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Master Thesis

Moral dilemmas in a stressful VR environment

Authors:
Eric Wong (4319990)

Supervisors:
Iulia Lefter
Laurens Rook
Francis Brazier

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Abstract

In this research the influence of induced stress with a virtual reality (VR) game on moral dilemmas was investigated. VR is a topic that is becoming more and more researched, but studies about the induction of stress and the effects are scarce. By placing participants in a VR environment, where they have to defuse a bomb with the help of another participant, the influence could be analysed. A test group was selected which would perform relaxation exercises after the VR game to relax them. Afterwards, they filled in a survey which measured their stress/anxiety level and gave them social dilemmas to answer. During the whole experiment, participants wore wristbands that measured their biometric data to see if there were any physical signs of stress.

From the data it was confirmed that the VR induced stress in the participants. The data for heart rate, electrodermal activity, and heart rate variability showed an increase in stress level during the VR; Temperature did not show a difference. From the linear regression analysis done, no significant influence of stress on responses to moral dilemmas and a significant influence of personality type was confirmed.

The possibilities of VR in the field of psychology has the potential to improve research regarding stress. VR can be used as a coping method but also as a stress inducing activity. Future research should focus on discovering new possibilities for VR to be used. By improving the research about stress, an improvement of our lifes will follow.

Contents

1 Introduction

Decisions are made every day. When people wake up, when they decide if they want to get up or stay in bed longer. When they go to the bathroom or when they decide if they want to brush your teeth first. What kind of breakfast are they going to eat? How will they travel to work? Do they talk to their co-worker when meeting them in the elevator? What will they eat for dinner? Many different decision and most of them are made without consciously thinking about it. And all these decisions are influenced by everything. Cold weather? Wear something warm. Rain outside? Bring an umbrella. Any human-being is making decision all the time. So it is important to understand how people get to these decisions and what influences them.

1.1 Background

Stress is a concept that every single person experiences in their life, it is the standard response of the body and mind to any form of demand (NIMH, 2021). Be it performance, changes in daily life and routines, or traumatic events. In work and personal environment, people feel stress because of the pressure that is put on them by others or themselves (Stanton et al., 2001; Khamisa et al., 2017). And that kind of pressure takes a certain toll on someone on a physical and cognitive level (Yaribeygi et al., 2017; Hammen, 2005). The last few decades, it has become more clear that stress is a big factor in how people experience life. In some instances, this can be positive as people will be more alert and focused on the task at hand (Wester, 2011). Stress is also linked to negative impact, like a decline is mental well-being (Pearlin et al., 1981). If someone feels constant stress, their body will be in a constant state of fight or flight, which puts a certain strain on the body and mind (Blankenship, 2007).

And decision making is also impacted by stress levels, which leads to sub-optimal decision making (Youssef et al., 2012). Many different factors change the way people approach a problem and change the decision made for that problem. For example, the way children, teens and adolescents are educated has a great impact to the risk they are willing to take in their decisions in the rest of their lives (Tmsley et al., 1995; Paulsen et al., 2011). It also has an effect on the choices that define their eating patterns (Kilanowski, 2016), how much they decide to trust other people (O'Brien et al., 2021), or how they approach the problems of the world like global warming (Ballantyne et al., 1998; Dunlop et al., 2021).

And even morality is heavily influenced by stress (Starcke et al., 2011a). In Caviola et al. (2014) it was concluded that people are following their gut-feeling when under stress when making moral dilemma choices. In normal circumstances these people would not have made these choices, but under stress they acted without rationality. This is also impacted by personality types (Murphy et al., 2011). Murphy et al. (2011) uses the social value orientation (SVO) method to link a personality type to a certain individual. It shows the "social preference" of the participant and the magnitude of concern for other people. A competitive personality type will prefer to choose the beneficial option for himself compared to a more altruistic personality type, who will choose the benefit for someone else.

With the rise of technology, the possibilities using these technologies creates new ways of research and topics to investigate. Virtual Reality (VR) is one of the most promising piece of technology that has the potential to shape the research field (Annerstedt et al., 2013). The VR environment people are placed in has massive customization pos-

sibilities, which makes the total uses almost endless. Research for mental diseases like post-traumatic stress disorder (PTSD) can be conducted (Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001), in which participants were exposed to their trigger for exposure therapy, or participants can be placed in a nature and calm environment as a relaxation method (Soyka et al., 2016), and placing someone in a moral dilemma to discover if they would make the same decisions in VR as they would on paper. The remote nature of VR creates an easy way to apply it without many restrictions.

In a world where everyone is connected with one another, there will be many different situations in which one decision will influence someone or a group of people. To help people in these types of situations, it is important to understand how stress influences the decisions people tend to make. This research will focus on how stress influences the decision making in social situations. Another subject which will be touched is to see if relaxation will lead to more rational decision making. For most people it is important to make decisions that will help other people and are more pro-social. Under stress people tend to overestimate their decision making capabilities and make more risk-full choices (Kahneman & Tversky, 2013). Supporting people in making decisions that they would be happy about after the stress fades away could be important for people that find it difficult to deal with stress.

1.2 Research goals

This research will focus on moral dilemmas for decision making. Moral dilemmas are ethical problems which do not necessarily have a correct answer, depending on your personality the choices made differ from person to person. Research on VR with moral dilemmas has only showed that there is a more intense reaction compared to research without VR (Navarrete, McDonald, Mott, & Asher, 2012; Skulmowski, Bunge, Kaspar, & Pipa, 2014). The aim of this research will be to understand how and if moral judgement will be influenced by VR induced stress, for this the following main research question has been formulated:

How does stress induction in a VR environment influence the way people respond to moral dilemmas?

Virtual reality in combination with stress and decision making is a subject that has not been widely researched. The possibilities VR offers for research are almost endless and this research will try a possible way of using VR in stress research. It has often been used as a method of therapy for relaxation or aiding with mental diseases (Rothbaum et al., 2001; Wiederhold & Wiederhold, 2008), as it can be easily customized for the needs of the patient. But research about the induction of stress and decisions that come from it have not been widely researched yet.

To answer the main research question, sub-questions were created which can be answered throughout the experiment:

1. *Can a VR game induce stress?*
2. *In what way does stress influence the choices made in moral dilemmas, and can this be impacted by relaxation?*
3. *How does social value orientation influence choices in moral dilemmas?*

Sub-question 1 investigates the effect of the VR environment on the induction of stress. Subquestion 2 will then look how the participants respond to moral dilemmas and the

influence of relaxation. In subquestion 3 the personality types of the participants and the influences of it in their moral judgement is investigated.

1.3 Structure Research

This chapter introduced the research topic and main research question. In the remaining document more context and the steps of the research will be further explored. In chapter 2 relevant works and research will be explored. Chapter 3 explains the methods and experimental procedure used in this experiment. The results of the experiments are shown in chapter 4. In chapter 5 the implications and limitations of the results and future research are discussed. Lastly, in chapter 6 the conclusion of this research will be presented.

2 Literature Review

In this chapter the concept of stress and decision making will be introduced. First, section 2.1 will explore the early studies of stress and how that evolved to what is known now. Section 2.2 introduces the process of decision making and what influences decision making. Lastly, section 2.3 discusses the effect of stress on decision making.

2.1 Stress

This section will introduce the early concept of stress in section 2.1.1, which will lead to the different effects stress can have on a person in section 2.1.2. Coping methods to deal with stress will be explained in section 2.1.3. Lastly, VR in stress research will be investigated. 2.1.4.

2.1.1 Early Research

Stress is a concept that is still not understood completely. Many different theories have been defined, but there is no universally accepted definition to this day (NIMH, 2021). One of the earliest findings about stress is from Hans Selye (1957). He was the first person to define stress as a "non-specific reaction of the body any demand for chance", which is quite abstract and does not say much about what stress does or how it influences an individual. Selye also developed the theory of the general adaptation syndrome-model (GAS) (Selye, 1951) Selye stated that, influenced by some external stressor, humans first try to react by mobilizing our physical resources to prepare for the external stressor or to escape from it. This was called the 'alarm' stage. The following stage, called 'resistance', was defined by attempts to cope or adapt to the external stressor. The last stage of 'exhaustion' happened when an individual was repeatedly exposed to the stressor and was unable to cope or escape. This started a series of experiments in which Selye discovered that not only the mind was affected by stress, but also the physical condition (Selye, 1976a; M. Jackson, Ramsden, Cantor, et al., 2014). In the decades after Selye's theory, the GAS theory has been disproven(Nageishi et al., 2015). It was discovered that each person experiences stress differently and the reaction varies from person to person. Even though the theories of Selye mostly have been disproven (Nageishi et al., 2015; McCarty, 2016), his theories revolutionized research regarding stress and it was the basis of many different theories about stress.

With time, the concept of stress became more researched and a clearer understanding of its effects was obtained. Even though, there is still not an universal accepted definition, different studies have tried to define stress. Looking at the different studies conducted regarding stress, there are three crucial features each one has when defining stress (Hutmacher, 2021).

First, most of them roughly describe stress as a concept when *things are getting too much and/or out of balance*. It is an overload of chronic pressure of demands and specific events that are a burden on a person. In other words, stress occurs when an individual is overwhelmed by the environment. Second, the response of individuals is viewed as *a complex pattern of combination of reactions that take place on several levels, including physiological, behavioral, emotional, and cognitive* (Hutmacher, 2021). The effects of stress is different for each person and varies. Lastly, stress is *a common component of everyday emotional life as every individual (or even organisms) face challenges from its environment or social needs*(Lazarus & Folkman, 1984). Stress is almost always induced by outside factors and linking stress and environmental factors are key to understanding

stress.

In general, stress can be defined as the standard response of the body and mind to any form of demand (NIMH, 2021). It is the body's natural response to possible danger or challenge to prepare itself for the upcoming event.

2.1.2 Effects of Stress

With the increase of research regarding stress, it became more clear how stress can be detected and what the effects are on individuals. In general, the reaction the body has to stress is different for most people, but they tend to be grouped in three different categories: fight, flight and freeze (Selye, 1957). These three states are often mentioned in a survival situation, but they can also be seen in stressful situation. The people that have the fight reaction are the people that often function well under stress, they can quickly get an overview of the situation and make a decisive decision based on their observations. The people that have the flight reaction do not enjoy being in a stressful environment, they try to ignore the problem in the hope that it will go away. The people that freeze are incapable of making a quick decision when put under a certain amount of stress. They get flustered and are not able to make any decision when required of them.

Research has found that stress induced a certain physiological reaction in people. For instance, the concentration of cortisol in someone's blood will increase when that person is put under stress. This can be a accurate indication of the amount of stress someone experiences (Putman et al., 2010). Other indicators are an increase in heart rate and blood pressure (Vrijkotte et al., 2000; Laitinen et al., 1999), increase in sweat on the skin (Liu & Du, 2018; Reinhardt et al., 2012; Kamei et al., 1998), decrease in effectiveness of the immune system (Segerstrom & Miller, 2004), or temperature (Ogorevc et al., 2011; Herborn et al., 2015). All of these reactions are preparing your body for the upcoming challenge or event that is stress inducing. And not only a physiological reaction is induced, stress can also help with improving cognitive functions as an enhanced short term memory or heighten senses (Vedhara et al., 2000). Even an increase in nerve cells was observed in lab rats when put under stress (Kirby et al., 2013). Stress helps people to be more prepared for certain events or challenges that are coming to them, these people tend to have the "fight" reaction" to the upcoming event/challenge that is upon them.

But there are also negative effects linked to stress. Deadlines for school or work, pressure to meet a certain standard or social pressure to behave in a socially accepted way can cause the body to react in different negative ways. It is shown that it can impair the attention span someone has during that time (Geurts & Sonnentag, 2006), increase the rate at which people age on a physiological level (Yiallouris et al., 2019) or completely freeze them so they are not able to respond (Geurts & Sonnentag, 2006). And not only physically, but mentally there are reactions from the body (Hish et al., 2019). Burnouts, depressions, mental breakdowns can be seen more and more within all layers of society (Maslach et al., 2001; Hammen, 2005; Pearlin et al., 1981), as the pressure grows on people from the environment. And not all factors that induces stress has to be something that is controllable. During these trouble times with COVID-19, in which uncertainty is a constant fear people have in their minds, it shows the impact it has on people (Taylor et al., 2020). The uncertainty and social isolation puts a continuous stress level on people and it shows in the amount of people that deal with depression or burnouts (Bueno-Notivol et al., 2021).

One factor that has a major influence on the performance of an individual is the perception of stress (Starcke & Brand, 2012). When the stress inducing event or task is perceived as a challenge, the performance increases (Kassam et al., 2009a). And when the stress inducing activity is perceived as a threat, a decrease in performance can be measured (Kassam et al., 2009b). Every individual perceives a certain task differently, which creates a different reaction in different individuals. Some people might find giving a speech in front of people fun and challenging, while some are terrified by the idea of public speaking.

But not only the perception of stress, but also other aspect in individuals can be influenced by stress. Women tend to take less disadvantageous and risky decisions while men are more prone to take more risk (Kudielka et al., 2009), younger people tend to be more negatively influenced by stress compared to older people (Raz et al., 2005), people from different countries experience a stress inducing task differently (Spradley & Philips, 1972; Sawang et al., 2006; Hashim, 2003) and the situation in which people are in, like COVID-19, also changes the way people handle and perceive stress (Husky et al., 2020; Kujawa et al., 2020; Taylor et al., 2020).

2.1.3 Coping with Stress

With the increased awareness of stress and the effects of stress, research about the relaxation of stress and coping methods to reduce stress has also been increased. Many different theories have been defined, but two of the most widely accepted coping method are cognitive behavioral therapy (CBT) and emotional cognitive behavioral therapy(eCBT) (Hofmann & Hayes, 2018). The theories are based on the cognitive model developed by Beck (2013), which states that "how people feel is determined by the way in which they interpret situations rather than by the situation per se" (p.579). The cognitive model is used as a framework to understand a person's mental state or problem and with this understanding a way to aid them (Fenn & Byrne, 2013).

CBT aims to teach individuals to become their own therapist to help them cope with stress with problem focused coping (Folkman & Lazarus, 1980). This is done by teaching individuals to change the source of the stress to relieve them from stress (Folkman & Lazarus, 1980). CBT can be used in various ways to aid the individuals: by writing down recent stressful events, students were able to improve their general mood and increase their GPA (Lumley & Provenzano, 2003) or showing them appraisal in stressful situations reduces their stress level (Jamieson et al., 2013). Patients are taught to recognize signals of stress and the perception of stress. By changing their own negative perception of the stress to a more positive version, they can reduce the reaction they have to stressors (Folkman & Lazarus, 1980). It also tries to change the behavior that comes with the stress reaction. Negative behavior (e.g. stress eating, negative thoughts or sleep deprivation) are investigated and mediated by therapy or trainings (Fenn & Byrne, 2013). By changing both the perception and behavior, it is claimed to reduce the stress reaction people have to stressors.

eCBT is becoming more and more researched in recent years and focuses on managing emotional distress on a personal level to cope with stress (Folkman & Lazarus, 1980). By teaching patients methods to evaluate their emotional state and distress, by teaching them what these emotions are and how to handle them. This reduces the need for dysfunctional coping methods (e.g. substance misuse, harmful eating behaviors or mental misbehavior). It ought to stabilise the emotional state of a stressed individual without necessarily looking at the source of the problem (Afshari, Neshat-Doost, Maracy, Ah-

mady, & Amiri, 2014). Often eCBT is a mix between therapy, in which the emotional distress and changes are discussed, and relaxation through music (Salamon et al., 2003), physical therapy like yoga or mindfulness (Stein, 2001) or physical activity (Peluso & Andrade, 2005; Warburton et al., 2006; Kokkinos, 2012; E. M. Jackson, 2013).

As each individual perceives stress differently, personality type also plays a vital part in the coping of stress (Connor-Smith & Flachsbart, 2007). Because everyone reacts differently to stress, it can be seen that some people thrive when put under stress and perform better than normally, while other people perform worse than when they are placed in a calm and stable environment (Brand et al., 2008). Connor-Smith et al. (Connor-Smith & Flachsbart, 2007) claim that there is a relationship between how people cope and the Big Five personality traits. Personalities with strong Extraversion and Conscientiousness lead to more preference to problem-solving solutions like CBT, while personalities with Neuroticism preferred emotion-focused coping. Aiding people with coping methods requires not only an understanding to the stress itself but also how the individual reacts to the coping. This complex system creates a variety of different theories as to what is the best way to help people cope with stress (Starcke & Brand, 2012).

2.1.4 Virtual Reality and Stress

Virtual reality (VR) puts people in a customized virtual environment. It is possible to place the person in the VR environment on the top of a mountain, in a forest surrounding nature sounds or on a battlefield with gunfire all around. Because of the flexibility of the content shown in VR, it has been used in various research to test various subjects. Most research has focused on relaxation of stress by placing participants in a calm and relaxing environment (Annerstedt et al., 2013; Soyka et al., 2016). Other researches have tried to use touch as a relaxation method (Serrano et al., 2016; Riches et al., 2021). By placing the participants in a field of grass, where they could "touch" the grass in the VR environment, the participants showed a significant reduction in their stress levels compared to the group that did not "touch" the grass.

But it also can be used for the induction of stress in people (Zimmer, Buttlar, Halbeisen, Walther, & Domes, 2019). The standard way of inducing stress is using the Trier Social Stress Test in which participants are placed in front of interviewers and are ordered to give a presentation (Kudielka, Hellhammer, & Kirschbaum, 2007). This creates a stressful situation as the participants are not prepared and put on the spot. In the research of Zimmer et al. (2019), the participants were placed in a similar situation, only in a virtual world to induce stress. The virtual version induced the same amount of stress compared to the real world version.

In cognitive research, VR was found to be suitable to aid mental patients in dealing with their mental diseases (Rothbaum et al., 2001; Wiederhold & Wiederhold, 2008). Patients with PTSD were treated with VR exposure therapy to aid them and enhance traditional CBT for PTSD patients. It showed a significant difference compared to patients that did not have the VR exposure therapy and it improved the conditions of the patients.

2.2 Moral Decision Making

Decisions play a prominent role in daily lives, almost every single action or activity that is taken is made after a decision is done. On a basic level, decisions can be differentiated by the degree of uncertainty it has (Weber & Johnson, 2009). The uncertainty about the outcome influences how easy or hard it is to make a rational decision. If the outcome is

known, there are less factors to take into account, but if the outcome is less known or even completely unknown, the difficulty of the decision increases. In situation in which uncertainty is low, people tend to make more strategic choices after weighting the pros and cons of their decision (Van den Bos, Harteveld, & Stoop, 2009).

But in situation in which uncertainty is high, people tend to base their assumptions of the outcome on heuristics, biases or non-rational factors (Gigerenzer & Todd, 1999). They are more prone to rely on their intuition and emotions when deciding which leads to non-rational decisions (Loewenstein & Lerner, 2003). And are more willing to make assumptions which are based on false information (Kahneman, 2011). In some cases, emotions and feelings are important factors to take into account when deciding, for example if you are deciding something that will influence the emotions or feelings of someone else. But on a strategic level, the variety in which people can let emotions influence their decisions is often not preferable (Pham, 2004). It often leads to more individualistic choices, which is not optimal for a community.

And this gets more complicated with moral decision making. Compared to other forms of decision making, moral decision making often does not have a "right" or "wrong" answer. The outcome of all possible choices is negative in some way and making a decision on which negative outcome should be the final outcome is ambiguous. According to the research of van Lange et al. (1999a), predictions about how people will react to moral/social dilemmas are almost impossible to make. The dynamic interaction between people influences the way people make decisions. It is easier to give €100,- to one's parent than it is to give it to a complete stranger (in most cases). Depending on the situation and context of a situation the choices people make in moral dilemmas will change.

In the famous trolley problem by Thomson (1976), the participant are placed in front of a lever of a train track. If the participant does not pull the lever, a train will run over an innocent bystander. If the participant does pull the lever, the train will switch tracks and run over five innocent bystanders. Many different studies and variation of this problem have already been conducted (Lanteri et al., 2008; Kamm, 2015; Nyholm & Smids, 2016; Greene, 2016). Of all these studies, no solution of this problem has been provided, only discussions as to how people come to their decisions and what influences them. In the study of Nyholm (2016), a more recent example of the trolley problem is discussed. Self-driving cars have to be programmed to decide how they should react in certain situations. But because no right answer can be given and every decision is different, a "correct" way of programming self-driving cars is impossible. Creating frameworks to understand how people make decisions and what influences them is important for many different fields.

Similar to stress, there are many different factors that influence decisions. The perception of the problem or challenge determines which reaction the mind has (Williams & Noyes, 2007). If the individual perceives the decision as hard or dilemma, the body will react and go in the "flight" or "freeze" state, which makes making decisions harder. Experience in these situations can then be an important factor aid in the response of an individual (Klein, 2017). If people have been in similar situation or have experience of the subject, it makes it easier to come up with a solution and make decision based on experience. Sudden or new experience often create a more intense reaction (Sumpter, Krause, James, Couzin, & Ward, 2008).

And not only perception plays a factor in decision making. Different internal and external variables, determine the current emotional en mental state of a person which has an

influence on decision making. Factors like age and gender (de Acedo Lizárraga et al., 2007), personality type (Byrne et al., 2015), or social pressure (Galam, 1997; Sumpter et al., 2008) have been proven to influence the decision people make. Especially personality type can have a heavy influence on the decisions people make. Personality types in the Big Five personality test are shown to impact the decisions people make (Byrne et al., 2015). For example, neuroticism predicted a negative performance under pressure, but did not predict a change in decision making. Personality types that indicate social preferences, like "pro-social" or "competitive", can predict decision making well (Murphy et al., 2011). Social Value Orientation (SVO) is a clear indicator of social preference and shows the magnitude of concern for other people. People with the more altruistic personality type tend to make more choices that benefit other people compared to competitive personality types, that will choose there own benefit over others. "Pro-social" personality type also tend to be more willing to cooperate with other people compared to "competitive" personality types (Van Lange, 1999b).

All these different factors make it difficult to pinpoint the exact process of decision making in people. Each individual has it's own way of making a decision which is based on their own experiences.

2.3 Stress on Decision Making

Many decisions are made under a certain amount of stress. In situations in which stress is induced, performing or making decisions can be a tough challenge. It is often noticeable that people are getting stressed; They start to sweat, they start to stutter, the heart rate raises and their skin shows a hint of redness (Chrousos, 2009). Examples of this can be answering a question on an exam, choosing a meal when the waiter is close or making a decision of a work dispute. And these decisions can in return create stress responses in the person making these decisions. Stress and decision making are linked and they influence each other. So how does stress impact the decision making process of people?

The effects of stress on decision making have already been widely researched in many studies (Burke et al., 2005; Hellhammer et al., 2009; Starcke & Brand, 2012; Knight et al., 2021).In laboratory research many different effects of stress on decision making have been found. In a research by Starcke et al. (2008) students were put under pressure with an upcoming speech they had to do. When they had to make decision under the pressure, the students had the tendency to make more disadvantageous choices and decisions compared to when they did not feel the pressure. Stress also increases the reliance of the decisions of others (Driskell & Salas, 1991), it leads to less morality (Starcke et al., 2011b, 2011a) and men tend to make more disadvantageous and risky decisions compared to women under stress (Van den Bos et al., 2009; Preston et al., 2007).

Stress leads to a decrease of cognitive processes in the mind of individuals, which leads to susceptibility to framing effects (Masicampo & Baumeister, 2008). Depending on how the decision is framed, the answers of stressed individuals changed. This also leads to more risk involved decisions when stress is put onto the situation (Pfister & Böhm, 2008). But because stress is a concept which in itself is not measurable, it often leads to inconclusive results in researches. In Zellner et al.(2006) and Zellner et al. (2007) one study claims a preference for unhealthy food under stress while the other claims a preference for healthy food. Youssef et al. (2012) shows that behavior regarding moral decisions are prone to influence of stress, but whether it is advantageous or disadvantageous is not concluded.

It shows that stress is a concept that is not fully understood yet and that research always has to be done in multiple variations to rule out any external variations that were not incorporated in the research.

One theory as to why is the depletion of mental capacity in an individual (Pocheptsova, Amir, Dhar, & Baumeister, 2009). It has been found that when people are put under mental effort which is bigger than they are capable of taking their willpower and self-control decreases, which is called ego depletion (Baumeister & Newman, 1994). By being put under pressure (e.g. stress) the mind is overcapacity and less resources are allocated to the decision making itself. Coping and relaxation methods are helpful for individuals as they can improve the mental load they can take.

Morality in general is heavily influenced by stress (Starcke et al., 2011a). In Caviola et al. (2014) it was concluded that people are following their gut-feeling when under stress when making moral dilemma choices. Depending on their personality type, they decided what they thought was best without looking at the rationality. In Selart (2011) managers under pressure at work were found to behave unethically and even conducted illegal activity. In normal circumstances these people would not have made these choices, but under stress they acted without rationality.

The topic of morality has also been discussed in the context with VR. The trolley problem in which a person has to make a choice between the death of five people on a track or changing tracks to kill one person was done in a VR environment (Navarrete et al., 2012; Skulmowski et al., 2014). Instead of making their decision on paper or telling their answer, the participants had to virtually flip the switch to make their decision. It showed a bigger response in the physiological data when they actually had to make that decision and looking at their "victims" brought more distress than without the VR environment.

2.4 Summary

This chapter discussed the history of stress and its development up until the present day. Many theories regarding stress have been defined, but no universally accepted definition have been found. Selye (1976b) defined stress as "the standard response of the body and mind to any form of demand" (p.137), which is the most accepted definition to this day. Coping methods to aid people in reducing their stress or give them tools to handle stress are dependent on many variables, which leads to different methods in coping.

Moral decision making dependent on many different variables. The current stress level of an individual impacts the moral decision making positively when the stress is seen as a challenge, but negatively when it is seen as a threat. But also other factors like, age, gender and childhood impact the decision making. The correlation between stress and decision making is a topic that is widely researched, but there are still question marks as to how it exactly works. VR is a relatively new topic in the field of psychology. Most research has focused on the coping of stress, but few have used it as a stress inducing method.

3 Methods

In this section the complete setup and explanation of each step in the experiment will be shown. Section 3.1 gives the permission by the TU Delft ethics commission, while section 3.2 explains the sample group used in the experiment. In section 3.3 all the materials and measures used in the experiment will be introduced. The experimental procedure is explained in section 3.4. Lastly, section 3.5 defines the used collected measures.

3.1 Human Research and Ethics Committee

To conduct this experiment, the Human Research and Ethics Committee of the TU Delft approved this experiment on 28 August 2021. The letter of approval can be found in the Lab Servant environment of the TU Delft.

3.2 Participants

The research was conducted at the TOPdesk Netherlands office in Delft. All the employees in the Delft office were sent an email with the request to participate in the experiment and help with this research. Some participants joined when they were asked to help at the TOPdesk office.

In the end, there was a total of 36 participants, from which 22 were female and 14 were male. The age ranged from 21-43. The participants were divided in two different at random, one test group which followed the whole experiment including the relaxation method while the control group did not do the relaxation method. The pairs were also chosen at random. A detailed description of the sample can be found in table 1.

Table 1: Participant description

Description	Summary	N (test)	N (control)	N (total)
Gender	Male	5	9	14
	Female	13	9	22
Age	18-24	9	9	18
	25-34	8	7	15
	35-44	1	2	3

3.3 Materials

The materials used during this experiment will be described in this section.

3.3.1 Empatica E4 Wristbands

The Empatica E4 wristbands were provided by the Technical University of Delft and functioned as the measurement tool for stress. There are a variety of sensors in the wristbands that were used for the measurements. The Empatica E4 wristbands are capable of measuring blood volume pulse (BVP), heart rate and heart rate variability (HRV) using a PPG sensor, electrodermal activity with a GSR sensor, acceleration across three axis and temperature with an infrared thermopile (Empatica, 2021).

Additional software is also provided which can be used to live-track data from the wearer of the wristband. It has also been reported that the wristbands can have artifacts in the data, which results in a significant loss in detected interbeat intervals (Ollander, Godin, Campagne, & Charbonnier, 2016). One of the major problems when using the Empatica E4 wristbands, is the inaccuracy in the data when there is a lot of movement (Milstein

& Gordon, 2020). Participants were tasked to stay seated during the baseline readings to ensure a stable reading.

A few metrics were retrieved from the data to analyze for this research. The following data was used: heart rate, heart Rate Variability (HRV), electrodermal activity (EDA) and temperature. Using this data, the physical condition of the participants was determined during the whole experiment. The wristbands also has the option to tag a specific point in measurement to give the user more tools to find the correct part of the data that corresponds to specific points during the measurements.

Heart Rate and HRV

Using the PPG sensor in the wristbands, the heart rate and subsequently HRV can be obtained, the wristband obtains data in 1 Hz interval. This data is used to determine the stress level of the participant. Heart rate and HRV should increase during the stress inducing test when the participants become more stressed (Vrijkotte et al., 2000).

For the heart rate, the average value over a 10 second period was used to determine the value at a certain time. To calculate the HRV, a period of 1 minutes was used for analysis so the beat-to-beat interval (or NNI) can be obtained. For the HRV analysis the package provided by Aura Healthcare to calculate HRV is used (2018).

EDA

With the GSR sensor the electrodermal activity of someone's skin can be determined. An increase in the value of EDA should be observed when the wearer's stress level starts to increase (Reinhardt et al., 2012).

The GSR sensor collects data over a 4 Hz interval. Averages over 10 seconds were used to determine the EDA value at specific points in time.

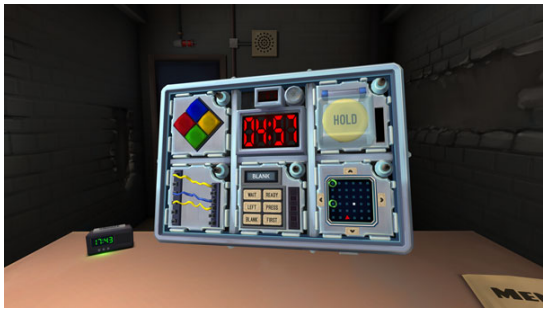
Temperature

The temperature of someone's skin decreases when stress is induced (Ogorevc et al., 2011; Herborn et al., 2015). The thermopile collects data over a 4 Hz interval. Averages over 10 seconds were used to determine the temperature value at specific points in time.

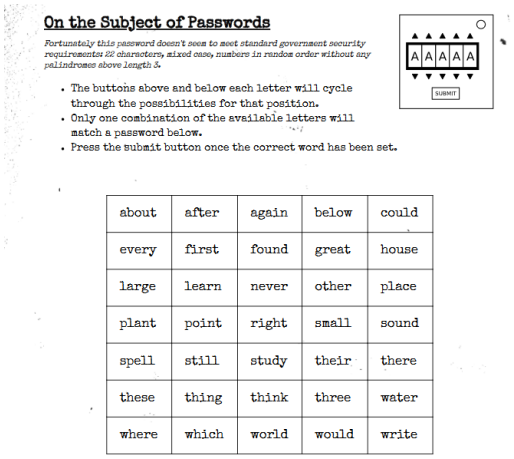
3.3.2 Keep Talking and Nobody Explodes

The virtual reality game "Keep Talking and Nobody Explodes" was used to induce stress within the participants (SteelCrateGames, 2021). "Keep Talking and Nobody Explodes" is a game where one participant is inside a virtual world with a bomb in front him/her. The bomb is divided in different compartments which each hold a different puzzle on it. One or more participants is next to that person with the manual to defuse this bomb. They have to communicate how the bomb looks and what action the person in the virtual world has to take to defuse the bomb. Figure 1 shows what each participants sees during the game. There is a time limit before the bomb explodes and only three mistakes can be made, after which the bomb explodes too. There is a visible timer on the screen, the bomb makes noises and occasionally the light goes out in the room and an alarm goes off to induce some stress. If you have less than a minute the time to defuse the bomb, the music goes louder and you hear a beeping sound to indicate that the timer is almost done.

The level used in the experiment was "2.2 - Double your Money".



(a) In-game still of "Keep Talking and Nobody Explodes"



On the Subject of Passwords

Fortunately this password doesn't seem to meet standard government security requirements: 22 characters, mixed case, numbers in random order without any palindromes above length 3.

- The buttons above and below each letter will cycle through the possibilities for that position.
- Only one combination of the available letters will match a password below.
- Press the submit button once the correct word has been set.

about	after	again	below	could
every	first	found	great	house
large	learn	never	other	place
plant	point	right	small	sound
spell	still	study	their	there
these	thing	think	three	water
where	which	world	would	write

(b) Manual of a puzzle

Figure 1: Examples of what participants could see while playing the game

3.4 Experimental Procedure

To ensure the integrity of this research each experiment must follow the same steps during each phase.

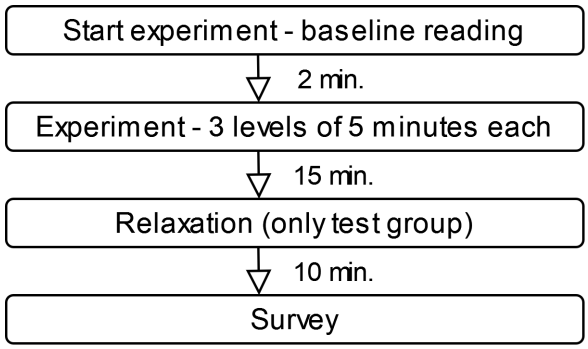


Figure 2: Flowchart of experimental procedure

Each participant had to fill in a consent form before the start of the experiment for the use of their biometric data in this research. In the first step of the experiment the participants were told the procedure of the experiment and the explanation of the VR game. Instruction of the controls and general goal of the game were given, no explanation about the puzzles found in the game were given. The participants were given no time to read the manual or prepare for the puzzles ahead. During this time the baseline reading was performed over a period of 2 minutes for the HR, EDA and temperature readings.

The participants tried to complete level 2.2 in "Keep Talking and Nobody Explodes". Each level took roughly 5 minutes each and every pair had three chances to try to complete the level. Between each level the participants tagged the timestamp. After finishing the last try, the participants were put in separate rooms. The test group started listening to nature sounds and colored in a drawing for 10 minutes (appendix C).

Nature sounds has been proven to be an efficient way of dealing with emotions and lowering the negative thoughts someone has in their mind (Robb, 2000). It is also an easy

method to achieve for working people, which makes it easy to carry out during a working day. Nature sounds were played to create a calm environment for the participants. While listening to the relaxing sounds, the participants also colored a picture to keep themselves busy and have them focus on something else (appendix C). Drawing has shown to be a viable way for people to cope with stress and negative emotions (Smolarski, Leone, & Robbins, 2015).

The test group will be relaxed after the induced stress test, while the control group immediately started with filling in the survey (appendix A, B and D). The test group started after their 10 minutes were over.

When the participants had to fill in their survey, the participant wearing the VR was placed in a separate room to limit the influence the participants would have on each other. This would also reduce the influence of room temperature on the results of the measurements.

The participants were also observed in their interaction as a duo. In a few instances, the participants were recorded on video for further research.

During the start of each different step and at the end of the experiment, the participants tagged the time on their wristband to indicate the start of the next step.

3.5 Measures

3.5.1 STAI

The State Trait Anxiety Inventory (STAI) is one of the most used methods of measuring stress (Vitasari, Wahab, Herawan, Othman, & Sinnadurai, 2011). STAI was used to measure the anxiety level in the participants, which correlates to the stress levels. The STAI scores measures the anxiety/stress level in an individual on a scale of 20-80. The higher the value of the STAI score, the higher the anxiety/stress level is. The STAI-test has been one of the most used methods of measuring stress in the last couple of decades. In appendix A the questions of the STAI can be seen.

3.5.2 Social value orientation

The social value orientation (SVO) method, created by Murphy et al. (2011) was used to determine the behaviour the participants had towards each other. Six questions were asked to the participant as to how much money the would allocate to themselves and their experiment partner (appendix B) The results of the SVO test shows the "social preference" of the participants as an angle which can determine their personality type.

3.5.3 Dilemma's

To measure the decision making of the participants under stress every day moral dilemmas were used, as they are a clear indicator of moral judgement (Li, Gao, Zhao, & Li, 2019; Starcke, Ludwig, & Brand, 2012). There will be three types of dilemmas used: non-moral, impersonal and personal dilemmas. 9 dilemmas (3 of each type) are based from Greene et al. (2001). In the analysis of this research question 1,2 and 3 were excluded as they had the same result for all the participants. Each question will have a more pro-social choice and a more individualistic choice. *Dilemma score* will be determined by the amount of pro-social choices made.

The non-moral dilemmas will offer a dilemma in which morality is not involved, for example:

During a hot day in the office, there are two available spots to work at. The first spot has an airconditioner next to it. While the other spot does not have a airconditioner next to it.

Is it appropriate for you to take the spot with the airconditioner?

The impersonal dilemmas show a dilemma in which you do personally have an influence in, but indirectly can change the outcome of the problem:

You are working in the office and just grabbed a cup of coffee. While you are making the coffee you see that there are no more beans left in the coffee, but there is just enough for your cup.

Do you take the time to fill up the machines with new beans?

Personal dilemmas are dilemmas in which you directly can influence the outcome of the problem, you are personally responsible for the outcome:

While working at a project, each individual team member has their own tasks to do. One day, you have finished all your tasks before the end of the day. You were working hard on your own tasks the whole day, so you did not see how hard the rest worked. Your coworker did not finish his tasks in time.

Do you stay longer at work to help your coworker finish his tasks?

These questions were asked in the survey after "Keep Talking and Nobody Explodes"-game for the control group and after the relaxation for the test group.

4 Results

In this chapter the results of this research will be discussed. First, the descriptive values of the measurement will be shown in section 4.1. The observed behavior from the participants during the experiments will explained in section 4.2. In section 4.3 analyses the impact of stress on the decision making. Section 4.4 the results from the Empatica E4 wristbands will be discussed.

4.1 Descriptive values

In table 2 the values for the *STAI score*, *Dilemmas score* and *SVO Angle* is shown. The test group filled in their survey after the relaxation, while the control group started after the last level of the VR. The data of the *STAI score* clearly shows a distinction between the control group (45.50 ± 12.4) and the test group (32.67 ± 7.24). The test group showed a significant reduction of their stress level compared to the control group. The *Dilemma score* showed a slight increase from the control group (4.51 ± 0.85) and the test group (5.00 ± 0.77). The values for the *SVO Angle*, were similar for both the test (38.39°± 3.01) and the control (37.85°± 7.29) group.

Table 2: Descriptive values for *STAI score*, *Dilemma score* and *SVO Angle*. The *STAI score* was measured on a scale from 20 to 80, with higher numbers meaning higher level of stress. The *Dilemma score* was on a scale from 0 to 6, each question the participants answered more pro-social their score increased. And the *SVO Angle* indicates the personality type on a scale of -70° to 120°, with leaning towards -70° indicates a competitive personality type and 120° an altruistic personality type.

Variables	Control group (SD)	Test group (SD)
STAI score	45.50 (12.47)	32.67 (7.24)
Dilemmas score	4.61 (0.85)	5.00 (0.77)
SVO Angle	38.39°(3.01)	37.85°(7.29)

The values of the physiological data is shown in table 3. The *Baseline* was taken before the VR game. Each reading of the level was done after completion (or failure) of the level and the *End* reading was done 10 minutes after the VR game. The test group did relaxation in that time, while the control group filled in the survey.

Table 3: Descriptive values stress variables. *HR* is measured in beats per minutes, EDA is micro Siemens [μS], temperature is Celcius [°C] and NNI in milliseconds [ms].

Parameter	Group	Stage				
		Baseline	1st level	2nd level	3th level	End
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
HR [bps]	All	76.06 (11.83)	79.94 (9.51)	76.03 (11.55)	82.38 (13.03)	79.00 (10.77)
	C	76.05 (12.03)	78.05 (9.53)	74.41 (10.39)	82.97 (10.75)	80.37 (10.24)
	T	76.06 (11.63)	80.87 (9.40)	81.22 (12.55)	81.67 (14.48)	77.62 (11.18)
EDA [μS]	All	0.57 (0.41)	0.74 (1.05)	0.90 (0.88)	1.05 (1.34)	0.64 (0.26)
	C	0.59 (0.52)	0.92 (1.38)	1.09 (0.98)	1.30 (1.62)	0.93 (0.86)
	T	0.55 (0.21)	0.46 (0.45)	0.71 (0.72)	0.80 (0.82)	0.34 (0.56)
Temp [°C]	All	30.58 (1.65)	30.66 (1.62)	30.69 (1.81)	30.57 (1.82)	31.00 (1.34)
	C	30.76 (1.54)	30.72 (1.63)	30.63 (1.77)	30.71 (1.82)	31.07 (1.46)
	T	30.40 (1.74)	30.59 (1.74)	30.74 (1.81)	30.44 (1.82)	30.93 (1.24)
NNI [ms]	All	809.61 (93.84)	801.76 (84.98)	781.90 (81.62)	760.93 (83.91)	787.38 (88.62)
	C	812.36 (99.23)	801.31 (83.17)	792.16 (81.21)	778.80 (79.04)	782.58 (97.15)
	T	806.85 (88.03)	781.61 (85.17)	761.81 (85.18)	743.06 (84.83)	792.18 (77.39)

For the *HR*, *EDA* and *NNI* there was clear difference between each stage of the experiment, while the temperature stayed stable throughout the VR game and slightly increased after VR. For the HR, the mean for both the control and the test group increased, which correlates to a higher stress level. After 10 minutes after the end of the game, the test group did 10 minutes of relaxation and the control group filled in the survey. The control group showed a reduction of HR of -3.14% and the test group had a -5.18% reduction.

The results from the EDA showed similar results. Throughout the VR game, the EDA values increased up until the end of the 3th level. 10 minutes after the 3th level, the EDA value reduces during that time. The control group showed a reduction of -28.46% and the test group had a -57.50% reduction.

No indication of an increase of stress was found from the temperature data. The temperature of the participants stayed stable during the VR and increased at the end. An increase in temperature could indicate a reduction of stress (Ogorevc et al., 2011), but no conclusion can be formed as there is no evidence of an increase in stress levels found during the VR.

NNI showed a decrease during the VR game and a slight increase for the test group during relaxation. A lower number indicates a higher bps and therefore a higher stress level. All participants showed an increase during the VR. Both groups lowered their NNI 10 minutes, with the control group a decrease of $3.78ms(-0.49\%)$ $49.12ms(-6.6\%)$

This data confirms subquestion 1, as the VR was able to increase the stress levels in the participants. A more extensive analysis of the physiological data can be found in section 4.4.

4.1.1 SVO Slider

The SVO sliders indicate how people cooperate with another person. The personality trait that is bound to one, shows how much they are willing to help someone else. Different SVO angles ranges indicate different personality types, which shows how much a person leans towards a certain personality type. A lower score shows a more individualistic personality type, while a higher a more altruistic. Figure 3 shows the frequency of each range of angles occurrence in the participants, which shows that most of the participants were in the 35-50 range. Table 4 shows the personality type linked to the SVO angle.

Table 4: SVO personality types

SVO Personality type	
Pro-social	Individualistic
35	1

From the 36 participants, 35 were categorized as the personality type "pro-social" while only one had "individualistic". Which indicates that the participants used in this research were a homogeneous sample size.

4.2 Observed Behavior

Video footage of five pairs were taken. During the experiment it was observed that each group followed a similar pattern trying to solve the level. The groups were minimally instructed about the game, only the goal of "dismantling the bomb" and the manual was provided without time to read the manual.

The majority of the groups started describing the environment they were in before they investigated the bomb. Each group then failed to complete the first level without solving the majority of the puzzles, most groups showed high levels of energy during the first

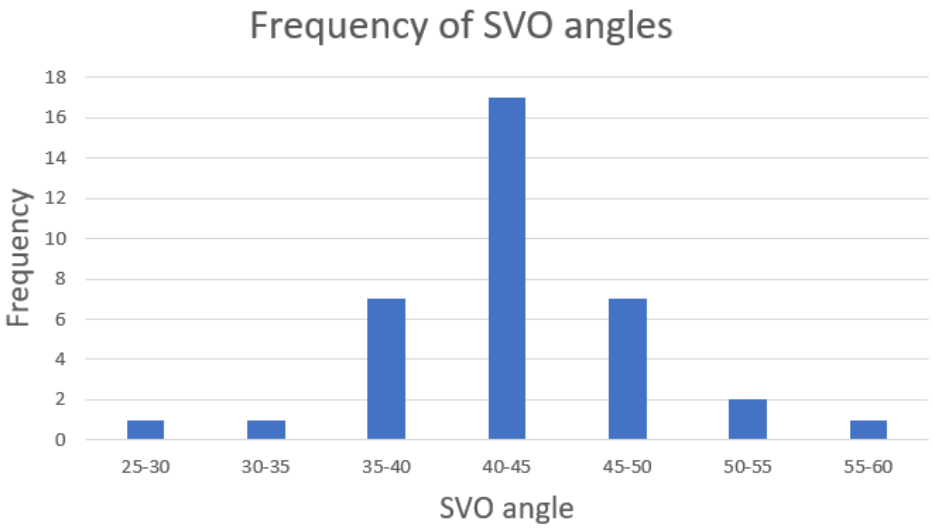


Figure 3: Frequency of SVO angles

level. During the second level the groups got further in the level, but failed without being able to solve the last 1-2 puzzles. During this level, the level of energy dropped visibly and stressful behavior, like talking louder or faster, was less observed. In the third level, most group realised they were capable of solving the bomb as they were close the last time. This increased the level of energy again and it is observed in the descriptive values of table 3. The control group decreased their HR during the 2nd level and the test group remained stable. This increased again during the 3th level, which most pairs were only 1 puzzle away from solving it.

Three pairs were successful in completing the level. The pairs that were able to dismantle the bomb often showed more composure and calmness during the VR game, while groups that failed communicated less clearly. Most group struggled with clear communication.

4.3 Statistical analysis

To determine if the variables influence *Dilemma score* of the participants, a linear regression analysis was performed to analyse the influence of the variables. A linear regression analysis determines if there is a linear relationship between the dependent variables and the covariates. In table 5 the results of the linear regression analysis is shown. The dependent variable is the *Dilemma score* and the covariates the *STAI score* and *SVO angle*. STAI was picked as the indicator of stress. The coefficient of determination is $R^2 = 0.962$ with $F = 434.06$ and $p < .001$. Which shows a significant result from the variables to the *Dilemma score*, and indicates that the covariates have a significant influence on the *Dilemma score*

Table 5: Linear regression analysis of the different variables against the social decision-making

Variables	β	t	p
STAI score	-0.004	-0.018	0.986
SVO Angle	0.861	8.038	$< .001$

From this it is seen that the *SVO angle* has a significant influence on the *Dilemma score* of the participants, while *STAI score* had no significant impact. *SVO angle* has a

$\beta = 0.861$, $t = 8.038$ and $p < .001$, which indicates that the higher the *SVO angle*, the higher the *Dilemma score* will be. This correlates with the meaning of the *SVO angle*, as a higher value is linked to a more altruistic personality type.

From this result, subquestion 2, 3 and the main research question can be answered. There was no evidence found of any influence of stress on *Dilemma score*, which answers subquestion 2. The result answers subquestion 3 by showing the correlation between personality types and moral dilemma judgement, a more altruistic personality type correlates to a more pro-social decision making. For the main research question, no influence of the VR game induced stress on moral dilemmas was found.

4.4 Physiological Data

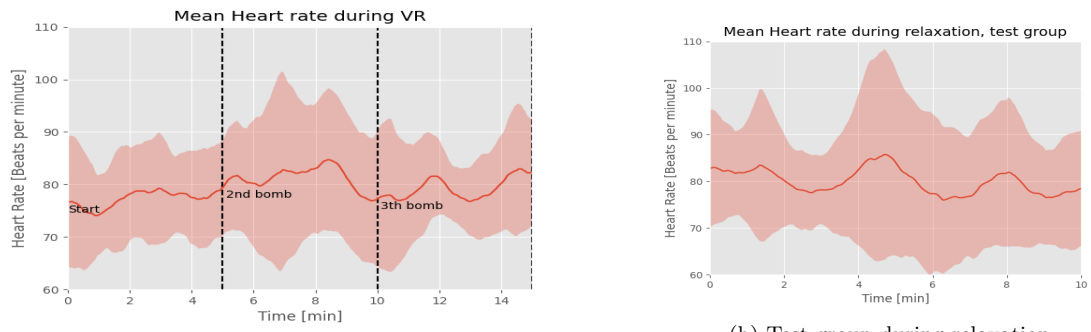
In this section, the results of the physiological data obtained from the Empatica E4 wristbands will be discussed. In section 4.4.1 the data from the heart rate sensor will be explained. Section 4.4.2 shows the collected EDA data and section 4.4.3 the temperature data.

4.4.1 Heart Rate and HRV

The HR data was collected from the Empatica E4 wristbands. In figure 4 the mean HR with error bands are given during the different stages of the experiment. The error bands give the standard deviation for each data point over the duration of the measured data. Figure 4a shows the mean HR of all the participants during the VR and and figure 4b shows the HR of the test group during relaxation. The mean HR for both the test and control group went up and down during the measurement but ended up higher when they finished the VR compared to the baseline. This indicates that there is an increase in stress levels during the VR. The test group lowered their heart rate during the relaxation by 4.05 *bps* (5.18%) and ended up slightly higher compared to their baseline; While the control group decreased by 2.60 *bps* (3.14%).

In figure 4, a decrease in HR during the 2nd level of the VR game is visible. This was also observed during the experiments when the participants dropped their level of energy during the 2nd level after realising they were not able to dismantle the bomb in time. An increase during the last minutes of the 3th level is seen. This shows the increase in activity of the participants during the last minute to finish the level in time.

Mean Heart rates test and control group



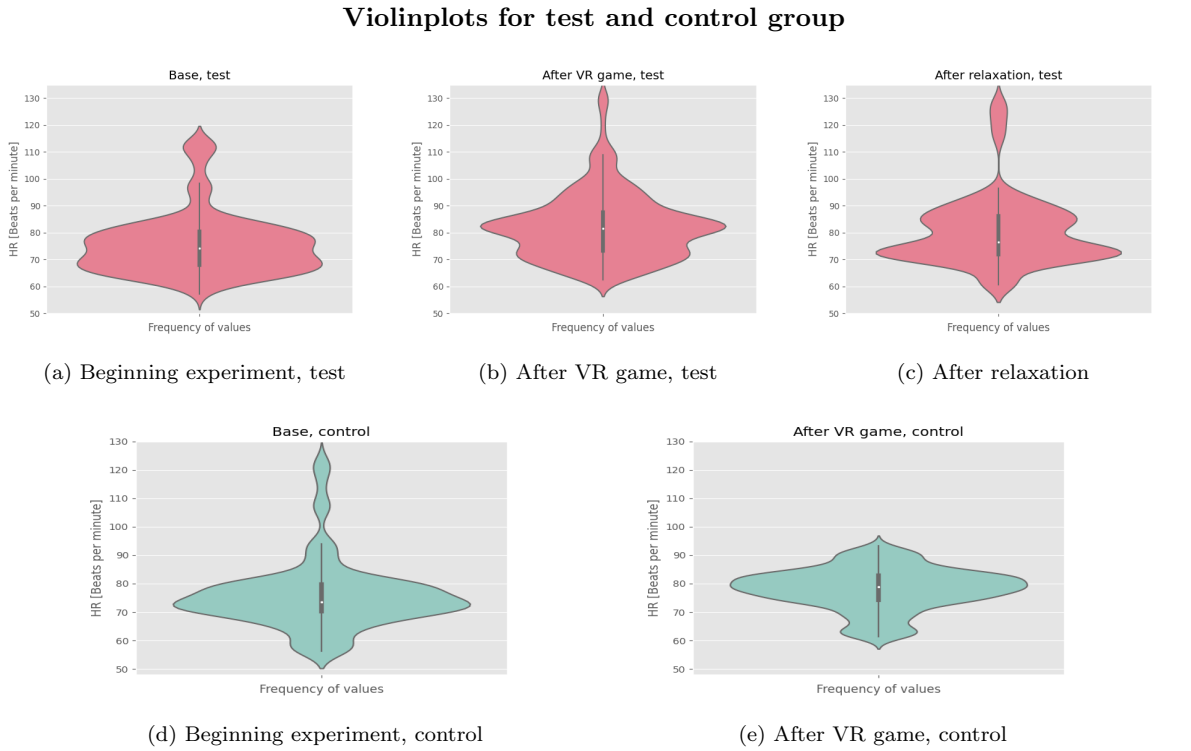
(a) All participants

(b) Test group during relaxation

Figure 4: Mean of heart rate with error band. The first vertical line in fig 4a indicates the end of the 1st level, the second line, the end of 2nd level.

Violin plots were plotted to show the probability density of the HR during the experi-

ment. It gives a clearer picture in what way the values of the heart rate increased. In figure 5 the violin plots for each phase during the experiment for the test and control group can be seen. The box in the middle of the images indicates the mean value for that phase.



(a) Beginning experiment, test

(b) After VR game, test

(c) After relaxation

(d) Beginning experiment, control

(e) After VR game, control

Figure 5: Violinplots of the HR for different stages during the experiment

It is clear to see that the mean value went up after the VR game compared to the baseline and the mean value decreased for the test group after the relaxation. From the probability density it is shown that overall the HR decreased during the relaxation for the test group. After the VR game, most values were measured between 85-90 bps, while after the relaxation it was between 70-75 bps. Looking at the control group, there were some participants that had high HR values during the baseline reading. However, the mean HR value across the whole group did increase from the base line reading until the end of the VR game. This shows that the VR game "Keep Talking and Nobody Explodes" succeeded in increasing the stress level of the participants, for both the participant in the VR and out of the VR.

HRV

Table 3 shows the mean NNI difference and the SDNN difference obtained from the HRV analysis. Table 3 indicate the difference between the start of the survey and the beginning of the experiment. The HRV values on each measure point in the experiment were obtained over a period of one minute and the mean NNI difference between the control group and test group are shown. Figure 6 shows the NNI during various stages of the experiment.

From the data it is seen that NNI decreased during the VR and increased during relaxation for the test group, which indicates an increase in stress levels during VR and a decrease during relaxation.

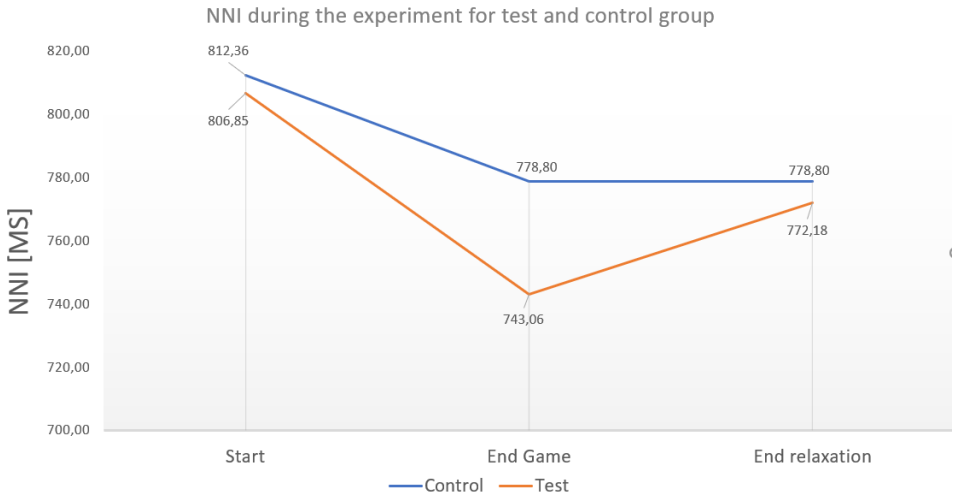


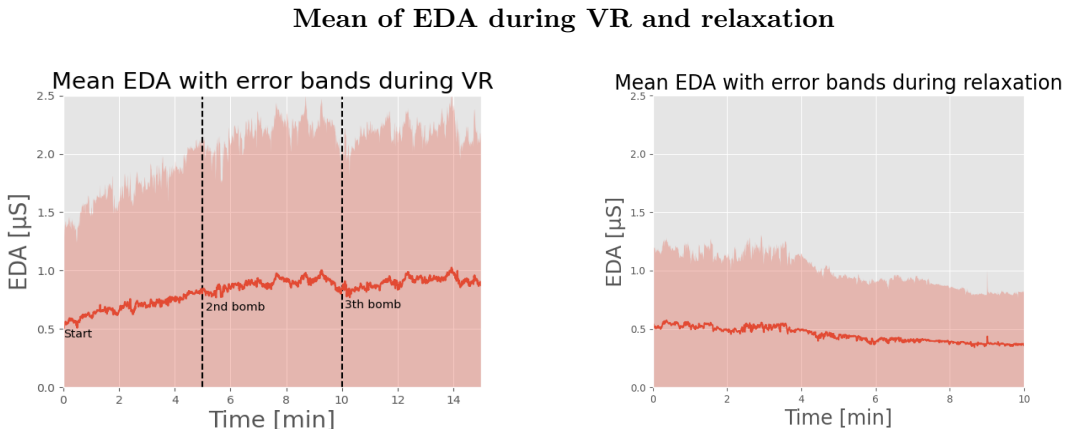
Figure 6: NNI during the experiment

4.4.2 EDA

Similar to the HR, plots for the mean EDA over time were made in figure 7. In figure 7a the mean EDA for all participants during VR is shown and in figure 7b the mean EDA during relaxation for the test group. Looking at the two figures, the participants had an increase in EDA during VR which dropped for the test group during relaxation. The EDA decreased for the test group during relaxation by $0.46S$ (57.50%) and ended up slightly higher compared to their baseline; While the control group decreased by $0.37S$ (28.46%). This indicates that there is an increase in stress levels during the VR.

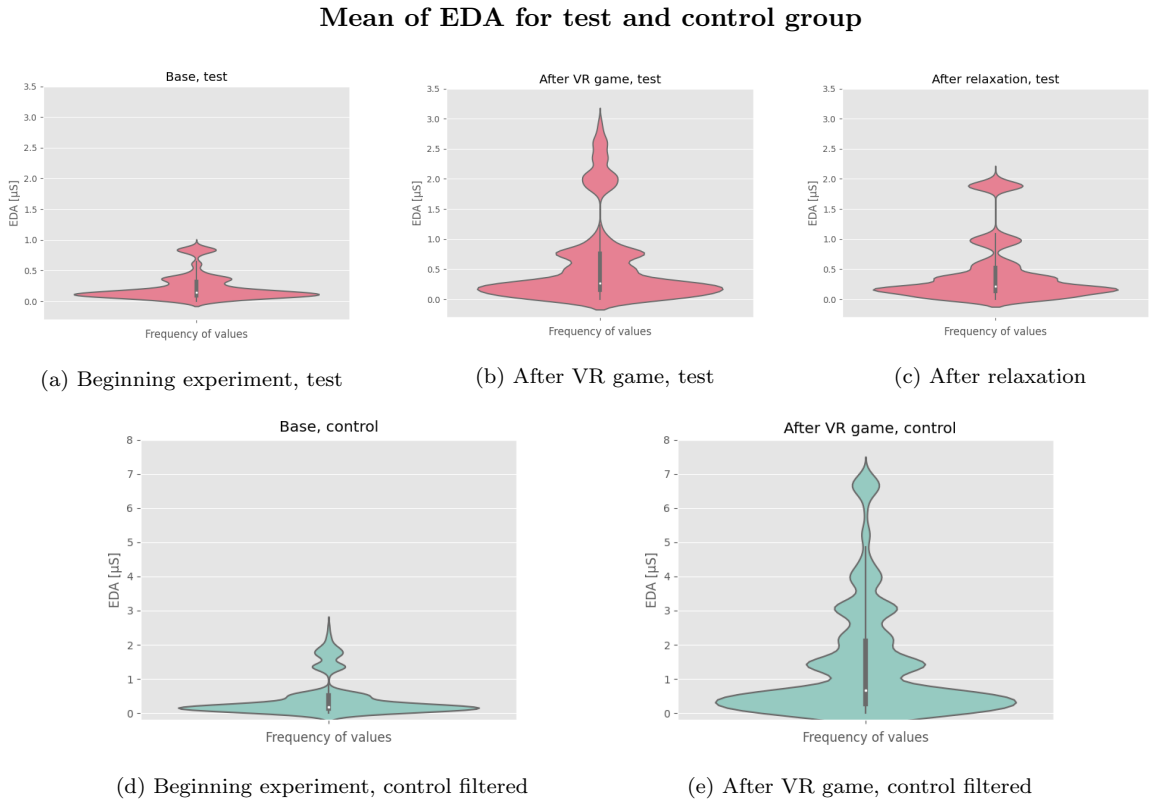
The last minute before the end of the 2nd level, a drop in EDA values is seen. As was the case for HR, this can be explained by the participants failing the level for the second time. A more gradual increase of EDA, compared to HR, is observed at the 3th level.

The data in figure 8 informs more about the probability density of all the participants with violin plots. All of the test group showed no value of $\mu S < 1$ during the baseline reading, which is lower than previous research has shown (Liu & Du, 2018). After the stress inducing test, the mean value increased and now there were no values of $\mu S < 3$. This decreased again after the relaxation. The control group showed a significant difference between the baseline reading and the end of the VR.



(a) All (b) Test group

Figure 7: Mean of EDA with error band. The first vertical line in fig 7a indicates the end of the 1st level, the second line, the end of 2nd level.



(a) Beginning experiment, test (b) After VR game, test (c) After relaxation

(d) Beginning experiment, control filtered (e) After VR game, control filtered

Figure 8: Violinplots of EDA for different stages during the experiment

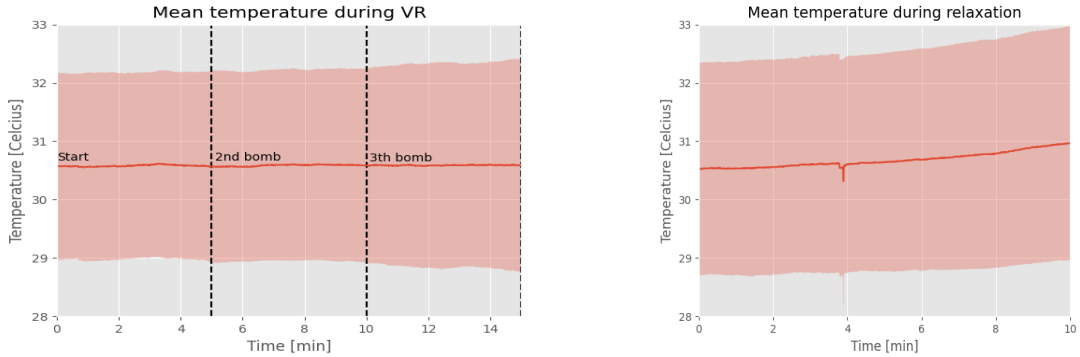
4.4.3 Temperature

The last set of data used from the Empatica E4 wristbands was the temperature data. Plots have been made of the mean temperature over time with error bands in figure 9. As is seen in the descriptive data from table 3 and figure 9a the temperature did not fluctuate for all the participants during VR.

A slight increase in temperature for the test group during the relaxation phase was measured, which is shown in figure 9b. The increase in temperature indicates that there is a reduction in stress in the test participants during relaxation (Ogorevc et al., 2011).

From the results, it can be included that relaxation helps the participants in reducing their stress levels.

During the relaxation phase, figure 9b shows a trough at minute 4. This was due to one participant 5-01 having a period of zero measures around that time. While an increase in temperature during relaxation was found, the measurement of temperature was found to be not a viable indicator of stress levels in participants as there was no difference between the baseline and the end of the experiment.



(a) All participants

(b) Test group during relaxation

Figure 9: Mean of temperature with error band. The first vertical line in fig 9a indicate the end of the 1st level, the second line, the end of 2nd level.

5 Discussion

The goal of this research is to find evidence of the influence of VR game induced stress on moral dilemmas. VR has been an upcoming technology in the field of psychology and researches about coping mechanics with the help of VR have already been conducted (Rothbaum et al., 2001). Research on inducing stress through VR has not been widely researched.

The main variables that were investigated were the effect of personality type (*SVO angle*) and stress level (*STAI score*), on moral dilemmas. The result of this research was found to be a strong correlation between the personality type of an individual and their choices for moral dilemmas. No significant result was found for the influence of stress level and moral dilemmas.

In chapter 4 the main research question: *How does stress induction in a VR environment influence the way people respond to moral dilemmas?* was answered. The results showed a non-significant influence of stress level induced by VR on moral dilemma judgement. In this chapter, more context will be given to this conclusion.

The results are further discussed in this chapter. First, the results and the scientific relevance of these results are discussed in section 5.1, which will follow into the practical relevance in section 5.2. The limitations of the study are explained in section 5.3. Future research is then discussed in section 5.4

5.1 Scientific Relevance

This research was focused on finding the influence of VR game induced stress on responses to moral dilemmas. In section 5.1.1 a closer look of the relevance of the found results is shown. In section 5.2 the concepts around VR are discussed.

5.1.1 Moral dilemmas

Two variables were used in the analysis of *Moral dilemmas*, *STAI score* for stress levels and *SVO angle* for personality type. In the following section both variables will be further explained.

Stress and moral dilemmas

According to literature, individuals who are stress are more prone to make fewer utilitarian judgements (Starcke et al., 2012). From the analysis in section 4.3 in this research, it was observed that there is no significant relationship between stress and moral judgement.

Stress was found to be induced by the VR using the physiological data, which can be viewed in section 4.1 and 4.4. A clear increase in stress level could be observed for the majority of the participants and a reduction of stress level during relaxation. Similar results can be found in different studies. An overall increase in HR, EDA and HRV correlates to a higher stress level (Vrijkotte et al., 2000; Liu & Du, 2018), which was confirmed in this research.

The main research question: *How does stress induction in a VR environment influence the way people respond to moral dilemmas?* can then be answered. Moral dilemma judgement was not influenced by stress levels induced by VR. This is different from the literature, as stress was expected to make the participants more individualistic (Starcke

et al., 2012). In the research of Skulmowski et al. (2014) it was shown that moral dilemmas in VR game induced the same amount of stress in the VR environment as the real-life version. This research confirmed the induction of stress through VR, but no effect of stress induction on moral dillemmas was found.

Subquestion 1 (*Can a VR game induce stress?*) can also be answered from these results. VR was capable of inducing a stress reaction in the participants. From previous research it was clear that a replication of Trier Social Stress Test (TSST) was able to induce stress in participants (Kudielka et al., 2007). This research investigated the stress inducing capabilities of the VR game "Keep Talking and Nobody Explodes". Participants using the VR and communicating outside of the VR showed a clear increase in stress levels from their physiological data (section 4.1.

For subquestion 2 (*In what way does stress influence the choices made in moral dilemmas, can this be impacted by relaxation?*) there was no influence of stress on the choices made in moral dilemmas. In table 2 it shows that no significance was found of the influence of stress on moral dilemmas. For the relaxation, no evidence was found for significant impact. The internal validity of the impact of relaxation does have some remarks, which will be further discussed in section 5.3.1.

SVO angle and moral dilemmas

In section 4.3 the result of the influence of *SVO angle* and *Moral dilemmas* can be observed. The result show a significant influence of *SVO angle* on the moral dilemma choices made by the participants. A stronger indication of altruism correlated with a more pro-social decision making, while individualism correlated with a more individualistic decision making.

This is according to the literature, as it has been proven that personality type influences moral judgement (Byrne et al., 2015). People who are more individualistic tend to make less pro-social compared to more altruistic people (Lee-Baggley et al., 2005). This was confirmed by this research. The participants who scored lower on the *SVO angle* tended to answer more individualistic choices compared to the participants who scored higher. In figure 10 *SVO angle* is plotted *Moral dilemma* against with a trendline. It clearly shows that when the SVO angle increases, the more pro-social choices are made.

This answers subquestion 3 (*How does social value orientation influence choices in moral dilemmas?*), as the SVO showed a significant influence on moral dilemmas in this research. The more pro-social an individual is, the more his moral judgement will lean towards pro-social choices.

5.1.2 VR as research tool

In the last 15 year, VR has been seen more in research. In most studies, VR is used as a coping method for different types of stress (Rothbaum et al., 2001), where participants were put in a relaxing environment to reduce stress levels. It has shown positive results as an exposure therapy for war veterans (Wiederhold & Wiederhold, 2008). Stress has also been induced in a replication of the TSST to induce stress (Zimmer et al., 2019) and as a tool for placing people in a simulated trolley problem for moral judgement research (Skulmowski et al., 2014).

From the research of Zimmer et al. (2019) it was shown that VR was capable of inducing stress in participants. In this research the focus was on the inducing of stress with the VR game "Keep Talking and Nobody Explodes", where participants had to dismantle a

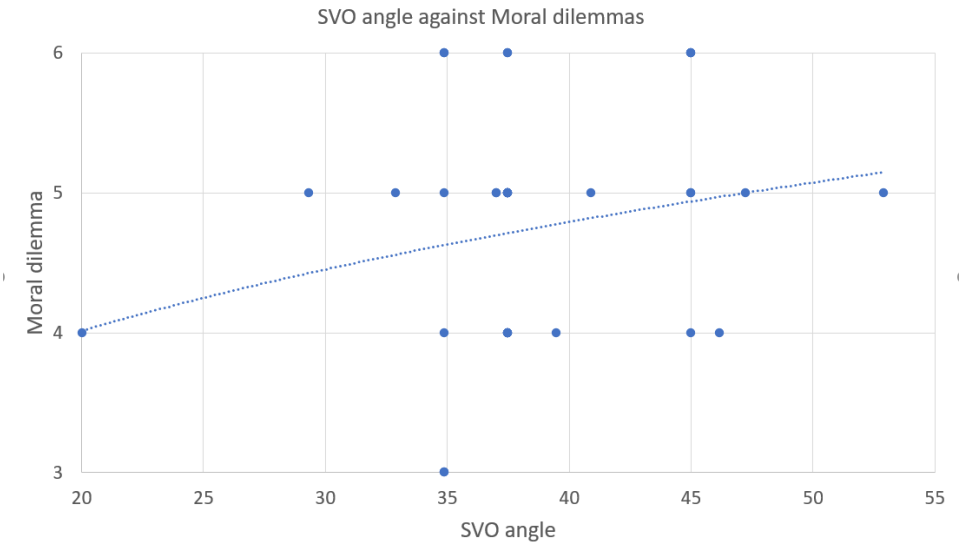


Figure 10: Moral dilemma against SVO angle with trendline

bomb while getting instructions from a other participant outside of the VR. As mentioned before, the VR game was able to induce stress in the participants and subquestions 1 has been answered by the confirmation that VR is able to induce stress with the right VR environment.

The usage of "Keep Talking and Nobody Explodes" has shown possibilities in research with pairs. In this research, the behavior of the participant was not the focus during the experiment. However, the interaction between the participants showed patterns during communication. The pairs that completed the level were often groups with a calm composure during the VR. Most pairs showed signs of stress during the VR, as communication got louder and more frantic. The VR game has potential to be used for research regarding cooperation between two individuals and the behavior between them. It shows problem solving skills and the communication style between the participants.

5.2 Practical Relevance

The main research question can be answered by the result that the response to moral dilemmas is not influenced by VR game induced stress. With this result, the option opens up to let people practice making decisions in a VR environment. Experience and frequent exposure to stress has been proven to help in making decisions (Van den Bos et al., 2009). By placing people in situations in which they have to make moral decisions, they can prepare themselves for future situations.

In the research was found that personality did have a significant influence on the response to moral dilemmas. Participants who leaned more towards the competitive personality type, made less pro-social decisions to participants who leaned more towards the altruistic personality type. For work that involves caring many different people, it could prove to help if a more altruistic person is placed in that position compared to a more competitive type. While a competitive person is more capable of making choices that benefit a business.

For the VR, this creates new possible ways of using VR in laboratory studies regarding stress. VR has already been used by researchers as a relaxation method (Zimmer et al., 2019), but with the results of this research new ways of inducing stress can be explored.

Customized situations for different types of research can be created. For example, when exposure therapy is used for people with anxiety, they can be placed in a situation which triggers their anxiety.

With "Keep Talking and Nobody Explodes" a new method was found to induce stress while creating a task which was done in duos. The interaction between the two participants is an interesting dynamic that was not further explored in this research. But it provides an option to study the behaviour of people in a stressful environment while they are working together with someone else.

From the results it is shown that relaxation for 10 minutes proves to be a viable way of decreasing someone's stress level. With the increased pressure of everyday life, taking 10 minutes after a stressfull event is useful in quickly relaxing someone and mitigating any harmful effects the stress could have.

5.3 Limitations

A few limitations of this study are discussed in this section. First, the internal validity of this research is discussed in section 5.3.1. Secondly, the used participant sample is discussed in section 5.3.2. Thirdly, the used dilemmas will be discussed in section 5.3.3. Afterwards, section 5.3.4 explain the issues and problems with the Empatica E4 wristbands. And lastly, section 5.3.5 the effects of COVID-19 on this experiment will be considered.

5.3.1 Internal Validity

One major limitation of this research is the internal validity during the experiment. For the *STAI score* and *Dilemma score*, a baseline was not obtained to compare to. The *STAI score* could not have been influenced by the VR, which would let subquestion 1 unanswered. The physiological data does confirm that the stress levels of the participants were increased, from which can be assumed that *STAI score* would also have been influenced. For a more conclusive result, the *STAI score* should have also been administered at the start of the experiment to observe the impact of the VR.

This also shows in the result of the *Dilemma score*. The *Dilemma score* of the participants did not have a baseline before the induction of stress, which leads to inconclusive results for the effect of stress on *Dilemma score*. Only the effects between the two group can be observed, which showed no significant influence of stress on moral judgement. Three moral dilemma questions were also discarded in the analysis as they showed similar results for all participants, this reduced the data set on which the analysis was based on. A second set of moral dilemmas as a baseline would increase the internal validity of the *Dilemma score*. The impact of stress can then be observed by comparing the two sets and a larger data set could be used.

The effect of the relaxation can also not be completely determined in this research. The control group filled in the survey right after the end of the VR, while the test group started their 10 minutes of relaxation. From the physiological data a clear decrease of stress levels for the test group could be observed. A baseline was measured at the start of the experiment, but without internal validation of the actual impact of the relaxation on stress no conclusive results can be given.

5.3.2 Participants

This research was done at TOPdesk in Delft. All the participants were gathered from this company by requesting for there help with this research by email; This influenced

the sample size of the participants regarding personality type. Because only people were used from the same company, a very homogeneous sample size was obtained as often people within the same company often have the same way of working together. As was clear from the SVO slider, almost everyone leaned more towards the "prosocial"-personality type. And by asking for there help, only people who were willing to help the research were included. It was to be expected that the participants were more "pro-social". Even with the sample size, a significant difference was shown between the different participants based on their personality type. With a more broader group, a clearer distinction between the personality type can be made.

5.3.3 Dilemmas

The dilemmas used were provided by Greene et al. (2001). From a set of 27 questions, 9 questions were chosen and edited to be more relatable to the participants (appendix D). Because only 9 questions were chosen, there were not many differences in most answers for the participants. Question 1,2 and 9 were the same for all participants, which reduced the amount of data we could use for the analysis. A broader amount of dilemmas could improve the validity of the answers and create more distinction between the results, which would lead to a more conclusive results.

5.3.4 Empatica E4 Wristbands

One of the main issues with the Empatica E4 wristbands is that it has difficulty creating clear readings when movement is involved (Schuurmans et al., 2020). When the users are moving their arms, it creates artifacts in the data where the data is slightly distorted. The participants that were using the VR, moved there arms to look around the bomb and click/move objects on the bomb. Peaks and drops could be seen within the data which indicated that the participant moved. The data from the participants that did not use the VR equipment had less distorted area's, but still points in the data with random artifacts.

This was also the case for the EDA readings, which were lower than what was expected. Normal readings for humans are values between $1 - 20\mu S$, while our data mostly ranged between $0 - 1\mu S$ (see figure 8). Only one person had a EDA that was higher than $10\mu S$, which was the outlier of the EDA data. Two different wristbands were used for both participants and both wristbands saw similar issues with reading the EDA-values. Zero-values in the data were a common occurrence, which sometimes spanned seconds of data. The participants were particularly instructed to make sure the contact points of the EDA-sensor touched their skin, but that was not the solution for this problem. Movement could be a possible explanation for these occurrences, but no evidence of this was found in the data. In figure 11 a plot of participant C5-01's EDA is shown. Volatile peaks can be seen throughout the whole plot, which indicates that stable readings are difficult to obtain. To counter this, a moving average was done over the whole duration to smooth out the data.

5.3.5 COVID-19

This research was done during the COVID-19-era, which meant that there were restriction in how the research was performed. The biggest restriction was the availability of people. Most people were still working from home and were only once per week (or less) at the office. This limited the amount of people willing to help as time spend at the office was often used for meetings or work tasks, which resulted in limited time available for the experiment. Even though enough people participated for the research, a greater

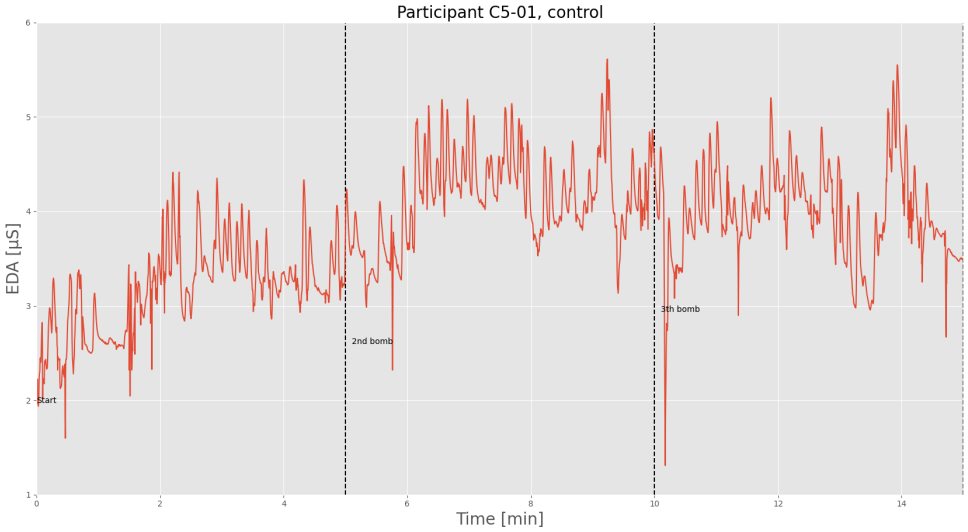


Figure 11: Plot of EDA, participant C5-01

group of people would have made the results more accurate. In a few cases, there were huge outliers (control group participant 8-01 for EDA or control group participant 7-01 for SVO Slider) which greatly impacted the results of this research. More people would mean the error margin would be less and more accurate conclusion could be made based on the results.

COVID-19 has also been shown as a major influence on the stress levels of people (Husky et al., 2020; Kujawa et al., 2020). The continues uncertainty and feel of danger has a permanent effect on the stress level (Taylor et al., 2020). In this research the impact of COVID-19 was not measured. Without a baseline reading for stress with *STAI score* the starting point for stress was not found. This could have impacted the results of the influence of stress on moral dilemmas.

5.4 Future Work

In future research, the lack of internal validity has to improve to improve on the conclusions. By measuring a baseline reading for both the *STAI* and the *Dilemma score*, a more conclusive analysis could be obtained. The *STAI* could be improved by filling in the test before the VR, this way the influence of the VR on stress level can be observed. The *Dilemma score* can also be twice during the experiment. By using more moral dilemmas provided by Green et al. (Greene et al., 2001), the effect of stress on moral dilemma judgement can be analysed. A broader set of moral dilemmas for each measurement point would also help in creating a more distinctive result.

Further research in VR is important in improving research regarding stress, as research has already shown that VR can be a useful tool in coping with stress (Rothbaum et al., 2001) and inducing of stress (Navarrete et al., 2012). The possibility of customizing virtual environments for specific purposes create new theories that can be observed. VR can place people in specific situations for their own needs. Exposure theory is a interesting possibility as it makes it easier for people to face their specific fears (Annerstedt et al., 2013). Due to the virtual nature of VR, it is also possible to conduct experiments with groups of people which are not in the same physical location. Group studies

in which participants are placed together are possible with VR and specifically during the COVID-19 times where group studies are difficult to conduct. Limitations that are created by outside factors can be overcome when VR is used.

The results from the choice in moral dilemmas in this research was found to be not influenced by stress. However, this was noted with different reasons as to why this results occurred. The limited variety in sample size and the specific questions asked could have an influence in the outcome of this research. In future research, more emphasise on the social decision making itself could prove to be more accurate in the analyses of the impact of stress.

Personality type did show a significant influence on the moral dilemma judgement. Participants were more pro-social when they leaned more towards altruism, which was confirmed in literature (Byrne et al., 2015). In future research, a closer look can be given to the different personality types and in what way each is impacted by stress. In this study, we only observed a sample size which was quite homogeneous. The impact of stress on their moral decision making did not influence their decision making, but it could have for other personality types. More extensive research, in which more personality types can be observed, can help in determining in what way each personality type differs more from eachother and if there are ways to help them cope with stress if necessary.

The interaction between the participants in "Keep Talking and Nobody Explodes" is also an interesting topic to be researched. The communication and cooperation between the two participant has not extensively been studied in this research, but patterns in different groups have been observed. With the knowledge of personality type, differences between personality types and the interaction between the participants can be studied to improve the understanding of how people interact and communicate with someone else. For future studies, the VR game can be used as a method to create an interaction between two participants in a stressful environment.

6 Conclusion

In this research the influence of VR game induced stress on the responses of moral dilemmas was investigated. This was done to investigate working with VR in the field of psychology, as VR has not been widely used yet.

An experiment was conducted to place participants in a stressful VR environment. 36 participants working at TOPdesk Delft were randomly separated in two groups and pairs were made. The participants were given Empatica E4 wristband to measure their physiological data (HR, HRV, EDA and temperature) during the experiment. Each pair played the VR game "Keep Talking and Nobody Explodes" in which the participants had to work together in order to dismantle a bomb. Three levels were done and between each level the timestamp was tagged for the analysis. When the VR game finished, the test group was instructed to conduct 10 minutes of relaxation by listening to nature sounds and coloring a drawing. After which they started filling in the survey for evaluation their stress levels, personality type with Social Value Orientation sliders and moral dilemma questions.

It was found that VR game induced stress did not influence moral dilemma judgement in a significant way. From the physiological data it can be observed that the participants increased their stress levels during the VR. From the data of HR, HRV and EDA a clear increase in stress levels could be measured from the beginning of the VR game until the end of the game, but no influence on responses to moral dilemma was found. *STAI score* was higher for the control group compared to the test group who took the relaxation step. Although, the internal validity cannot be completely accepted, it is a significant difference between the two groups. Personality type did show a significant influence on moral dilemma judgement. It was confirmed that a more individualistic personality type lead to less pro social choices.

Even though it was found that stress did not influence the responses to moral dilemmas of our participants, research regarding moral dilemmas and stress are still worthwhile to conduct. Due to the many variables that influence the way choices are made, approaching this intricate problem from different angles might create different results. As decision making is one of the pillars of ones life, it is important to understand how it works and create solutions when people struggle to make decisions. By reducing the overall stress level in people or relaxing them for even a short time, they can improve their lives. Especially during these times, were everyone feels the constant pressure of performing well, meeting social standards, living in fear of COVID-19 or other external factors they have no control over. Mediating these factors and gaining an understanding of how stress influences our decision making could improve the lives of people who struggle under stress.

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A STAI

How are you feeling?

These next few questions will be about your current state of mind. A statement will be given, and you have to indicate as closely as you feel. There are no wrong or right answers. Try to answer them as honest as possible.

	Not at all	Somewhat	Moderately so	Very much so
I feel calm	○	○	○	○
I feel secure	○	○	○	○
I am tense	○	○	○	○
I feel strained	○	○	○	○
I feel at ease	○	○	○	○
I feel upset	○	○	○	○
I am presently worried over possible misfortunes	○	○	○	○
I feel satisfied	○	○	○	○
I feel frightened	○	○	○	○
I feel comfortable	○	○	○	○
I feel self-confident	○	○	○	○
I feel nervous	○	○	○	○
I am jittery	○	○	○	○
I feel indecisive	○	○	○	○
I am relaxed	○	○	○	○
I feel content	○	○	○	○
I feel worried	○	○	○	○
I feel confused	○	○	○	○
I feel steady	○	○	○	○
I feel pleasent	○	○	○	○

Figure 12: STAI questions asked to the participants

B SVO

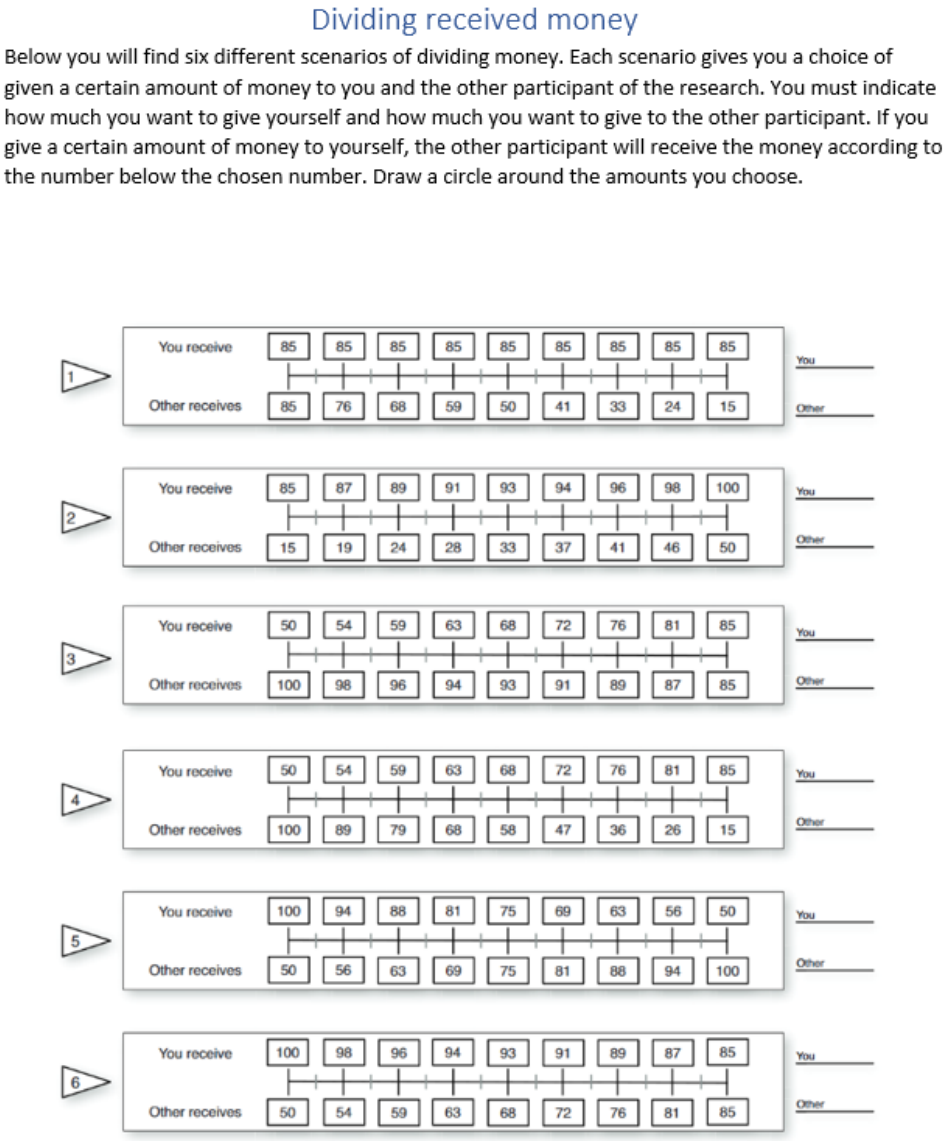

Figure 13: SVO Slider questions asked to the participants

C Drawing

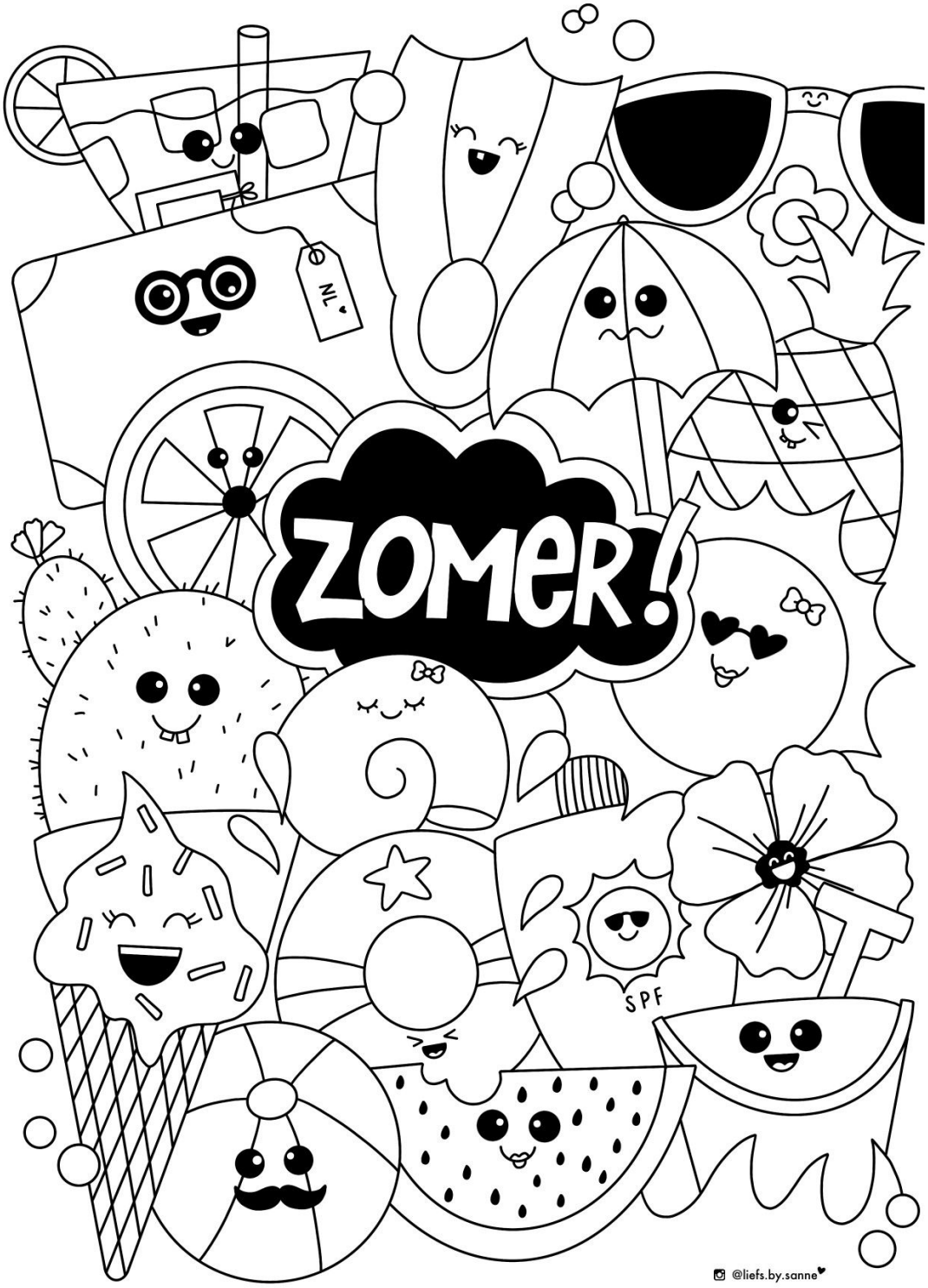

Figure 14: Drawing participant had to color in

D Dilemmas

The non-moral are dilemmas which do not have any morality involved:

1. During a hot day in the office, there are two available spots to work at. The first spot has an airconditioner next to it. While the other spot does not have a airconditioner next to it.

   Is it appropriate for you to take the spot with the airconditioner?

2. Two customers call for an appointment next Monday. There is an open spot at 10.00 and one at 13.00. Customer A is rather flexible and is free all day. Customer B has a tight schedule and only has room between 12.00-14.00.

   Is it appropriate to schedule customer B at 13.00 and customer A at 10.00 to fit them both in on Monday?

3. You intend to accomplish two things this afternoon: going for a long walk and doing some paperwork. In general you prefer to get your work done before your walk.

   The weather is nice at the moment, but the weather forecast says that in a couple of hours it will start to rain. You very much dislike walking in the rain, but you don't care what the weather is like while you do paperwork.

   Is it appropriate for you to do your walk now with the intention of doing your paperwork in a couple of hours?

The impersonal dilemmas show a dilemma in which you do personally have an influence in, but indirectly can change the outcome of the problem:

1. You are working in the office and just grabbed a cup of coffee. While you are making the coffee you see that there are no more beans left in the coffee, but there is just enough for your cup.

   Do you take the time to fill up the machines with new beans?

2. You are working on a solution for a specific problem in TOPdesk. Four customers have this problem and are unable to work efficiënt. With this solution only three customers will be helped. For the other customer, the problem would only become worse.

   Is it okay to implement this solution in order to help the three customers while the one customer will have more problems?

3. You are the owner of a small business trying to make ends meet. It occurs to you that you could lower your taxes by pretending that some of your personal expenses are business expenses.

   For example, you could pretend that the stereo in your bedroom is being used in the lounge at the office, or that your dinners out with your wife are dinners with clients.

   Is it appropriate for you to pretend that certain personal expenses are business expenses in order to lower your taxes

Personal dilemmas are dilemmas in which you directly can influence the outcome of the problem, you are personally responsible for the outcome:

1. You are talking on the phone to a big customer when a topic comes up that is a big frustration for the customer. He starts an enormous rant about what is wrong and what TOPdesk needs to be better.

   Eventually the customer starts to scream a little and it feel like a personal attack on you about what is going from for them.

   Is it appropriate for you to just hang up the phone?

2. You are a team lead of a group of 6 people. 5 of those people have some financial problems and really need this job to not be in financial trouble. They are not the best employees, but are doing decent. The sixth person is financially healthy and is the hardest worker in the company.

   Due to COVID-19, the company is in trouble and budget cuts needs to be made. One person has to be fired to make sure the company does not go bankrupt.

   Is it appropriate to fire the sixth employee to help the other 5 financially?

3. You are sitting alone after office hours after work, when you made a grave mistake while working and the consequence will be that millions of euro's will be lost by TOPdesk. If someone finds out that you did it, then you will be fired and legal steps will be taken.

   The only way to erase your tracks is to go to the server room and shut down everything and delete the backups to cover your tracks. If you shut down the server, every customer will have a downtime of three days. No one will ever know that you were the one that shut down the server.

   Would you shut down the server to save yourself from the consequences?