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Stress response coherence: Does self-perceived stress and its interaction with physiological measures depend on the kind of stressor?

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Abstract

We all experience the feeling of stress from time to time. It is often assumed that this feeling correlates with physiological measurements of stress (e.g. heart rate), a concept referred to as response coherence. While these correlations are often addressed in literature, the existence of response coherence remains controversial among researchers. This study discusses these inconsistencies and aims to make a contribution in understanding coherence. Therefore, this study examines whether the correlation between self-perceived stress and physiological measures exists, and if so, if these correlations depend on the type of stressor. A social stressor (the Sing-a-song Stress Test), an environmental stressor (a noise stress test) and a cognitive stressor (the beauty contest game) as well as baseline relaxation periods were presented in a controlled environment. During the experiment, electrodermal activity, heart rate and self-perceived stress were measured. For each stressor, at least one correlation between a physiological measure and self-perceived stress was found. The environmental stressor showed correlations for every used measurement. However, the differences in correlations between the three stressors were not significant. This experiment cannot decisively conclude whether response coherence exists. However, it seems that response coherence does not vary on the type of stressor. This conclusion underlines that response coherence is a complex concept. The results can help giving directions to future studies that aim to detect the underlying mechanisms in stress coherence.

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1 Introduction

Stress is a feeling we are all familiar with. Whether we face life-altering changes such as a new job, a strict deadline or an everyday situation like catching the bus; everyone faces stressful situations from time to time. The intensity of this stress varies, depending on the situation as well as the person (Silverman, Eichler, & Williams, 1987). As a person, being able to assess one's own level of stress offers multiple applications, for example, when judging if we have to act and do something about a situation, in order to communicate our stress to others, as well as making judgement calls on whether or not we can handle a situation. Unfortunately, assessing the level of stress we are experiencing does not seem as easy as we intuitively think.

While people generally assume that they can estimate their own emotions quite well (Barrett, 2006), the majority of the research done on this topic contradicts this view. Among others, Campbell and Ehlert (2012) have found that perceived emotions do not necessarily correlate with physiological measures of these emotions. Some researchers report weak relations among different emotions (Mauss et al., 2004), some found none at all (Edelmann & Baker, 2002) and Buck (1980) even reported negative associations. These inconsistencies in findings prompt questions about the so-called coherence framework, which states that stress causes a coordinated response at the level of the subjective emotional experience, the behavioral, physiological and endocrine systems (Andrews, Ali & Pruessner, 2013). As the many contradicting studies show, the coherence model does not seem to be a successful prediction. To gain more insight into stress coherence this paper studies the effect of differing kinds of stressors on the coherence process. This paper will examine the effect of a social, an environmental and a cognitive stressor on stress coherence with an experiment. If the results show that coherence does depend on the stressor, it is an indication that the way in which the stress systems have been triggered, are vital to the coherence process. If the results show no coherence depending on the stressor, it would be likely that the reason for incoherent stress studies lies elsewhere. It would be a first indication that the type of stressor might be excluded as an explanation for inconsistencies in coherence studies.

1.1 Evidence for and against the coherence view and previous coherence studies

A stimulus has to be recognized as stressor first in order to trigger the other stress systems, which flow together in the central nervous system (Chrousos, 2009). That makes a functional interaction of the stress systems seem natural (Andrews et al., 2013). Additionally, the stress systems regulate each other in order to keep a balance. Some researchers define stress as the interruption of this homeostasis of stress systems (Chrousos, 2009; Hjortskovet al, 2004; Mauss, Levenson, McCarter, Wilhelm & Gross, 2005; Ulrich-Lai & Herman, 2009), which presupposes that the interaction exists. However, if the stress systems strive to remain at homeostasis, one would expect unambiguous coherence results, which is often not the case.

Could coherence studies come to less ambiguous results if those studies would look at coherence more thoroughly and differentiate between studies while examining differing facets? Evers et al (2014) did this by suggesting that coherence responses are a collective function of two largely independent systems, one automatic and the other reflective. The automatic system refers to the reaction of the body and is fast, efficient, costs no or little cognitive effort, has a low threshold for processing incoming information and happens unconsciously. Automatic responses prepare the body for immediate action. The reflective system on the other side is based on knowledge about facts and values (Strack & Deutsch, 2004). It puts the received input in context and processes the information consciously and deliberately. Evers et al. (2004) found that response coherence exists for measures from the same system, but not across them. This means that they found coherence between two automatic responses as well as between two reflective responses, but not between an automatic and a reflective response.

While Evers distinguished between two differing systems, this study aims to gain more insight into coherence by focusing on another facet of stress coherence. This is done by distinguishing between various types of stressors. Multiple researchers argue that stress responses are based on the type of stressor presented (Allen, Kennedy, Cryan, Dinan & Clarke, 2014; Mauss et al, 2005; Mason, 1971; Oldehinkel et al., 2011; Schlotz, 2013; Skoluda et al., 2015; Stroud et al., 2009). By using different types of stressors the stress systems are affected in differing ways (Armario, 2006). The assumption is that every stressor used in this experiment triggers the stress systems in a different way, which could result in varying difficulty of assessing the own level of stress.

Whereas some researchers state the importance of the effect of the stressor on coherence results, a coherence study using multiple, differing stress stimuli as well as relaxation baselines has not been done yet. In order to examine whether coherence studies that used the same type of stressor, came to similar results, existing coherence studies were sorted depending on the type of stressor used for the experiment. This means that studies which measured coherence using a social stressor were compared to other coherence studies using a social stressor, etc. The results were inconclusive. There are few stress studies which focus on coherence while using a cognitive or an environmental stressor. Therefore, a comparison between multiple coherence studies that used an environmental or cognitive stressor cannot be made. However, a meta-study done by Campbell and Ehlert (2012) reviewed 49 stress studies that all used the same social stressor. They found coherence between physiological measures and subjective experience in only approximately 25 % of these studies. Despite the fact that these studies used the same social stressor, many characteristics of the particular studies differed tremendously in important matters as duration of the task, time, the amount and characteristics of participants, procedure, measurements and time delay between the stressor task and the measures. The lack of studies, which combine multiple types of stressors in one study while using exact same measures for every stressor, is the starting point for this experiment.

In order to further examine stress coherence, clear definitions of stress and the stress systems are needed, which will help to understand in more depth why using differing stressors makes sense. This research paper compiles these definitions and discusses the interaction of the stress systems. Subsequently the stressors and the measurements employed in this study are presented. Lastly, this introduction is completed by specific hypotheses relating to stress coherence.

1.2 Stress

Stress is a complex emotion and originally described as an emergency response (Carter & Delahaye, 2005). It is a feeling all human beings can experience when facing a situation one may not be able to master satisfactorily. It refers to biological as well as to psychological responses (Bourne & Yaroush, 2003). The purpose of this stress is to prepare the body and mind for the upcoming or current situation. In terms of biological responses our survival can depend on the appropriate physiological response to threats (Ulrich-Lai & Herman, 2009). In case of encountering a wild animal, the body will be prepared for a fight or flight action. In terms of psychological response, the human’s social well-being depends on it. While giving a speech or singing a song in front of an audience, the person will be more alert which helps to act in a way others would approve. Stress can therefore generally be defined as a disruption of homeostasis (Ulrich-Lai & Herman, 2009) whereby the anticipation of a stressful situation can also be enough to trigger a stress response (Hermann, 2005).

1.3 The stress systems

Since stress varies in intensity, the systems that regulate stress will be more closely depicted. When it comes to stress regulation, two biological systems are especially important: the autonomic nervous system (ANS) and the hypothalamus-pituitary-adrenal axis (HPA).

1.3.1 The autonomic nervous system (ANS)

The autonomic nervous system (ANS) is located in both the central nervous system and the peripheral organs (Chrousos, 2009). The system is called automatic because it regulates and adjusts vital processes inside the body unconsciously and automatically. It provides the quickest responses to a stressor (Ulrich-Lai & Herman, 2009) and is divided into the sympathetic nervous system and the parasympathetic nervous system. Together they continuously regulate basic physiological responses, such as body temperature, heart rate or blood pressure (Czura & Tracey, 2005).

The parasympathetic nervous system is responsible for the body regulation when the body is at rest, and regulates processes such as digesting (Schiller, 2003). At the physiological level, the sympathetic nervous system (SNS) is the most important system associated with the stress response (Andrews et al., 2013). It initiates the so-called "fight or flight" reaction (Bourne & Yaroush, 2003; Cohen, Kessler & Gordon, 1995). Within milliseconds of perceiving a stressor the system is activated, which results in an increase in heart rate, sweating and energy mobilization (Andrews et al., 2013). Therefore ANS activation is often measured using heart rate (HR), electrodermal activity (EDA) or salivary alpha-amylase (sAA). However, these measures have a downside. Baseline Heart Rate seems to be age related (Kelly et al., 2008) and sAA activity might be influenced by the method of saliva collection (Skoluda et al., 2015). The latter two might be factors that disturbed earlier coherence studies. The SNS is triggered by stressors that contain tasks with effortful tasks (Lundberg & Frankenhaeuser, 1980). The SNS quickly returns to normal - with the aid of the parasympathetic system - as soon as the stressor is extinct.

1.3.2 The hypothalamus-pituitary-adrenal axis (HPA)

The second stress system of the human organism is the hypothalamus-pituitary-adrenal (HPA) axis (Andrews et al., 2013). The HPA originates in the hypothalamus and is a complex set of direct influences and feedback loops from the hypothalamus, pituitary gland and adrenal glands (Foley, & Kirschbaum, 2010). The HPA is more reactive to psychosocial stressors (Hermann et al, 2005; Het, Rohleder, Schoofs, Kirschbaum & Wolf, 2009; Kudielka, Buske-Kirschbaum, Hellhammer & Kirschbaum, 2004; Kudielka, Schommer, Hellhammer & Kirschbaum, 2004). Linked with this observation, Hermann et al. (2005) state that it also gets activated when threats and negative consequences are anticipated. The anticipation is enough to trigger activity and therefore the HPA can be triggered before threats occur and even if they eventually do not occur at all. As a consequence, this system can be chronically active over longer periods of time when anticipating a negative event (Andrews et al., 2013). As another characteristic, this system is much slower in comparison to the SNS (Andrews et al., 2013) with its peak 10 minutes after a stressor occurred (Ulrich-Lai & Herman, 2009). HPA activity is often measured using cortisol. This is a measurement that is sensitive to the time of the day (Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004), which is another factor that may have adulterated earlier coherence studies.

Oldehinkel et al (2011) report that cortisol regulates perceived stress. Het et al (2012) suggest that the influence of cortisol on perceived stress may be inhibiting in nature, as cortisol helps to perceive stress as less intense. These findings suggest that people have difficulties in estimating their own level of stress, as the perceived stress is distorted by cortisol.

1.3.3 The Interaction of the SNS and HPA

The SNS and HPA are both connected with the central nervous system (Andrews et al, 2013; Chrousos, 2009). Therefore an interaction between these two systems is often assumed. Human and animal studies focusing on exploring the working memory did reveal a tight interaction between the HPA and the SNS (Schoofs, Preuß & Wolf, 2008). Andrews et al. (2013) state that the interaction of these systems is inverted, with one being suppressed as long as the activation of the other one is increased. The body tries to gain homeostasis by adjusting and assimilating the stress response in order to optimize the body’s reaction to stress. It is assumed that the stressor is first perceived as such and then activates the SNS as well as the HPA. Since this interaction has not been thoroughly investigated in research (Andrews et al., 2013) and conducted studies found differing results (Campbell & Ehlert, 2012), further research on this topic is needed.

There are several reasons why looking at SNS and HPA activation makes sense. There is evidence that the sympathetic nervous system (SNS) and the hypothalamus pituitary adrenal axis (HPA) are triggered differently. As an example, Andrews et al. (2013) argue that "the HPA appears more reactive to psychosocial stressors" such as social evaluation, public speaking, or singing in front of a researcher. The coherence process may differ depending on the triggered system, which would suggest once again that different kinds of stressors may result in differing coherence effects.

1.4 Measurements of stress

1.4.1 Stressors

Since different kinds of stressors may result in differing coherence effects, three different stressors were used in this experiment: a social stressor (Sing-a-Song Stress Test), an environmental stressor (noise test) and a cognitive stressor (beauty contest game). All three stressors represent different situations which can happen in everyday life, which enabled the measurement of stress reactions.

The stressors in this study are short and direct and have been used in this or a similar form before in other research (Bali & Jaggi, 2015). By using three differing stressors, a broad range of stressors have been covered. These three groups of stressors have shown to be valid and stressful stressors (Bali, & Jaggi, 2015), that can affect stress and the perception of stress in different ways. These stressors match the requirements that Mason (1968) described as the main specific determinants for the stress response: novelty, unpredictability, and uncontrollability.

1.4.2 Physiological measures of stress

Stress is associated with various physiological responses. Due to the provided advantages as well as practical reasons, this study used electrodermal activity and heart rate as measures for the physiological measures of the stress response. Cortisol has not been used as a measure because it peaks 10 minutes after the stressor occurred. Using cortisol as a measure interferes with the setup of an experiment which studies the short and direct reactions to stress. Perceived stress was measured using questionnaires.

1.4.2.1 Electrodermal activity (EDA)

Electrodermal activity (EDA) is one of the most widely used measurements in psychophysiology (Dawson, Schell & Filion, 2007). EDA is an indicator for autonomic emotional and cognitive processing as well as for sympathetic activity (Braithwaite, Watson, Jones & Rowe, 2013). The sweat glands are innervated by the sympathetic nervous system alone (Jacobs et al., 1994), therefore it can be assumed that the measurements of physiological changes are automatic responses. The perspiration of a person can be gauged with the aid of a skin conductance meter. When a person experiences stress, sweat secretion will increase by the sweat glands, which can be measured using a low steady voltage. In order to do so, micro-Siemens (μS) - the unit of electric conductance - is used as the common unit of measurement. EDA is the umbrella term for electrical signal in the skin. This signal can be divided into (1) tonic EDA, which includes the skin conductance level (SCL) and (2) the phasic EDA, which includes non-specific skin conductance response (NS-SCRs) and event-related skin conductance response (ER-SCRs).

The most common measure is the skin conductance level (SCL) which shows gradual changes in conductance, which reflect the autonomic arousal and alertness (Braithwaite et al., 2013). The fact that perspiration can differ hugely between people does not make this a good measurement for between-person comparisons. SCL can be used to examine fluctuations of perspiration to explore differences between conditions for each participant (within-person).

The skin conductance response (SCR) - or phasic skin conductance response - is a proper measurement for emotional arousal (Miller, 1997) and can be classified as not event-related (NS-SCRs) or event-related (ER-SCRs). An SCR is classified as an ER-SCR when the latency period between stimulus onset and the first significant deviation in the signal is between one and three seconds (Braithwaite et al., 2013). Figure 1 shows an ER-SCR with its latency, response onset and peak.

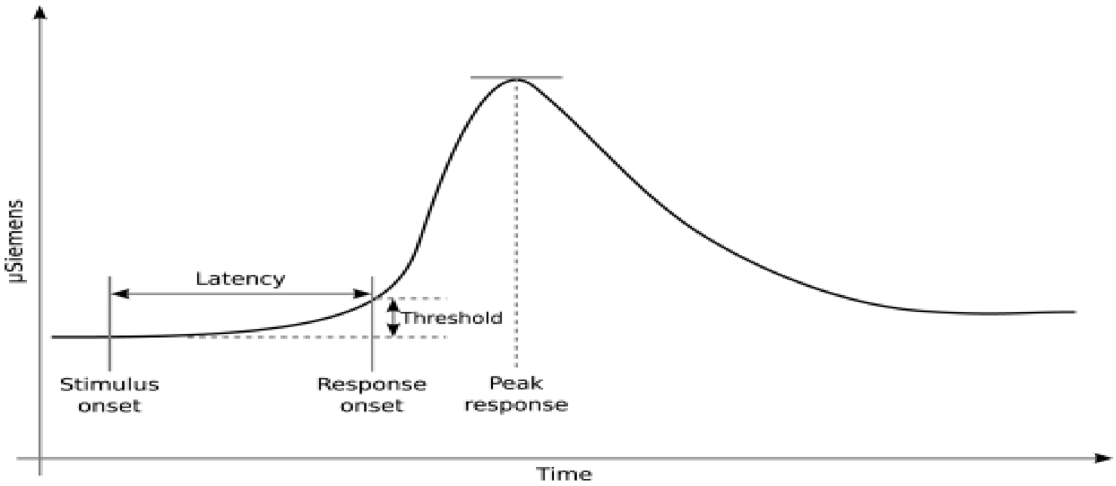

figure 1. an ER-SCR with its latency, response onset and peak

According to Braithwaite et al (2013) analyzing the amplitudes of NS-SCRs and the standard deviation of them could also provide additional indicators of tonic arousal. They state the importance of using differing parts of EDA measures in order to get additional information. Figure 2 shows an EDA measure in which multiple SCRs can be seen.

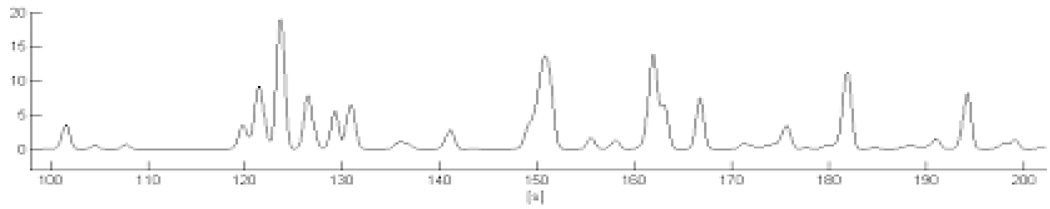

Figure 2. An EDA measure with multiple SCRs

1.4.2.2 Heart rate

It is well known that heart rate (HR) responds to stress (Schubert et al., 2009). Heart rate has therefore frequently been used as a measurement in stress and stress coherence studies (for example Brouwer & Hogervorst, 2014; Kelly, Tyrka, Anderson, Price & Carpenter, 2008; Meehan, Insko, Whitton & Brooks, 2002; Ohlsson & Henningsen, 1982). According to Qin, Hermans, van Marle, Luo and Fernández (2009) heart rate can be used to measure the effects of stress on the SNS and the HPA axis activation, which is in line with the findings of multiple studies which found an increase in heart rate during a stressor. Psychological stressors cause the nearly immediate secretion of epinephrine and norepinephrine by the sympathetic nervous system, which typically increases heart rate. The heart can switch from one state to the other quickly (Schubert et al., 2009), which makes heart rate a good measurement for short and direct stressors.

1.4.3 Perceived stress

Stress does not only evoke bodily reactions, it is also perceived as an emotion by the human mind. This perception of the mostly unpleasant emotion can be measured with interviews or questionnaires. In this study, questionnaires are used because they fit the experimental setup, whereby the researcher is an observer and does not interfere with the participant.

Questionnaires are often used in order to measure perceived stress (Bali & Jaggi, 2015). Many of these validated questionnaires measure very specific responses, and are therefore only suitable for specific situations. As examples, the Bergen Social Relationships Scale can be used to measure chronic social stress, the Job Content Questionnaire is related to job stress and the Survey of Recent Life Experiences measures daily hassles which happened in the past month (Kopp et al., 2010). Due to the specificity of these stress questionnaires the available questionnaires could not be used in this study. To my knowledge, there are no validated questionnaires that can be used for measuring three different short and direct stressors in the same and therefore comparable way. This is why four general stress experience questions have been asked during the questionnaire, which are suited for each stressor alike.

1.5 Aim of the study and hypothesis

This study aims to contribute to the understanding of stress coherence by measuring coherence effects for differing short and direct stressors. If this study does find coherence, it implies that coherence exists. If the coherence results differ significantly from each other depending on the stressor, this is an indication that the stressor - and therefore the way in which stress is induced - does affect the coherence process. It may even indicate that previous inconsistencies in other studies were due to overgeneralizing or methodological mistakes, such as the above mentioned method of sAA collection which involves the risk of influencing the results. In order to study whether coherence exists and whether it depends on the stressor, the following hypothesis were formed:

(1) During a social stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire

(2) During an environmental stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire

(3) During a cognitive stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire

(4) The correlations between physiological measures of stress and perceived stress differ significantly from each other depending on the type of stressor

2 Method

2.1 Participants

This research included a convenience sample of eighty-five participants (40 % female), being between eighteen and thirty-six years old (M = 24.14, SD = 4,3). Participants with any health issues like heart diseases or epilepsy were excluded from the study. Basic English knowledge and legal age were required for participating. Each participant was informed about the ethical approval of the experiment, as well as the exclusion and inclusion criteria and signed an informed consent before the experiment started. The data of nine people was not properly saved or adulterated by other circumstances such as the participant's movement. The data of another thirteen participants was not used due to fuzzy heart rate data, leaving sixty-two participants for statistical analysis.

2.2 Materials

2.2.1 Tasks

The experiment included a (1) relaxation baseline, an (2) occupation task, which should create relaxation by distracting the participant from the stress task by keeping her/him occupied with easy cognitive tasks, the (3) three stressors and (4) the perceived stress questionnaire. All tasks and all instructions were in English. During the relaxation task the participant was told to focus on her/his breathing and relax for two minutes. The occupation task consists of easy cognitive tasks, for example "think of animals that start with the letter p" or "think of objects you can find in a kitchen". In order to prevent them from moving their hands, the participants only had to think of objects instead of filling them in. Those tasks were included to create the same level of relaxation and baseline for each participant. The relaxation tasks were used in order to create a calm baseline before each stressor and to calm the participant down after a stressor.

2.3.1.1 Stress tasks

2.3.1.2 Sing-a-song Stress Test

The first stressor was an adapted version of the Sing-a-Song Stress Test (SSST), which proved to be a very effective social stressor (Brouwer & Hogervorst, 2014). The adapted version of the SSST includes a relaxation baseline and the occupation task. Afterwards, the participants were told that they had thirty seconds to think about a song they could sing after these thirty seconds. After the time interval elapsed the text "Now sing a song aloud over the next 30 seconds and try to keep your arms still. Keep singing!" appeared on the screen. In furtherance of the participant's stress, the researcher would sit right next to the participant during the whole experiment.

2.3.1.3 Noise stress task

The second stressor used was an environmental stressor. Noise is a pervasive and influential source of stress (Szalma & Hancock, 2011) and a commonly used form of an environmental stressor (Bali & Jaggi, 2015). In this experiment, noise was applied via headphone. The participants had to listen to the noise in form of 1000Hz beep sounds, which lasted for 200 milliseconds each and were approximately 75 dB loud. This stressor included 26 beep sounds in total and lasted five minutes. One beep sound would not follow right after the other, allowing to match the participants reaction in terms of EDA and HR data to each particular beep sound. Therefore the sounds had at least a window of 7 seconds between each other, with an average of 11.38 seconds (SD = 2.87). The presentation time of beep sounds were randomly generated beforehand in order to prevent the participant from recognizing a pattern in the sounds, which would make the listening task less stressful. The same sequence of sounds was used for each participant to make the experiment and the data comparable.

2.3.1.4 The beauty contest game (BCG)

The beauty contest game (BCG) was used as a cognitive stressor in this experiment. Originally used by Leder, Häusser & Mojzisch (2015) the BCG was introduced to study the effects of stress on decision making. The BCG is a simple experiment, where participants are offered a price - in this study a 25 euro voucher - if they win the game. In order to win the game the participant should pick a number between 0 and 100, which should be closest to the target number. The target number is 2/3 of the average number all participants had chosen. Since the player does not know, which number the others players chose, he has to reflect about other player’s choices (Leder, Häusser & Mojzisch, 2015).

2.3.1.5 The perceived-stress questionnaire

After each stress task, the participant had to fill in a short questionnaire on the laptop provided in the experiment. The questionnaire contains four questions about the intensity level of stress the participant experienced (1) before the task started, (2) during the task, (3) right after the task and (4) at the current moment. The participant had to answer on a 7 point Likert scale, with 1 indicating a low stress level and 7 indicating a high stress level. This questionnaire was used to measure the self-perceived stress.

2.3.2 Equipment

Two laptops were used for this experimental setup. The first laptop would be used by the participant during the experiment and will be referred to as the experimental laptop. On the experimental laptop, Python 2.7 and PsychoPy were installed and the E4 wristband was connected to this laptop in order to synchronize time. The heart rate meter and skin conductance meter were connected to the second laptop, which will be referred to as the device laptop.

2.3.2.1 Python 2.7 and PsychoPy

The experiment was programmed using Python version 2.7 and used PsychoPy 1.83.04 to present the experiment to the participants. Timestamps from the python program were added to the physiological data (via the serial port and a voltage isolator) for experimental events. The python program also wrote timestamps for these events and the self-reports of participants to separate text files.

2.3.2.2 The E4 wristband

The E4 wristband is a sensor, which can be used to monitor physiological signals in real-time (www.empatica.com, 2016). The device reminds of a normal wristwatch in terms of weight (25g) and size (110-190mm) and is worn like one on the left wrist. Therefore it can be assumed that the wristband did not influence or hinder the participant. The E4 wristband was used as part of another experiment, which lies beyond the scope of this paper. For this study, it was used to cover up the true purpose of the study, as the participants were told beforehand that the study was about validating the E4.

2.3.2.3 ProComp Infiniti System

The ProComp Infiniti was used in this experiment to measure the skin conductance and heart rate. The ProComp Infiniti is an eight channel, multi-modality encoder that gives real-time biofeedback in any clinical setting (www.thoughttechnology.com, 2016). It is used in combination with the ProComp Infiniti BioGraph software, which was installed on the device laptop. The EMG and EKG electrodes were attached to a sensor extender cable and wrist bands and afterwards connected to both wrists of the participant. The finger band electrodes were attached to the index- and the ring finger of the right hand, as shown in figure 3. The skin conductance sensors were connected to port 1 and 4 of the ProComp and sampled all signals with a 256 samples/second frequency. The device has an overall system accuracy of 5 % and has been validated (www.thoughttechnology.com, 2016). The downside of this measurement device is that it has to be connected to the laptop and therefore binds the participant to the laptop. It is also sensitive to the movement of a participant, which demands that the participant moves as little as possible. The Infiniti data was saved on the device laptop as .txt files for both the heart rate and the skin conductance meter.

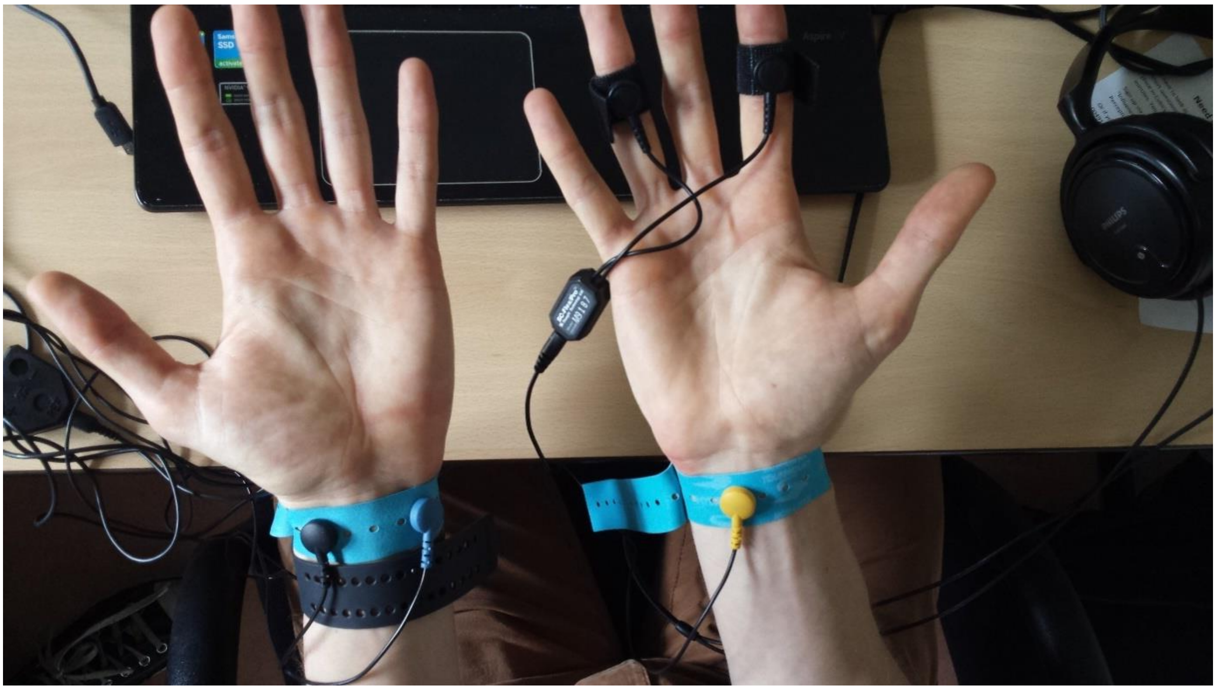

Figure 3. Participant wearing the E4 wristband, the ProComp Infiniti EMG, EKG and finger band electrodes

3 Design and procedure

In preparation for the participants arrival, the measurement devices, headphones and laptops were plugged in and switched on, and a printed informed consent was provided. The volume of the experimental laptop was set to 82 percent. When the participant entered the room he was welcomed by the researcher. The experiments were run by three different researchers that were all students of the University of Twente. In order to minimize the effect of different researchers a strict protocol was followed.

After being welcomed by the researcher the experiment was explained to the participant, without going into detail nor telling the true purpose of the study. The participant was told that the study was about the validation of the E4 measurement device and that he/she would sit behind the laptop screen, follow the instructions on the screen, should not talk to the researcher and that the researcher was not allowed to answer questions during the experiment. It was explained that the participant would be connected to the skin conductance meter, the heart rate meter and the E4 measurement device during the experiment and was instructed to move as little as possible in order to get usable data from the measurement devices.

After the explanation the participant read and signed the informed consent. Then the participant was connected to the skin conductance meter, the heart rate meter and the E4 wristband and put on headphones. The researcher checked whether all devices were recording. The participant number and gender was filled in by the researcher. When the participant was ready, the experiment was started by the researcher by clicking on the Python run button. The design of the experiment is displayed in figure 4. In order to not influence participants in different ways, every researcher would sit on the same place, so that the participant could see him/her on the left and the researcher would use his own laptop all the time. Using his laptop, the researcher made notes in the logbook on whether the participant sang or not during the SSST, on which number the participant picked during the BCG, and on possible special anomalies. Noteworthy anomalies were, for example, people talking next to the room and disturbing the experiment with noise, or a participant that would move a lot. Events like that were recorded with an exact timestamp.

After the experiment was finished, the researcher would disconnect the participant from the devices and debrief the participant about the true purpose of the research. The participant was told to not talk to other people about the research purpose or the included research tasks. Lastly the test person was thanked for his/her participation.

PSQ → R → O→S1→R→PSQ→R→O→S2→R→PSQ→R→O→S3→R→PSQ

Figure 4. Design

Note. R= Relaxation task, O = occupation Task, S = Stressor, PSQ = perceived stress questionnaire

4 Data analysis

Using MATLAB (www.mathworks.com) the data was prepared for data analysis. The EDA data was down sampled to 16Hz. Then the EDA data was processed using a Continuous Decomposition Analysis (CDA) as executed in Ledalab (Benedek, & Kaernback, 2010). This CDA was used to obtain an estimate of the skin conductance level (SCL). A Trough-to-Peak analysis was then conducted where the phasic activity was reported. SCR amplitude was set at a threshold of .01 µS (Boucsein, 2012). Boucsein (2012) recommended the use of visual checks performed on plots of skin conductance data. Visual checks were performed in order to identify failed measurements and incorrect classification of SCRs. The (mean) scores normalized to a duration of one minute of each EDA measure were computed for the baseline as well as the stressors in order to create one single score per block.

Further analysis was done with SPSS 22. First, change scores were calculated in order to identify individual changes between each stage of the experiment. For example, the change score of the SCR of the SSST was calculated by subtracting the score of the baseline SCR from the SCR during the SSST. This was repeated for each stressor and also done for each measure (SCL, AMP, HR and perceived stress). These change scores represent the relative increase in stress depending on each stressor and were therefore used for the analysis.

Then, the descriptive statistics, such as minimum, maximum, mean and standard deviation were calculated. Stem-and-leaf plots, crosstabs, Q-Q Plots and boxplots were done in order to get a better understanding of the data distribution. It was checked whether or not the data was normally distributed, in order to determine which test could be used to calculate the correlation between the perceived stress measurements and the EDA measurements during the stressors. According to the Shapiro-Wilk test not all change scores were normally distributed. Scatterplots were used in order to check whether the data may be normally or curvilinear distributed. A check on the residuals supports the findings that not all scores were normally distributed (for detailed information see appendix). In order to keep the results comparable all correlation calculations were performed with a non-parametric test. Spearman's Rho was used to calculate the correlation between physiological measures and perceived stress.

Next, confidence intervals were calculated for these correlations for each stressor. Therefore, Fisher's r-to-z transformation with the following formula was used:

$$Z = \frac{1}{2} * \ln\left(\frac{1 + r}{1 - r}\right)$$

The standard error was calculated with this formula:

$$\sigma_{Z\prime} = \frac{1}{\sqrt{N - 3}}$$

The confidence interval was calculated with the formula:

$$CI_{low} = z - 1{,}96 * \sigma$$

for the lower bound of the interval and:

$$CI_{upp} = z + 1{,}96 * \sigma$$

for the upper bound of the interval.

If the confidence intervals do not overlap, they differ significantly from each other. Fisher's z-transformation is mainly used for parametric tests. However, according to Myers & Sirois (2006) this formula works well for non-parametric tests, too.

A general linear model ANOVA was used to check whether the stressors succeeded at inducing stress. A multivariate analysis, including all stressors and depending variables, was done in order to detect relations between the variables. Pairwise comparisons were carried out in the interest of getting a better understanding of the directions of the effect.

5 Results

Averaged, all three stressors showed an increase in both the self-perceived stress as in physiological measures compared to the baseline ($F(4;58) = 51.67$; $p < 0.05$; $\eta_p^2 = .78$). These increases in stress from baseline to stress-task differed depending on the stressor ($F(8;238) = 14.56$; $p < 0.05$; $\eta_p^2 = .33$). Pairwise comparisons with a 95% Confidential Interval Bonferroni corrected show a decline in physiological measures during the cognitive stressor when compared to the baseline, as for example the measure heart rate [-0.11 ; -0.01]. All other measures show an increase (see table 1), with the strongest effects during the social stressor, as for an example the measure heart rate [0.18 ; 0.44].

Table 1. Mean, standard error, significance and the 95% Confidence Intervals for the difference between measures during the stressors and measures of the appendant baseline.

Measure	Stressor	Mean Difference	95% Confidence Interval for Difference	
			Lower Bound	Upper Bound
subjective	social	1.589**	1.2	1.98
	environmental	1.306**	1.04	1.57
	cognitive	.323*	.07	.58
amplitude	social	.087**	.06	.12
	environmental	.030**	.01	.05
	cognitive	.015	-.03	.06
no_SCR	social	1.589**	1.2	1.98
	environmental	1.306**	1.04	1.57
	cognitive	.323*	.07	.58
SCL	social	3.495**	2.62	4.38
	environmental	.531*	.05	1.01
	cognitive	2.695**	1.8	3.59
heart rate	social	.310**	.18	.44
	environmental	.055	-.0	.12
	cognitive	-.060*	-.11	-.01

Note. * p < .05, ** p < .01

1 *During a social stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire*

No correlation was found between the averaged amplitude and perceived stress (spearman's rho = .14, p = .3), between SCL and perceived stress (spearman's rho = .18, p = .16) and between HR and perceived stress (spearman's rho = .15, p = .24). Only the number of SCR showed a significant correlation with perceived stress (spearman's rho = .27, p < .05). The data of participants who sang during the social stressor might have been altered due to movement. If the same test is carried out including only those participants who did not sing, correlation is found for the number of SCR and perceived stress (spearman's rho = .59 , p < .01). For SCL (spearman's rho = .12, p < .64), HR (spearman's rho = .35, p < .15) and AMP (spearman's rho = .44, p < .7) no significant correlations with self-perceived stress are found.

2 *During an environmental stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire*

When looking at the environmental stressor, there is a correlation between all physiological measures and self-perceived stress. The highest correlation has been found between the amplitude and perceived stress (Spearman's rho = .45, p < .01) and between SCL and perceived stress (Spearman's rho = .33, p < .01). While these correlations were highly significant, the correlation effect is not strong. According to Cohen (1962) the effect would categorize as moderate for the correlation between the amplitude and perceived stress (.40 < .45 <.59) and weak for the SCL and perceived stress (.20 < .33 < .39). The effect found between the number of SCR and perceived stress (Spearman's rho = .26, p < .05), as well as the effect between HR and perceived stress (Spearman's rho = .25, p < .05) was smaller, but still statistically significant.

3 *During a cognitive stressor, physiological measures of stress correlate with perceived measures retrieved from the questionnaire*

During the cognitive stressor, there was correlation between the SCL and the perceived stress (Spearman's rho = .-27, p < .05). Note that the coefficient is negative. Crosstabs show that 7 people indicated a low level of stress while the SCL data suggests that the stress level was high. 36 people indicated a higher level of stress on the questionnaire than the SCL data would suggest. There was no correlation between the amplitude and perceived stress (Spearman's rho = .02, p = .9), between the number of SCR and perceived stress (Spearman's rho = .01, p = .96) or between HR and perceived stress (Spearman's rho = .07, p = .58).

The results of the three above mentioned hypotheses are summarized in figure 5 and show the Spearman Rho correlations between subjectively experienced stress and the respective objective measures for the three stressors.

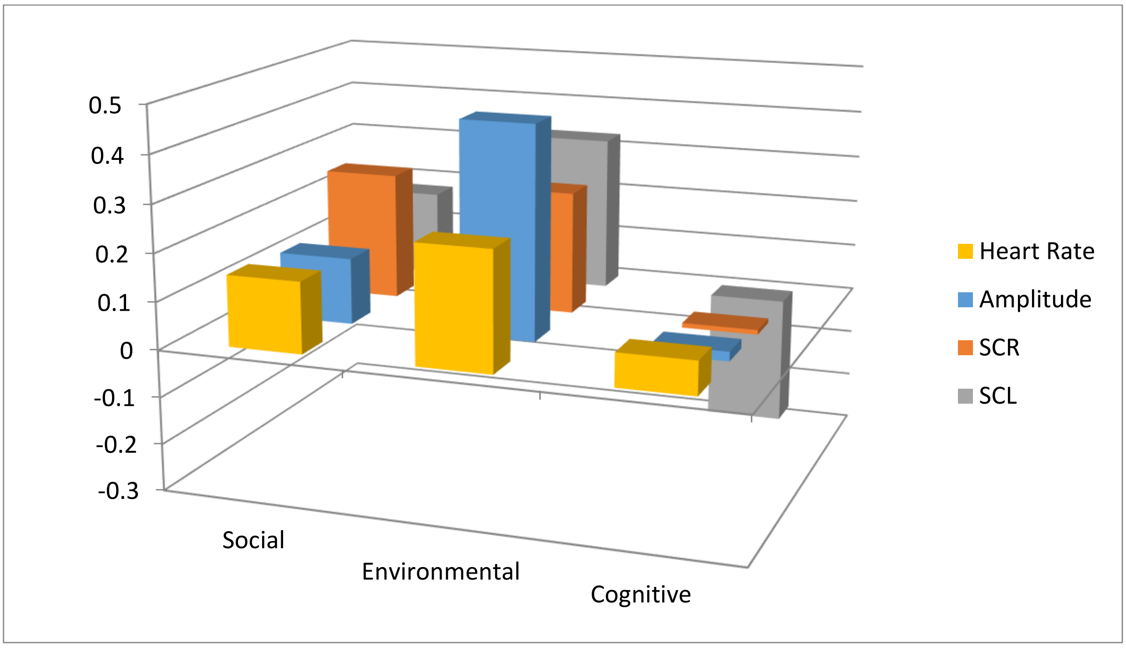

Figure 5. Spearman Rho Correlations between subjectively experienced stress and the respective objective measures for the three stressors.

4 The correlations between physiological measures of stress and perceived stress differ significantly from each other depending on the type of stressor

The correlation intervals in-between the differing objective stress measures do overlap with the correlation intervals of the same objective measure during other stressors (see table 2). That means, that the intervals do not significantly differ from each other. Therefore it cannot be concluded that the correlations of physiological measures with self-perceived measures of stress do differ depending on the stressor.

			Objective stress change			
	Stressor	N	amp	No_scr	Scl	hr
All participants	Social	62	[0.11 ; 0.4]	[0.02 ; 0.53]	[-0.07 ; 0.44]	[-0.10 ; 0.41]
	Environmental	62	[0.23 ; 0.74]	[0.01 ; 0.52]	[0.09 ; 0.6]	[0 ; 0.51]
	Cognitive	62	[-0.24 ;0.28]	[-0.27 ; 0.25]	[-0.53 ; 0.02]	[-0.19 ; 0.32]
Only singing	Social(SSST)	43	[-0.25 ; .37]	[-0.18 ; 0.44]	[-0.02 ; 0.6]	[-0.11 ; 0.51]
Not singing	Social(SSST)	19	[0.02 ; 1]	[0.19 ; 1]	[-0.3 ; 0.68]	[-0.16 ; 0.82]

Table 2. Confidence Intervals between the variables per stressor for Rho correlations

6 Discussion

This study attempted to examine whether correlation between self-perceived measures of stress correlate with physiological measures of stress, and if so, if those correlations differ depending on the type of stressor. Correlations for at least one of the physiological measures with self-perceived stress were found during each stressor; but not always for the same physiological measure. The only stressor that showed significant correlations for every used measure was the environmental stressor. For the cognitive stressor, the only significant correlation found was between perceived stress and SCL. That correlation was negative.

The overall correlation results leave a weak impression due to inconsistent findings. Although the findings on the environmental stressor seem promising, there is no statistical evidence that the correlations during the environmental stressor differ from the correlations during the other two stressors. Only the correlations for SCL between cognitive and physical stressors differ significantly, which can be traced back to the negative correlation of the SCL during the cognitive stressor. The inconsistencies in findings are in line with the results of previous research. Many researchers report inconsistencies in findings and found negative, positive or no correlations between stressors and physiological measures of stress, often even within one kind of stressor (for example during the SSST, see Campbell & Ehlert (2012)).

A new trend in explaining inconsistencies in findings would be to assume that correlations are not linear (Mauss et al., 2005), but instead curvilinear (Campbell & Ehlert, 2012) or more loosely coupled. However, scatterplots of the data-distribution do not support that theory. Therefore, it is not likely that this explanation holds true for the data in this experiment.

The intensity of the stressor as a possible explanation for inconsistencies in coherence studies has often been discussed in previous research (Mauss et al., 2005; Sze, Gyurak, Yuan & Levenson, 2010). Davidson (1992) states that higher intensities of an emotion lead to a higher response coherence. Russel (2003) goes one step further by arguing that even weak response coherence effects can only be observed during high intensity periods of emotion. However, these assumptions are not supported by the data in this experiment, as the social stressor seems to elect the highest amount of stress and did not find more correlations than the other stressors.

A possible explanation for the negative correlation between SCL and perceived stress during the cognitive stressor may lie in social desirable answers. As the experimenter sat right next to the participant, the participant may have wanted to hide that he did not find the stressor stressful. While this factor may have led to a negative correlation during the cognitive stressor, it may have influenced all answers during the whole experiment. That would mean that the participants who gave socially desirable answers felt less stressed than they indicated. However, the cognitive stressor elicited the least amount of stress and therefore the participants may have felt the need to exaggerate only during the cognitive stressor. On the other side, participants may have not wanted to admit that they felt stressed . Possibly they did not want to admit that they had difficulties in handling a stressor while the researcher sat next to them and give therefore smaller ratings on the perceived stress questionnaire. Whether any of these factors did play a role for some participants is difficult to determine. If they do play a role, it would contribute to explain why the physiological measures do not (always) match the answers on the perceived stress questionnaire. Future studies could include questionnaires which measure the participants inclination of giving socially desirable answers.

Another speculation would be that people cannot fully interpret all physical reactions at once. They may, for example, judge their self-perceived stress based on heart rate one time, and based on their raising sweating the other time. This might even happen unconscious. The fact that there was at least one correlation for each stressor would support that speculation. This would also be in line with speculations from previous research, which states that people can at least interpret the direction of their physical reactions (McLeod, 1986).

Feldmann Barret (2006) offers a completely different approach to explaining inconsistencies in coherence studies. She states that emotions are human-made. If emotions would be independent constructs, as widely believed, it should be able to measure emotions clearly and consistently (Barret, 2016). This raises the question whether emotions have to be defined in a new fashion before coherence studies can find consistent findings. While emotion studies today focus on a few variables that have been defined as a part of a certain emotion, there is no attention for the variety and the diversion of these emotions. As such, defining emotions may therefore be more difficult than previously thought. Russel (2003) shares the view that emotions have not yet been defined in a satisfying way. He uses an example as a clarification for this claim. If a girl is confronted by a bear on her path, she will mostly likely feel fear. Is this feeling of fear the same feeling of fear the girls experiences when she watches a horror movie, although she might find the movie enjoyable and wants to watch it again? The reactions to those two kind of feelings would be clearly different although they would both be described with the word fear. This example shows, that there are more degrees on emotions than people might think. This view fits the findings of this study as it offers an explanation for the inconsistencies in results. Acknowledging that this view automatically means, that the physiological measures used to measure stress may also measure other emotions, offers another explanation for the BCG correlations. Participants may have gotten excited and mistook the slight raise in heart rate for a feeling of stress. Future studies could control this by adding a fourth task, which is not stressful.

6.1 Limitations

Due to practical reasons the experiment was conducted in one session. The order of the stressors may influence the outcome in two ways. First, the first stressor might have created a certain expectation on what comes next for the participant. As the first stressor was the most stressful one, other stressors could have seem less stressful in comparison. Second, the experiment started with a social stressor, which is known to provoke the release of cortisol. Cortisol has a restricting effect on subjective perception of stress (Het et al, 2012) and peaks 10 minutes after the stressor occurred. It is agreeable that the cortisol release, activated by the first stressor, peaked during the second stressor and influenced the perception of the second stressor by making the environmental stressor seem less stressful. Therefore, the results could have been adulterated by the order of the stressors. This study did try to minimize the effect of other stressors by adding relaxation tasks between the stressors and calculated with the relative change score of each stressor. Still, future research could switch the order of the stressors or even test the stressors in three different sessions in the interest of ruling out order effects completely.

This experiment relies on the participants retrospection for the self-perceived stress. Hellhammer and Schubert (2012) showed that stress perception was significantly higher during the TSST as compared to post-TSST ratings in their experiment. They argue that emotions or their intensity can change within seconds. Therefore, asking a participant about their self-perceived stress level can reflect the emotion with either increased or decreased intensity or even a different emotion. However, measuring self-perceived stress during the stressor without disturbing the stressor itself is a difficult task. Researchers have still not agreed on a reliable way to do so (Schooler & Schreiber, 2004).

This study included a convenient sample with participants being mostly highly educated young individuals. Urry and Gross (2010) argue that older people are better at regulating their emotions. One might speculate that this could be due to higher awareness of emotions and thus older participants might show higher response coherence. Hellhammer and Schubert (2012) found that younger participants were associated with higher heart rate increase and higher heart rate maximum during exposure to a social stressor. This is in line with Tanaka et al (2001) observations of the effect of age on heart rate during stressful and stress-free moments. Therefore, choosing young participants may have led to higher heart rate measures. However, we corrected for the latter by calculating with the relative heart rate increase by subtracting the heart rate value during the baseline from the stressor.

6.2 Future research

Future research could add additional measures in order to gain new insights. Unfortunately the current study was limited to EDA and HR data. Adding salivary alpha-amylase (sAA) and cortisol as measurements could help keeping track of the HPA activation. Therefore, it is recommended to conduct a study that combines all the physiological measures in one experiment. It would be interesting to add questionnaires about the differing characteristics, most notably the participants self-awareness. That would allow to do research on individual differences and examine whether some individuals can estimate their stress better than others, and if so, which characteristics they have.

6.3 Concluding comment

The presented study aimed at contributing to the understanding of response coherence by studying the effect of differing stressors on stress coherence. The results of the experiment cannot give a clear answer to the question whether or not response coherence exists. It does, however, indicate that stress coherence does not depend on the kind of stressor. Being the first study that combined three different kinds of stressors in one single experiment, it suggests that inconsistencies in previous coherence studies were not due to incomparability of these studies. Finding the reason for the inconsistencies lies beyond the scope of this study. However, the results do suggest that coherence does not depend on the type of stressor and therefore this study provides a contribution to understanding the complex construct of stress coherence.

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Appendix

Appendix A: Informed consent

Informed consent

Titel: a validation study: how does your body respond?

Introduction

We are Tabea, Daniel and Daniela, all students of the University of Twente, and we are doing research on the validity of the E4 wristband. The Empatica E4 wristband is a new device to monitor physiological signals in real-time and it is being used in all kinds of research topics that involve physiological measures such as epilepsy and alcoholism. As part of this validity research we will ask you to do three different tasks, while being attached to some measurement devices: the E4 wristband, a skin conductance sensor and a heart rate monitor. The tasks you will have to do are presented by the computer screen and we ask you to move as little as possible in order to get flawless data.

We will give you an opportunity at the end ,to review your remarks, and you can ask to modify or remove portions of those, if you do not agree with our notes or if we did not understand you correctly.

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact any of the following:

Tabea Bonus: t.r.bonus@student.utwente.nl

Daniel Lutscher: d.lutscher@student.utwente.nl

Daniela Guddorp: d.guddorp@student.utwente.nl

Informed consent

I explain that I am informed about the nature, method, and goal of the research. I know that the data and the results are being used anonymously and confidential and will solely be used for scientific analysis and presentation. My questions about the research have been answered satisfactorily.

Participation in this research is completely voluntary and you can ask questions or stop with your participation at any time. You do not have to take part in this research if you do not wish to do so

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Print Name of Participant__________________

Signature of Participant ___________________

Date ___________________________

Appendix B:Research protocol :

Before the participant enters the room:

1) Control the devices

Control the laptops

- are both laptops turned on?
- are both laptops being charged?
- Does the time of both laptops match?

Is the heart rate meter ready to use? (batteries?)

Is the skin conductance sensor ready to use?

2) Start the programs for the e4 wristband and the heart measurement device
3) Check whether all 3 devices save the log data
4) Check the volume of the speakers

5) Lay a printed version of the informed consent and a pen on the table

When the participant entered the room:

1) Welcome the participant to the experiment
2) Explain the experiment shortly, not mentioning that it is about stress. Mention the following:
   There will be 3 different tasks which the participant has to do
   That the screen will explain to him what comes next and he should follow the instructions
   That he will be attached to the measurement devices the whole time
   That he should move as little as possible
   That he can stop with the experiment at any time and that the data will be used anonymously
3) Ask the participant to read and sign the informed consent

Attaching the devices:

1) Attach the E4 wristband on the participants left wrist
   Ask the participant if it is too tight
   Turn the wristband on by pushing on the button for some seconds
   Check whether you can still see the green light, adjust if necessary

2) Attach the heart rate meter wristband with 2 sensors on the participants left wrist
   Black should be left (next to the thumb),yellow right (not next to the thumb)
   Attach the heart rate meter wristband with one sensor to the participants right wrist

3) Attach the skin conductance meter
   The sensors should be in the middle of the fingers , being in the palm of the hand

   (in case you're not sure, check on the pc: thought technology-> infinity for instructions)

Run the experiment

1) Remind the participant of not moving
2) If it is the first participant, cllick on “new client” in the skin conductance program, otherwise on “new session”
3) Start python

End the experiment

1) Thank the participant for the participation
2) Give a short debriefing, explaining why we could not tell him that the experiment measures stress beforehand
3) Explain that he can contact us if he has any further questions
4) Remove the batteries from the device
5) Save all the log data online

Appendix C: Self-perceived Stress Questionnaire

Before starting the SSST:
1. How stressed are you at this moment?

After the recovery period of the SSST:
1. How stressed were you in the minute BEFORE singing the song?
2. How stressed were you WHILE singing the song?
3. How stressed were you RIGHT AFTER singing the song?
4. How stressed are you at this moment?

After the recovery period of the Noise Test:
1. How stressed were you BEFORE the Noise Test?
2. How stressed were you DURING the Noise Test?
3. How stressed were you RIGHT AFTER the Noise Test?
4. How stressed are you at this moment?

After the BCG:
1. How stressed were you BEFORE choosing a number?
2. How stressed were you WHILE choosing a number?
3. How stressed were you RIGHT AFTER choosing a number?

Appendix D: Instructions during the SSST

Screen instruction	Time
Sit quietly, try to relax and focus your attention on your breathing while you see the countdown.	2 Minutes
Think of different animals that start with the letter P.	30 Seconds
Think of things you can find in a kitchen.	30 Seconds
Think of several things that are important if you want to organize a wedding.	30 Seconds
Think of as many team sports practiced without a ball as you can.	30 Seconds
The next task will be to sing a song aloud - think of a song you can sing.	30 Seconds
Now sing a song aloud over the next 30 seconds and try to keep your arms still. Keep singing!	30 Seconds
Sit quietly, try to relax and focus your attention on your breathing while you see the countdown.	2 Minutes

Appendix E: Instructions during the BCG

Sit quietly, try to relax and focus your attention on your breathing while you see the countdown.	2 Minutes
Think of things you can find in a living room.	30 Seconds
Think of different animals that start with the letter C	30 Seconds
Please work on the following decision task: Each participant of this study will write down a number between zero (0) and one hundred (100). Zero and one hundred are also possible. We will calculate the average, which is the mean of all numbers picked. Then we will multiply the mean with 2/3. The resulting number will be the target number. To win the game, you	40 Seconds

should pick a number that is as close as possible to this target number.	
The participant whose picked number is closest to the target number, 2/3 of the mean, will win the game and receives a 25 Euro voucher. Please say your chosen number out loud when the countdown has expired. Please do not move.	60 Seconds
Please say your chosen number out loud. Do not move.	10 Seconds

Appendix F: Logboek voor SSST_2016

Date	**Sona Nr./ Age**	**Participant Nr.**	**Researcher**	**Room temp.**	**Did the pp. Sing?**	**Chosen number?**	**Comments**
11-04-16	43024/21	1	Daniel	-	yes	28	
15-04-16	20	2	Tabea	22.2	yes	49	
15-04-16	22	3	Tabea	22.8	yes	22.23	
18-04-16	43258 23	4	Tabea	20.3	no		15:02:00 experiment had to be stopped because of CPU usage of the Laptop
20-04-16	42109, 20	5	Daniela	22.2	yes	50	Not correct timestamp E4
21-04-16	23	6	Tabea	22.1	yes	50	12:22:20 light movement but directly after movement the questionnaire started 12:27 participant asked me if the Laptop had broken down (but it didn't)
21-04-16	43531, 20	7		22.4	no	21	1.43.25 scratching the head
21-04-16	22	8	Daniel	23.0	yes	19	
25-04-16	20	9	Daniel	19.5	yes	3	
26-04-16	40561/ 27	10	Tabea	18.2	yes	60	
26-04-16	23	11	Tabea	18.8	yes	34	
26-04-16	21	12	Daniel	19.3	yes	82	-13:05:26: When SSST preparation started, the participant moved and laughed -Baseline after noise test artifacts through moving Beginning baseline bcg movement
26-04-2016	23	13	Daniel	19.3	yes	44	Participant moved while filling in the questionnaire after SSST

							-baseline bcg movement at the beginning
28-04-2016	21	14	Tabea	14.7	yes	48	9:52:30 moved quite a lot while singing 10:12:10 moved a lot during the last questionnaire (after BCG)
28-04-2016	22	15	Tabea	16.3	yes	33	she does not move a lot (the data already seems “stressed” even before the stressors) 10:55:10 moved her head 11:08:20 I had to sneeze 11:15.. said the number out loud before she was asked to.
28-04-2016	22	16	Tabea	17.5	yes	20	talks and laughs when she knew she had to sing. Did not sing until the very end 12:53:50 asks a question about BCG
28-04-2016	30	17	Tabea	18.3	yes	17	when he was told that he would have to sing, he wanted to start immediately. But as he realized that he has to sing when the countdown has expired he was quiet and waited. (Haartslag ziet er in het algemeen niet normal uit. Maar ik heb twee keer gecontrolleerd of alles juist is aangesloten). 13:36 voices from the other cuibcles
28-04-2016	22	18	Tabea	18.8	yes	67	HR beetje raar (vooral in het begin) 14:52:20 light movement laughs when he sees that he will have to sing and starts to sing immediately. Stopps then and waits until the countdown has expired. 15:08:40 moves his hands lightly 15:09:50 yawns 15:12:10 moves 15:12:45 scratches his cheek!!
28-04-2016	20	19	Tabea	19.5 the thermometer has to be broken it shows at 30.3 the end.	yes	30	15:52:20 somebody came into the room because he needed the data on the pc in here! (shortly before the SSST, but the participant did not move during this or looked to the door) this participant sits perfectly still

29-04-2016	26	20	Daniela	20.3 new thermometer	yes	27	
29-04-2016	23	21	Tabea	20.3	yes	66	
29-04-2016	23	22	Tabea	19.7	yes	42	12:19:10 asked if he should already sing
29-04-2016	22	23	Tabea	20.2	no	66	asked if he really has to sing when the countdown expired (i did not say anything) and he said he already knew this experiment so he would prefer not to sing 13:28:30 moved his hand because he had to scratch and talked
29-04-2016	27	24	daniela	23,4	yes	48	Was expecting the SSST, did did not know for sure
02-05-2016	23	25	Tabea	19.0	yes	35	11:08:05 laughs 11:11:30 moves
02-05-2016	22	26	Daniel	20.5	Yes	21	-Mark 4 move -Laugh instruction ssst -Marker baseline after noise: moving -marker 1st sentence bcg: moving
03-05-2016	19	27	Tabea	21,6	yes	44	
03-05-2016	34	28	daniela	23,5	no	33	Nervous body language while he should sing, moves
03-05-2016	30	29	daniela	23,4	no	23	Says that he got autism and that people have always trouble with getting skin conductance /heart rate data from him
03-05-2016	22	30	Daniel	21,6	Yes	25	E4 time stamp is correct again Ssst: moves
03-05-2016	22	31	Daniel	22,1	Yes	40	Prepare SSST: “I didn’t understand/read the task, what do I have to do?” and moved a lot Noise test 1st : moving Noise test 3rd :moving finger BCG: said the number before right at the start of the countdown
04-05-2016	22	32	Daniel	19,3	Yes	84	- Marker: preparation SSST, laughed - Said she did the SSST a year ago
04-05-2016	24	33	daniela	22,6	yes	9	Moved while singing
04-05-2016	22	34	Daniel	20,9	yes	14	Marker Prepare SST: already starts singing

							"old" laptop screen turned black at the beginning of CBG (for around 1 second)
09-05-2016	22	35	Tabea	23.2	no	48	13:44:10 people talking when he should start to sing. He asked if he really has to sing 13:55:05 moved 13:59:15 moved 14:04:10 said the number out loud before the countdown expired, -the e4 has not recorded the data (2 sessions of 1 minute instead of one session of half an hour) sorry! I'll search for a new participant in exchange
09-05-2016	20	36	Tabea	23.8	no	45	15:56:20 people are talking and laughing outside when he should sing he asked if he really has to sing because he can not sing
10-05-2016	25	37	Daniel	22.2	yes	42	- Preparation SST: moves - SSST: laughed, looked at me and said "I don't know what to sing, I cant sing"
11-05-2016	23	38	Daniel	23.0	no	55	- Participant said that she has impaired hearing - Preparation SSST: moved left hand - Marker SSST: "Do I really have to sing now?" – Didn't sing - 10.57.35: someone in another room closes a window very loudly - 10.59.11: door closes loudly
11-05-2016	22	39	Daniel	23.2	no	42	- SSST: "Do I have to sing now?" - 13.28.48: Loud noise from another room
11-05-2016	29	40	daniela	25	no	68	14.44.50coughing 14.48.38 coughing He does NOT get stressed ever

							said he recognized that he had to sing aloud 20 sec too late Overweight – switched places of the blue wristband and e4 because the e4 would only fit directly under his hand
11-05-2016	21	41	Daniel	23.9	yes	12	- Participant said that she had a slight heart rhythm disorder - SSST: Had to laugh while singing
12-05-2016	22	42	Daniel	22.5	No	56	- Preparation SSST + SSST: Moving his head, not singing (maybe singing in his head?)
12-05-2016	26	43	daniela	24,1	no	0	Asks "do i really have to sing?"
13-05-2016	22	44	Daniel	22.1	yes	35	- Preparation SSST: laughs - Starts singing during preparation of SSST - Begin SSST: moves hand
13-05-2016	30	45	Daniel	22.0	yes	33	- After 2 beep sounds of noise test: "Is it normal that it beeps? It is really annoying!" -
13-05-2016	21	46	daniela	23,2	yes	93	
13-05-2016	21	47	daniela	27,4	yes	43	13.39.57 changes position
13-05-2016	36	48	daniela	27,2	yes	36	15.22.47 changes position,scratches nose.23,24 partcipant gets a call, ignores it Participant has quite a few limitations, problems with his nervous system, can not feel his fingers /toes, born with diabetes 2. Participant startet singing for ~5 seconds after the frist instruction / before the countdown expired and moved a lot.
13-05-2016	20	49	daniela	26,7	no	7	
14-05-2016	36	50	daniela	27,2	no	32	15:16:14 participant gets a sms 15.24.34 coughs 15.27.25 scratches head

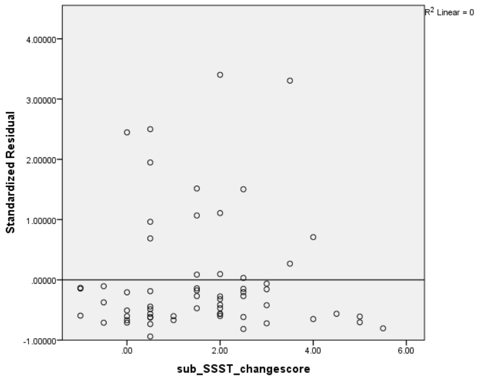
							15.30.50 - 15.31.25 moves, scratches head, moves fingers of the left hand Said the number before the cd expired Asked whether he really had to sing
14-05-2016	34	51	daniela	28.5	no	75	Moves head almost not noticeable but a bit nervously while she should sing Said afterwards that she sang a song in her head to "fullfill"the task at least half
14-05-2016	34	52	daniela	23.5	yes	24	I did something really stupid. I had to sneeze while saving the infinitidata and accidently hit the "not save" button. I guess the infiti data is gone...i am so sorry :(
14-05-2016	35	53	daniela	23,8	yes	12	Participant laughed when he first read the instructions from the SSST, again when the CD started. Sang for 3 sec and said "fuck, ik kan deze niet" Mentioned afterwards that he found the noise really annoying
18-05-2016	21	54	Daniel	19.7	no	23	
18-05-2016	19	55	daniela	21,4	yes	68	
19-05-2016	26	56	daniela	22,3	yes	17	~11.33.00 screen says that we should register windows, participant had to click it away
19-05-2016	26	57	daniela	23,5	yes	1,75	12.21.29 changes position,knew the BGC in a slighty diffrent version (take ½) from his study
19-05-2016	26	58	daniela	22,9	yes	31	
19-05-2016	25	59	daniela	21,9	yes	42	Sang before the cd
19-05-2016	25	60	daniela	22,7	yes	17	Sang before the cd ~15:37:00 computer asked to download updates/register. Had to click it away
24-05-2016	32	61	daniela	20.6	yes	14	Sings for 3 seconds "verder weet ik de hele tekst niet" 10:45:29 changes position 10:46:17 moves and says " die piepjes mogen wel stoppen. Die vind ik heel vervelend" 10:47:40 moves, coughs 10:48:00 moves

							10:48:44 "begint echt vervelend te worden die piepjes" and moves hand all the time, changes position Experiment afgebroken omdat de participant niet tegen de piepjes kon, headset afgenomen en beweegt, wil wel naar de baseline weer doorgaan (ongeveer laatste paar seconden van de noise test dus niet gedaan) 10:54:00 coughs and moves arm 10:55:30 coughs and moves arm Says the number before the cd expired, moves Moves feet alot during the whole experiment
24-05-16	Florence, 30	62	Tabea	22.1	yes	78	said the number when the countdown started
24-05-16	(Popakademie), 22	63	Tabea	23.3	yes	57	16:29:15 coughs a bit said the number when the countdown started
25-05-2016	23	64	Daniel	18.7	yes	60	10.15.17 reads instruction preparation and said "Oh my god!" and started singing right away, moved a bit and laughed 10.21.35 short laugh when heard marker 2 of noise test
25-05-2016	20	65	daniela	21,7	nee	27	Said number before the cd expired
26-05-2016	23	66	daniela	21.1	ja		Sang before the cd expired, de procomp is uit gegaan (aangezien die laatste keer begon te blinken had ik nog gecheckt of die dit keer weer zou blinken. Deed die niet, dus ben ik ervan uitgegaan dat het wel goed zit), experiment daarom afgebroken. Ik heb zelf nog de perceived vragenlijsten ingevuld zodat het eerste deel van de data niet kwijt is. Vanaf de noise test de data van python dus niet gebruiken
27-05-2016	peter	67	Daniel	18.7	yes	20	11.14.03.: shrugs his shoulder
27-05-2016	24	68	Daniel	19.8	yes	30	14:12:25: "Do I have to sing?" looks at experiment leader, moves

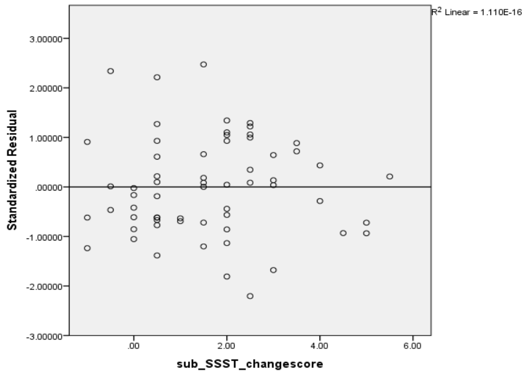
							14:18:04: moves 14:23:14: moves left hand
27-05-2016	23	69	Daniel	20.4	yes	28	15:07:26: During baseline he started to laugh for a second Marker prep. Song: “Am I supposed to sing?” starts singing and laughing, moving hands End of singing a song: weird heartrate measurements. Heart rate electrodes were re-applied during SSST questionnaire 15:18:28: starts laughing after beep sound 15:29:30: moves hand during BCG task description
27-05-2016	22	70	daniela	20.9	nee	37	
01-06-2016	24	71	daniela	22,8	ja	38	Vraagt bij de instrunctie van de SSST "ja echt??"
01-06-2016	23	72	daniela	23,6	nee	53	Participant seemed very stressed and confused when entering (he was also 15 minutes late). Told me that he had'nt slept in a while. I asked wether he really wanted to participate and /or wanted to relax/cool off before. Particpant laugehed a lot at random moments of the experiment and asked a lot of question (do i have to write this down etc). He got nervous about the SSST instruction and told me "nono,sry, i really can't do that". Took the breathing instructions very serious.
1-6-2016	23	73	daniela	24	ja	37	Sang before the cd, sang again during the task, since 14.44 til 14.47: people talking outside
1-6-2016	25	74	daniela	24,2	ja	55	Clicked on the mouse because she wanted to start the experiment during the "welcome to our study" screen, said "oh i like this question" while answering the question "how stressed are you",clicked on the screen for next again during "think of..", said that the answer was "pig"

							Asked "should i sing?" And looked at me for 5 seconds 15.22.20 moves hand 15:33.10 loud noise from the other room Participant moves feet,head a lot and sometimes the right hand (playing with the electrodes)
2-6-2016	23	75	daniela	23,7	ja	45	Askes 2 times wether she really had to sing, (she is a singer in a band) 10:53:10 people talking on the floor, Said the number before the cd expired
2-6-2016	27	76	daniela	24,1	nee	20	
2-6-2016	21	77	daniela	24,7	ja	43	
2-6-2016	21	78	daniela	24,8	ja	22	
8-6-2016	33	79	daniela	23,7	nee	45	Had heel erg last van zijn keel, vroeg 2moet ik echt hardop gaan zingen?" 11:28 participant moest meerdere keren hoesten
8-6-2016	28	80	daniela	24,5	ja	24	
8-6-2016	26	81	daniela	25,1	nee	26	15:13:50 scratches nose Changed position while reading the BCG task
9-6-2016	18	82	daniela	23,4	nee	32	
10-6-2016	22	83	daniela	22,2	fluit	18	Fluit tijdens de sst een beetje,zingt niet, lacht vantevoren ook tijdens het lezen van de instructie 12:26:58 en ~12:27:20 changes position
10-6-2016	19	84	daniela	23	ja	29	13:09:46 "ik moet nu zingen?"
10-6-2016	19	85	daniela	23,6	nee	30	"moet ik echt zingen?" Said number before the cd

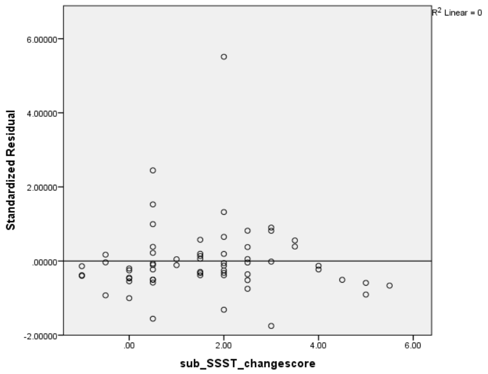
Appendix G : normality check of the residuals



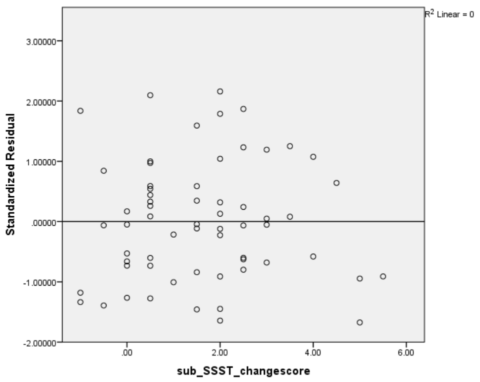
subjective and amplitude



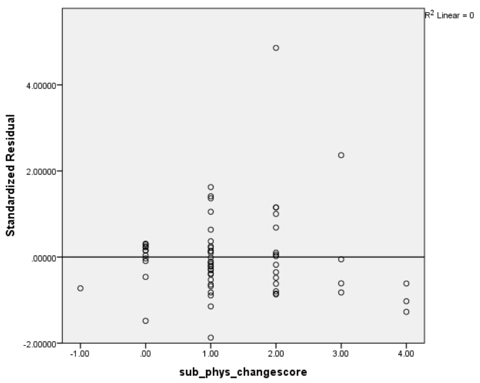
Subjective and no_scr



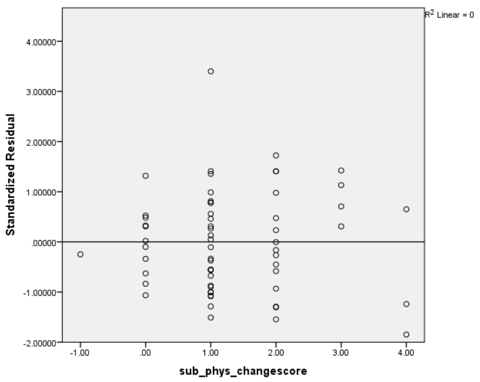
Subjective and scl



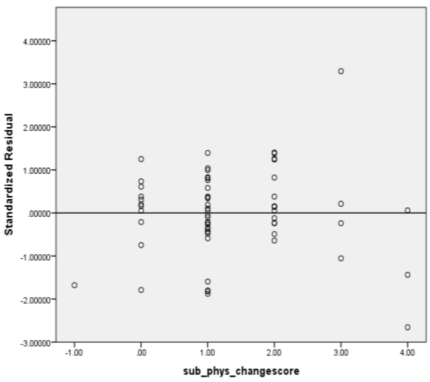
Subjective and HR



Subjective and amplitude



Subjective and no_scr



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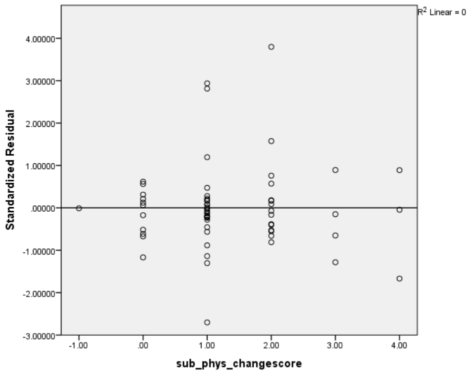
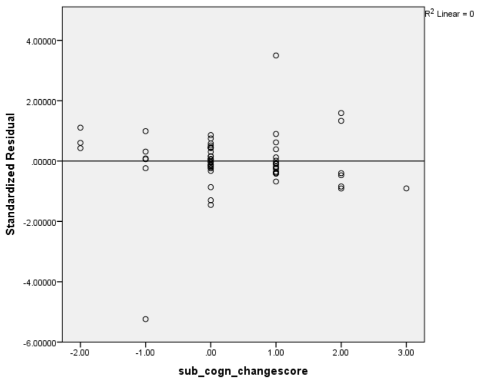
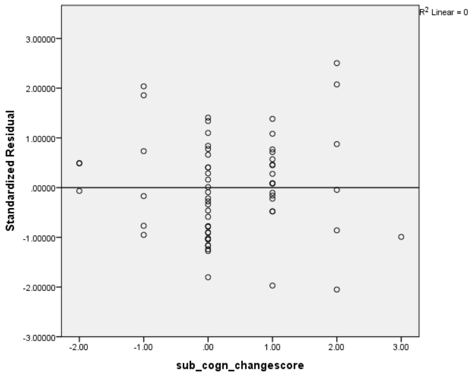


Subjective and HR



Subjective and amplitude



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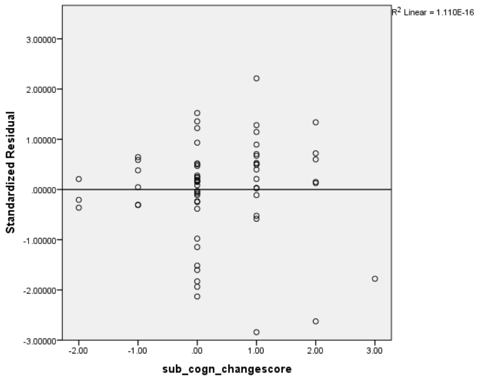

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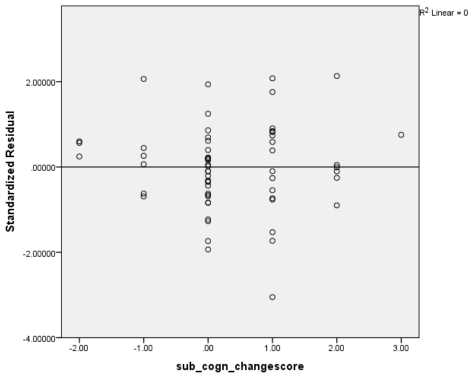

Subjective and HR