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OBJECTIVELY MEASURING STRESS

- How understanding stress helps us improve leadership

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Abstract

Stress is at an all-time high in our society, and given its dangerous personal, occupational and societal affects, this thesis sets out to establish a way of objectively measuring stress in real-life situations—and furthermore, examine how stress affects the leadership process. Several studies have found heart rate variability (HRV) measures, to be good explanatory proxies to assess the function of an individual's autonomic nervous system (ANS). The sympathetic- and parasympathetic activities generated by the ANS can be assessed by analyzing the changes in HRV that manifests, based on different physiological and psychological states, such as stress. To investigate this, HRV data was collected from a participant over a three-week period along with self-reported data about his perceived stress level. The findings generated by this study, found that objectively measuring and assessing stress in real-life situations is difficult—because the many variables and stimuli that affect HRV, cannot be controlled for. Therefore, objectively stating that a reduction in HRV is caused by stress, is not possible without additional information. This thesis also found a clear connection between stress and leadership, given that stress affects an individual's ability to dedicate significant cognitive resources to decision-making and problem-solving; two fundamental aspects of good leadership.

Key Words: HRV, Stress, Objective Stress (OS), Leadership, LMX Theory.

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List of abbreviations

Abbreviation	Explanation
ANS	Autonomic nervous system.
BP	Blood pressure.
BRS	Baroreflex sensitivity.
CNS	Central nervous system.
CV	Cardiovascular.
ECG	Electrocardiography.
EL	Event load.
HF	High frequency.
HPA	Hypothalamic-pituitary-adrenal.
HR	Heart rate.
HRM	Heart rate monitor.
HRV	Heart rate variability.
LF	Low frequency.
LMX	Leader-member exchange.
M-DSI	Modified Daily Stress Inventory.
M-SOS	Modified Short Stress Overload Scale.
OS	Objective Stress.
pNN50	Total amount of RR intervals that are greater than 50ms away from the previous.
PNS	Peripheral nervous system.
PV	Personal vulnerability.
RMSSD	Root mean square of the successive differences between adjacent RR intervals.
SDNN	Standard deviation of the NN times series.
ULV	Ultra-low frequency.
VLF	Very-low frequency.

1 Introduction

‘’Everyone knows what stress is, but nobody really knows.’’

The quote above, comes from the man who first coined the term ‘stress’ as we know it today—and perfectly illustrates one of the most difficult aspects of examining and analyzing any phenomenon from a scientific perspective; a clear definition (Hobfôll, 1989). The goal of this thesis is to work towards establishing a way to objectively measure stress in real-life situations, given its dangerous personal, occupational and societal effects. Both acute- and chronic stress can severely affect our musculoskeletal system, respiratory system, cardiovascular system and our endocrine system—leading to increased risk of diseases such as chronic fatigue, metabolic disorders (e.g., diabetes, obesity), depression, immune disorders, hypertension, heart attack and stroke (APA, 2019).

Statistics show that 10-12% of the Danish population, experiences serious stress symptoms daily, which amounts to approximately 430.000 people. 500.000 feel burn-out due to job stress and about 250.000 suffers from serious stress. Untreated stress is the cause of over 50% of all depressions and anxieties and leads to 30.000 hospitalizations every year, resulting in about 1.400 deaths (Stressforeningen, 2019). These statistics show a troublesome tendency that needs to be addressed, both at an individual level, but also at an organizational level; through knowledge, enlightenment and competent leadership.

1.1 What is stress?

A very common and general description of stress is ‘’...*a feeling of being under abnormal pressure, whether from an increased workload, an argument with a family member, or financial worries*’’ (Stressforeningen, 2019; MHF, 2019). Andrew Abbott, who wrote about the history of stress research, described the concept of stress as ‘’*the general idea that life places difficult demands on individuals, who then succumb under the strain to psychological or biological disease*’’ (Abbott, 1990, p. 437). Hans Selye first defined stress as we know it today, back in 1936 as ‘’*the non-specific response of the body to any demand for change*” (AIS, 2019).

For the purpose of clarity and precision, and to avoid any misunderstandings in relation to this highly subjectively understood concept, a more concise definition of stress must be established.

However, understand why this is a difficult task, a short historical review of stress will be presented, the importance of which will become apparent.

1.1.1 The two antithetical sides of stress

Roughly, there seems to be four major themes involved in our popular literature on stress and the diseases that follow; a concern about anxiety, an ambivalence about mind and body, an image of performance under pressure, and a general theory of adjustment (Abbott, 1990). Ultimately, these four major themes boil down to two antithetical sides of one problem—the relationship between the individual and society, in modern industrialized societies.

One side examines the individual's performance under pressure within specified roles, focusing on issues such as efficiency and optimality, which has clear ties to scientific management and rationalization. In short, this side focuses on the optimal utilization of the individual in society, essentially—how can we maximize that efficiency by properly adjusting the individual to society. The other side, conversely, views these events and phenomena, not in terms of their disutility to society, but in terms of their actual damage to the individual, by focusing on the impact the new social structure has on the individual (Abbott, 1990).

One of the obvious issues that arise from to the duality of stress as a concept, is the act of measuring it; which has proven to be a controversial topic in the stress literature. Many researches have argued about the right mixture of self-report, performance, psychophysiological and biochemical measures in determining stress, particularly because of their diverse temporal relations to the ''stress process'' (Abbott, 1990).

The literature on stress clearly shows how this duality affects research conducted in the field. The tension often revolves around choosing between indicators such as stress and distress; psychological or somatic; and performance or debility (Abbott, 1990). These differences arise because of the antithesis central to the cultural concept of stress—mind and body on one side, and performance and anxiety on the other.

Ultimately, these two antithetical sides of stress can be boiled down to a positivistic- and an interpretivist view on stress, two philosophical theories not prone to working together. However, in the case of stress, positivism and interpretivism are not total opposites, just two sides to the same coin (Abbott, 1990).

1.2 Problem statement and research question

The purpose of this thesis is to establish a method for objectively measuring stress in real-life situations, by examining and analyzing heart rate variability (HRV) metrics. Several studies, such as Hjortskov et al., (2004), Anderson et al., (2016) and Castaldo et al., (2015) conclude that HRV metrics can be used to assess if an individual experiences stress. Stress in the context of this thesis, is defined as the physiological response our body initiates in response to what it perceives as a potential dangerous or threatening situation, which from this point on will be referred to as Objective Stress (OS). It is my hope that findings generated by this thesis will provide valuable information that can be implemented into organizational- and leadership theory to deepen our understanding of how OS manifests in real-life scenarios. In addition, the relationship between OS and leadership will be examined to analyze how OS affects the leadership process—and how effective and competent leadership can help combat its effects.

This boils down to the following overarching research question:

How can HRV metrics be used to measure OS in a real-life situation? and how does OS affect the leadership process?

1.3 Limitations

Research consistently shows that, as mental workload increases, heart rate (HR), blood pressure (BP) and HRV decreases. Although not much research has been done on the topic, the limited studies conducted suggest that baroreflex sensitivity (BRS) also decreases when mental workload, or stress, increases. The benefits of examining BRS in relation to HR and HRV however, lies in the time dependency of HR and HRV. Studies conducted where experiments lasted in excess of 45 min., found that HR and HRV levels trended back towards baseline levels, while BP and BRS remained at a distinctly lower levels (Anderson et al., 2016). This means that analyzing BP and BRS in relation to HR and HRV provides a more comprehensive explanation of the experienced cardiovascular (CV) changes, especially during prolonged mental tasks.

The reduction in HRV, in relation to increased mental effort, is related to a reduction in the low frequency (LF) power band (0.07 – 0.14 Hz), which is associated with regulation of arterial BP through the baroreflex loop (Anderson et al., 2016). Under normal conditions, the baroreflex loop tightly regulates BP through regulation of sympathetic- and parasympathetic outflow via modifications in effectors such as HR, myocardial contractility, and arterial resistance. During emotional excitement when the ''fight or flight'' response is activated, BRS is inhibited by influences of the telencephalon and diencephalic systems, specifically the rostral ventrolateral medulla, which allows for inconsistent increases in both HR and BP (Anderson et al., 2016). Therefore, reductions in BRS may explain the shift in HR and HRV towards baseline during prolonged mental tasks.

Measuring BRS however, requires more advanced technology, not currently accessible to me, and will therefore not be examined further in this thesis—despite its relevance in relation to measuring OS in prolonged sessions. This thesis will therefore only use HRV analysis to measure OS.

1.3.1 Artefact correction of electrocardiography (ECG) data

Artefacts are abnormalities, that can lead to distortions of the ECG data and can either be generated by internal causes e.g., motion or muscular activity, or external causes e.g., electromagnetic interference or electrode malfunction. Artefacts can lead to distortions of individual or all components of the ECG, which can lead to misleading data. The process of locating and correcting artefacts, however, requires medical- or technological knowledge, along with information about what caused the artefact, to properly assess what could be an artifact, a myocardial ischemia or infarctions (Kligfield, et al., 2007). In this thesis, artefact correction is integrated into the software used to collect and register the HRV data, no further information can therefore be provided regarding the correction process and will therefore not be mentioned further.

1.3.2 The ULF and VLF component of HRV

The ultra-low frequency (ULF) and very-low frequency (VLF) components of HRV, lack consensus in the literature (Shaffer & Ginsberg, 2017) and will therefore not be analyzed and concluded upon exclusively—only in relation to total power generated.

2 Theory

2.1 How OS manifests in our bodies

OS can affect people in several different ways, both physically and emotionally, and in varying intensities. When our bodies experience acute OS, our muscles tense up to guard us from injury and pain—when the OS passes, the tension releases. Chronic OS however, causes our bodies to be in a more or less constant state of guardedness, which can lead to musculoskeletal OS-related disorders such as tension-type- and migraine headaches, which are associated with chronic muscle tension in the area of the shoulders, neck and head. OS can also affect our respiratory system to induce shortness of breath or rapid breathing, due to constriction of the airway between the nose and lungs. For people with a healthy respiratory system, this is generally not a problem, but for people with asthma or other respiratory diseases; acute OS can be dangerous (APA, 2019).

When we perceive a situation to be challenging, threatening or uncontrollable, our brains initiate a series of events that involve the hypothalamic-pituitary-adrenal (HPA) axis—which is the primary driver of the endocrine stress response. The result of this series of events, is an increase in the production of steroid hormones called glucocorticoids; which includes cortisol, that is often referred to as the 'stress hormone' (APA, 2019).

Glucocorticoids are essential for regulating the immune system and reducing inflammation. Chronic OS, however, can lead to an impairment of the communication between the immune system and the HPA axis, which has been linked to the development of numerous physical and mental health conditions, e.g., chronic fatigue, metabolic disorders (diabetes and obesity), depression and various immune disorders (APA, 2019).

Acute OS causes a series of hormones, namely adrenaline, noradrenaline and cortisol, to be released into the body. Adrenaline and noradrenaline raise blood pressure and reduces blood flow to the skin and stomach, increasing the heart rate and perspiration, preparing the body for an emergency response. Cortisol releases fat and sugar into the bloodstream to maximize available fuel levels (APA, 2019). These physiological changes are facilitated to make it easier for our bodies to fight or run away, commonly known as the ''fight or flight'' response (Hjortskov, et al., 2004).

Chronic- or prolonged OS can contribute to long-term problems for our heart and blood vessels. The rapid and repeated cycle of increases in HR, elevated levels of stress hormones, and BP can take a grievous toll on the body and may contribute to inflammation in the circulatory system, particularly in the coronary arteries, and increases the risk of diseases such as hypertension, heart attack and stroke (APA, 2019).

OS is not necessarily a bad thing. Research has consistently shown that OS helps people be more alert, perform better and be more productive. This is, however, only the case if the OS is short-lived; chronic- or prolonged OS has only been found to have negative consequences (MHF, 2019).

2.2 HRV

The analysis of HRV has emerged as one of the most rapid and noninvasive methods used to obtain reliable and reproducible information on the autonomic modulation of the heart rate. Simply put, HRV represents the fluctuation between intervals of consecutive heartbeats, resulting from the nonstationary autonomic influence (Massaro & Pecchia, 2019).

2.2.1 The anatomo-physiological foundations of HRV analysis

The human nervous system is composed of the central nervous system (CNS), consisting of the brain and the spinal cord, and the peripheral nervous system (PNS), which connects the CNS to other parts of the body, as illustrated in Figure 1. The ANS is an anatomical division of the PNS, and is responsible for the innervation of internal organs, whose activity is independent from our voluntary control. Functionally, the ANS involves both peripheral and central elements: Ganglia (i.e., groups of nerve cell bodies) and nerves spread through the body while several centers and nuclei (i.e., large aggregates of neurons) are located in the CNS. The central component is distributed throughout the neuroaxis (i.e., the axis of the CNS) and has a primary role in instant control of visceral function, internal regulation, and adaptation to external challenges. The peripheral component consists of nerves that develop from the brainstem (i.e., the posterior part of the brain that connects with the spinal cord) and the spinal cord to reach the autonomic ganglia, and from there, other nerves connect with the peripheral tissues, including the cardiac muscle. The ANS helps regulate several bodily functions through two complementary activities, called sympathetic and parasympathetic.

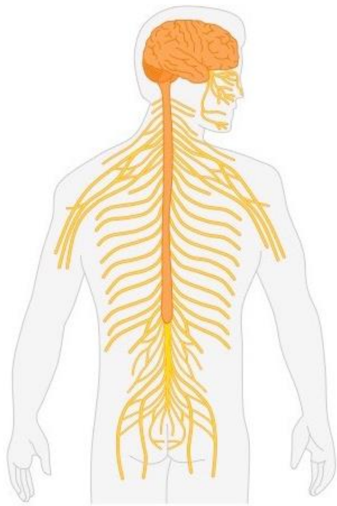

Figure 1 - Visual representation of the CNS (orange) and the PNS (yellow).

Sympathetic activity is primarily connected to the preparation of the body for response to action in demanding and/or worrying situations; the ‘‘fight or flight’’ response.

Parasympathetic activity functions under more restful situations and counteracts the effects of sympathetic activity to reinstate and keep the body in a balanced state, called homeostasis. Parasympathetic activity is commonly referred to as the ‘‘rest and digest’’ or ‘‘feed and breed’’ response. Table 1 shows the main ANS sympathetic- and parasympathetic stimulations and how they affect the different organs.

Table 1 - Main sympathetic- and parasympathetic stimulations (Massaro & Pecchia, 2019).

Structure	Sympathetic Stimulation	Parasympathetic Stimulation
Heart	Heart rate and force increased	Heart rate and force decreased
Iris (eye muscle)	Pupil dilation	Pupil constriction
Salivary glands	Saliva production reduced	Saliva production increased
Oral and nasal mucosa	Mucus production reduced	Mucus production increased
Lung	Bronchial muscle relaxed	Bronchial muscle contracted
Stomach	Peristalsis reduced	Gastric juice secreted; motility increased
Intestine	Mobility reduced	Digestion increased (small intestine); secretions and motility increased (large intestine)
Kidney	Decrease urine secretion	Increased urine secretion

The ANS is always working, under normal circumstances, to maintain a dynamic and complex state of equilibrium between these two activities. Notably, while our heart is an organ that can operate and respond independently of neural control systems, thanks to its pacemaker tissues, its activities are strongly influenced by these ANS functions. Indeed, the heart is innervated by both sympathetic and parasympathetic nerves as well as by an intrinsic complex system of nerves. Altogether, this autonomic activation influences the heart rate, conduction, and hemodynamic, as well as cellular and molecular properties of individual cells. Speaking generally, parasympathetic stimulation, mainly through the action of the vagus nerve, slows heartbeat variation. Conversely, heartbeat variation increases in response to the sympathetic modulation, contributing to produce chaotic fluctuations in recordable signals. This modulation occurs because the ANS innervates the cardiac pacemaker tissues (i.e., sino-atrial and atrio-ventricular nodes of the heart) responsible for initiating and spreading electrical signals during each heart cycle, making them subject to the paired and opposed ANS influences just described (Massaro & Pecchia, 2019).

The heart of a normal healthy individual is constantly subject to these activities and maintains a natural status of balance, often referred to as the sympathovagal balance. Importantly, these features also reflect an individual's ability to react, for instance, to external threats and/or internal emotional changes and restore homeostasis once the eliciting situation is gone. We can therefore readily recognize that the ability to measure variations in several heart activities, including rhythm and rate, can offer explanatory proxies to assess the activity of the nervous system as well as people's psychological states and behavioral responses (Massaro & Pecchia, 2019).

2.2.2 The relationship between HRV and OS

OS influences the ANS, which controls our capacity to react to external stimuli. This means that OS can be evaluated with non-invasive biomarker measurements; which are considered reliable estimators of ANS statuses. This is the case of HRV, which is considered a reliable means to indirectly observe the ANS, also in real life settings (Castaldo, et al., 2015). HRV refers to the variations of both instantaneous heart rate and the series of inter-times between consecutive peaks of the R-wave of the ECG, knows as the RR series. This variation is under the control of the ANS, which through the parasympathetic- and the sympathetic branches, is responsible for adjusting the HRV in response to external or internal physical or emotional stimuli. A normal subject shows a good degree of variability of the heart rate, reflecting a good capacity to react to those stimuli (Castaldo, et al., 2015).

A decrease in HRV indicates a disturbed ANS and has widely been associated with OS. The decrease in HRV may be a sign of lack-of-ability to respond by physiological variability and complexity, thus making the individual physiologically rigid, and therefore more vulnerable (Hjortskov, et al., 2004).

Hjortskov and colleagues (2004) found that the high frequency (HF) component of HRV reduces in situations of high OS, which increases the LF/HF ratio. Both the LF and HF component of HRV were higher during rest, compared to during work sessions, and the LF/HF ratio was significantly reduced during rest. Furthermore, the study found that HRV indices of parasympathetic activity are sensitive indicators of OS. These findings are consistent with several studies, such as the systematic literature review conducted by Castaldo et al. (2015) which demonstrated that four HRV measure (RR, RMSSD, pNN50 and D_2) decreases during OS. Most of the studies included, agreed that SDRR and HF decreased during OS, while LF/HF and LF increased during OS.

2.3 Computing HRV values

2.3.1 Time-domain analysis

The simplest HRV analyses are the time domain estimates. These are descriptors of the NN time series and are usually divided into statistical and geometrical methods. Statistical measures are standard deviations of the RR intervals, which reflect the overall variation within the RR interval series. Time domain measures are strongly influenced by changes in both sympathetic and parasympathetic activity, making most nonspecific measures of autonomic modulation.

SDNN

The SDNN is the standard deviation of the NN time series. A high SDNN correlates with a high HRV, and a low SDNN correlates with a low HRV. Greater HRV comes from greater parasympathetic tone, and vice versa. Therefore, a decrease in the SDNN points towards a rise in sympathetic tone. SDNN is defined as,

$$SDNN = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}(RR_n - \overline{RR})^2}$$

pNN50

This measure calculates the total amount of RR intervals, in any given sequence, that are greater than 50ms away from the one before it. The pNN50 is therefore a measure of the percentage of RR intervals that are greater than 50ms away from their adjacent ones. A greater pNN50 is a sign of a greater HRV and vice versa. pNN50 is defined as:

$$pNN50 = \frac{NN50}{N-1}\, x\, 100\%$$

It is, however, important to note that pNN50 does not take into account the actual distance between RR intervals—it does not matter whether the interval is 51ms or 150ms apart. Caution is therefore advised when drawing conclusion, solely based on pNN50.

RMSSD

The RMSSD is the root mean square of the successive differences between adjacent RR intervals and provides a measure of parasympathetic activity. It is given by:

$$RMSSD = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N-1}(RR_{n+1} - RR_n)^2}.$$

2.3.2 Frequency-domain analysis

Frequency domain analyses require a more sophisticated knowledge of the HRV signal because they rely on the estimation of power spectral density (PSD), which is the description of how the power of the signal is distributed over frequency.

Frequency bands

High frequency (HF), Low Frequency (LF) and Very Low Frequency (VLF) are bands representing main oscillatory components of the HRV power spectrum (i.e., the distribution of frequency components of the signal), and yield explanatory insights on the ANS outflow. Generally, VLF is measured between 0 ≤ 0.04 Hz, LF between 0.04 – 0.15 Hz, and HF between 0.15 – 0.4 Hz. HF bands primarily reflect efferent vagal nerve activity, which is parasympathetic activity. LF represents both parasympathetic and sympathetic activity (Massaro & Pecchia, 2019).

Power ms^2

The power ms^2 is a measurement of the power generated in the corresponding frequency band. It is important to note that power ms^2 is relative to the individual, caution is therefore advised when comparing between subjects.

Power %

This measurement portrays the same values as power ms^2, but computed into percentages, normalizing the data, facilitating easier comparison both within- and between studies and subjects.

LF/HF

LF/HF represents a ratio of sympathetic to parasympathetic activity. Greater LF/HF ratio is indicative of greater sympathetic activity. Some research indicates that the ratio of LF to HF power (LF/HF) can possibly represent an informative index of the sympathovagal balance. This value would characterize relative shifts toward either parasympathetic or sympathetic dominance on cardiac function, offering a simple means to extract information on ANS activity from HRV. In general, a low

LF/HF ratio is believed to reflect greater parasympathetic activity than sympathetic; however, this value is often altered due to a greater depression of LF power than of HF power. The relationship between sympathetic and parasympathetic modulations in generating LF bands is nonlinear and contingent on experimental conditions. Therefore, inferences on ANS outflow derived from frequency domain outputs, and LF/HF values in particular should always be interpreted with caution, especially in the presence of short-term excerpts (Massaro & Pecchia, 2019).

In order to accurately measure something, it must first be understood. The sections up until now have described and explained OS; how it manifests in the body, and how it can be measures through HRV metrics. The next part will elaborate upon the perspective on leadership used to assess how OS affects the leadership process—and the people within that process.

2.4 Using LMX theory to examine leadership

In order to achieve and establish a more balanced and complete understanding of the leadership process, and how OS affects this process, a taxonomy needs to be developed that accurately reflects the multi-faceted nature of leadership, and the situations that constitute leadership (Graen & Uhl-Bien, 1995). Leader-Member Exchange (LMX) Theory does this by expanding the classification system beyond the leader, to include the follower and the interactive relationship between the two, as seen in Figure 2. Given that effective and productive leadership involves all three domains, focusing only on one domain, leads to the generation of specific and valuable information—only about that particular domain. This can result in relevant and often critical aspects of other domains being overlooked, leading to reduced generalizability, and a lessening of the predictive power of the information produced. Instead, when conducting investigations into leadership, all three domains should be examined for a more comprehensive understanding of leadership processes (Graen & Uhl-Bien, 1995). It is important to note that the taxonomy above, refers to the three domains within the construct of leadership; which means that each domain can be analyzed on many different levels, e.g., individual, small group or even larger collective.

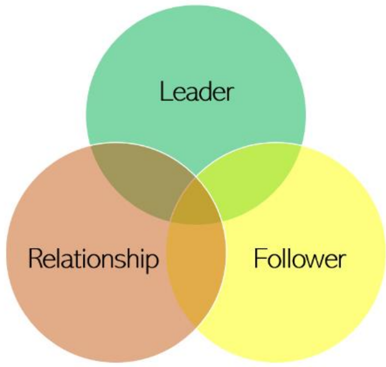

Figure 2 - The domains of leadership (Graen & Uhl-Bien, 1995).

Fundamentally, the core proposition of LMX theory is ''...*effective leadership processes occur when leaders and followers are able to develop mature leadership relationships (partnerships) and thus gain access to the many benefits these relationships bring*'' (Graen & Uhl-Bien, 1995, p. 225). LMX theory contains three dimensions, fundamental to obtaining a mature relationship—respect, trust and obligation. These three dimensions are some of the most important characteristics of a good working relationship, as opposed to a personal or friendship relationship, and refers to the individuals' assessment of each other, in terms of their professional capabilities and behaviors (Graen & Uhl-Bien, 1995).

3 Methods

OS, as defined and examined in this thesis, is a physiological response, that can be examined by analyzing the ANS outflow, by way of HRV analysis. OS is therefore a positivistic phenomenon, viewed from a positivistic perspective. At the heart of positivism lies the fundamental belief, that it is only through the scientific method, that actual factual knowledge can be obtained. Positivistic research solely concentrates on objective facts, which is why researchers become inherently independent of the research they conduct (Dudovskiy, n.d.). Positivistic research continuously develops our collective understanding of humans, and the events that take place in the areas of social research—based on clear evidence. The understanding of phenomena in reality, must therefore be measured and supported by evidence; leading to a high-quality standard of validity and reliability, which can then be generalized to the large scale of population (Pham, 2018).

3.1 Data gathering

Two different types of data will be gathered from our participant, a 29-year-old man who works as a consulting engineer, over the course of 3 weeks, from the 9th to the 29th of December. Firstly, biometric data consisting of RR intervals used to computed HRV values. Secondly, self-reported data in the form of questionnaires regarding perceived stress levels on a daily- and situational basis. The combination of the two types of data will allow us to examine the OS responses generated in the body and compare them to the participants perceived stress level. A short overview of the different tools and methods utilized to collect the two different types of data, can be seen in Table 2.

Table 2 - Biometric- and self-reported data chart.

Biometric data		
Tool	**Function**	**Description**
Polar H10	Measures ECG.	Heart rate monitor (HRM).
Elite HRV	Records RR-Intervals.	Mobile App that connects to the HRM.
Kubios HRV Standard 3.3.1	Computes HRV metrics.	Analytic software.
Self-reported data		
Modified Short Stress Overload Scale (SOS-S)	Measures self-reported stress levels daily.	A 10-item stress scale that uses a Likert-Scale to estimate stress overload.
Modified Daily Stress Inventory (M-DSI)	Measures self-reported stress on a situational basis.	A 5-point Likert-Scale with no prescribed items, giving the individual freedom to describe the stressor.

3.2 Biometric data

3.2.1 Polar H10

The Polar H10 is a small HRM connected to a chest strap, fitted with electrodes. The chest strap has several small silicone dots that keep the strap firmly in place, even during heavy physical activity. The device can connect to several different apps and gadgets using both ANT+ and Bluetooth connection (Polar, n.d.). The electrodes on the strap facilitate the collection of ECG data.

ECG is the process of recording the electrical activity of the heart, over a period of time, using electrodes placed on the skin. The electrodes detect the small electrical changes on the skin that arises due to the heart muscle's electrophysiologic pattern of depolarizing and repolarizing during each heartbeat, also known as the thoracic impedance. Through this process, data can be collected in order to retrieve the different peaks and valleys of each heartbeat, making it possible to measure the interval between the R Waves (de Geus, Willemsen, Klaver, & van Doornen, 1995). For a more detailed explanation, see Appendix I.

3.2.2 Elite HRV

Elite HRV is a free app that collects raw RR interval data from a connected HRM and exports the data in .csv, or .txt format, rendering them readable by more sophisticated analytic software to allow for more complex analyses. The collection of RR interval data relies on the tracking of small changes in the intervals between successive heartbeats, as shown in Figure 3. The RR interval is a measure of the range of variation from beat-to-beat, and analyzing these number collectively gives us HRV.

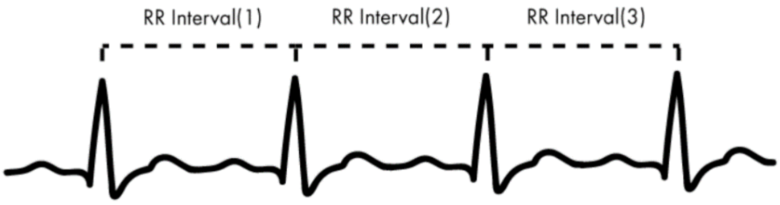

Figure 3 – Visual depiction of R-R intervals.

3.2.3 Kubios HRV Standard 3.3.1

Kubios HRV Standard 3.3.1 is a freeware HRV analysis software developed for scientific and professional use. It supports RR data from HRMs and computes all commonly used time- and frequency domain HRV parameters. For more information on the software and its capabilities, see (Kubios, HRV Standard, 2019).

3.3 Self-reported data

3.3.1 Modified Short Stress Overload Scale (M-SOS)

The original Short Stress Overload Scale (SOS-S) is a short version of the longer version, Stress Overload Scale (SOS), created by James H. Amirkhan in 2012. The SOS-S was constructed by selecting the strongest of the SOS items, in relation to psychometric strength, and is designed to measure ‘‘stress overload’’, a state described in stress theories as occurring when demands overwhelm resources (Amirkhan, 2016). The respondent answers by using a 5-point Likert scale (1=not at all, 5=a lot) to indicate their subjective feelings and thoughts experienced over the prior week. The SOS-S examines two factors underlying stress overload, Personal Vulnerability (PV) and Event Load (EL), where PV is a representation of an individuals’ resistive resources, and EL is a representation of external factors. It is important to distinguish between these two factors, because a person faced with many demands (high EL) but who has adequate resources to counter them, may be considered more ‘‘challenged’’ than stressed. Conversely, a person with depleted resources (high PV) but faced with no, or only few demands, would be more accurately deemed ‘‘fragile’’ than stressed. Feeling challenged or fragile might not be pleasant experiences, however, it is not the same as feeling stressed. Furthermore, research has shown that these states are theoretically less likely to yield pathology than true stress overload, hence the importance of including both factors in measuring stress overload. The even numbered items on the scale comprise EL, and the odd numbered items comprises PV. Summing up these scales provides an indication of the stress overload the participant has experienced during the past week, and can then be compared to future results to capture how the participants perceived stress overload changes over time (Amirkhan, 2016).

The further modification of the SOS-S into the M-SOS lies in the translation from English to Danish and the conversion from a weekly-, to a daily scale. The participant whom will be filling these questionnaires, is a Dane, and given the importance of language in relation to properly understanding terms and words that describe highly subjectively felt emotional states—I felt it necessary to translate the scale for easier and better understanding. These alterations clearly affect future attempts to relate the information to other studies, however, the purpose of the self-reported data is to compare it to the collected biometric data and study the connection between what we can measure in the body, and what the participant experiences. The results stemming from the self-reported data, can therefore not be used to make comparisons between subjects or other studies.

3.3.2 Modified Daily Stress Inventory (M-DSI)

The M-DSI is a modified version of the Daily Stress Inventory (DSI) and is created to allow additional information to be gathered after a perceived stressful event, in relation to HRV measures. The original DSI, is a 58 item self-report scale that allows a person to indicate events that they have experienced in the past 24 hours and evaluate to which extent these events caused stress. First the events that have taken place are marked—then rated in relation to their stressfulness on a 7-point Likert-type scale from, ‘‘occurred but not stressful’’ to ‘‘caused me to panic’’. At the end, two blank items are provided to allow individuals to indicate the occurrence of events that were not included in the 58 items (Brantley, Waggoner, Jones, & Rappaport, 1987).

The M-DSI is meant as a situational report that provides insight into the stressful events, right after they have transpired. Unlike the DSI, no items are provided to the individual, instead, whatever stressor they experience, is written down, described and then rated on the Likert-type scale. Having situational information in relation to HRV measures, increases our ability to examine and analyze the link between OS and self-reported levels of stress.

3.4 Data collection procedure

The participant began each day by equipping the HRM and starting a reading session, then proceeded to wear the device throughout the day until he came home again, at which point he would end the session. This was done over the course of the three weeks, with a few exceptions due to illness or technical issues. The Elite HRV app was used to collect the RR interval data gathered by the HRM, which means that every reading was initiated and ended from the app—the participants cellphone therefore had to be in close proximity throughout every reading, which resulted in a few situations where data was lost due to him momentarily leaving his cellphone.

It is important to note that the act of self-reporting on perceived stress, has a high probability of affecting said stress level. Asking people to think cognitively about their own emotions is not a reliable source of data, both because bias and heuristics are evident in most thinking, as Kahneman (2011) illustrated. The simple act of asking certain stress related questions might in fact make the individual more conscious about the stress they experience and might also alter to what degree they feel stressed, especially in a study that lasts multiple weeks. Furthermore, how the questions are framed and how the individual understands them also affects results.

Modern psychology has repeatedly shown us that people very often say one thing and think and do a completely different thing; which has considerable consequences for any findings stemming from self-report measures. Humans are emotional creatures, driven by simple- and emotional impulses, which means that emotions precede and influence rational thought. It is therefore insufficient to rely only on self-reported measures when examining any psychological or physiological phenomenon (Bonga, 2017).

Specifically, in relation to stress, self-report measures have been criticized extensively for their reliance on retrospection about stressful events, their aggregated weight schemes and their assumptions about additivity. Furthermore, self-report methods have been criticized for having temporal problems, namely the negligence of the effects of recency, salience and duration of events, as well as criticisms regarding psychological phenomena such as confounding and contagion (Abbott, 1990).

Previous research has shown that moods and emotions are driven by processes operating below the level of conscious awareness, which essentially means that we have little control over them (Bonga, 2017). It is therefore a reasonable assumption that people might not know exactly *how* they feel—or even *what* they feel and would certainly not be able to express it precisely. Every attempt to extract information from an individual has the potential to alter said information, the problem however, is that we cannot know *how* the information is altered, only that it *is altered*. Great care should therefore always be exercised when collecting, utilizing and presentation self-reported data.

4 Research Design

4.1 Biometric data collection

A key preliminary step in computing HRV analysis involves the choice of the time length of the signal to analyze. The length of the excerpts is chosen according to the phenomenon under observation, the experimental conditions, the research question of the study, as well as the research subjects' personal circumstances and physiological cycles, such as circadian patterns and menstrual cycles. The literature considers three main standardized lengths: (a) long term, which refers to nominal 24-hour HRV excerpts; (b) short-term, which refers to five-minute excerpts; and (c) ultra-short-term, which refers to excerpts under five minutes (Massaro & Pecchia, 2019).

It is important to note that HRV measures do not follow a Gaussian distribution; the interpretation of this type of data therefore requires caution. Frequency domain analysis is better observed together (i.e., total and relative power) and not by focusing only of the LF/HF ratio. Misleading LF/HF values can be calculated through several changes in the numerator, the dominator, or both. This consideration applies to both intersubject and intergroup study designs.

4.1.1 Computing HRV analyses

Most studies that analyze OS, compare relatively short excerpts collected during stressful events and compare them to other short excerpts collected during a rest period. The goal of this thesis, however, is to establish a way of measuring OS in real-life situations, therefore, the analyses conducted will primarily be on the full length of the HRV readings.

As explained above, long-term excerpts usually refer to nominal 24-hour HRV excerpts, the excerpts collected from the participant however, ranges from about 2-12 hours, which means two things: first, the excerpts do not fall into the standardized lengths generally analyzed by the literature, and second, excerpts of unequal length will be analyzed and compared. This has a possibility to affect the degree to which the findings and results of this thesis, can be validated and reproduced. I, however, believe that this is less relevant, due to the fact that HRV metrics, as a consequence of their nature, greatly differ from individual to individual.

HRV measures are strongly influenced by changes in both sympathetic- and parasympathetic activity, meaning that they are nonspecific measures of ANS modulation. Therefore, circadian rhythms, core body temperature, metabolism, the sleep cycle and the renin-angiotensin system (a blood pressure- and fluid regulating system in the body) contribute to long-term HRV excerpts, more specifically 24 hour excerpts which are considered the ‘‘gold standard’’ for clinical HRV assessment (Shaffer & Ginsberg, 2017). In the case of this thesis, obtaining 24-hour excerpts was not technically possible.

According to Massaro and Pecchia (2019), excerpt length should be chosen in accordance with the overall research question. It can therefore be argued, that in the case of this thesis, where the goal is to measure OS in real-life scenarios, analyzing HRV excerpts that reflect different parts of the participants day will provide us with a wide variety of information, increasing the possibility that we will observe both moments of OS along with moments that reflect an undisturbed ANS. Ideally, the participant should be able to go about his day as usual to provide as accurate data as possible, showing how his day is generally, and not try to alter it due to the experiment. The data collection has therefore been worked around his personal- and work circumstances to be the least intrusive.

4.2 Establishing baseline HRV values

A study conducted by Corrales et al., (2012) measured HRV by recording beat-to-beat activity during a 30-minute rest. This was done to measure and compare differences between 200 participants, and subsequently, how activity levels affected their different results. For the purpose of this thesis, establishing a baseline to which the HRV data collected in the field, can be compared, will allow us to measure and examine the extent to which the participants HRV is reduced, compared to a baseline value.

As described above, many variables have the potential to affect HRV variables, which cannot be controlled for. Emotional stimuli, visual stimuli, different psychological states etc., all have the potential to negatively affect HRV values, producing lower baseline values. Which means that events that transpire the same day the baseline measures are collected, or even events from previous days, depending on their intensity, has the possibility to skew the results. To try and alleviate this issue, two separate rest sessions have been conducted, both following the same procedure as explained in Corrales et al. (2012)—a 30-minute rest while the participant laid in a supine position. The rest session that provided the best HRV values, was set as the estimator for the overall baseline values.

Establishing baseline values to which the data recorded in real-life situations can be compared, is paramount in measuring and assessing OS—which is central to this thesis. It is only possible to assess the degree to which an individual is experience OS, if the observed levels can be compared to a normal or baseline state.

5 Findings

5.1 Baseline HRV values

The two rest sessions were conducted in different locations, but the same procedure was used each time. The participant laid in a supine position alone and began an HRV reading. During the reading, he was to relax and not conduct any activity—meaning no texting, talking, playing games or listening to music. This was done to eliminate any obvious stimuli that could contaminate the results, however, given that his thoughts cannot be controlled, the degree to which this is possible, can certainly be debated. The total reading time was about 35-40 minutes for both sessions, allowing the participant to enter a relaxed state before the actual data collection began. At the end of each reading, a timer would ring to indicate that the reading was finished. Rest session I provided the best HRV values as seen in Table 3—which was then selected as the baseline to which the collected HRV data was compared.

Table 3 - HRV metrics collected during rest sessions.

HRV metrics	Rest session I (16/12)	Rest session II (30/12)
SDNN (ms)	64,30	61,50
pNN50 (%)	38,00	38,92
RMSSD (ms)	67,90	56,80
LF (ms^2)	2355,00	1950,00
HF (ms^2)	1536,00	1321,00
Total power (ms^2)	4099	3560
LF (%)	57,46	59,61
HF (%)	37,47	40,37
LF/HF	1.533	1.476

5.2 Long-term HRV excerpts

In general, longer recording periods provide more data about cardiac reactions to a greater range of environmental stimuli—hence the preference of 24-hour recordings. The longer an excerpt is, the more generalized the data becomes, making it less sensitive to short-term fluctuations, short-term activity influences and signal disturbances. In our case, the computed HRV values only reflect part of a full cycle. All HRV values are computed from the RR interval data streams, and given that the measurements differ in length each day, it is highly probable that the results are affected in a number of different ways, depending on the time of day, activities conducted in the specific time intervals, and circadian patterns influences.

The HRV data presented below has been collected from the participant over the course of three weeks, resulting in 144,6 hours of RR interval data. Table 4 shows the relevant computed HRV values generated by analyzing all excerpts in their entirety (all full reports, as well as situational reports, have been attached as separate appendices).

Table 4 - Complete chart of all computed HRV metrics.

Week 50							
Date	09/12	10/12	11/12	12/12	13/12	14/12	15/12
SDNN (ms)	58,00	62,50	65,40	60,40	55,70	59,90	70,30
pNN50 (%)	16,70	21,87	18,86	23,03	15,58	16,14	20,72
RMSSD (ms)	44,80	49,20	50,70	52,10	43,00	44,50	59,00
LF (ms^2)	2405	2767	3147	2324	2310	2897	3456
HF (ms^2)	610	773	770	931	539	632	1199
Total power (ms^2)	3.325	3.862	4.272	3.565	3.104	3.916	5.136
LF (%)	72,31	71,63	73,62	65,16	74,39	73,94	67,26
HF (%)	18,33	20,01	18,03	26,1	17,36	16,14	23,33
LF/HF	3.944	3.580	4.084	2.496	4.285	4.581	2.883
Week 51							
Date	16/12	17/12	18/12	19/12	20/12	21/12	22/12
SDNN (ms)	70,70	64,90	55,70	63,30	61,00	94,30	59,50
pNN50 (%)	29,85	16,23	15,48	20,94	13,01	33,59	14,06
RMSSD (ms)	60,20	50,50	40,90	49,90	44,50	102,30	46,70
LF (ms^2)	3320	3193	2333	2884	2973	6580	2550
HF (ms^2)	1228	868	505	885	685	2807	784
Total power (ms^2)	4.982	4.412	3.113	4.085	3.929	10.156	3.613
LF (%)	66,61	72,34	74,92	70,58	75,66	64,76	70,53
HF (%)	24,65	19,66	16,21	21,66	17,42	27,63	21,69
LF/HF	2.702	3.679	4.621	3.258	4.344	2.344	3.251
Week 52							
Date	23/12	24/12	25/12	26/12	27/12	28/12	29/12
SDNN (ms)	67,40	69,20	72,50	60,50	75,10	70,40	54,30
pNN50 (%)	20,14	18,97	29,07	10,97	31,91	18,77	12,44
RMSSD (ms)	51,30	52,90	60,90	39,00	75,10	59,00	40,40
LF (ms^2)	3510	3794	3776	2979	3628	3490	2242
HF (ms^2)	848	828	1159	515	1585	1189	556
Total power (ms^2)	4.696	4.944	5.261	3.756	5.611	5.062	3.091
LF (%)	74,72	76,71	71,74	79,28	64,64	68,9	72,5
HF (%)	18,04	16,74	22,02	13,71	28,23	23,48	17,98
LF/HF	4.142	4.581	3.257	5.783	2.290	2.934	4.033

5.2.1 SDNN

Figure 4 shows the participants computed SDNN over the course of the three weeks where data was collected. SDNN is as previously described, the standard deviation of the NN time series, where a high SDNN is correlated with a high HRV, and conversely, a low SDNN is correlated with a low HRV. Because an increase in HRV comes from greater parasympathetic tone, a decrease in SDNN points towards a rise in sympathetic tone (Massaro & Pecchia, 2019).

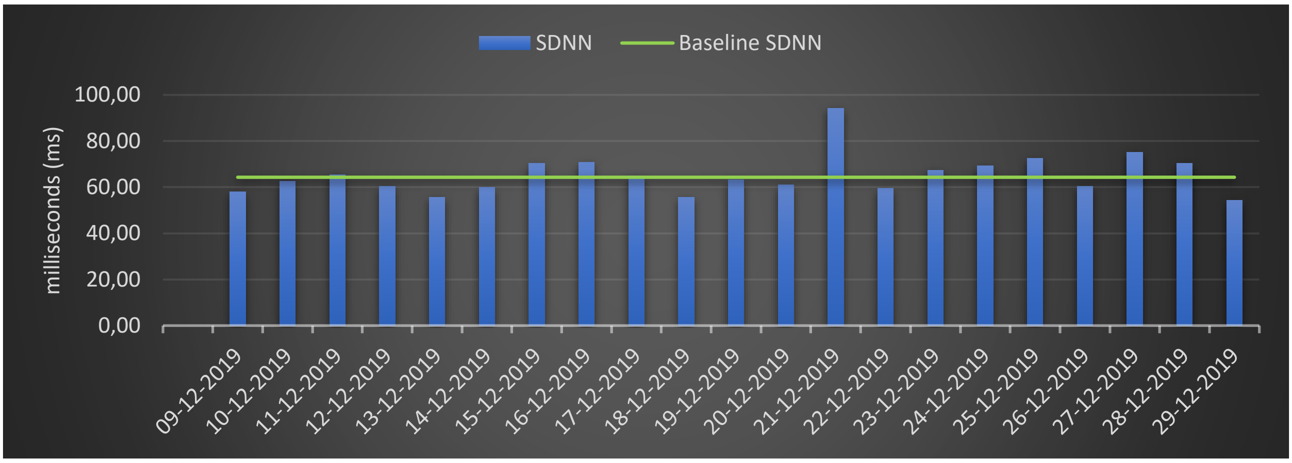

Figure 4 – Visual representation of the computed SDNN values.

5.2.2 pNN50

The HRV metric, pNN50, is tightly related to parasympathetic activity, but as previously described, this measure does not take into account the actual distance between waves, just that they are more than 50ms away from the previous—which can lead to misleading conclusions on the basis of these measurements, exclusively.

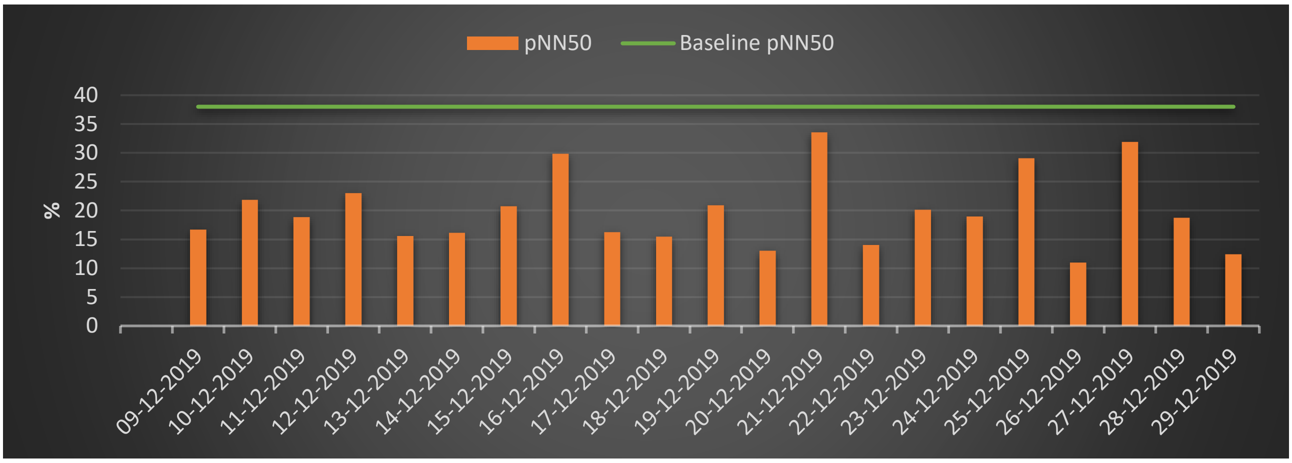

Figure 5 – Visual representation of the computed pNN50 values.

5.2.3 RMSSD

RMSSD reflects the beat-to-beat variance in HR and is the primary time-domain measure to estimate the vagally mediated changes reflected in HRV. It is identical to the non-linear metric SD1, in that it reflects short-term HRV. Long-term RMSSD measurements are strongly correlated with pNN50 and HF power. RMSSD is more influenced by parasympathetic activity than SDNN. Because RMSSD, along with pNN50, is calculated using the differences between successive NN intervals, the measures provided are largely unaffected by trends in an extended time series, and are strongly correlated with parasympathetic activity (Shaffer & Ginsberg, 2017).

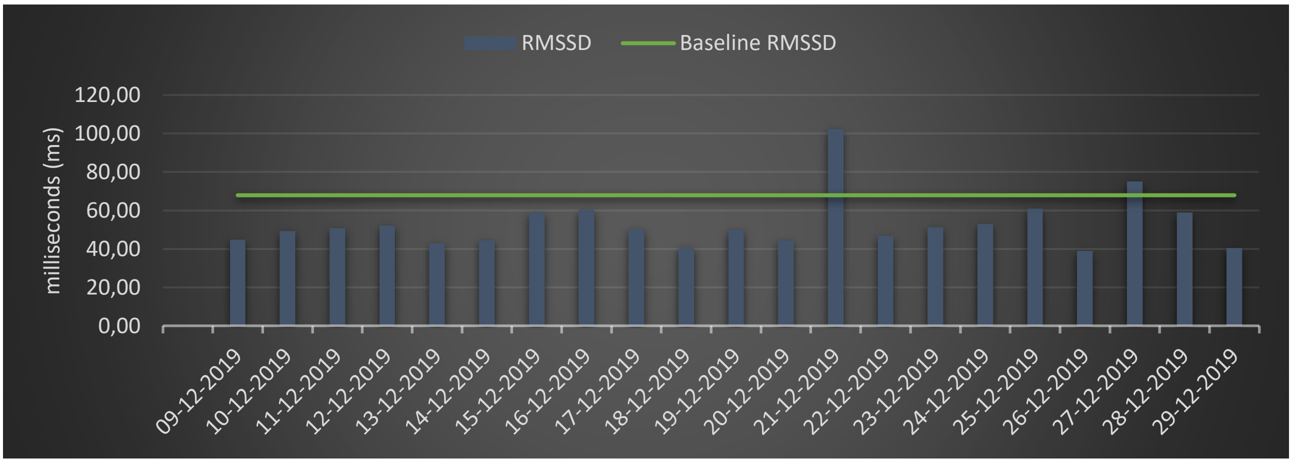

Figure 6 – Visual representation of the computed RMSSD values.

5.2.4 LF

Both LF and HF metrics are values indicating the power generating in the corresponding power frequency band. As previously stated, the power generated in the different frequencies is relative to the individual, which is why converting the values into percentiles can help facilitate easier comparison. When analyzing, it is important to examine both the actual power generated along with the percentages, for a more complete assessment.

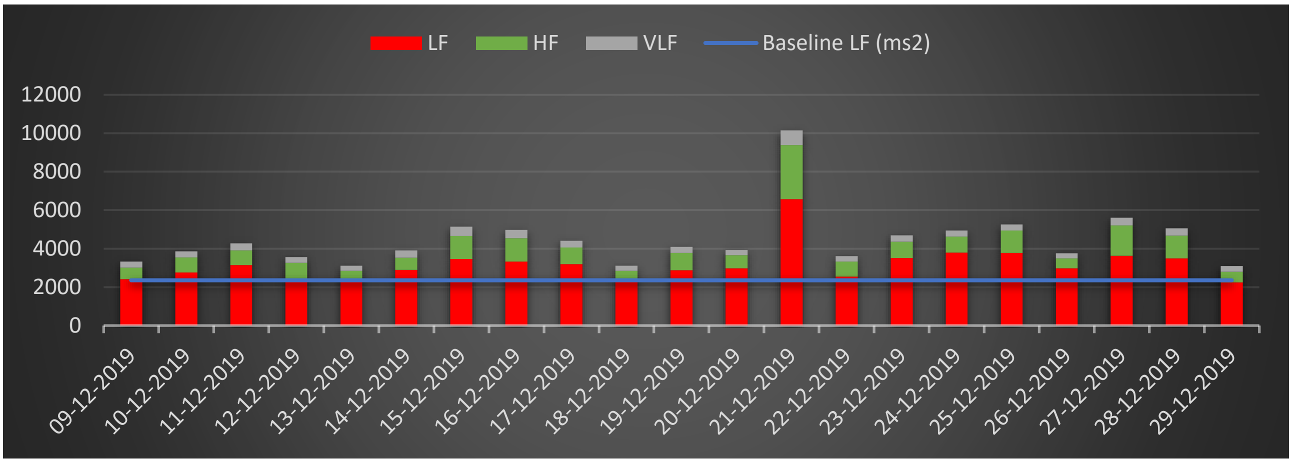

Figure 7 - Visual representation of the LF power band compared to the baseline.

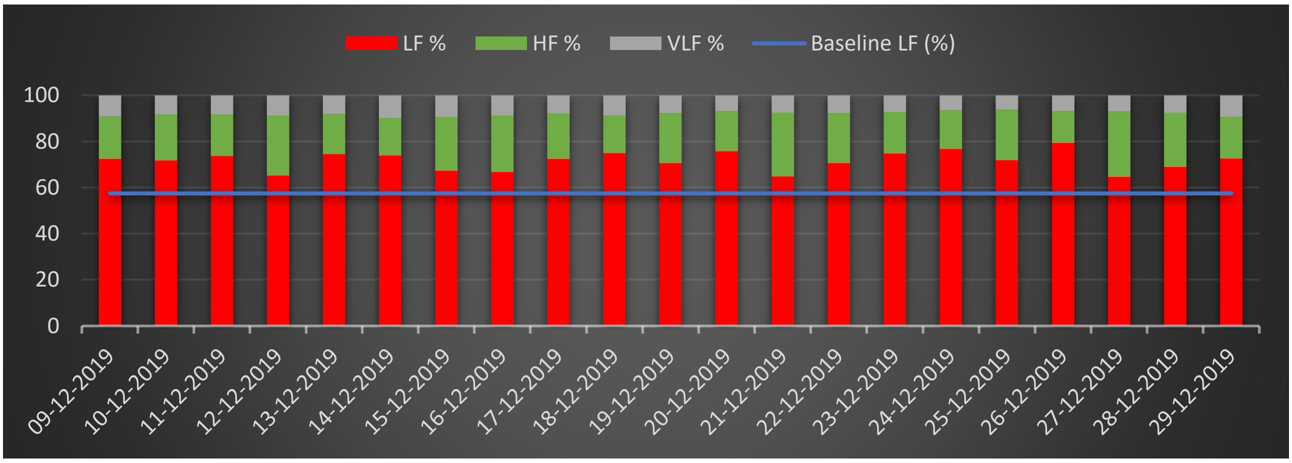

Figure 8 - LF power in percent, compared to the baseline.

5.2.5 HF

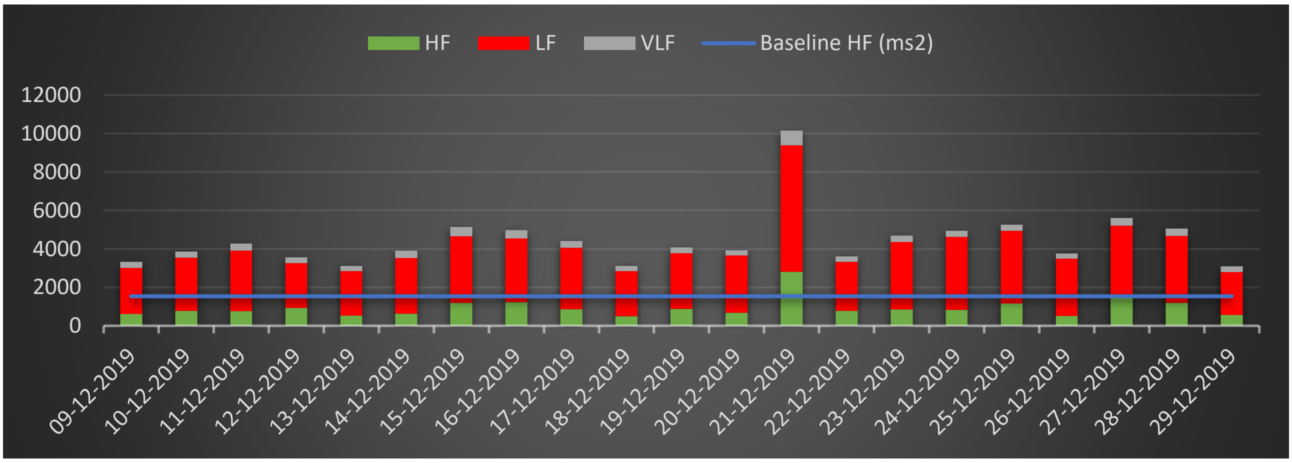

Figure 9 - Visual representation of the HF power band compared to the baseline.

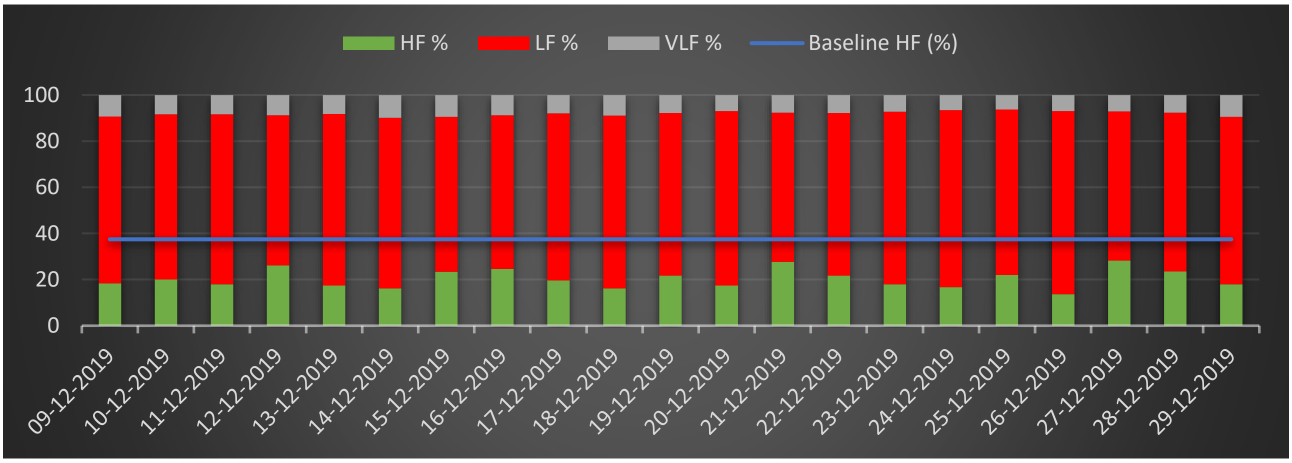

Figure 10 - HF power in percent, compared to the baseline.

5.2.6 LF/HF Ratio

The LF/HF ratio is essentially meant to represent the sympathovagal balance—where a low LF/HF ratio represents parasympathetic dominance, which means that behaviors related to the ''feed-and-breed'' mechanism are dominant, and conversely, a high LF/HF ratio represents sympathetic dominance, where ''fight-or-flight'' behaviors are dominant. This is based on the assumption that both parasympathetic and sympathetic activity contributes to LF power and parasympathetic activity primarily contributes to HF power (Shaffer & Ginsberg, 2017).

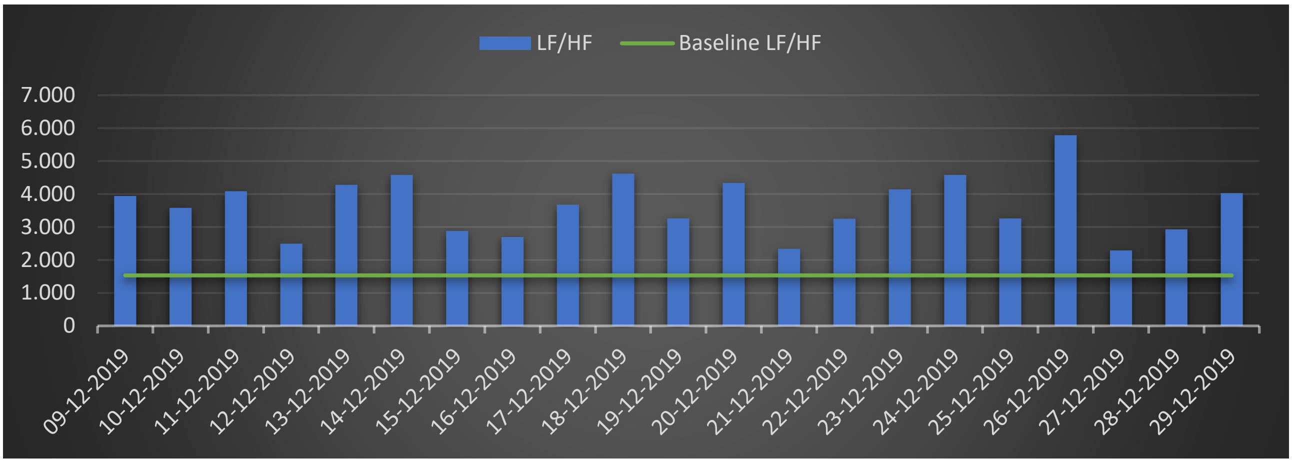

Figure 11 - Computed LF/HF ratios.

The figures and tables presented above represent the HRV information recorded throughout the experiment, that describes changes in the participants ANS outflow. Collectively assessed, these measures and metrics should present us with an indication of the amount of OS the participant experienced.

5.3 M-SOS Reports

The M-SOS reports provide us with information about the participants perceived stress level. Table 5 shows all data collected from the reports. To view the questions, see Appendix II.

Table 5 – M-SOS result sheet.

M-SOS Result Sheet										
Questions	1	2	3	4	5	6	7	8	9	10
09/12	1	1	3	5	3	4	2	3	1	3
10/12	3	4	4	5	3	4	3	4	1	3
11/12	x	x	x	x	x	x	x	x	x	x
12/12	5	4	4	5	3	1	4	4	2	4
13/12	1	2	3	4	3	2	1	4	2	5
14/12	1	2	2	1	2	2	1	2	1	3
15/12	2	3	2	2	1	1	2	1	1	3
16/12	1	2	1	5	4	1	2	4	3	4
17/12	1	1	1	1	2	1	3	3	2	3
18/12	1	3	5	5	4	4	5	4	3	5
19/12	3	4	4	5	4	3	4	5	4	5

20/12	5	4	5	5	5	1	5	1	5	5
21/12	1	1	1	3	3	1	1	1	1	1
22/12	1	1	2	5	5	1	1	1	1	1
23/12	2	1	2	3	2	2	1	1	1	1
24/12	1	1	1	2	1	1	1	1	1	1
25/12	1	1	1	1	1	2	1	1	1	1
26/12	2	1	1	2	1	1	1	1	1	1
27/12	1	1	1	3	3	1	1	1	2	1
28/12	1	1	1	2	1	1	1	1	1	1
29/12	1	1	1	2	1	1	1	1	1	1

5.3.1 PV & EL

Figure 12 depicts the levels of perceived stress reported by the participant, split into PV and EL, converted into percentages.

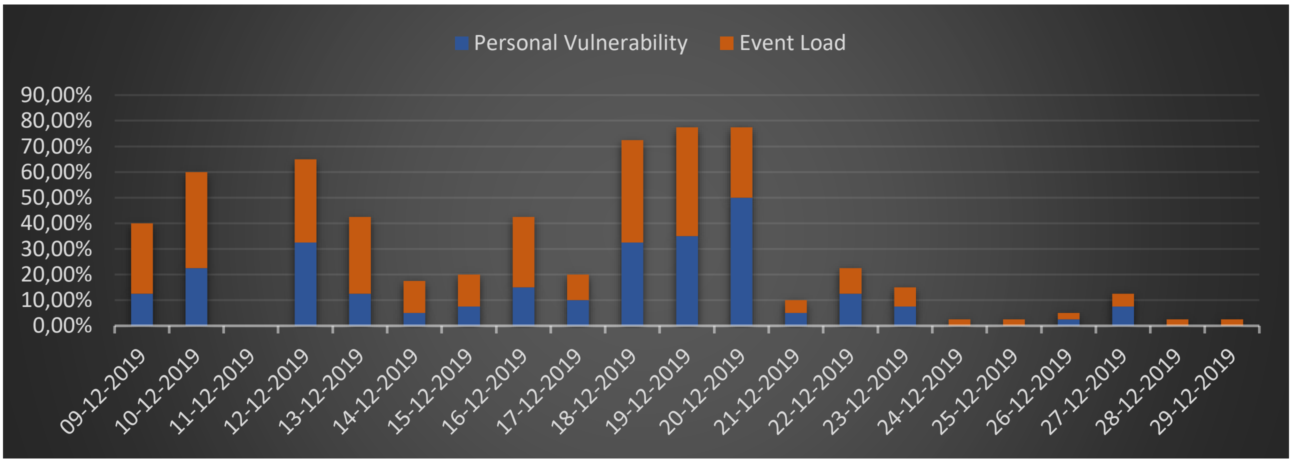

Figure 12 - PV and EL represented in percentages.

5.4 M-DSI Reports

The M-DSI reports filled by the participant will be presented in the discussion part, in relation to the individual days where they have been filled. However, a complete list of all 8 M-DSI reports can be found in Appendix III.

The information gained from the M-SOS and M-DSI reports provide us with a picture of how the participant perceives his own stress levels throughout the experiment and allows us to examine how these findings correlate with the obtained HRV data.

6 Discussion

6.1 The difficulties of establishing normative or baseline HRV values

As the technology used to measure HRV becomes more accessible and commonplace, the number of HRV research studies published increases—making it easier and more accurate to compare HRV scores and get an estimate of whether they are good or bad. However, there are several variables that affect HRV, which makes it problematic to accurately conduct intersubject comparisons.

6.1.1 Normative HRV values

A study conducting a meta-analysis of normal values for short-term HRV in healthy adults, set out to establish a set of normative values for HRV measures. The study included 21.438 adult participants of normal health, and was able to establish the values seen in Table 6 (Nunan, Sandercock, & Drodie, 2010).

Table 6 - Normative values for HRV metrics.

HRV metric	Mean	Range
NN (ms)	926 ± 90	785 – 1160
SDNN (ms)	50 ± 16	32 – 93
rMSSD (ms)	42 ± 15	19 – 75
In(rMSSD) (ms)	3.74	2.94 – 4.32
LF (ms^2)	519 ± 291	193 – 1009
HF (ms^2)	657 ± 777	83 – 3630
LF/HF	2.8 ± 2.6	1.1 – 11.6

As Table 6 shows, normative HRV values *can* be calculated. However, given that HRV values do not follow a Gaussian distribution and are readily affected by dozens of different and uncontrollable variables, these mean values can lead to some very misleading comparisons—especially when analyzing frequency-domain values. As previously stated, frequency-domain metrics should always be analyzed by both examining total and relative power, in relation to one another. The values provided above however, only represent a mean, following a rather large range of values. The lack of explanatory proxies to shed further light on the context of the computed values, renders the nominal values, in a best-case scenario, problematic. To further understand how- and why nominal HRV values are difficult to establish and utilize, we examine a few—but important factors.

6.1.2 Age and gender

Age is one of the strongest factors that influence HRV. In general, low HRV indicates an increased biological age, and high HRV correlates with increased fitness, health and youthfulness. It is important to distinguish between biological- and chronological age, because it is biological age that corelates with the body's homeostatic capacity; the body's ability to self-stabilize in response to OS, which does not necessarily correspond with an individual's biological age.

Gender also plays a significant role when assessing HRV metrics. Studies have found that men in general have a lower HRV than women, within the same age ranges. This indicates that men exhibit stronger sympathetic tendencies over parasympathetic, compared to women—which essentially means an increased probability of ''fight or flight'' responses (Voss, Schroeder, Heitmann, Peters, & Perz, 2015).

The study conducted by Voss et al., (2015) examined short-term HRV indices for 1906 healthy individuals aged 25 – 74 and analyzed them in order to determine the effects gender and age has on HRV. The findings show that women under 55, exhibit higher RMSSD, pNN50 and HF, and lower LF and LF/HF ratio than men in comparable age ranges. Particularly the notably higher RMSSD, and lower LF/HF in women below 55, demonstrate increased parasympathetic dominance. With age, follows a considerable loss of HRV and complexity, mainly caused by changes in the cardiovascular structure through the loss of sinoatrial pacemaker cells or decreased arterial flexibility and functional changes in other regulatory processes that occurs during aging—which makes age and gender important variables to include when examining HRV (Moore, HRV Demographics, Part 1 - Age & Gender, 2019).

6.1.3 Aerobic fitness

Another important variable that significantly impacts an individuals' HRV, is their fitness level, which contributes to increased recovery, muscle regeneration, energy levels, immune function and memory (Moore, HRV Demographics, Part 2 - Fitness Level, 2019). A high HRV is typically correlated with regular aerobic fitness, given that physical activity can improve cardiovascular function and health, which is measured indirectly through HRV. A study conducted on 200 participants between the ages of 18-25, measured the difference between active individuals and athletes, by measuring their HRV values during a 30-minute rest period (Corrales, Torres, Esquivel, Salazar, & Orellana, 2012). The results showed a significant difference in HRV measures across sedentary, active and athletic individuals. It is therefore important to include the participants level of fitness, when trying to compare the collected data to nominal HRV values.

In conclusion, gender, biological age and fitness level, to a substantial degree, affects HRV values, which makes it difficult to establish credible and reliable nominal HRV values, without segmenting the nominal values into different categories. Therefore, until all these variables can be effectively and systematically controlled for, the best way of establishing good comparable values, is establishing personal baseline values for each participant—based on their own data.

6.2 Objectively measuring- and assessing OS

Measuring OS in the real world, is not a straightforward process. The human mind is a complex organ that reacts to all kinds of stimuli throughout the day, and the act of accurately examining, controlling for, or explaining each one—is an impossible endeavor. As this thesis has shown, it is possible to objectively measure changes in the sympathetic- and parasympathetic branches of the ANS, by analyzing an individual's HRV. Unlike controlled experiments however, we have no control over the stimuli the participant is reacting to and have no way of testing if the moments of low HRV coincide with actual OS, or if it caused by a combination of other stimuli. As previously mentioned, Anderson et al., (2016) reported that HR and HRV levels could trend back towards normal levels due to a reduction in BRS, which means that prolonged OS can be present without it being detectable by HRV metrics. Furthermore, the relationship between LF- and HF power is complex, non-linear and frequently non-reciprocal. Which means that the actual power output generated from each channel can fluctuate independently, and without further contextual information, objectively stating that all reductions are caused by OS would be inaccurate.

To further illustrate some of the difficulties of objectively measuring and assessing OS, we examine a few of the days where data was collected, in more detail.

6.2.1 12th of December

LF/HF ratio is one of the popular metrics used to quickly assess whether an individual is experiencing an increased amount of OS, because a rise in LF/HF ratio correlates with increased sympathetic activity, and vice versa. pNN50 is similarly used to assess the degree to which an individual's parasympathetic system is active. The data collected on the 12th is an excellent example to demonstrate why LF/HF ratio and pNN50 can be problematic to conclude anything upon alone. According to the LF/HF ratio, the 12th was the day in week 50 where the participant experienced the lowest amount of OS, with a ratio value of 2.496, compared to the baseline value 1.533. This is corroborated by the HRV metric pNN50 which is 23,03%, the highest measured throughout the week. However, this does not correlate with the rest of the HRV data. Both the SDNN and RMSSD are higher on the 15th compared to the 12th. The RMSSD clearly shows that parasympathetic activity on the 12th is lower than on the 15th, which is to be expected, given that the 12th is day spent at work, and the 15th was a weekend day. But, when examining pNN50, the value computed for the 12th is larger than the value computed for the 15th, 20,72%, which is an indication of superior parasympathetic activity on the 12th. The explanation lies in the total power generated in all frequency bands. The total power generated on the 12th (3015 ms^2) is considerably lower than the power generated on the 15th (4655 ms^2) which, according to Hjortskov et al., (2004), is an indication of OS, due to the reduction in the total power ms^2 generated in all frequency bands—despite the low LF/HF ratio.

The M-SOS reports from the 12th show a perceived stress level of 65%, equally divided between PV and EL. This measure is the highest reported all week. Objectively stating why this is, is not possible. It is possible, however, to shed some light on the discrepancy between the computed HRV measures and the perceived stress levels reported by the participant, beginning with the examination of the PV and EL variables.

PV is defined as a representation of an individuals' resistive resources and explains the degree to which the individual feels vulnerable or inadequate. A high PV score is therefore an indication of fragility and an increased sensitivity to stressful situations (Amirkhan, 2016). PV is substantially higher on the 12th, than any other day of the week, so despite EL being relatively stable over the course of week 50, the increased PV could explain why the participant experienced this day as the most stressful throughout the week. To further investigate why the 12th was perceived as the most stressful day in week 50, we examine M-DSI report no. 4.

Table 7 - M-DSI report no. 4.

12/12 - 2019	Time: 13:10 – 16:10	Stress: 4/5 – 5/5
''I was at a construction meeting with a builder – I prepared for the meeting according to what I was told we would be discussing, but when the builder went through the things we would be discussing, I realized that none of it has anything to do with the things I prepared for, which resulted in me feeling ill prepared and that I had possibly misunderstood the meeting. Turns out when the meeting starts that it is actually the things, I had prepared that we were discussing, which meant that I could answer most questions. There were though, several questions sent my way, that made me feel inadequate, because I don't have enough experience with what I am working on right now to answer him, and it suddenly became too technical for me''.		

Several points in the participants explanation, could potentially explain why his level of PV might have increased, compared to the rest of the week. Additionally, one of the main criticisms of self-reported measures of stress is recency, and as seen in M-DSI report no. 4, the stressful incident lasted until 16:10, which is only 80 minutes prior to the HRV reading ending, and an M-DSI report being filled. One could argue that because of the short time duration between the perceived stressful situation and the debrief, negative emotions could have been more ''fresh'' in his memory, leading to a higher perceived level of stress.

Because we have HRV data readings obtained in the timespan where the participant reports to have been in a stressful situation, we can compare them to see what the HRV measures indicate.

Table 8 – HRV metrics computed from daily- and situational excerpt.

HRV metrics	Daily values	M-DSI no. 4
SDNN (ms)	55,70	56,00
pNN50 (%)	15,58	16,94
RMSSD (ms)	43,00	44,2
LF (ms^2)	2310	1955
HF (ms^2)	539	621
LF (%)	74,39	69,34
HF (%)	17,36	22,03
LF/HF	4.285	3.148
Total power (ms^2)	2849	2576

Table 8 displays the computed HRV values in the timespan indicated in M-DSI report no. 4, compared to the HRV values computed for the day, which show a slight increase in SDNN, pNN50 and RMSSD, along with lower LF power, higher HF power, but a lower total power ms^2. No strong conclusion can be drawn on the basis of this comparison, however, given that the participant reported this particular event as very stressful, classifying it as a 4/5 – 5/5 in intensity; a reasonable expectation would be at least a consistently visible reduction in HRV metrics, compared to the rest of the day.

In short, the HRV data obtained does not corroborate the participants self-reported experience. As explained previously, self-reported measures are affected by a series of variables, that we cannot control for. However, one explanation for the 'lack' of objective data to back the participants perceived experience, could be the time dependency of HR and HRV, as reported by Anderson et al., (2016). The HRV values could have trended back towards a homeostatic state, during the 3-hour period the participant described. However, if we examine the HRV data collected during the first 30-min. period, compared to the last 30-min. period of the perceived stressful incident, as seen in Table 9—all values indicate a decrease in HRV and a decrease in both HF and total power, which correlates with increased OS.

Table 9 - HRV metrics computed from the first- and last 30 min. of M-DSI report no. 4.

HRV metrics	First 30 min.	Last 30 min.
SDNN (ms)	61,60	54,60
pNN50 (%)	19,29	16,81
RMSSD (ms)	56,00	41,3
LF (ms^2)	1934	1959
HF (ms^2)	1102	502
LF (%)	59,82	71,2
HF (%)	34,09	18,25
LF/HF	1.755	3.902
Total power (ms^2)	3230	2750

Ultimately, it is impossible to accurately explain why there is a discrepancy between the measured HRV values and the self-reported data. It is however most likely the case, that the participant simply did not objectively or accurately measure and report the timespan or intensity of the incident, which resulted in the discrepancy presented above.

6.2.2 14th & 15th of December

Another interesting couple of days to examine is the 14th and 15th—the weekend. According to the LF/HF ratio, the 14th was the day where the participant experienced the highest amount of OS in week 50, with a ratio value of 4.581, and the 15th the second least, with a LF/HF ratio of 2.883. If we examine the time-domain metrics presented in Figure 13, we can see that the SDNN and RMSSD do not corroborate either claim.

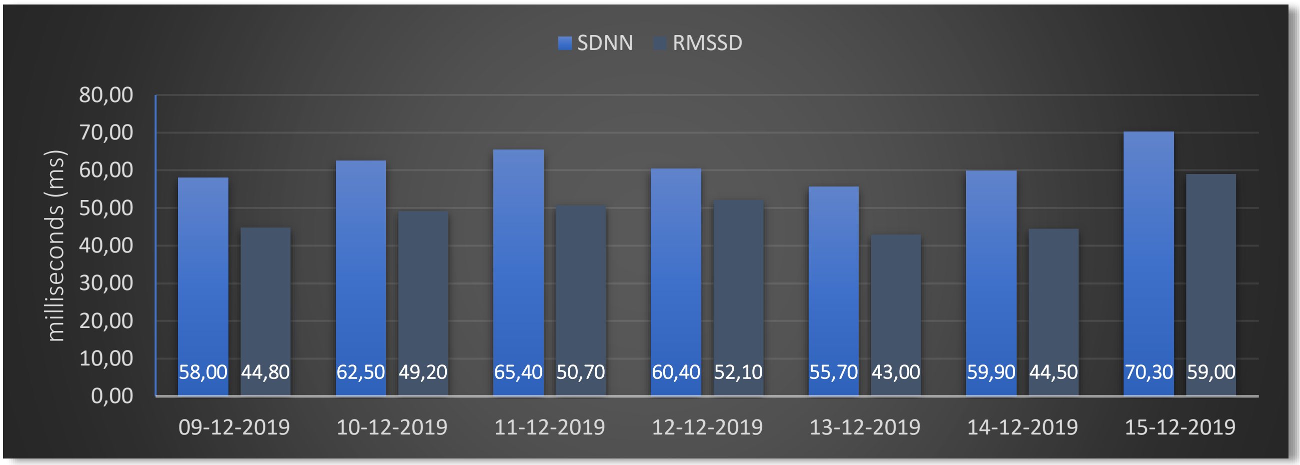

Figure 13 – Visual representation of the computed SDNN & RMSSD values.

SDNN and RMSSD values for the 15th are markedly higher than any other day throughout the week, which indicates the lowest levels of OS experienced, and values for the 14th show that at least one other day, the 13th, measured higher levels of SDNN and RMSSD, which indicates higher levels of OS. However, according to the participants M-SOS reports, the 14th was reported as being less stressful than the 15th, with a total perceived stress level of 17,5% on the 14th and 20% on the 15th. Even though these perceived stress levels are relatively close, the accompanying HRV metrics indicate that there should be a visible difference in the perceived stress.

It is important here to remember that SDNN represents HRV; and that sympathetic activity lowers HRV but does not necessarily correlate with increased OS. Similarly, RMSSD represents parasympathetic activity, which means that reductions do not necessarily indicate increased OS, e.g., physical movement also lowers parasympathetic activity. To gain further insight into the discrepancy between the low HRV values on the 14th and the low self-reported stress, we examine the frequency-domain values.

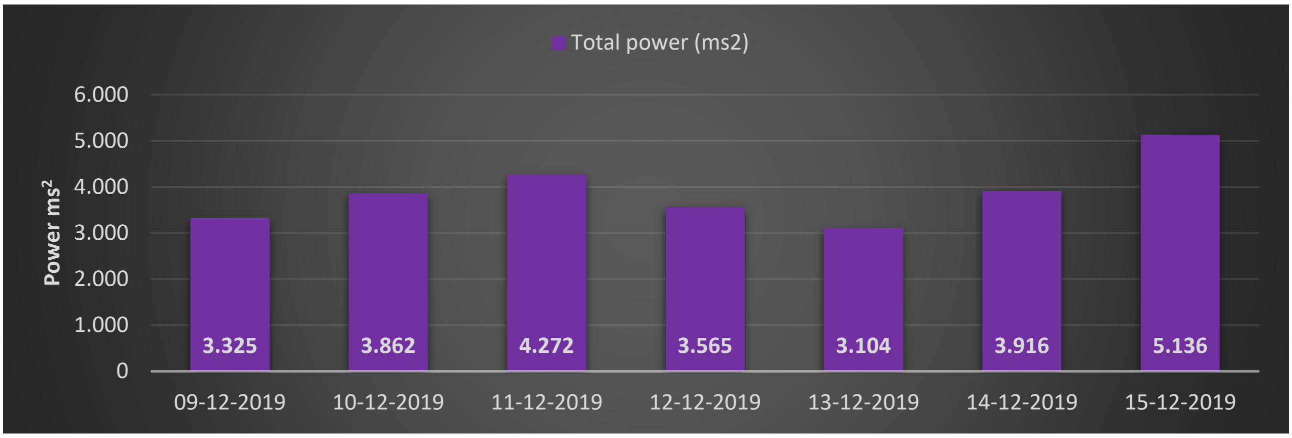

Figure 14 – Visual representation of the total power ms² generated throughout week 50.

Figure 14 shows the total power ms² generated each day throughout the week and as previously stated, a reduction in the total power ms² generated can be an indication of an increased level of OS (Hjortskov et al., 2004).

The 11th, 14th and 15th were all days where the participant was not at work and the total power generated on all three days is higher, than the days where the participant went to work—suggesting that rest and relaxation is associated with higher total power ms². The total power ms² generated on the 14th however, is markedly lower than the other rest days, the 11th and 15th. The explanation for this could be linked to the activities the participant conducted on the 14th. Examining how the power is distributed between the different frequencies could therefore provide us with a better understanding, by assessing the sympathovagal balance, which indicates the balance between the sympathetic- and parasympathetic branches of the ANS.

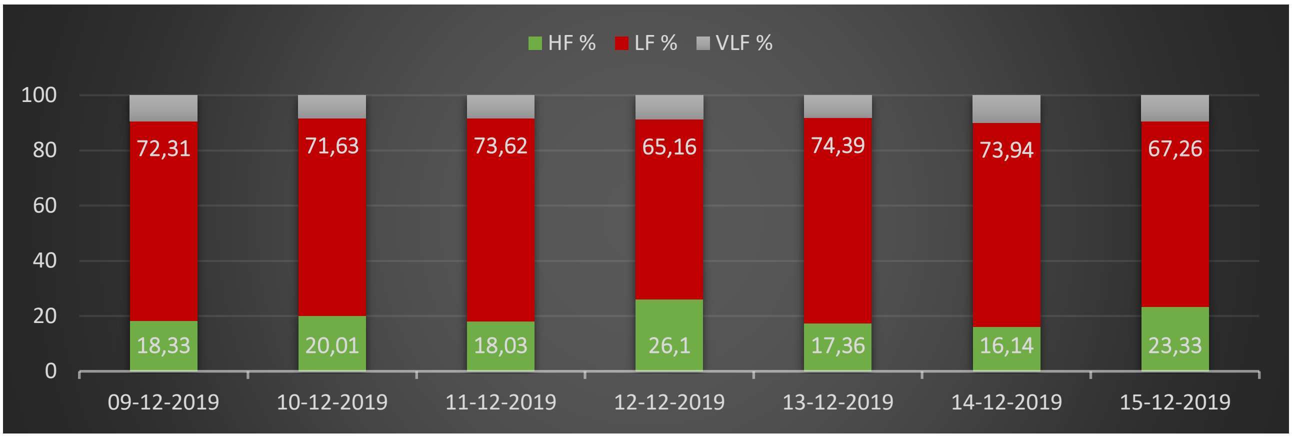

Figure 15 - Power generated, in percentages, in each frequency band.

Figure 15 shows the percentage of power generated in the HF, LF and VLF frequency. If we examine the 14th, only 16,14% of the total power generated was in the HF band, which indicates a sympathovagal balance that tips heavily towards sympathetic dominance. This results in the pNN50 and LF/HF ratio assessing the day as one where the participant experienced high levels of OS, even though the total power generated is relatively high, compared to the rest of the week.

Therefore, even though the 14th shows higher values of sympathetic- and lesser values of parasympathetic activity compared to the 12th, the overall total power is also larger, which is an indication of a less OS. As previously concluded, sympathetic activity is not necessarily a negative thing and is often accompanied by movement and activity—which could explain the increased sympathetic activity on the 14th. There is however, no information to shed light on the reduced total power generated on the 14th, compared to the 11th and 15th, which clearly shows that measuring HRV metrics can provide insights into the outflow of the ANS, it does not however, provide an explanation or a clear indication of the reasons behind the HRV measurements.

6.2.3 18th, 19th and 20th of December

According to the M-SOS reports, these three days are the most stressful throughout the entire experiment. The 18th has a total perceived stress level of 72,5%, split between 32,5% PV and 40% EL; the 19th has a total perceived stress level of 77,5%, spilt between 35% PV and 42,5% EL; and the 20th has a total perceived stress level of 77,5%, spilt between 50% PV and 27,5% EL.

Table 10 - HRV metrics compared to baseline HRV values.

HRV metrics	18/12 - 2019	19/12 - 2019	20/12 - 2019	Baseline values
SDNN (ms)	55,70	63,30	61,00	64,30
pNN50 (%)	15,48	20,94	13,01	38,00
RMSSD (ms)	40,90	49,90	44,50	67,90
LF (ms^2)	2333	2884	2973	2355
HF (ms^2)	505	885	685	1536
LF (%)	74,92	70,58	75,66	57,46
HF (%)	16,21	21,66	17,42	37,47
LF/HF	4.621	3.258	4.344	1.533
Total power (ms^2)	3.113	4.085	3.929	4.098

Table 10 shows the computed HRV values for all three days, compared to baseline values. Interestingly, the 18^{th}, with the lowest perceived stress level, registers according to the HRV analysis, as the day with the lowest HRV, between the three days. The time-domain metric, SDNN is the second lowest recorded on the 18^{th}, during the entire three weeks, while the 19^{th} and 20^{th} are much closer to the baseline values. pNN50 is as previously explained difficult to conclude anything from, but RMSSD also reports significantly reduced parasympathetic activity on the 18^{th}, the third lowest recorded. The frequency-domain metrics also paint a similar picture, with a low total power ms^2 generated on the 18^{th}, the third lowest recorded—with LF levels equal to baseline values, but HF power markedly reduced.

One reason for this discrepancy, could be some kind of emotional spillover, meaning that the events that transpired on the 18^{th}, spilled over to the next days, increasing the participants perceived feelings of stress, leaving him more vulnerable or fragile—which falls right in line with some of the mainstream criticisms of self-reported measures of stress (Abbott, 1990).

The 18^{th} indicates significantly higher levels of OS—more than what is experienced on the 19^{th} and 20^{th}, which is contrary to the M-SOS reports. Figure 16 shows the M-DSI report filled on the 18^{th} and might provide further insight into the discrepancy between the HRV metrics and the self-reported stress levels.

18/12 - 2019	Time: 09:45 – 10:00	Stress: 4/5
''Departmental meeting where we discussed the firing of […] and how we are supposed to use […] from HR as a confidant (tillidsperson), I then asked how she could be both a part of hiring and firing, and then also be our confidant – which she didn't see any problem with, while stating that she wasn't an official confidant''.		

Figure 16 - M-DSI report no. 5

The description provided in M-DSI report no. 5, is part of a longer series of events that have taken place at the participants workplace. A former coworker he worked closely with, was suddenly and without explanation, fired from his team some time ago. This left his department in an uneasy state, because no proper explanation was given, other than he was to expensive compared to the work he did—an explanation that did not sit well with his fellow coworkers. The employee mentioned from the HR department played a central role, because the talk around the office was, that she had passed on information to supervisors and immediate leaders—information that was supposed to be confidential, leading to the dilemma explained in the M-DSI report. The meeting only lasted 15 min., it should therefore be relatively straightforward to examine any increase in OS experienced during the meeting, given the short time span.

Table 11 - HRV metrics computed from daily- and situational excerpt.

HRV metrics	Daily values	M-DSI no. 5
SDNN (ms)	55,70	56,60
pNN50 (%)	15,48	11,04
RMSSD (ms)	40,90	40,80
LF (ms^2)	2333	2041
HF (ms^2)	505	700
LF (%)	74,92	69,35
HF (%)	16,21	23,78
LF/HF	4.621	2.916
Total power (ms^2)	3.114	2.943

Similar to previous comparisons, the HRV metrics provide inconclusive results, as seen in Table 11. SDNN and RMSSD values are almost identical; pNN50 is slightly reduced; LF- and total power is slightly reduced; and HF power is slightly increased, which results in a significant reduction in LF/HF ratio. Explaining why the perceived incidents of stress do not correlate with the collected HRV metrics is not possible. The most probable explanation is most likely that the participant failed to objectively assess his level of stress, or perhaps inaccurately recorded the time in which the incident took place.

This is not the case however, regarding M-DSI report no. 6, filled on the 19th.

19/12 - 2019	Time: 09:00 – 10:30	Stress: 3/5
''Meeting with a contractor, where I'm responsible for the technical inspection of all plumbing installations. The meeting was about a problem with fluctuating water temperatures in the new bathrooms (435 in total). There is an area in the building where people complain and report that the water turns, either ice cold or very hot, while showering. At the meeting was also an expert in regulation, sent from the company whose equipment was installed in the bathrooms along with one from the property office – so there were many eyes on me given that is my company who is responsible for evaluating the installation and in the end, we are the ones responsible if all else is in order. It was a good meeting and I think the dialog between us was very good, but on top of all the other assignments I have, I found it hard to focus.''		

Figure 17 - M-DSI report no. 6.

At first glance, the meeting seems to have gone well, and according to the reported perceived stress level, 3/5, the event was not considerably stressful. The information from the HRV analysis, however, does not corroborate this conclusion. Contrarily, the HRV analysis comparing the HRV metrics collected during the meeting, with HRV metrics collected throughout the day, as seen in Table 12, shows a significant and consistent reduction of HRV.

Table 12 - HRV metrics computed from daily- and situational excerpt.

HRV metrics	Daily values	M-DSI no. 6
SDNN (ms)	63,30	57,60
pNN50 (%)	20,94	17,66
RMSSD (ms)	49,90	43,00
LF (ms^2)	2884	2449
HF (ms^2)	885	550
LF (%)	70,58	75,56
HF (%)	21,66	16,98
LF/HF	3.258	4.450
Total power (ms^2)	4.087	3.242

All time-domain metrics are reduced along with reductions in both HF, LF and total power—followed by an increase in LF/HF ratio, which according to the findings of both Hjortskov et al., (2004) and Castaldo et al., (2015) is indicative of an increase in OS. This again, does not correlate with the information provided by the M-SOS reports.

M-DSI report no. 7 filled on the 20th, show clear signs of emotional distress and the participant describes pain that is associated with chronic- or prolonged OS (APA, 2019).

20/12 - 2019	Time: 12:30 – 13:00	Stress: 4/5
''I have for a long time been walking around with the feeling that I have too much stuff on my shoulders, which today resulted in a conversation with my project leader and the head of my department. The conversation was about removing one or more of the assignments given to me, and both my project leader and the head of department agreed that it wasn't a good situation and that some of my assignments would be allocated to someone else. It was accompanied with good deal of sadness, because the assignment I gave away was just my cup of tea, but after having headaches every other day for about 4-6 weeks, it's about I give away some if this work and then I hope it'll helps my health''.		

Figure 18 - M-DSI report no. 7.

This could explain the dramatic rise in PV from 32,5% on the 18th, to 50% on the 20th. The information in the report could also explain why the perceived stress increases despite EL dropping from 40% to 27,5%.

Table 13 - HRV metrics computed from daily- and situational excerpt.

HRV metrics	Daily values	M-DSI no. 6
SDNN (ms)	61,00	56,8
pNN50 (%)	13,01	8,84
RMSSD (ms)	44,5	36,70
LF (ms^2)	2973	2529
HF (ms^2)	685	467
LF (%)	75,66	78,46
HF (%)	17,42	14,50
LF/HF	4.344	5.411
Total power (ms^2)	3.930	3223

As seen in Table 13, all time-domain metrics are markedly reduced, as well as all frequency-domain metrics. In this case, the HRV data corroborates the M-DSI report, showing consistent reduction in HRV, which correlates with increased OS.

Ultimately, any explanation provided as to why the HRV data does, or does not, corroborate the self-reported data, is conjecture—that is however, a general criticism pointed towards the examination of most psychological phenomena; thoughts cannot yet be controlled for, measured or examined; conclusions can therefore not be based on a purely objective basis.

6.2.4 21st of December

The HRV data recorded on the 21st clearly showcase some of the difficulties related to analyzing and concluding upon HRV values—especially regarding baseline values. Ideally, baseline values would represent the participant in a relaxed and comfortable situation, resulting in a good HRV. Therefore, when OS is experienced, the relative decrease compared to the baseline, can provide an estimate as to the degree to which the participant experiences OS. However, the HRV values computed for the 21st, as seen in Table 14, display values that are significantly higher than those measured during the rest sessions.

Table 14 - HRV values computed for the 21st, compared to baseline values.

HRV metrics	21/12 - 2019	Baseline values
SDNN (ms)	94,30	64,30
pNN50 (%)	33,59	38,00
RMSSD (ms)	102,30	67,90
LF (ms^2)	6580	2355
HF (ms^2)	2807	1536
LF (%)	64,76	57,46
HF (%)	27,63	37,47
LF/HF	2.344	1.533
Total power (ms^2)	10.156	4.098

Without having additional situational information, no apparent conclusions as to why the HRV values measured that day, are so high compared to all other collected data. The only information the participant provided about this day, is that he was home relaxing all day. This unfortunately means that conjecture is the only tool available to possibly shed some light on these high values. One explanation could be the fact that the 21st, perhaps was the only day recorded where the participant had an entire day at home with rest and recuperation. If we hypothesize that the numbers generated on the 21st represent a more accurate picture of the normal functioning of the participants ANS, then the established baseline values severely skew the results of the HRV analyses; which leads to a consistent underestimation of the OS the participant experiences throughout the experiment.

6.2.5 29th of December

The 29th of December is a puzzling day to examine, due to the high discrepancy between the HRV measurements and the participants subjective assessments of the day. Firstly, if we examine the M-SOS reports, the 29th is, along with the 24th, 25th and 28th the only days where 0% PV is reported and only 2,5% EL, which means that according to the participants own assessment—these days are practically stress free. However, when examining the collected HRV data, a different story reveals itself.

If we examine the time-domain metrics, SDNN on the 29th is 54,3ms, the lowest recorded during the entire experiment; pNN50 is the second lowest measured at 12,44%; and RMSSD the second lowest at 40,4ms—which collectively, indicates that the participant experienced a substantial amount of OS on the particular day. This is corroborated by the findings of both Hjortskov et al., (2014) and Castaldo et al., (2015). The frequency-domain metrics tell a similar story, with a total power of 3.091ms^2; the lowest recorded throughout the experiment.

To shed further light on the discrepancy, the participant was asked about the day and to explain in more detail, the activities he had conducted during the reading session, he replied with the following:

''I went hunting with my girlfriend, for the first time. We went out for about 2 hours and saw several animals in that 2-hour period, but only one animal that was 'bad' (eligible for shooting), we then tried to circle around it when it was far away, but that failed. Afterwards, we went home to my parents where I helped my little sister with installing some Phillips Hue lightbulbs she got for Christmas, but it was really tricky, and I couldn't get it to work properly''.

If we examine the events that transpired on the 29th, first the hunting trip where the animal got away, and afterwards the failed attempt to install the Phillips Hue lightbulbs, a possible reason for the discrepancy comes to light. It could be that the participant undermined the negative emotions experienced, because he wanted the first hunting trip with his girlfriend to be a positive experience, leaving them with a good memory of the day. If we assume that this analysis of the situation holds at least some truth—then it fits together with one of the main criticisms of self-reported data, which is the difficulty of tying emotions to specific events, both in relation to time and intensity (Abbott, 1990). People often do not know *how* they feel—let alone *why* they feel as they do. Furthermore, if the emotions felt are not wanted, or perhaps even inappropriate, they may be suppressed or denied. It is therefore a reasonable assumption and perhaps conclusion, that most people are unable to objectively measure and report their own stress levels throughout a day.

6.2.6 Summary

This thesis set out to measure OS in a participant over the course of three weeks. During this experiment, several realizations occurred that problematize the overarching goal, which will be touched upon in the following section.

Measuring OS is not an easy task and as showcased in this thesis, there are very apparent discrepancies, both between self-reported measures of stress and OS, assessed by way of HRV analysis. But also in between the HRV measurements themselves. The relationship between the different HRV metrics is complex, non-linear and often non-reciprocal, it is therefore not easy to compute a simple and straightforward index to assess OS. Understanding HRV metrics to a degree that would allow for the computation of a weighting scale to accurately measure OS—if even possible, would require extensive technical, mathematical, neurological, psychological and physiological knowledge.

As previously mentioned, 24-hours HRV excerpts are considered the 'gold-standard' in medical research, because it provides a complete picture of how the individuals ANS responded to all stimuli throughout an entire day, including how active the individuals parasympathetic system is during sleep, which is of major importance in properly assessing the functioning of an individual (Shaffer & Ginsberg, 2017). Integrating that data into our examination of OS, will therefore only improve our ability to accurately assess and measure it. However, as in the case of this thesis, no technology currently exists that can accurately measure ECG over the course of three weeks continually, while the individual goes about his/her day undisturbed.

This is not to say that trying to measure OS is a hopeless endeavor, but perhaps the perspective should be shifted away from stress as a concept—with is polluted and antithetical understandings and definitions, towards more scientifically comprehensible phenomena, such as mental workload or mental bandwidth; terms that do not have such deep roots in our culture, as previously suggested by Hinkle (1974). This goes back to the quote I began with, ''*Everyone knows what stress is, but nobody really knows*''—because almost all people have their own conception of what stress is, how it feels, and what is does to them, every attempt to objectively measure or assess it, ultimately falls short because it cannot fully encapsulate what we have all come to know as stress.

Ultimately, HRV metrics can provide numbers, guidelines and estimators that can be used to assess changes in the functioning of an individual's ANS, but that is not the same as objectively stating the degree to which that individual is experiencing OS. There is also a substantial difference between testing how an individual's ANS responds to stressful stimuli, e.g., a Stroop Word Test, in a controlled setting, compared to measuring how dozens of unknown stimuli, that cannot be controlled for, affects an individual—both physiologically and psychologically. Therefore, when variables cannot be isolated and tested for individually, reductions in HRV metrics simply have too large a range of probable causes, to objectively state that OS is the reason.

6.3 Leadership and OS

Throughout history, leadership has been defined and understood in a myriad of different ways, beginning with theories such as the Great Man Theory (Carlyle, 2013/1841)—where history is viewed as a result of the actions of great men, all the way up till today with theories such as Servant leadership (Ingram, 2016)—where a leader is seen as servant first; where serving others and placing the good of others and the organization comes become the leader's self-interest.

Despite the obvious differences in perspective between these two leadership styles, they both have the same fundamental goal in common—getting things done, effectively. Therefore, whether you recognize and subscribe to relational, social or contextual approaches to leadership, or approaches that emphasize the characteristics, skills and actions of individual leaders—or even both; ultimately, it is all about getting things done effectively. Implicit in this line of thinking, is the underlying assumption that the cognitive capabilities of the individuals situated in an organization, to competently act out their prescribed roles, is at a constant.

What this means more precisely, is that leadership theories in general do not take into consideration, any variables that might inhibit or decrease an individual's ability to perform at their peak level of performance; such as OS. High levels of OS has been linked to lower levels of complex cognitive functioning, increases in the use of heuristics and aggressive behavior, and a decreased likelihood of considering alternative solutions to problems; which essentially means that OS effectively inhibits effective problem-solving and decision-making—and by extension, the leadership process. This is supported by research conducted in the fields of leadership and stress, which continually shown that the two are inextricably linked with one another (Harms et al., 2016).

This e.g., has severe consequences for many of the underlying assumptions linked to leadership theories in general, e.g., the underlying assumption linked to contingency-, situational- and contextual theories of leadership; which is that context determines leadership response (Grint, 2005). It is implicit in this assumption that the leader can objectively, or at least to a substantial degree, objectively assess the situation, and based on that assessment, determine the right course of action. It is however, not possible for human beings to be completely objective in any matter, let alone obtain full information about a given situation—it therefore becomes a subjective assessment, shaped and molded by the leader's understanding *of* the situation, from which the ''right'' thing to do is determined.

To further exemplify this issue, we examine how Grint (2005) links the different typology of problems, to different styles of leadership. Critical problems call for coercive leadership; tame problems call for calculative leadership; and wicked problems call for normative leadership. This realization is nothing revolutionary—different problems call for different solutions. However, given that objectively assessing the problem relies on the leader's ability to *be* objective and understand the situation in its entirety, the objective link between problem and solution transforms into a persuasive rendition of the context, followed by a persuasive display of the appropriate authority style.

This shows that the appropriate actions taken by a leader, are determined by how the situation is framed *by* the leader; making it more a matter of perspective or personal preference, than objective assessment. This all boils down to the fact that leadership is synonymous with people; it either emits from them, or between them and as already established, OS severely affects peoples cognitive- and reasoning abilities, it also therefore affects their ability to effectively participate *in* leadership, regardless of type and style.

This makes LMX theory a suitable lens through which we can examine the effects OS has on leadership, because it analyzes both leaders, followers and the relationships they have with one another (Abbott, 1990).

Despite the usefulness of utilizing LMX theory to examine and assess the effects OS has on leaders, followers and relationships—recent meta-analyses of LMX ignored the subject of stress (Gerstner & Day, 1997; Dulebohn et al., 2012; Martin et al., 2015).

For the purpose of this thesis, three elements regarding leadership and OS will be discussed along with their implications. This first is how OS affects leaders, and second, how OS affects followers—which will be discussed simultaneously, given that both leaders and followers are individuals who suffer similarly to the effects of OS. The third element will examine how OS affects the relationships between leaders and followers.

6.3.1 Leaders, followers and OS

Generally, when leadership theories focus on leaders, it is usually parameters such as a leader's traits, behaviors, personality variables, attitudes, perceptions, and their power and influence that are examined. Alternately, theories that focus on followers, examine how those parameters affect the followers who are exposed to it (Abbott, 1990). However, it does not take long to realize that OS can negatively affect *every* single parameter mentioned—which puts OS as one of the foundational pillars of any leadership theory, and in any context where leadership is enacted.

High levels of OS can undeniably cause leaders to make bad decisions, followers too. This is because, implicit in all decision-making, problem-solving and leadership processes; is that to effectively act, the individual must be able to dedicate significant cognitive resources, while maintaining awareness of the factors and circumstances that may influence or alter these processes. It is here OS becomes an important factor, because OS, as previously stated, has been found to actively impede these processes (Harms et al., 2016).

Research conducted specifically on leader behavior in relation to OS, show that as OS increases, leaders become more self-focused and less likely to assume a team-perspective. Furthermore, studies have found that simply the act of engaging in cognitively demanding tasks, can lead to higher likelihoods of leaders engaging in abusive behaviors (Harms et al., 2016).

Generally, when companies perform poorly, an atmosphere of worry, tension and uneasiness spreads that affect the people situated in the organization—which can result in increased levels of OS, affecting both leaders and followers alike. As argued previously, increased levels of OS in leaders, leads to an increase in abusive tendencies. This relation can partly explain why research has found a positive correlation between poor company performance, and ''strongman'' behaviors from leaders. Studies conducted in military settings, with an innate high-stress environment, also showed an increased tendency for ''strongman'' leadership behavior, which corroborates the previous statement (Harms et al., 2016).

It is important to note that leaders not only have the potential to be the main cause of increased OS for their subordinates, but also have the potential to be a substantial buffer against work stressors, which is a fact broadly agreed upon in the leadership literature (Harms et al., 2016). One of the reasons why an immediate leader is important in regard to work-related OS, is that for many employees, their immediate leader is considered the ''face'' of the organization, and often works as a lens through which their work experiences are viewed. This means that their interpretation of the tasks they perform; the relationships they form with their coworkers; and the fairness with which they are treated, become inherently tied to the way their immediate leader treats them (Harms et al., 2016).

One way this can manifest itself is if a subordinate faces ongoing abuse from their immediate leader. These confrontations will likely lead to the subordinate allocating a substantial amount of their cognitive resources to processing these confrontations, effectively reducing their efficiency, not only during the confrontations, or right after—but continuously, because they would have to monitor their relationship with that leader on a continual basis, only further exaggerated by the asymmetrical power gap between the two (Harms et al., 2016). Ultimately, the subordinate is likely to perceive the abuse as a threat, both to the accessibility of material resources but also their own person and future in the company. When people perceive something, or someone, as a threat, sympathetic activity spikes and the body readies itself for action; the ''fight or flight'' response activates. In the situation as described above, neither is possible, the person would therefore be subject to prolonged OS, which eventually leads to the negative effects touched upon earlier, if nothing is done to escape or alter the situation.

Therefore, when a leader's cognitive resources are significantly reduced due to OS, the probability of that leader engaging in positive leadership behaviors is markedly reduced—increasing the probability of that leader acting in destructive and abusive ways towards their subordinates. This can potentially lead to the situation described above, where followers gradually experience higher and higher levels of OS, leading to lower levels of efficiency, decreased decision-making and problem-solving skills and increased employee turnover rates.

This is especially worrisome in today's climate, where most managers and leaders feel more competent with the technical administration part of their job, than the leadership part (Graen & Schiemann, 2013). Proper engagement of members and employees is often sacrificed for ease of command. In situations where there are sufficiently talented employees, operating at peak performance is not a necessity—this however, is contra productive and effectively inhibits possible performance improvements, reductions in employee turnover rates and increases in internal and external customer satisfaction (Graen & Schiemann, 2013).

We have as a society and species attained an extraordinary level of insight into the human condition—we should therefore integrate this knowledge into how we run businesses and utilize our human resources. People deserve to be managed by professionals, certified as competent and accepted leaders of people. This would maximize the potential of our future leaders, managers and employees. Peoples overall wellbeing, including to what extent they experience OS, must be considered worthy of both time and resources. Leaders that suffer from prolonged- or chronic OS, make for less effective leaders; followers that suffer from prolonged- or chronic OS, make for less effective employees.

6.3.2 Relationships and OS

When examining relationships, focus is put on the interactive relationship between leader and follower. Investigation in this domain focus on identifying characteristics of interactive relationships, such as trust, respect and mutual obligation and evaluating the reciprocal influence between leaders and followers e.g., examining how these interactive relationships are correlated with outcome variables of interest, and researching how effective leadership relationships can be developed, maintained and combined into collectivities of leadership structures (Graen & Uhl-Bien, 1995).

If material exchange is the basis for the relationship between the leader and follower, then the process is not really leadership, but closer to ''managership'' or ''supervision''. It is in these situations where the employment contract is the basis for behaviors, by both the leader and follower. The contract is fulfilled at the most basic level, by testing various contingencies of behavior and reciprocal compensation. In a case as such, no leadership at all would be necessary, and only minimal amounts of managership (Graen & Uhl-Bien, 1995).

When a leader upholds a close leader-follower bond, it reduces the probability of followers experiencing OS and burnout—and a way of effectively assessing these bonds is by utilizing LMX theory, which assess the quality of the relationship between leaders and followers, and can be used as an appropriate operationalization of the bond felt by a subordinate for their leader, and the degree to which they believe they can count on them for support (Harms et al., 2016).

By providing the followers with emotional- and material support, which is a characteristic of a close leader-follower bond, the leader can instill a positive outlook and vision in the follower, and also act as reassurance in times of turmoil and hardship, which then allows the follower to more effectively deploy their cognitive resources. This statement is backed by meta-analytic evidence showing that supervisor support can hamper both feelings of stress and burnout (Harms et al., 2016). These findings are further corroborated by findings stemming from attachment theory, which postulates that leaders often serve as attachment figures for their subordinates, and the closer the bond between them, the better the leader can serve to reduce anxiety and stress (Harms et al., 2016).

It is therefore a reasonable to assumption that closer bonds between leaders and their subordinates, leads to decreased levels of OS in followers, effectively allowing the followers to better utilize and distribute their cognitive resources. The possibility for leaders to act as both a stressor and buffer, is therefore a tremendously important realization, that must be taken serious by any leadership theory—and any individual situated in any leadership position.

To properly understand the importance of close bonds and healthy relationships between leaders and subordinates, one must understand that all human beings are social creatures that just want to belong. Studies conducted in the field of psychology has concluded that human beings are fundamentally and pervasively motivated by a need to belong, that is, by a strong desire to form and maintain enduring interpersonal attachments. People seek frequent, affectively positive interactions within the context of long-term, caring relationships (Baumeister & Leary, 1995).

This understanding of humans and their underlying fundamental needs and motivations, fits well together with the understanding of leadership, as proposed by Graen & Schiemann (2013), which is that the reality of leadership in organizations is centered around a humble feeling of vulnerability and aloneness, in the face of the task of organizing and running a business unit or an organization—it is not about heroic leaders, nor about transforming people, trough fancy words and charisma, into ''believing followers''. An important aspect of success within the context of an organization, lies in the successful establishment of functional and reciprocal relationships as the following quote illustrates:

''*we found that our star performers were not more intelligent, did not have more beneficial personalities, and did not work harder than their slower peers, but their careers were characterized by their ability to forge unique strategic alliances*'' (Graen & Schiemann, 2013, p. 455).

The quote clearly illustrates the importance of forging bonds between people within an organization. People, depending on their upbringing, circumstances and environment respond and interact differently. It is therefore important that our understanding of leadership, evolves along with society and the new generations that are entering the work force. Recent data has shown that the millennials entering the workforce are not responding well to the leadership styles that dominate the business world today (Graen & Schiemann, 2013). Therefore, to avoid missing out on the innovation, creativity and productivity the new generations are bringing with them, we must align the managerial and leadership climate to the new people on the scene. Misaligned management practices must be realigned to fit society as it changes; and society today calls for leaders who are people experts.

7 Conclusion

The goal of this thesis was to work towards establishing an objective measure of stress, herein defined as Objective Stress (OS), by analyzing HRV metrics collected from a participant during a three-week period. Because the human heart is constantly subject to the sympathetic- and parasympathetic activity generated by the ANS, HRV metrics can provide explanatory proxies to assess the function of an individual's nervous system, as well as psychological states and behavioral responses.

The results generated by this thesis have shown that measuring OS by analyzing HRV metrics, is a difficult task that does not provide straightforward answers—despite HRV metrics having been linked to OS in previous studies. The reason behind this might be the difference in experimental settings. Most studies conducted on OS are performed in a controlled setting, where variables and stimuli can be controlled for. The change in HRV metrics observed, can therefore be linked to the specific stimulus presented to the participant. In a real-life setting however, no variables or stimuli can be controlled for, the changes in HRV metrics can therefore represent several possible sources; one being OS.

In addition to measuring OS, this thesis examined the relationship between OS and leadership; more precisely, how OS affects the leadership process. Findings clearly show that leadership and OS are linked. OS affects the leadership process, because it affects our ability to dedicate significant cognitive resources to decision-making and problem-solving skills, while maintaining awareness of the factors and circumstances that may influence or alter these processes. This is true whether you believe leadership emits from a single individual or between them.

8 Further Research

The further research section will primarily discuss two topics. Firstly, the findings and difficulties this thesis stumbled upon in relation to measuring and assessing OS in real-life situations. Secondly, how knowledge of OS and its effects on people can help us better understand and improve the leadership process—regardless of which leadership school you subscribe to.

8.1 Measuring OS in real-life situations

Two clear problems, related to the measuring and assessment of OS in real-life settings by analyzing HRV metrics, was discovered during this experiment—first, obtaining sufficient amounts of HRV data, and second, the lack of supporting contextual information, besides the participants own thoughts and observations. Developing technologies that would allow for the continual collection of ECG data while allowing real-time analysis and comparison of data, would provide researchers with a more complete image of how the participants ANS responds to the multitude of stimuli it is exposed to, throughout the day. Excerpts that include the entire circadian rhythm would allow its influences to be properly controlled for and integrated, resulting in a more complete analysis of the functioning of the ANS—more specifically the functioning of both the sympathetic- and parasympathetic branches. A continuous stream of data would also help in the establishment of baseline values, because it would provide us with a much larger pool of data from which the baseline values could be computed.

The degree to which an individual can objective assess and measure their own feelings has already been extensively criticized. Furthermore, as the findings of this thesis established, objectively stating that reductions in certain HRV metrics e.g., HF and RMSSD together with increases in metrics such LF and LF/HF ratio, is caused by OS is not possible. Including additional biometrics parameters such as eye-tracking, Galvanic Skin Response (GSR) and facial expression analysis could therefore provide researchers with more data, and perhaps make it easier to assess whether the participant is experiencing OS or some other physiological or psychological phenomenon. The reality of the situation, however, is that measuring multiple biometrics in the field would be a troublesome affair and wearing that much technology would affect the participant in such a way, that the results would be considered useless in terms of assessing real-life situations.

More generally, there is a lack of long-term HRV studies conducted in real life settings, in the stress literature. More studies conducted on long-term HRV excerpts could therefore help better our understanding of how to properly analyze and interpret continual long-term HRV data, both in relation to assessing OS, but also in relation to building objective measures that are comparable between participants. One highly probable cause behind this deficit, is the lack of technology to conduct these kinds of studies in real-life settings; developing technologies that facilitate easy 24-hour data collection, live access to HRV data during collection and better storage and retrieval systems would therefore greatly improve, not only the number of long-term HRV studies, but also the quality, range and scope of HRV studies in general.

8.2 Integrating OS into leadership

To understand leadership, is to understand people—what drives them, motivates them, makes them feel afraid, nervous or courageous, and what causes them to set aside their self-interests, for the betterment of the group or organization. Knowing how to properly configure individuals to maximize their organizational potential, requires knowledge of the variables that affect them. OS severely affects the degree to which both leaders and followers can effectively utilize their cognitive resources to solve problems, make decisions or properly assess situations. It is therefore imperative that we integrate measures to actively combat the negative effects of prolonged- or chronic OS. There are a multitude of different ways this can be done, either by including the knowledge into existing- and future leadership theories, or by developing technological tools that can accurately measure OS, allowing organizations to preemptively combat its effects.

One future scenario could be to establish an organization-wide measuring system that analyze the entire organizations biometrics via smart and subtle HRMs e.g., company provided watches. All this data would feed into an analytic software set to watch out for prolonged high levels of OS. Should a possible case pop-up, the information would be sent to employee X's immediate leader, and the two could start a conversation to further investigate why employee X is experiencing prolonged OS. An organization-wide monitoring system like the one described here, would probably scare most people today. The feeling of being under constant surveillance, having your employer known things about yourself and your state of being—information you yourself are not even aware or knowledgeable of, is one of many probable concerns related to similar monitoring systems.

Therefore, if a system as described above is developed, certain privacy, ethical and security measures should be implemented to eliminate or minimize personal access into the system and the degree to which the information could be misused. A system as described above, would function as a tool that lets you know *something* is wrong with employee X, not *what* is wrong. The reality of this scenario is highly debatable; however, it is only meant illustrate how measuring OS could be implemented into an organization, and how it would benefit leadership.

Similar to the notion of The Economic Man, many leadership theories carry underlying assumptions of human beings as rational agents, that assess situations and through objective analysis—determines the course of action that maximizes their utility. However, the notion of human beings as rational actors is an illusion that has been extensively debunked by researchers and psychologists e.g., Kahneman (2011). Human beings are emotional creatures driven by impulses; influenced by biases and irrational thoughts. It is therefore time that we integrate the knowledge we have accumulated on the human condition, into the realm of leadership. More specifically, how OS if not handled properly, can lead to less effective leader, less effective employees and a multitude of devastating diseases.

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Appendix I – HR

Heartrate is defined as the number of contractions of the heart, commonly known as heartbeats, per minute (bpm). A heartbeat is caused by impulses arising from two distinct groups of cells within the heart muscle. The Sino-Atrial (SA) node, located in the wall of the right atrium, initiates the beat, and the Atrioventricular (AV) node, positioned between the ventricles, continues to distribute the wave of impulses, a visual representation is presented below, see Figure 19.

As depicted in Figure 19, a heartbeat consists of three peaks and two valleys. An additional figure, Figure 20, will be presented below picturing the ventricles.

P Wave (Atrial Systole)

first the SA node fires causing the atria contraction, which forces blood into the ventricles, emptying the atria.

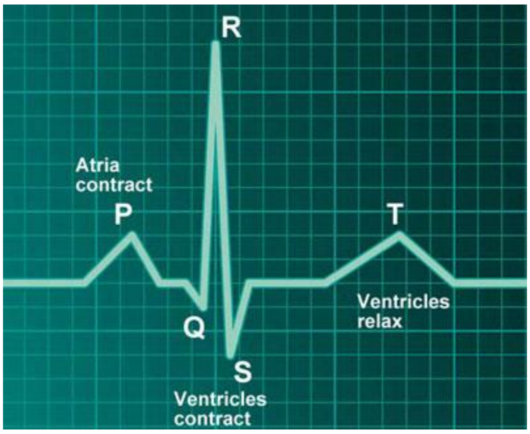

Figure 19 - Visual representation of an ECG wave.

QR Interval (End of Ventricular Diastole)

This leads to the QR interval, where the AV valves remain open as all remaining blood is squeezed into the ventricles. The electrical impulse from the SA node reaches the AV node which then spreads the signal throughout the walls of the ventricles. The R peak is the end of the ventricular diastole and the start of systole.

RS Interval (Ventricular Systole)

As the blood is now all within the ventricles causing pressure to be higher here than in the atria, the AV valves close. The ventricles start to contract although pressure is not yet high enough to open the Semilunar (SL) valves, located between each ventricle and the artery leaving the heart.

ST Segment (Ventricular Systole)

Pressure increases until it equals Aortic pressure, which opens the SL valves. The blood is ejected into the Aorta (and pulmonary artery) as the ventricles contract. At this time the atria are in diastole and filling with blood returning from the veins.

T Wave (Ventricular Diastole)

The ventricles relax, and ventricular pressure is once again less than the aortic pressure, so the SL valves closes again.

TP Interval (Ventricular Diastole)

Atria and ventricles are relaxed, blood is flowing into the atria from the veins. As the atrial pressure increases above that of the ventricle, the AV valves open, allowing blood to flow into the ventricle. This completes a full cycle, a single heartbeat.

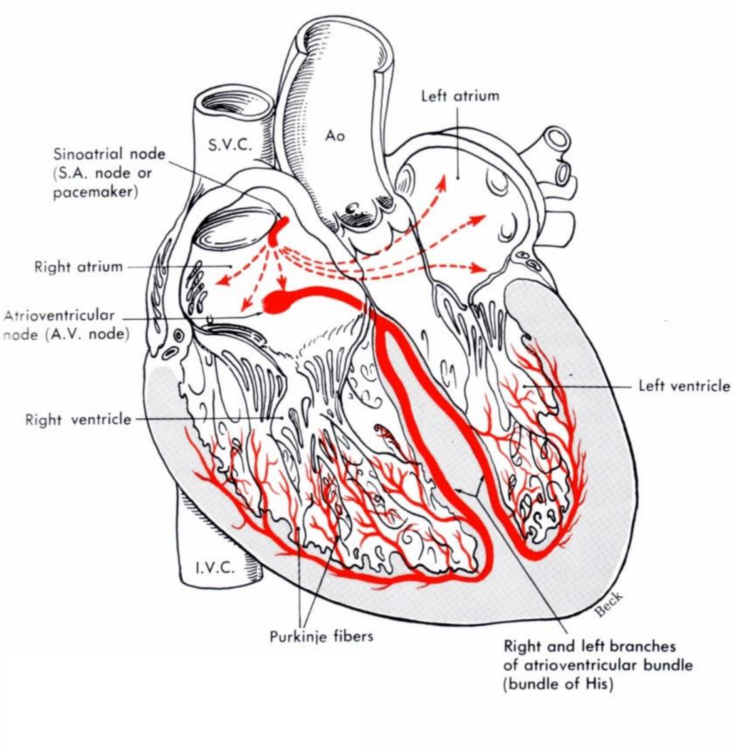

Figure 20 - visual representation of a heart, showing the SA- and AV nodes.

Appendix II – M-SOS Report

Figure 21 shows a blank SOS-S report, which was answered daily by the participant after each ended HRV reading session. The questions are written in Danish, as explained in the paper, for English, see Figure 22.

Dagligt Stress Skema					
	Nej **1**	En enkelt gang **2**	Et par gange **3**	Flere gange **4**	Hele dagen **5**
1. Har du i løbet af dagen følt dig utilstrækkelig?					
2. Har du i løbet af dagen følt dig overvældet af dit ansvar?					
3. Har du i løbet af dagen følt at oddsene var imod dig?					
4. Har du i løbet af dagen følt at der ikke har været nok tid til at nå det hele?					
5. Har du i løbet af dagen følt at intet er gået som det skulle?					
6. Har du i løbet af dagen følt dig skyndt på?					
7. Har du i løbet af dagen følt at du ikke har kunne flygte?					
8. Har du i løbet af dagen følt at der er kommet mere vægt på dine skuldre?					
9. Har du i løbet af dagen haft lyst til bare at give op?					
10. Har du i løbet af dagen følt at du har båret rundt på for meget?					

Figure 21 - Blank M-SOS report.

Daily Short Stress Overload Scale					
	Not at all **1**	Once **2**	A couple of times **3**	Several times **4**	A lot **5**
1. In the past day, have you felt inadequate?					
2. In the past day, have you felt swamped by your responsibilities?					
3. In the past day, have you felt that the odds were against you?					
4. In the past day, have you felt that there wasn't enough time to get to everything?					
5. In the past day, have you felt like nothing was going right?					
6. In the past day, have you felt like you wew rushed?					
7. In the past day, have you felt like there was no escape?					
8. In the past day, have you felt like things kept piling up?					
9. In the past day, have you felt like just giving up?					
10. In the past day, have you felt like you were carrying a heavy load?					

Figure 22 - English version of the M-SOS.

Appendix III – M-DSI Reports

M-DSI Report no. 1

09/12 - 2019	Time: 08:00 – 11:00	Stress: 4/5
*''I have been answering complicated mails from an architect that we're working with on a case called *****, since 8 o'clock. It is extremely hard, because I'm not able to provide them with a direct answer, if I did, it could mean substantial financial trouble for […]''.*		

HRV metrics	Daily values	M-DSI no. 1
SDNN (ms)	58,00	61,50
pNN50 (%)	16,70	25,81
RMSSD (ms)	44,80	50,80
LF (ms^2)	2405	2482
HF (ms^2)	610	796
LF (%)	72,31	67,93
HF (%)	18,33	21,79
LF/HF	3.944	3.117
Total power (ms^2)	3.325	3.654

Situation 1 - 09/12 - 2019	Time: 08:00 - 11:00	Stress : 4/5
''I have been answering complicated mails from an architect that we're working with on a case called *****, since 8 o'clock. It is extremely hard, because I'm not able to provide them with a direct answer, if I did, it could mean substantial financial trouble for *****''.		

M-DSI Report no. 2

09/12 - 2019	Time: 14:00 – 15:30	Stress: 5/5
''I was at a meeting where the purpose was that […] wanted a document created that explains with plans and text how we conduct drains from P-basements, which isn't a field I know a lot about, but it was an exciting meeting but also pretty stressful because I don't want additional work since I'm already completely booked up. The meeting		

resulted in me getting a less demanding role, where I have to gather information from old cases where P-basement have been constructed – but now the glass is even more filled than it was before.

HRV metrics	Daily values	M-DSI no. 2
SDNN (ms)	58,00	52,70
pNN50 (%)	16,70	9,57
RMSSD (ms)	44,80	34,60
LF (ms^2)	2.405	1802
HF (ms^2)	610	387
LF (%)	72,31	70,18
HF (%)	18,33	15,09
LF/HF	3.944	4.651
Total power (ms^2)	3.325	2.567

M-DSI Report no. 3

10/12 - 2019	Time: 08:15 – 09:00	Stress: 5/5
''Conversation with my mom about Christmas. My sister and her boyfriend would rather celebrate Christmas alone, and I find that super frustrating because of our old grandma. I spoke to my colleague […] for 15 min., who has kids, and he told me about what it's like to be parents and why might prefer to celebrate it at home. I think I'll have a conversation with my sister's boyfriend about us celebrating Christmas at their house, on the condition that they let us sleep there''.		

HRV metrics	Daily values	M-DSI no. 3
SDNN (ms)	62,50	66,10
pNN50 (%)	21,87	29,80
RMSSD (ms)	49,20	53,40
LF (ms^2)	2767	3081
HF (ms^2)	773	873
LF (%)	71,63	73,11
HF (%)	20,01	20,71
LF/HF	3.580	3.529
Total power (ms^2)	3.863	4.214

M-DSI Report no. 4

12/12 - 2019	Time: 13:10 – 16:10	Stress: 4/5 - 5/5
''I was at a construction meeting with a builder – I prepared for the meeting according to what I was told we would be discussing, but when the builder went through the things we would be discussing, I realized that none of it has anything to do with the things I prepared for, which resulted in me feeling ill prepared and that I had possibly misunderstood the meeting. Turns out when the meeting starts that it is actually the things, I had prepared that we were discussing, which meant that I could answer most questions. There were though, several questions sent my way, that made me feel inadequate, because I don't have enough experience with what I am working on right now to answer him, and it suddenly became too technical for me''.		

HRV metrics	Daily values	M-DSI no. 4
SDNN (ms)	55,70	56,00
pNN50 (%)	15,58	16,94
RMSSD (ms)	43,00	44,20
LF (ms^2)	2310	1955
HF (ms^2)	539	621
LF (%)	74,39	69,34
HF (%)	17,36	22,03
LF/HF	4.285	3.148
Total power (ms^2)	2.849	2.576

M-DSI Report no. 5

18/12 - 2019	Time: 09:45 – 10:00	Stress: 4/5
''Departmental meeting where we discussed the firing of […] and how we are supposed to use […] from HR as a confidant (tillidsperson), I then asked how she could be both a part of hiring and firing, and then also be our confidant – which she didn't see any problem with, while stating that she wasn't an official confidant''.		

HRV metrics	Daily values	M-DSI no. 5
SDNN (ms)	55,70	56,60
pNN50 (%)	15,48	11,04
RMSSD (ms)	40,90	40,80
LF (ms^2)	2333	2041
HF (ms^2)	505	700

LF (%)	74,92	69,35
HF (%)	16,21	23,78
LF/HF	4.621	2.916
Total power (ms^2)	3.114	2.943

M-DSI Report no. 6

19/12 - 2019	Time: 09:00 – 10:30	Stress: 3/5
''Meeting with a contractor, where I'm responsible for the technical inspection of all plumbing installations. The meeting was about a problem with fluctuating water temperatures in the new bathrooms (435 in total). There is an area in the building where people complain and report that the water turns, either ice cold or very hot, while showering. At the meeting was also an expert in regulation, sent from the company whose equipment was installed in the bathrooms along with one from the property office – so there were many eyes on me given that is my company who is responsible for estimating the installation and in the end, we are the ones responsible if all else is in order. It was a good meeting and I think the dialog between us was very good, but on top of all the other assignments I have, I found it hard to focus.''		

HRV metrics	Daily values	M-DSI no. 6
SDNN (ms)	63,30	57,60
pNN50 (%)	20,94	17,66
RMSSD (ms)	49,90	43,00
LF (ms^2)	2884	2449
HF (ms^2)	885	550
LF (%)	70,58	75,56
HF (%)	21,66	16,98
LF/HF	3.258	4.450
Total power (ms^2)	4.087	3.242

M-DSI Report no. 7

20/12 - 2019	Time: 12:30 – 13:00	Stress: 4/5
''I have for a long time been walking around with the feeling that I have too much stuff on my shoulders, which today resulted in a conversation with my project leader and the head of my department. The conversation was about removing one or more of the assignments given to me, and both my project leader and the head of department agreed that it wasn't a good situation and that some of my assignments would be allocated to someone else. It was		

accompanied with good deal of sadness, because the assignment I gave away was just my cup of tea, but after having headaches every other day for about 4-6 weeks, it's about I give away some if this work and then I hope it'll helps my health''.

HRV metrics	Daily values	M-DSI no. 6
SDNN (ms)	61,00	56,8
pNN50 (%)	13,01	8,84
RMSSD (ms)	44,5	36,70
LF (ms^2)	2973	2529
HF (ms^2)	685	467
LF (%)	75,66	78,46
HF (%)	17,42	14,50
LF/HF	4.344	5.411
Total power (ms^2)	3.930	3223

M-DSI Report no. 8

26/12 - 2019	Time: 17:10 – 19:00	Stress: 2/5
''First time meeting my new father-in-law. We went out eating with my girlfriend's dad and his wife to celebrate his birthday. The dinner went well, but I could feel that I was very nervous about something going sideways, in relation to the history between my girlfriend and her dad, and there was one time where I felt an awkward tension and my girlfriend became uncomfortable in the situation''.		

HRV metrics	Daily values	M-DSI no. 6
SDNN (ms)	60,50	62,2
pNN50 (%)	10,97	8,76
RMSSD (ms)	39,00	38,50
LF (ms^2)	2979	3277
HF (ms^2)	515	515
LF (%)	79,28	81,32
HF (%)	13,71	12,78
LF/HF	5.783	6.363
Total power (ms^2)	3.758	4030