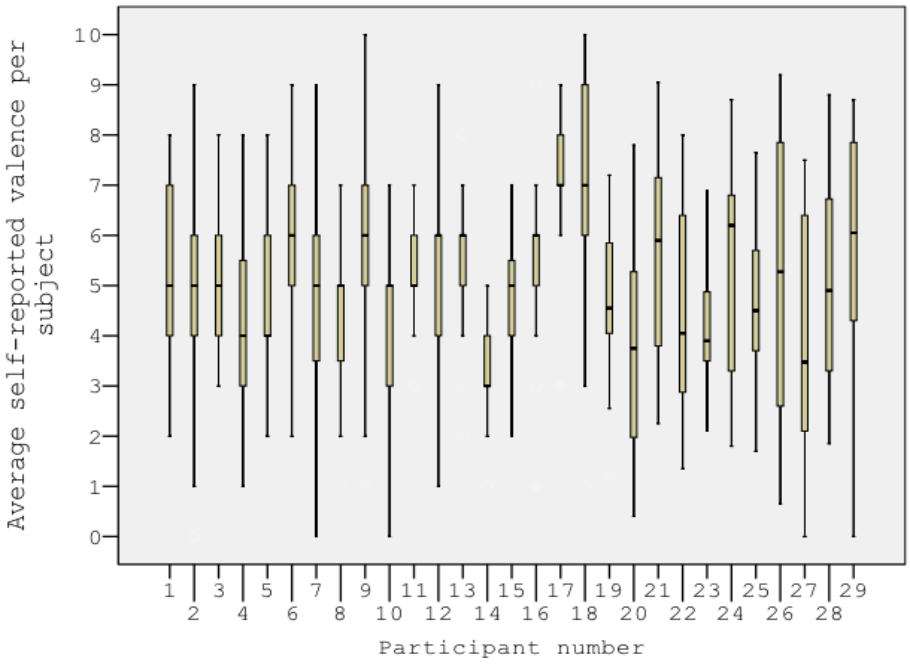


Figure 2. Average self-reported valence of each participant over study period

Results of the Analysis regarding the Within-Subject Correlation

The average within-subject correlation of HR and self-reported valence regarding the question about the current state is on average *r*=.01 (*SD*=.23*),* ranging from *r*=-.3 and *r*=.61. This is illustrated in Figure 3. The within-subject correlations of self-reported valence and HR include 18 negative and 11 positive correlations. Regarding the questions about the past two hours, the correlations range from *r*=.-.42 and *r*=.43 and an average within-subject correlation of *r*=-.01 *(SD*=.23*)* as illustrated in Figure 4. The within-subject correlations of self-reported valence and HR include 12 negative and 17 positive correlations.

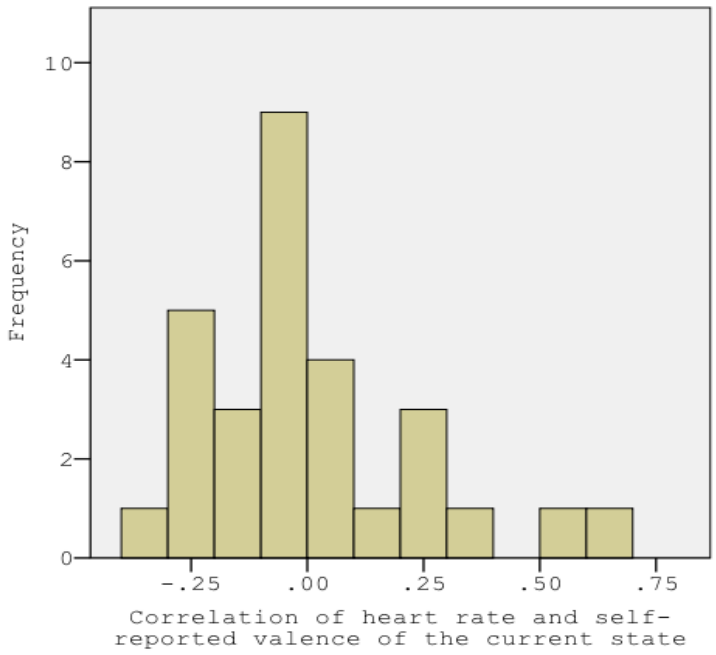


Figure 3. Histogram of the within-subjects correlation of HR and self-reported valence regarding the current state

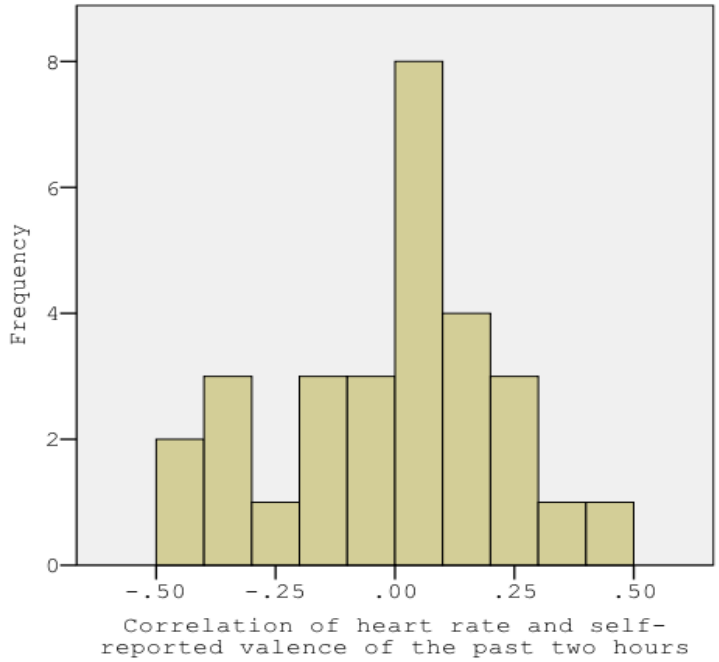


Figure 4. Histogram of the within-subjects correlation of HR and self-reported valence regarding the past two hours

Results of the Analysis regarding the Consistency of the Within-Subjects Correlations

In addition, a bivariate correlation was executed after the data of each participant was split twice, first time based and second time randomly. According to the results, the correlation of self-reported valence and HR differ within the subject in both techniques, randomly and time-related and for both question, with reference to the data of now and the past two hours. The differences in within-subject correlation with a random split are illustrated in Figure 5 and Appendix B. The time-related split differences within the subject are illustrated in Figure 6 and Appendix C.

The correlation from the randomized split of the first half ranges from r=-.77 and r=.83 with a mean of r=.065 *(SD*=.37*)* and for the second half from r=-.78 and r=.62 with an average correlation of r=-.02 *(SD*=.38*)* for the data regarding the question about the current state. Regarding the questions of the state of the past two hours, the correlations first half of the randomized split ranges from r=-.64 and r=.34 and an average correlation of r=-.03 *(SD*=.26*).* The correlations of the second half are between r=-.49 and r=.53 and have an average correlation of r=.02 *(SD*=.30*).*

The same results were found for the time-based split. Regarding the data about the current state, the within-subject correlations of the first time-related splitted half are between *r*=-.66 and *r*=.89 with an average correlation of *r*=.07 (*SD*=.41) and the correlations of the second half are on average *r*=-.01 (*SD*=.3) ranging between *r*=-.62 and *r*=.61. The data about the state of the past two hours ranged in the first half between *r*=-.53 and *r*=.61 with an average correlation of *r*=.05 (*SD*=.3). The average correlation of the second half is *r*=-.01 (*SD*=.28), ranging between *r*=-.5 and *r*=.76.

The results show inconsistency over time and in the data in general, based on both split methods. In addition, the correlation of both groups in both split methods showed differences in terms of strength. Data for both states, the current and the state of the past two hours range from a positive linear relationship to a negative linear relationship. Participant 4 for instance shows very contradictory data. The correlation of the first half of the random split is *r*=-.77, a strong negative relationship, whereas the correlation of the second half of the random split it *r*=.42, a moderate positive relationship. This example is also illustrated in Figure 5. The line in Figure 5 is used to make it more visible which points belong to participant 4.

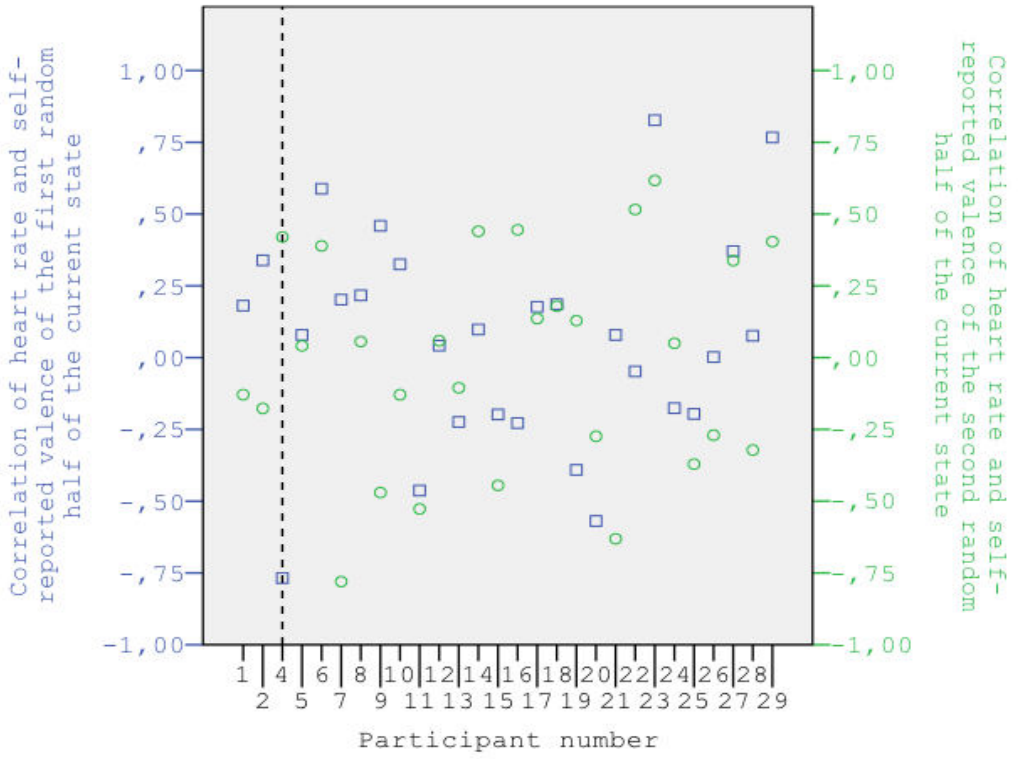


Figure 5. Scatterplot of the random half split of the correlations regarding the current state with a reference line examining the differences between the two halves

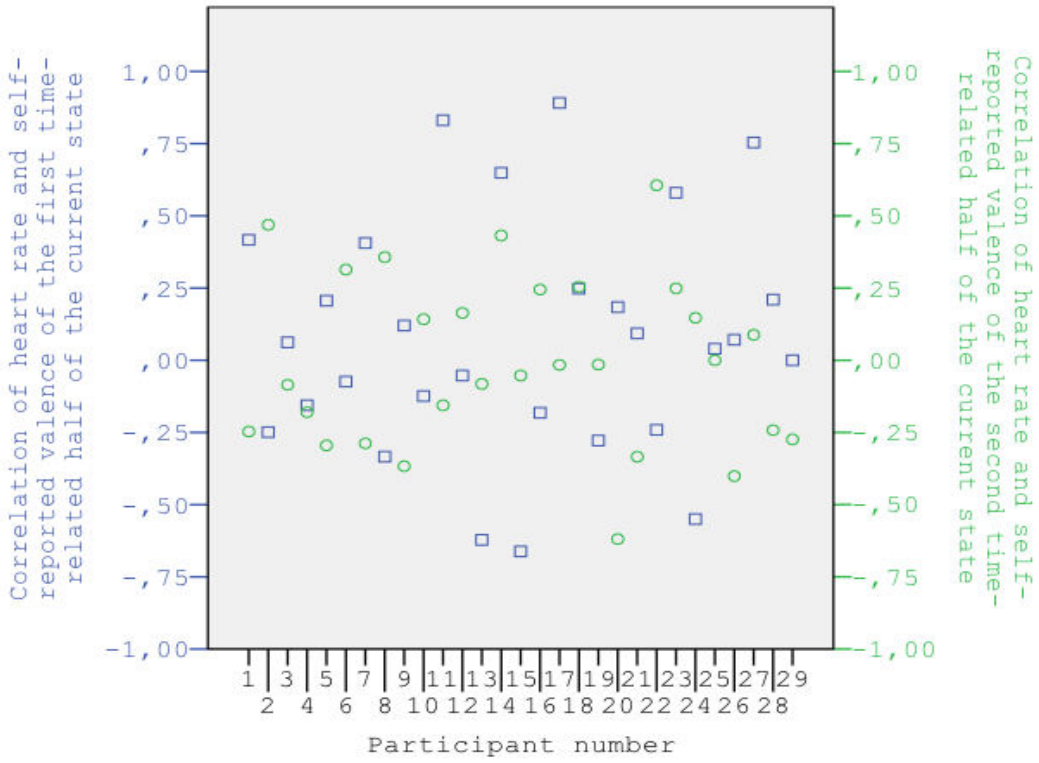


Figure 6. Scatterplot of the time-related half split of the correlations regarding the current state

Interpretation of the Differences among the Correlations

To interpret the differences among the correlations of the two halves of each split, Fisher's z was calculated. The mean of the differences among the time related split of the current state was z=.56 (*SD*=.45) with a maximum of z=1.44 and a minimum of z=.01. This is illustrated in Figure 7. As the T-Test indicates, 95% of the scores are in between CI [.42, .69] meaning they differed significantly. Regarding the data of the past two hours of the time-related split the mean difference was z=.36 (*SD*=.28) ranging from z=.00 and z=1.14, as illustrated in Appendix D. The 95% confidence interval of the time-related split of the data from past two hours ranges from CI [.25, .47]. The randomly split data showed differences ranging from z=.01 and z=1.46 and a mean difference of z=.42 (*SD*=.37), as illustrated in Figure 8, with 95% CI [.27, .56] regarding the data of the current state. The data of the past two hours showed a mean

difference of z=.21 (SD=18) with a maximum of z=.7 and a minimum of z=.01. This is illustrated in Appendix E. The 95% confidence interval for this data ranges from CI [.14, .28]. Concluding, on average the differences in correlations of the time-related split is higher than of the random split.

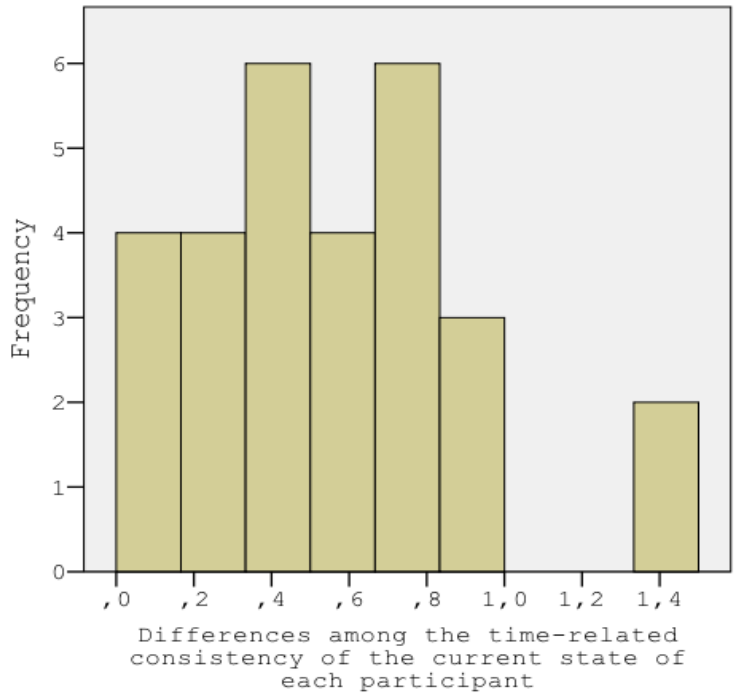


Figure 7. Differences among the correlations of the time-related half split regarding current state

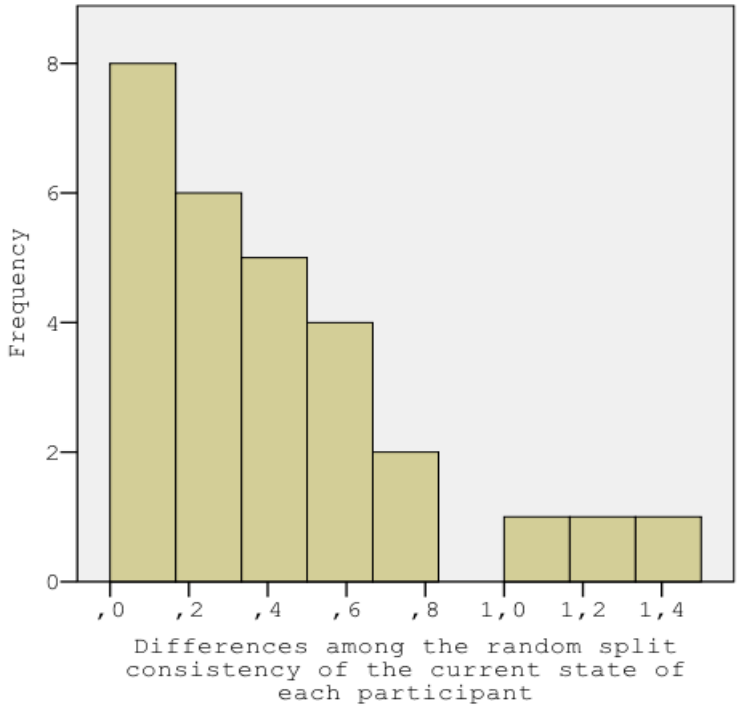


Figure 8. Differences among the correlations of the random half split regarding the current state

Discussion

Over a period of seven days, data about HR and self-reported valence of 29 participants was collected. With an intra-individual research approach, the correlation of HR and self-reported valence and its consistency over time was investigated. Contradicting the expectations, there is no correlation between HR and self-reported valence. Therefore, HR and self-reported valence do not have a linear relationship. In accordance with literature, the correlation of HR and self-reported valence is not consistent over time.

Key Findings

Investigating the relationship between self-reported valence and HR and its consistency, we found no consistent intra-individual correlation. HR is not increasing when self-reported valence increases. Based on the relatively equally distributed correlation, it can be concluded that there is neither a positive nor a negative correlation between self-reported valence and HR. Therefore it is concluded that neither self-reported valence influences HR nor is HR influencing self-reported valence in a consistent linear way. The correlations are not consistent over time.

Agreeing with the findings of Diener and Larson (1984) some individuals are more consistent in their self-reported answers than other individuals.

Interestingly, the correlations of the random split are more consistent than the correlation of the time-based split. The comparison of the time-based split and the random split indicates that the correlation is less consistent between the first three days and the last four days than when comparing the correlations randomly. This indicates a change in correlation over study period. This change could also be the reason for the inconsistency of the correlation when compared randomly. The change in correlation between self-reported valence and HR might be due to becoming more aware of one's feelings during this experiment. Farrell and Shaw (1994) argue for using awareness increasing technologies, such as the TIIM-Application used in this study, to increase the individuals' awareness of feelings. They assume that reflections of ones own feelings several times a day leads to an increase of awareness. In addition, they report that being aware of ones physical states by becoming aware of muscle tensions for example is another factor promoting awareness of feelings. This finding is explained by Bechara and Naqvi (2004) who argue that feelings represent changes in the body response. As the participants were also asked to rate their arousal during the experiment the results could be influenced by the enhances awareness of their feelings. Feeling aroused is likely involving movement, which again involves for example muscle tension (Ekman & Friesen, 1967). This indicates also that the correlation of HR and self-reported valence must be higher in the last four days of the study period. Contradictory, the results do not show a higher correlation in the last period of the study. Therefore, it cannot be concluded that the participants were influenced by their awareness of physical states as a promoting factor for become more aware of feelings. To get more insights about the possibly influencing factor of becoming more aware of ones feelings in general, it is recommended to use the data of the pretest and posttest of the TAS. The TAS is a questionnaire that gives insights about the individual's ability to understand, process and describe emotions. A change in the TAS-Score would confirm the increase of awareness due to the experiment.

Reflection of Findings in the Light of Previous Studies

The contradicting findings compared to earlier studies can be explained by differences in the study design. Jacob et al. (1999) used different terminology for the self-report of feelings. Possibly, the participants interpreted the descriptions differently. For example, Jacob et al.

(1999) use words such as happy and unhappy which are experienced individually differently whereas the words pleasant and unpleasant are likely to be experienced the same way. Finding money on the street can be described as pleasant as it is valuable but does not have to make someone happy. Using broader terms, here pleasant and unpleasant, which can be easily applied is an important advantage of this study.

Another difference among the present study and the study of Jacob et al. (1999) is the research design. In the present study an intra-individual design was chosen. This is based on the findings of Fisher et al. (2018) arguing that data with inconsistent variance and mean cannot be extended from the group level to the individual level. Therefore, the analysis of the data cannot warrant a generalization from the group level to the individual level. This indicates that the results of Jacob et al. (1999) might not have been correctly interpreted. The ecological validity of the study is consequently lower than in the present study. The results of the study do not give insights about the actual correlation of each individual and are therefore not representative. This is another strong advantage of the present study. The intra-individual design ensures that the data is representative for the population. For each individual a correlation is estimated based on all data available and the mean of all the individual correlations are generalizable to the population.

Ilies et al. (2010) found a significant correlation between positive and negative affect and HR. This finding is based on an intra-individual research design and thus generalizable for the population. There are two main differences among the present study and the study of Ilies et al. (2010). First, the material they used was the PANAS giving insights in positive and negative affect, which creates a difference to our study and can account for the different findings. Broadly these two have the same meaning. The main differences are that firstly, Ilies et al. (2010) use 20 items to describe ones state of feeling while within the present study the participant answers an one item questionnaire. Secondly, comparable to Jacob et al. (1999) the used terms differ from each other. Within the PANAS adjectives like “guilty” or “inspired” form items. These terms are difficult to compare with the affect dimension ranging from unpleasant to pleasant. It is possible that each individual perceives the feeling of inspiredness differently, some as very pleasant while others perceive it as less pleasant. Therefore, the PANAS gives insight in more precise feelings while valence as a dimension of core affect can only be rated broadly in between pleasant and unpleasant. This difference in specification of feelings and terminology is a possible explanation for the different findings of the study of Ilies et al. (2010) and the present study. Second, Ilies et

al. (2010) investigated the relationship between positive affect as well as the relationship between HR and negative affect and HR. They found a parabolic relationship between affect and HR based on using the two scales of negative and positive affect. Hence, positive and negative affect is related to HR. whereas the present study investigates a linear relationship between HR and self-reported valence by using one scale. Therefore, it can only be concluded that there is either a linear or no linear relationship. The results of the present study are thus only comparable to one scale of the study of Ilies et al. (2010), namely positive affect.

The studies of Jacob et al. (1999) and Ilies et al. (2010) did not evaluate the consistency of the correlations they found. Jacob et al. (1999) could not do that based on the applied deviating research design. But Ilies et al. (2010) used an intra-individual design that enables analyzing the consistency of the intra-individual correlations. As mentioned before the consistency of the correlations gives insights about possible changes for instance in awareness of feelings and also shows how representative the mean of the intra-individual correlation is. Consequently, one can question the representativeness of the intra-individual means of the study of Ilies et al. (2010).

In addition, neither the studies of Jacob et al. (1999) and Ilies et al. (2010) nor the present study gave the participants the possibility to choose the moment of self-report themselves. This is recommended for further research. An event-based sampling would have enabled to gather more representative data for the following reasons. Firstly, by doing so one would have avoided asking the participant to give a mean feeling about the past two hours. Levine and Safer (2002) state that one should consider self-reports about past feelings with caution. The recalls of past feelings are biased personality or coping effort for example. Coping effort means for example then when thinking and comparing to the past people tend to overestimate the difference between their present and past feelings to have the impression of improvement. Cutler, Larsen and Bunce (1996) investigated the relationship between personality and biases in self-report. They found that individuals with the personality trait anxiety report their past feelings more negative compared to the average score during the period of the experiment. Secondly, giving the participants additionally the option to report their feelings at a moment that they chose themselves could have the benefit of getting data of very aware feelings. If the participant were told to press a button when they have an intense feeling, the participant would be aware of the intense feeling in the moment of self-report. Therefore the gathered data would be very accurate.

By adding this option one would have the data of the daily life setting and the data of aware intense feelings. This awareness and insensitivity could lead to more accurate and representative results.

Limitations and Strengths

There are three limitations in the present study. First, collecting data in a daily life setting leads to less control over the variables that mediate or monitor the collected data. Therefore it is impossible to preempt possible external factor influencing the data and results of the study. Second, the measurement of the parameter HR of the present study should be considered with caution. There are two different types of HR, first psychological induced HR and second physiologically induced HR. In order to measure the first, it is important to correct the data from the effect of movement on HR. A possible correction method is a calibration technique by asking participants to do a physical activity and measuring heart rate variability in the meantime (Verkuil, Brosschot, Tollenaar, Lane, & Thayer, 2016). Despite the measurement of acceleration by the Empatica E4 no algorithm could be created yet to correct the data from the effect of movement. To find this algorithm further research is needed. To prevent this possible influencing factor, future research should consider using an algorithm that provides data about HR that is physiologically induced to ensure high validity. Third, participants owning an Apple iPhone mentioned that there were issues using the TIIM Application. The 3D Touch on Apple iPhones 7 and newer turned out to be incompatible with the application. Moving the dot in the graph on TIIM did not work properly. The participants were informed about that issue in advance. This issue could have influenced the self-reported valence values by making it harder to place the dot at the right place in the graph.

Several aspects are important strengths of the present study. First, the ecological validity of this study is enhanced due to a data collection in a real life setting. The participants experienced their daily life and feelings that occur naturally instead of experiencing artificially created feelings. The approach of the present study is valid for drawing conclusions regarding the daily life of individuals. This is an advantage over other studies investigating the relationship between HR and self-reported valence. Second, the intra-individual correlations based on analyzing within-subjects correlation are another strength of the present study. The intra-individual analysis ensures generalizability to the population and therefore enhances the

ecological validity of the present study (Fisher et al., 2018). Therefore it can be assumed that the gathered data and the conclusion based on that are accurate. Third, the length of the study in the real life setting is an important factor. Investigating the relationship of self-reported valence and HR for seven days in the participants' real life setting is enhancing the reliability of the findings. This is based on the fact that within this period it is likely that the participant experienced different levels of valence and HR, which makes it possible, to draw conclusions about every level of valence and HR. Hence, within the study period data of different feelings is gathered. That high range of feelings ensures making accurate conclusions based on the gathered data.

Implications for Practice

Murray, Weiner, Prabhakar and Fiedorowicz (2009) investigated the relationship between bipolar disorder and cardiovascular disease. They reported that individuals suffering from bipolar disorder experience twice the cardiovascular mortality compared to the population. Manic symptoms are assumed to predict cardiovascular disease. The manic episodes as one side of the bipolar disease are characterized by an increase in energy and good moods whereas depressive episodes are characterized as the opposite. The findings of the present study indicate that the increased cardiovascular mortality in bipolar disorder patients is likely not related to the positive moods experienced in manic episodes. It is concluded that there must be other influencing factors on cardiovascular disease than mood, for instance arousal or other symptoms occurring during manic episodes or in depressive episodes. This gives rise to investigate all influencing factors in order to find the most influencing one. This conclusion needs to be considered with caution because the present study only tested a limited linear relation between feelings and HR. There are other possibly influencing factors that need to be considered in order to draw a specific conclusion. Therefore, this is only a recommendation for further research in possible influencing factors related to mood and cardiovascular disease in mental health.

The American Psychological Association (2009) describes depression as experiencing lack of pleasure in daily life. In addition, negative feelings are one symptom of depression such as feelings of worthlessness, guilt, thoughts of death or suicide. These feelings can be described as highly unpleasant. Since previous studies indicated a relationship between intense feelings and HR there might be a link between changes in HR while feeling depressed. This is supported by Rugulies (2002) arguing that depression is a predictor for coronary heart disease. Contradicting,

the present study shows that feelings are not related to HR in a linear way. The results indicate that there must be another mediating factor in this prediction as negative feelings do not influence HR. Therefore, the findings regarding the relation between depression and changes in HR should be considered with caution. It is noteworthy that the present study did not investigate all possible relation between HR and feelings. Therefore, the conclusion should be considered with caution. It is therefore recommended to make further investigations about the underlying factor of this relation.

Conclusion

The present study aimed to investigate the intra-individual correlation of self-reported valence and HR. The results show that there is no consistent intra-individual correlation between self-reported valence and HR. Based on that it is concluded that there is either no linear relationship between the two variables or that there must be another variable influencing that relationship. A high amount of positive feelings is not influencing our health negatively. An increase in awareness of feelings is one possibly influencing factor to this relationship. It is recommended to investigate an increase in awareness of feelings to make judgments about the accuracy of the correlations. Since the data about HR is not corrected from the effects of movements, the findings should be considered carefully. Concluding, the saying that the heart beats fast when experiencing beautiful moments or moments of happiness cannot be proven based on the findings of the present study.

References

American Psychological Association (2009). *Depression.* Retrieved from https://www.apa.org/topics/depression/index.aspx

Anttonen, J., & Surakka, V. (2005). Emotions and heart rate while sitting on a chair. In Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 491-499). Portland, USA: ACM.

Bagby, R., Parker, J., & Taylor, G. (1994). The twenty-item toronto alexithymia scale--I. item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research, 38*(1), 23-32.

Bechara, A., & Naqvi, N. (2004). Listening to your heart: Interoceptive awareness as a gateway to feeling. *Nature Neuroscience, 7*(2), 102-3.

Brosschot, J., & Thayer, J. (2003). Heart rate response is longer after negative emotions than after positive emotions. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology,50*(3), 181-7.

Cacioppo, J. T., Tassinary, L. G., & Berntson, G. G. (2017). Strong inference in Psychophysiological science. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of Psychophysiology* (4th ed., pp. 3–15). Cambridge, UK: Cambridge University Press.

Csikszentmihalyi, M., & Larson, R. (2014). Validity and reliability of the experience-sampling method. In *Flow and the foundations of positive psychology* (pp. 35-54). Dordrecht: Springer.

Cutler, S., Larsen, R., & Bunce, S. (1996). Repressive coping style and the experience and recall of emotion: A naturalistic study of daily affect. *Journal of Personality, 64*(2), 379-405.

Diener, E., & Larsen, R. (1984). Temporal stability and cross-situational consistency of affective, behavioral, and cognitive responses. *Journal of Personality and Social Psychology, 47*(4), 871-883. doi:10.1037//0022-3514.47.4.871

Ekman, P., & Friesen, W. V. (1967). Head and body cues in the judgment of emotion: A reformulation. *Perceptual and motor skills*, *24*(3 PT 1), 711-724.

Farrell, J., & Shaw, I. (1994). Emotional awareness training: A prerequisite to effective cognitive-behavioral treatment of borderline personality disorder. *Cognitive and Behavioral Practice, 1*(1), 71-91. doi:10.1016/S1077-7229(05)80087-2

Fisher, A., Medaglia, J., & Jeronimus, B. (2018). Lack of group-to-individual generalizability is a threat to human subjects research. *Proceedings of the National Academy of Sciences of the United States of America,115*(27), 6115. doi:10.1073/pnas.1711978115

Ilies, R., Dimotakis, N., & Watson, D. (2010). Mood, blood pressure, and heart rate at work: An experience-sampling study. *Journal of Occupational Health Psychology, 15*(2), 120-30. doi:10.1037/a0018350

Jacob, R., Thayer, J., Manuck, S., Muldoon, M., Tamres, L., Williams, D., . . . Gatsonis, C. (1999). Ambulatory blood pressure responses and the circumplex model of mood: A 4-day study. *Psychosomatic Medicine, 61*(3), 319-33.

James, G. D., Yee, L. S., Harshfield, G. A., Blank, S. G., & Pickering, T. G. (1986). The influence of happiness, anger, and anxiety on the blood pressure of borderline hypertensives. *Psychosomatic Medicine*, *48*(7), 502-508.

Kuppens, P., Oravecz, Z., & Tuerlinckx, F. (2010). Feelings change: Accounting for individual differences in the temporal dynamics of affect. *Journal of Personality and Social Psychology, 99*(6), 1042-60. doi:10.1037/a0020962

Levenson, R. W. (2003). Blood, sweat, and fears: The autonomic architecture of emotion. Annals of the New York Academy of Sciences, 1000, 348– 366.

Levine, L., & Safer, M. (2002). Sources of bias in memory for emotions. *Current Directions in Psychological Science, 11*(5), 169-173. doi:10.1111/1467-8721.00193

Mehl, M., & Conner, T. (2012). *Handbook of research methods for studying daily life*. New York: Guilford Press.

Murray, D., Weiner, M., Prabhakar, M., & Fiedorowicz, J. (2009). Mania and mortality: Why the excess cardiovascular risk in bipolar disorder? *Current Psychiatry Reports, 11*(6), 475-480.

doi:10.1007/s11920-009-0072-3

Oxford University Press (2019). Definition of Mood. Retrieved from https://en.oxforddictionaries.com/definition/mood

Rugulies, R. (2002). Depression as a predictor for coronary heart disease. a review and meta-analysis. *American Journal of Preventive Medicine, 23*(1), 51-61.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110*(1), 145-172. http://dx.doi.org/10.1037/0033-295X.110.1.145

Schwarz, N. (1990). Feelings as information: Informational and motivational functions of affective states.

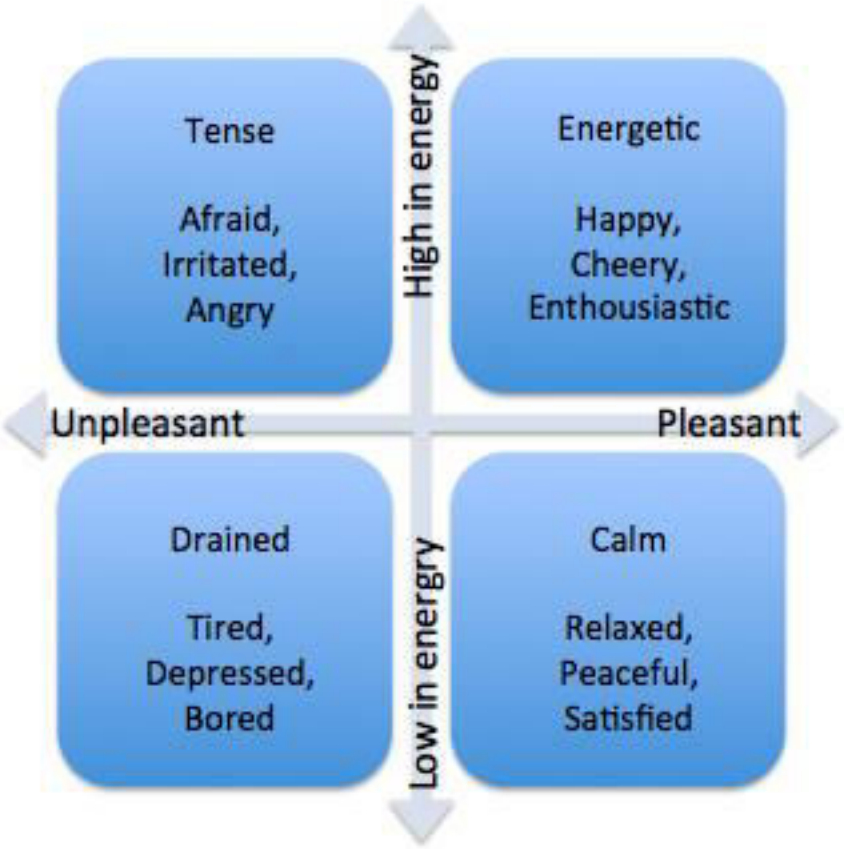
Sedgwick, P. (2012). Pearson's correlation coefficient. *Bmj*, *345*, e4483.

Thayer, J., Ph.D., Hansen, A., Ph.D., Saus-Rose, E., Cand. Psychol., & Johnsen, B., Ph.D. (2009). Heart rate variability, prefrontal neural function, and cognitive performance: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 37*(2), 141-153. doi:10.1007/s12160-009-9101-z

Verkuil, B., Brosschot, J. F., Tollenaar, M. S., Lane, R. D., & Thayer, J. F. (2016). Prolonged non-metabolic heart rate variability reduction as a physiological marker of psychological stress in daily life. *Annals of Behavioral Medicine*, *50*(5), 704-714.

Zajonc, R. B. (2000). Feeling and thinking: Closing the debate over the independence of affect. In J. P. Forgas (Ed.), *Studies in emotion and social interaction, second series. Feeling and thinking: The role of affect in social cognition* (pp. 31-58). New York, NY, US: Cambridge University Press.

Appendix A: One item questionnaire about self-reported valence and self-reported arousal



Appendix B: Comparison of the two random split halves regarding the data of the past two hours

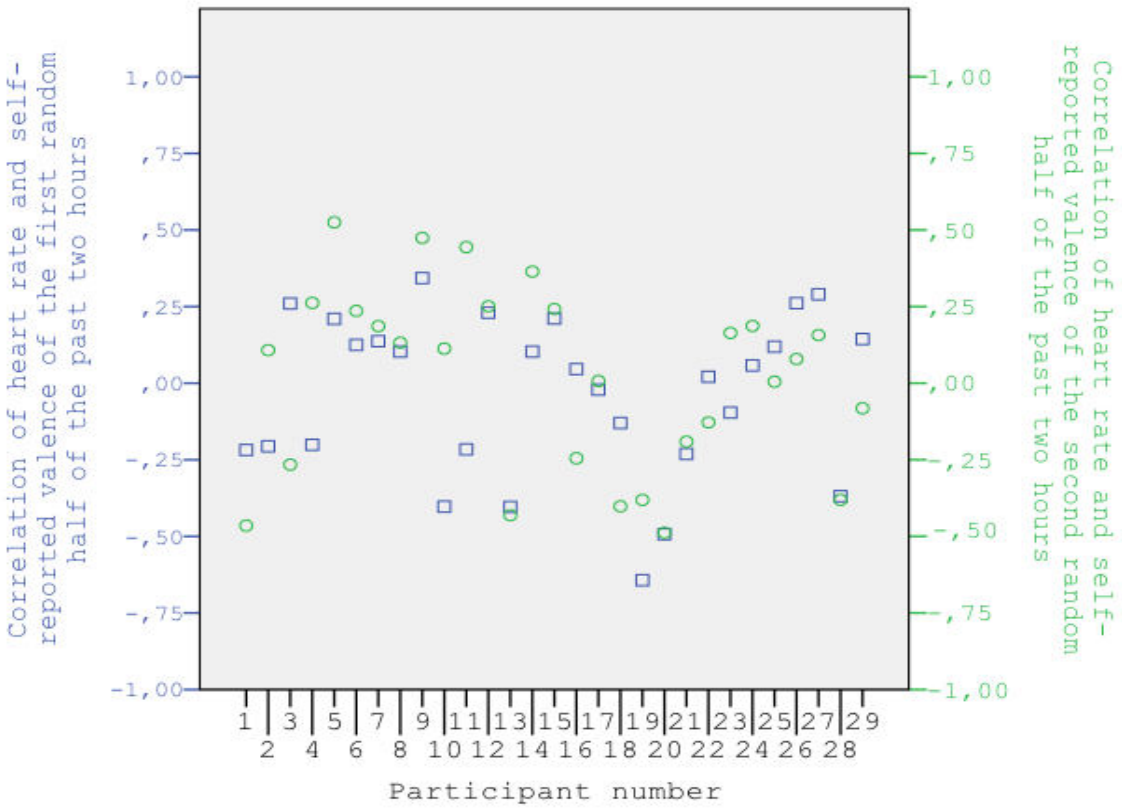


Figure B. Scatterplot of the random half split of the correlations regarding the past two hours

Appendix C: Comparison of the two time-related split halves regarding the data of the past two hours

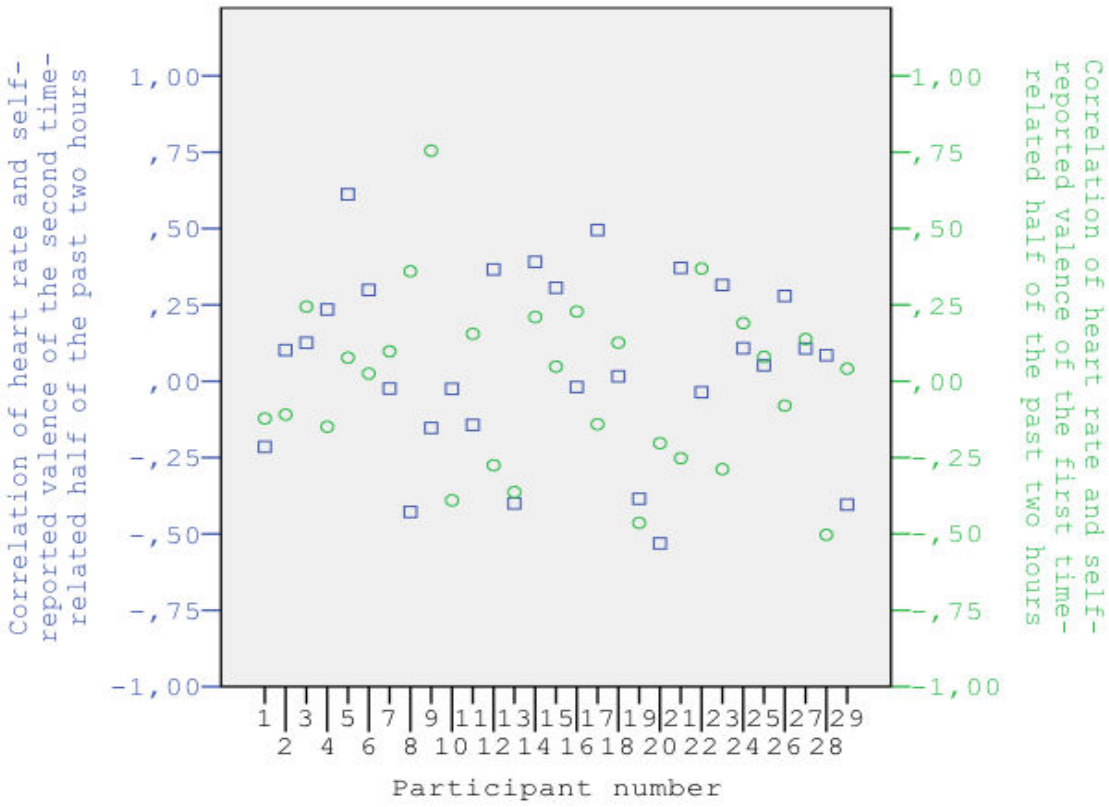


Figure C. Scatterplot of the time-related half split of the correlations regarding the past two hours

Appendix D: Differences among the correlations of the random split halves regarding self-reported valence and HR of the past two hours

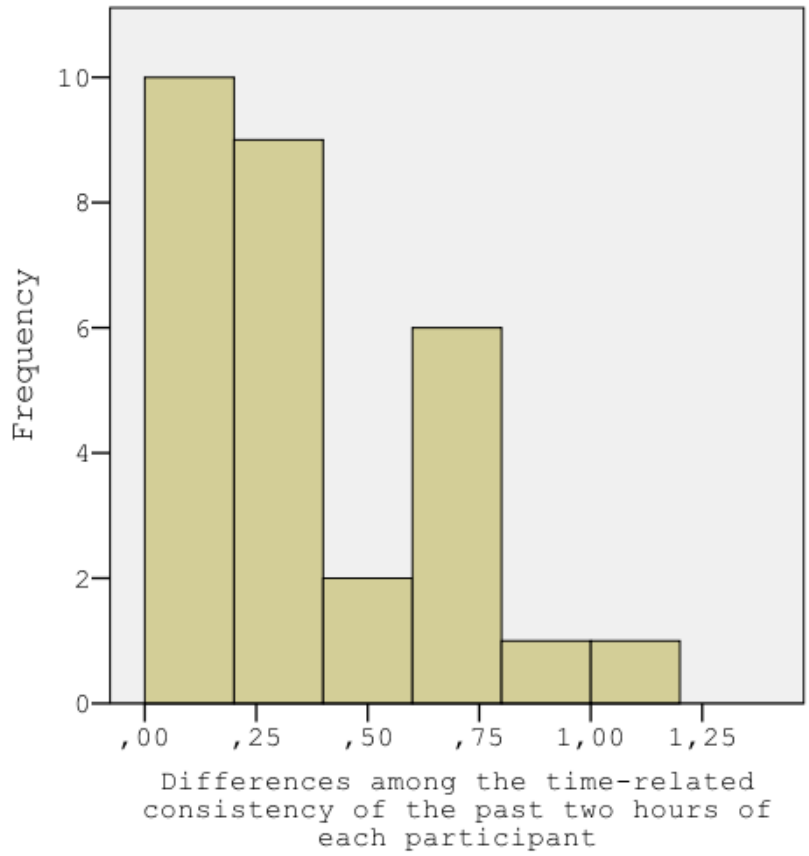


Figure D. Differences among the correlations of the time-related half split regarding the past two hours

Appendix E: Differences among the correlations of the time-related split halves regarding self-reported valence and HR of the past two hours

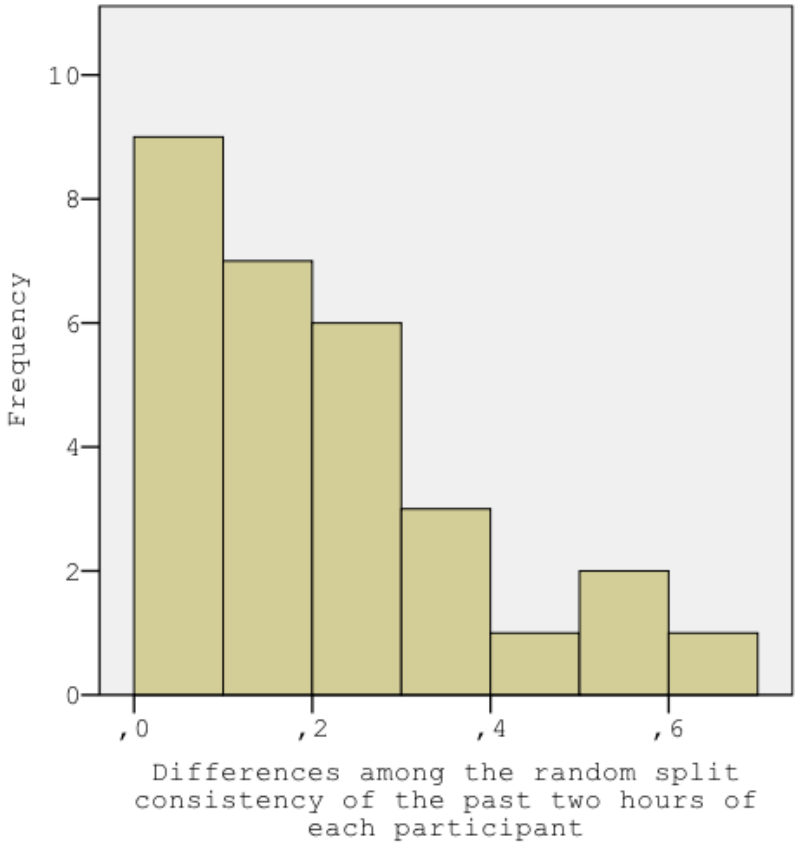


Figure E. Differences among the correlations of the random half split regarding the past two hours