The painful awareness of death: Influence of thoughts of death on behavioural and cerebral activity associated with painful nociceptive stimuli

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Declaration and COVID-19 impact statement

I declare that this thesis (titled: The painful awareness of death: Influence of thoughts of death on behavioural and cerebral activity associated with painful nociceptive stimuli) is my own work, unless it is stated otherwise. The first half of Study 1 (Section 5.2) as well as Study 2 (Section 6, without the somatosensory-evoked potentials) have been submitted for publication to Journal Psychophysiology (Gyimes IL & Valentini E, 2021, *The modulatory role of individual differences in personality on mortality salience: effects on pain perception and somatosensory related brain activity* and *Mindfulness in the face of death: as a buffer of mortality salience effects on pain perception and somatosensory related brain activity* respectively, in review) at the time of the submission of this thesis. All quotations are distinguished by quotation marks and all sources are cited according to the APA guidelines.

The University of Essex took steps in response to the then growing COVID-19 threat on March 13th, 2020. The requirement of remote working and banning of experiments involving facer-to-face participation in laboratory setting were among some of the changes that impacted me the most. Specifically, I could not increase the number of participants for the second study, which forced me to redesign it the statistical methodology and compare non-practitioners to meditation practitioners instead of comparing novice against expert meditation practitioners. While the new design allowed us to submit our results for publication, months' worth of analysis have been discarded forcing me to restart analysing and writing up Study 2.

In summary, COVID-19 is not only a great health safety risk, but a disruptor of our life. The change of working from home, the constant uncertainty and the inability of collecting additional data significantly affected our research. However, we were able to create valuable analysis from the data we collected and a solid contribution to the field of psychophysiology.

Submitted by: Istvan Laszlo Gyimes

Signature of the Candidate:

Date: 27 July 2021

Acknowledgements

In the following thesis, I will present the results of the past four years. However, before we dive into the long discussions and complex statistical tests, I would like to thank all who helped me completing this work.

First of all, I would like to thank the invaluable help of my supervisor, mentor and friend, Elia Valentini. He helped me pursue my dream in academic research by being an example as well as a guide. I cannot thank you enough for your teachings and support.

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3 General abstract

Terror Management Theory (TMT) attempts to explain how the awareness of mortality affects people. There has been a large volume of research investigating the changes of human behaviour triggered by awareness of mortality. However, much less is known about the underlying neural processes of these defensive behavioural changes. In this thesis, I will present two novel studies expanding on previous methodologies in order to investigate two types of potential moderators for the effects of death anxiety: Study 1 investigated the moderating roles of seven personality traits which were previously linked to the framework of Terror Management Theory. Study 2 explores the buffering effects of meditation techniques against death anxiety. We applied threatening somatosensory stimuli to investigate the effects of reminders of mortality on pain perception and on somatosensory brain responses. We also implemented linear mixed-effects modelling of the data. Mixed-effects models are better at tackling emblematic issues of electroencephalography (EEG) data, such as wide within-subject variability and unequal group sizes, than analyses of variance or t-tests. As such, we are presenting a more robust and appropriate method for analysing EEG and behavioural data.

We showed significant predictive ability of anxiety and depression trait scores on the effectiveness of reminders of mortality. Anxiety and depression scores predicted the efficiency of reminders of mortality both on behaviour and brain responses. Furthermore, we showcase the buffering effect of meditation practice against death anxiety. Thus, our results lay out groundwork for a) potential development of new analysis methods for neural data, b) the importance of personality trait measurements for studies using mind-set manipulation and c) the potential of practice in relaxation techniques in buffering death anxiety.

4 Literature Review

"No one knows when that day or hour will come —not the angels in heaven, nor the Son, but only the Father," Matthew 24:36

4.1 Introduction

Awareness of mortality is a side product of human awareness. Zygmunt Bauman (p12, 1992) stated that humans "[we] not only know, we know that we know. We are aware of being aware". We have numerous examples in cultural and religious history of humans incline that not only were we aware of our own inevitable death, but whole philosophies were created to deal with its looming presence. In Europe, the sentence "*Memento mori"* (Remember that you have to die) was frequently carved in gravestones during the medieval ages. This sentence and the whole literature behind it (i.e. Ars Moriendi) indicates the human awareness of death and mortality (Taylor, 1651).

Figure 4-1. The Dance of Death (1493) by Michael Wolgemut from the Nuremberg Chronicle.
Image url: https://www.1st-art-gallery.com/frame-preview/10356166.jpg?sku=Unframed&thumb=0&huge=1

The notion of mortality awareness was present not only in Europe's Christian beliefs but in other religions such as Buddhism, Islam, the belief system of the Bushido (the way of the samurai), to mention only a few ("The Book of Miscellany"; Tsunetomo & Scott, 2002; Rinpoche, 2003). Thus, we can see that humans are aware of their mortality and that it is a cardinal point of their worldview. However, it begs the question how people deal with this "Sword of Damocles" above their head. In this thesis, I will review our current understanding about the effect of death cognition and anxiety on the human behaviour and brain activity (Section 4) and present two original studies that addressed unanswered questions in the field (Sections 5 & 6), and then I will provide a discussion of these findings and attempt to integrate them into the literature (Section 7).

Figure 4-2. Triptych of Takiyasha the Witch and the Skeleton Spectre, c. 1844, Utagawa Kuniyoshi (1797–1861), V&A Museum no. E.1333:1 to 3-1922
Image url:
https://upload.wikimedia.org/wikipedia/commons/1/1a/Takiyasha_the_Witch_and_the_Skeleton_Spectre.jpg

4.1.1 Awareness of mortality

During its evolutionary journey, humanity developed several cognitive traits for survival. One of these traits is abstract thinking and the subsequent ability to predict future events based on past experience. Thus, it is unavoidable that humans realised their own mortality (Pyszczynski et al., 2015). As all living creatures strive to live, this knowledge is thought to cause cognitive dissonance and/or constant anxiety in humans. And yet, humans live their life mostly without being hindered by this anxiety or dissonance.

Numerous hypotheses were made to explain the lack of the conscious experience of constant death-anxiety. Bauman, among others, suggested that culture itself is a form of defence against the horror of death (Higo, 2012), the greatest fear of our species (Bauman, 1992). Freud believed that humans' substitutive formation merely helped to suppress this death-anxiety (Higo, 2012). Heidegger (1962) suggested that humans have two modes of existence: One is the so-called "forgetfulness" of being when a person merely lives and does their everyday duties unaware of the authorship they have of their life. The other is the so-called "mindfulness" of being when the observer is aware of everything around them as well as the end goal of their limited life, or more precisely they are aware of their existence with its limits (Woodgate et al., 2014). Heidegger assumed that certain urgent experiences or stimuli can bring a person to their "mindfulness" state.

Ernest Becker in 1973 wrote a book called "*The Denial of Death*" where he articulates his ideas about how humanity protects itself through cultural elements and symbolic interpretations against the constant fear of death. Becker takes his idea one step further to show that all our survival mechanisms, including emotional and intellectual as well as behavioural, can be traced back to this basic fear. He suggested that the basic dualism in humans (the physical and symbolic meaning of self) plays an important role in defending the mind from the fear of death. Becker suggested that humans created a “symbolic self” which is an ideal human. This symbolic self can have many aspects such as fearlessness, braveness, selflessness etc. This “symbolic self” can be immortalized through the religious or the cultural ideas.

The common denominator in all these theories is the presence of mental defence mechanisms. We can see that humans do not usually think about their mortality on a daily basis (Heidegger’s “forgetful” state). However, as certain impulses toss humans into the “mindfulness” state, other defences start to act. Culture offers a quasi-immortal image of the self, defined as the “symbolic self”. The idea of how this immortalisation works varies between theories. The term “symbolic self” is broad enough to include cultural ideals, religious beliefs, personal achievements and many other potential ways to immortalise a human existence. Cultural ideas or worldviews define an ideal person which the individuals try to become similar. Religious beliefs assure humans that death is merely a stage in their life and beyond it waits happiness and life forever. Personal achievements like writing a book, building a monument can immortalise one’s name, hence they live on in other’s memory. The easiest way to grasp this concept is the simplified version of Irvin D. Yalom’s (1989) passage about death in *Love’s Executioner and Other Tales of Psychotherapy* simplified and rephrased by Bansky: *“They say you die twice. Once when you stop breathing and the second, a bit later on, when somebody mentions your name for the last time”.*

Thus, humans create a “symbolic self” by attuning to one of the many ideals to quasi-immortalise themselves (Becker, 1973; Routledge et al., 2010).

4.2 Terror management theory

Sparked by the work of Ernest Becker (1973) three social psychologists, Jeff Greenberg, Sheldon Solomon and Tom Pyszczynski created Terror Management Theory (TMT) (Greenberg et al., 1986; Solomon et al., 1991). Originally, the aim of the theory was to offer an explanation to why self-esteem is important, why people are so adamant to stick to their own worldviews and why cultures divide humanity so strongly (Pyszczynski et al., 2015). As self-esteem had such cardinal role in the creation of TMT, I will explain the concept in depth linking it to the foundational tenants of the theory. However, TMT quickly grew out the concept of self-esteem opening a path to explain a complex, multilevel defence system humanity developed against existential-threat. Hence, after discussing the core hypotheses of TMT and the recent criticisms of it, I will also talk about the effects of several other personality traits which were subsequently linked to the defence mechanisms. Finally, I will discuss how meditation practice relates to these personality traits, presenting itself as a potential buffer against existential threat.

4.2.1 Self-esteem in the context of TMT

In order to understand the core tenants and conclusions of TMT, self-esteem has to be defined. The concept "self-esteem" became trivialised due to its vague and broad meaning (Orth & Robins, 2014). Self-esteem is defined as a subjective evaluation of one's worth (Orth & Robins, 2014). It is crucial to establish that self-esteem is a subjective and not objective measurement of someone's talents, abilities, achievements and failures. Furthermore, it is important to understand that high self-esteem does not necessarily predict egoism or superiority beliefs (Baumeister et al., 1996; Orth & Robins, 2014). Thus self-esteem shall not be confused by self-regard or self-aggrandisement (Ackerman et al., 2011). As self-esteem measures one’s subjective worth, it can be assumed to be linked to our cultural ideas (Pyszczynski et al., 2015). Despite its inherent subjectivity, self-esteem proved to be a reliable and useful measurement. Studies showed that self-esteem correlates negatively with anxiety (McFarland & Ross, 1982; Greenberg et al., 1986; Burish & Kent Houston, 2006). Moreover, correlation between self-esteem and psychological well-being and physical health in times of stress had already been suggested (Sedikides, 1993). People with higher or already elevated self-esteem show no reactions for reminders of death (Harmon-Jones et al., 1997). Studies done on this topic using implicit measurements of self-esteem (Schmeichel & Vohs, 2009) showed that increased implicit self-esteem reduced the defence of one's own beliefs. On the contrary, individuals with originally high implicit self-esteem may experience an elevation of their defences of their world views as a kind of promotion focus (McGregor et al., 2007).

By integrating self-esteem as a need in connection to the cultural ideas, TMT was able to give an answer of why humans need self-esteem in the first place. As mentioned above, human’s cognitive ability, which distinguishes us from animals, and instincts would clash over the fact that death is inevitable. While, as all animals, we strive to survive, our kind knows that death is only a question of ‘when’ not ‘if’. TMT builds on the idea that we create *literal immortality* (e.g. afterlife) or *symbolic immortality* (e.g. achievements) to avoid existential anxiety (Pyszczynski et al., 2015).

4.2.2 The core hypotheses of TMT

TMT incorporates three core hypotheses: the anxiety-buffer hypothesis, the mortality salience hypothesis and the death thought accessibility hypothesis (Pyszczynski et al., 2015). The anxiety-buffer hypothesis explains that self-esteem acts as a defence system against anxiety, and higher self-esteem predicts lower increase in anxiety caused by thoughts of death (Greenberg et al., 1993, 2003).

These thoughts and reminders were named as mortality salience (MS) in the second hypothesis. MS are reminders that cause the changes measured after reminders of mortality (increased defence of one's own worldview (Castano et al., 2002; Niemiec et al., 2010), increased need for self-esteem (Pyszczynski et al., 2015), close attachment (Mikulincer & Florian, 2000; Mikulincer et al., 2003), increased ingroup-outgroup preferences (Castano et al., 2002; Henry et al., 2010)). MS is the event described by Heidegger (1962) that drags us out from the usual "forgetful" state into a "mindfulness" state and directs our attention towards mortality and death in general. Mortality salience affects a person's desires for fame (Greenberg et al., 2010) and for a more self-esteem boosting type of romantic partners (Kosloff et al., 2010). These findings supported the importance of self-esteem in the context of mortality.

The third hypothesis states that any threat to these described defences and buffer systems increase the accessibility of death-related thoughts (Pyszczynski et al., 2015). Humans have a selective attention for death-related information (Hayes et al., 2008). The shorter latency for recognition of death-related words was not observed in other negative or neutral words. Death thought accessibility (DTA) investigations found a positive correlation between DTA and self-esteem, worldview defence and wish for close attachments (Greenberg et al., 1994). DTA and MS were eventually integrated into TMT as their effects were explained by it (Pyszczynski et al., 2015).

TMT strives to offer an explanation to the question of why we are not experiencing a constant existential-anxiety. The theory assumes the existence of a buffer system that counteracts this threat. However, the buffer system against existential threat is not a simple theoretical device. Researchers found an important operational issue with TMT during its early stages. If there was time passing by between the MS manipulation (i.e. reminders of death) and measurements, the expected changes were replicated, however, when the measurements were taken immediately after the MS induction then there was no change (Greenberg et al., 1994; Pyszczynski et al., 2015). The introduction of delay suggested there were two processes at stake, proximal and distal defence respectively. This interpretation was labelled dual-defence mechanism (Pyszczynski et al., 2015). Proximal defences occur right after MS introduction and, unlike the general theory would suggest, it deals with the threat itself directly. Proximal defences tilt the decisions towards more self-protective behaviours, and try to remove the idea of death from the focus of attention by denying or ignoring it (Wegner, 1994). However, proximal defences do not negate the anxiety rooted in the inevitability of death. On the contrary, distal defences work more similarly to the original TMT theory. They strengthen one's belief in their worldview even if that goes against self-protection. An experiment done on people's preferences in sunscreens provided supporting evidence. People tend to choose higher factor sunscreens immediately after MS introduction, but lower factor ones if time has passed (Routledge et al., 2004). As the main goal of the proximal defences is to remove the idea of mortality from the focus of the attention, the question arises if it is possible to bypass the proximal defences and trigger only the distal ones. The only two ways described so far that can elude the proximal defences are the subliminal reminders of death (e.g. the word 'death' presented very quickly) and when there is high cognitive load during MS introduction (i.e. during a task with high demand of cognitive processing power; Harmon-Jones et al., 1997; Arndt et al., 1997).

4.2.3 Criticisms of TMT

While TMT is considered the dominant theory in the field of existential threat research, it is not without criticism. It has been questioned whether the idea of death is the core reason for the changes experienced in TMT replication or if other, related factors are involved (e.g. non-death reminders, that can logically lead to the idea of death, like violence; differences in anxiety created by the reminders; differences in negativity between the reminders) (Pyszczynski et al., 2006). Advocates of TMT defended these claims by pointing out that certain scenarios can lead one's thoughts towards death and mortality. It is important to point out that the control condition is just as important as the experimental one. Several studies used neutral priming (for example the idea of watching TV) in control of MS (Schindler & Reinhard, 2015), while others use negative controls (for example, the idea of dental pain or exam failure) to assure that the difference is not caused by the difference in valence between the conditions (Pyszczynski et al., 2006; Henry et al., 2010; Valentini et al., 2014; Valentini & Gyimes, 2018). However, it is also important to remember that activating the anxiety-buffer system can cause increased DTA. Thus, a very negative mind-set potentially may trigger similar responses to the MS.

McGregor et al., (2001) pointed out that the reason we fear death is not defined, hence the effects can be caused by other factors such as fear of uncertainty or fear of nonexistence. Others pointed out that there is a difference between fear of death, fear of dying and fear of the unknown (Carleton, 2016a). Nevertheless, TMT theorists argue that uncertainty is present in our everyday life without being frightening. TMT critics pointed out that only uncertainties which have sufficient contextual certainty are not frightening (Carleton, 2016a, 2016b). Evolutionary psychologists also criticised TMT for depicting constant death anxiety as an existential threat as anxiety and fear are a necessary product of evolution, thus they cannot hinder the creature (Landau et al., 2007). TMT scholars agreed that fear is a useful evolutionary trait, however, they pointed out that animal and human behaviour shows clear avoidance of fear in adaptive and non-adaptive ways (Pyszczynski et al., 2015). Thus, they argued in defence of TMT that fear management is important in terms of evolutionary traits to limit non-adaptive fear responses (e.g. consumption of psychotropic substances and freeze in response to threat, among others) (Pyszczynski et al., 2015).

Recently, a substantial amount of studies failed to replicate previous findings within psychological sciences (Open Science Collaboration, 2015). Among others, TMT was also involved in this replication crisis. Specifically, the Many Labs 4 project failed to replicate the effects measured by previous TMT studies (Klein et al., 2019). The project investigated whether the involvement of original authors affected the replicability of TMT. For this purpose Klein et al. (2019) conducted a large scale data collection and meta-analysis of the data collected by several groups in the project. The project attempted to replicate the findings of Greenberg et al. (1994), specifically the induced worldview defence after reminders of death. Similarly to the original study (Greenberg et al., 1994), the Many Labs 4 project asked participants to evaluate pro- and anti-American essay authors (Klein et al., 2019). While Klein et al. (2019) reported failure of replication, they did not address it as a reason to disregard TMT. As Klein et al. (2019) pointed out, replication failure could be due the difference between political climate in the US when TMT was originally tested (1980's, 1990's) versus when the Many Labs 4 testing happened (2016 – 2017). In response to this research project, an article was published by Chatard et al. (2020) claiming that the reason for the replication failure is not an issue with TMT. In their criticism, Chatard et al. (2020) pointed out that the pre-registered Many Labs 4 project did not deliver on the statistical power promised in their pre-registration. After excluding the labs with smaller than 80 subjects (40 per groups) and the labs which did not follow the advice of the original authors on the methodology, they reported significant findings (Chatard et al., 2020). However, it is worth pointing out that Many Labs 4 were attempting to replicate a key study of TMT where the sample size was 58 divided into 5 experimental groups (Greenberg et al., 1994). Thus questioning the validity of the claim that lower than 40 people per experimental group cannot provide valid results in the field of TMT. Particularly, as in the study by Greenberg et al. (1994), a hallmark TMT study, found significant results/effects with a sample number far below 40 (Study 1 had an average (± standard deviation) group size of 11.800 (±0.400); Study 2 had an average group size of 12.857 (±0.990); Study 3 had an average group size of 11.800 (±0.748)). More importantly, the criticism did not address one of the main question of the Many Labs 4 project, namely if TMT can only be replicated by the involvement of the original authors. While the effects of MS are said to be robust and even the simple presentation of the word 'death' should act as MS (Pyszczynski et al., 2015), failures to replicate the findings question the uniqueness of death anxiety (Klein et al., 2019). As the debate is still ongoing, further experiments and replications are crucial to reinforce, modify, or challenge TMT.

4.2.4 The role of personality in TMT research

The role of personality traits as potential buffers against the effects of MS is a vital part of Study 1 (Section 5). For example, the aforementioned self-esteem has been classified as a cornerstone of TMT research (see Pyszczynski et al., 2015 for a review, and Section 4.2.1). However, there are other personality traits linked to MS. Trait anxiety and depression are particularly pertinent to TMT (Greenberg et al., 2003; Maxfield et al., 2014; Menzies et al., 2021).

Anxiety is defined as "*anticipation of future threat*" (Crocq, 2015). It is important to note, that anxiety and fear are distinct constructs. Fear is defined as a response to a specific immediate threat, while anxiety is more future-oriented and less specific (Crocq, 2015). Even though, they sound similar and interconnected, there are significant differences between them even in terms of physiological responses. Fear triggers active defensive responses, which quickly disappears when the imminent threat is gone. Anxiety on the other hand, elicits elevated arousal and vigilance (Davis et al., 2010). As such, anxiety is noted as an evolutionary benefit, as such elevated vigilance and arousal increases the chance of survival (Landau et al., 2007). There is intuitive continuity between the construct of anxiety and fear of death. Mortality is a future threat but crucially is unavoidable. The certainty about its manifestation is coupled with the uncertainty about when it will happen. This combination makes it a perfect cocktail of fear and anxiety.

As anxiety is an anticipation of future threat, it can be classified based on the type of threat. Anxiety related to fear of death is called death anxiety (Iverach et al., 2014). This basic anticipation of mortality has been linked to mortality salience showing that higher levels of death anxiety predicted exacerbated relationship between MS and burnout (Sliter et al., 2014). These results, together with the general understanding that anticipation of mortality is existential anxiety, provide strong justification for linking trait anxiety to MS.

Depression can be linked to MS via its relationship with anxiety. Depression and anxiety are established as opposite effects on the brain, while anxiety predicts neural excitability, depression predicts inhibition (Dobson, 1985; Clark et al., 2009). Depression affects motivation, thoughts, view about life, and more generally one's well-being (de Zwart et al., 2019). A recent work suggested that death anxiety can play an important role in multiple mental disorders, including depression (Menzies et al., 2021). Thus, depression or depressive mood could interact with the idea of mortality and existential threat. Additionally, depression was linked to the salience-network in the brain (Liu et al., 2015). This network in the brain is connected to MS and will be discussed later (Section 4.2.7). As such, there is existing evidence to link depression to MS.

Previous studies pointed out that people are more keen on initiating interactions with others after MS induction (Taubman-Ben-Ari et al., 2002). Taubman-Ben-Ari et al (2002) explained the relationship between close attachment type and TMT from an evolutionary perspective. They explained that close relationship means higher level of safety from an organism (Taubman-Ben-Ari et al., 2002). Other studies found that even the idea of separation from a romantic partner induced an increase in death-though accessibility and increased worldview defensive behaviour (Florian et al., 2002). Thus, as close relationships act as a buffer against distress (Bowlby, 1988), relationships play a major role in dealing with existential anxiety and are linked to MS.

In Study 1 (Section 5), we investigated the interaction between MS and seven personality traits (fear of death, fear of other’s death (in Experiment 1 & 2, Sections 5.2 & 5.3, respectively), anxiety, depression, self-esteem and anxious, close and dependent attachment types). As discussed above, traits such as self-esteem, anxiety, depression and attachment types are already linked with MS. We assumed that measures for fear of death can act as a complimentary measure next to anxiety and depression. By investigating the specific fear of death besides anxiety (which is distinguished from ‘fear’) we aimed to specify the most relevant personality traits for MS. Experiment 1 and 2 (Sections 5.2 & 5.3 respectively) used two different MS types. In Experiment 1 (Section 5.2) we used the mortality reminder described in the original TMT MS manipulation (Pyszczynski et al., 2015). However, we utilised a modified MS for Experiment 2 (Section 5.3), and later for Study 2 (Section 6), which reminded the participant for the mortality of their exclusive romantic partner. This modification was supported by the bulk of research showing the link between intimate relationship and existential anxiety (Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018). In sum, we tested the targeted personality traits as potential predictors for the efficacy of reminders of mortality in two experiments.

4.2.5 Meditation and TMT

Following the previous points, there is a significant link between certain personality traits and existential anxiety. However, it is worth investigating if the relationship between anxiety, fear or depression and MS is bidirectional. To answer this hypothetical question, we should talk about techniques which can influence one's level of anxiety, depression or just general well-being and see if practice in these techniques predicts a buffer against MS. In the following paragraphs, I will present evidence for the buffering effects of meditation practices against existential anxiety.

Meditation and inner focus date back for centuries in Western - and millennia in Eastern - tradition (Sampaio et al., 2017). While there are numerous different schools of meditation, the common theme is the withdrawal of the attention from the outside world to a specific idea (be that bodily sensations or metaphysical concepts; Sampaio et al., 2017). As such, meditation always includes the practice of controlling one's attention.

Meditation seems to play a role in the defence against anxiety from reminders of mortality. For example, studies have attempted to investigate how experience in meditation can buffer out the previously established changes after MS induction (Schultz & Arnau, 2017; Park & Pyszczynski, 2019). The rationale behind testing the moderating effects of meditation in TMT framework is the link between meditation and stress and anxiety reduction (Shapiro et al., 1998; Davidson et al., 2003; Ospina et al., 2007; Niemiec et al., 2010), changes in compassion (Lutz et al., 2008), attention and self-regulation (Brefczynski-Lewis et al., 2007; Tang et al., 2007), control of pain (Bushnell et al., 2013), depression (Shapiro et al., 1998; Bitner et al., 2003), and even between meditation and neural responses and structures (Davidson et al., 2003; Cahn & Polich, 2006; Hauswald et al., 2015). This body of literature provides a background to investigate how meditation can interact with MS. When mortality reminders are expected to induce existential anxiety as per TMT's main tenet, meditation could tackle anxiety even before the evolutionary defences kick in.

In Study 2 (Section 6), we aimed to investigate the buffering effects of meditation practice against reminders of mortality. The rationale behind meditation experience as a buffer for existential threat is twofold. First, previous studies showed that practicing meditation techniques can lead to decreased anxiety, depression, increased psychological well-being (Shapiro et al., 1998; Davidson et al., 2003; Bitner et al., 2003; Ospina et al., 2007; Niemiec et al., 2010), all of which traits are linked to MS (as discussed in Section 4.2.4) (Iverach et al., 2014; Sliter et al., 2014; Liu et al., 2015). Second, meditation expertise is linked with greater pain tolerance, self-awareness attention and self-regulation (Brefczynski-Lewis et al., 2007; Tang et al., 2007; Bushnell et al., 2013). These attributes can explain why previous studies found the effects of MS reduced in meditators (Schultz & Arnau, 2017; Park & Pyszczynski, 2019). In our experiment (Section 6), we aimed to investigate how people who practice meditation are affected differently by reminders of the mortality of their romantic partner.

4.2.6 Psychological and neuroimaging techniques relevant to the study of TMT

Investigating phenomena that overreach multiple areas of science requires a wide variety of techniques. TMT was born in the field of social psychology, using questionnaires and self-report measures. As the theory gained momentum and grew, neuropsychologists and psychophysiologists became interested in the underlying neural mechanisms of TMT. As a result, nowadays investigation of the changes in behaviour and brain activity after reminders of mortality is done by several different tools. In the following Sections, I will lay a background understanding for the most common techniques utilised in TMT research relevant for this thesis, namely self-report questionnaires and electroencephalography. As the main technique used in the studies for this thesis was electroencephalography, I will provide a more detailed explanation on it.

4.2.6.1 Self-report questionnaires

TMT originated from the field of social-psychology, thus the methodological centrality of self-report questionnaires is undeniable. It is a common practice to measure symptoms, behaviours, opinions, orientation and many other aspects of a person via questionnaires. There are different formats of questionnaires, such as Likert scale with ranked options, true/false, visual analogue scale, etc. Questionnaires are being constantly tested and validated to ensure that they are measuring what they are supposed to measure (Alfonsson et al., 2014; Balsamo et al., 2018; Kang & Demiris, 2018; Rose & Rimes, 2018; Speyer et al., 2019). These systematic reviews and re-tests are important, as self-report questionnaires do not have right or wrong answers. While self-report questionnaires have clear advantages, as people answer clear questions, there are several issues as well (Northrup, 1997). It has been suggested that participants may exaggerate responses, or shy away from honest responses (Northrup, 1997). Despite all these issues however, self-report questionnaires are widely used in science. Besides the constant validations, changes and revisions, the way of filling a questionnaire is slowly changing. The pen-and-paper questionnaires are slowly being overtaken by digital form questionnaires (for a systematic review see Alfonsson et al., 2014). In the studies reported in this thesis, we applied several self-report questionnaires to measure personality traits and states relevant for the topic of TMT, in both paper and digital format. I will elaborate on these questionnaires in Section 4.3.3.

4.2.6.2 Electroencephalography

When large numbers of neurons are activated simultaneously, a relatively large field's potential is changing in the brain. To understand this mechanism, one must be aware of how the brain is structured, how neurons are activated and what EEG can pick up from this. The cortex is a layered structure. Each structure is distinct based on the proximity from the *pia mater*, the neuron types within the layer and the positions of those neurons. For example in the first layer we cannot find a large number of neurons and most of them are inhibitory neurons. In the second layer we find a larger number of pyramidal cells. Pyramidal cells are considered to be the main source of signal recorded in the EEG. These cells are oriented at a 90° angle to the *pia mater* and they are present in large numbers. The dendrites of the pyramidal cells in the cortex are directed towards the *pia mater* and the axons are directed away from it. The majority of regulation on these cells are axo-dendritic (from an axon to a dendrite), but there are axo-somatic and axo-axonic regulations as well. Without activation or inhibition a neuron maintains a stable membrane potential. In the intracellular space of the neuron there is a higher amount of negative ions and charged proteins, while the intercellular matrix contains a higher amount of positive ions. This membrane potential (the difference between the two charges) is created by two mechanisms: the famous Na^+/K^+ pump, that pumps 3 Na^+ out of the cell and 2 K^+ inside the cell, and the membrane permeability for the ions defined by the Goldmann-Hodgkin-Katz equation. The latter shows that in a resting state the permeability of the K^+ is close to its balance potential. Thus, the real amount of work is done by membrane permeability and not by the Na^+/K^+ pump.

4.2.6.2.1 Sink-source model

Changes in membrane potential cause ion flow inside and outside of the neuron. Excitation of a neuron results in positive ions entering the intracellular matrix, shifting the intercellular matrix to be more negative. Inhibition causes the cell to take up more negative ions, making the intercellular matrix more positive. As the charge is changing with the movement of the positive ions mostly, the positively charged region is called the *source* while the negatively charged region is the *sink*. Positive ions are coming from the *source* and travelling towards the *sink*. By causing Na^+ flow inside a dendrite, the potential would change locally. The positive ions would move towards the soma where most of the negative ions can be found. If the change did not trigger an action potential, the Na^+ will be pumped out causing additional positive charges on the outside of the soma. The positive ions would move towards the dendrite where their amount had decreased creating a circular flow. When this happens on thousands of cells oriented similarly and in the same spatial angle, the EEG is able to measure the potential changes in the cortex (Lewine & Orrison, 1995). Both the strength and limitations of the EEG are rooted here. EEG can pick up relatively quick responses, unlike functional magnetic resonance imaging (fMRI). Following the logic of the *sink-source* model, EEG is capable of picking up signals on nearly any larger number of neurons as long as they are firing at the same time and positioned in the same spatial orientation. While one electrode cannot measure neural activity from cells that are parallel with the electrode, application of multiple electrodes can solve this issue. Despite certain neurons situating parallel to an electrode, thus their positive and negative poles summing up to zero, another electrode will pick up either the positive or the negative pole's activity of the neuron (Jackson & Bolger, 2014). Consequently, spatial resolution of EEG is relatively poor compared to fMRI as the potentials generated in the cortex are blurred when recorded from the scalp. EEG is a great tool for measuring quick cortical responses, but it is little to no use to understand the activity of deeper regions of the brain. Despite its shortcomings in special resolution, EEG allows us to investigate numerous attributes of cortical activities. In the following Sections (4.2.6.2.2.1 & 4.2.6.2.2.2), I will present the two most important attributes.

4.2.6.2.2 Event-related potentials

Event-related potentials or ERPs are brain potentials caused by an external or internal stimulus (Fabiani et al., 2007). As the brain's certain areas are activated simultaneously a greater change in the local-field potential is caused. These changes are directly related to the neural activity of that area. It is worth noting that the direction of the ERPs is complementary to the neural activity. When neurons are firing, the positive ions are flowing inside the neuron, creating a more negative potential in the intercellular matrix. And when neurons are inhibited, they are more negative on the inside and the intercellular matrix is more positive.

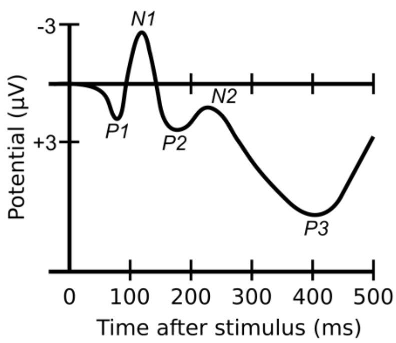

Figure 4-3. Event-related potential with components. Image url: https://upload.wikimedia.org/wikipedia/commons/thumb/a/ac/ComponentsofERP.svg/1280px-ComponentsofERP.svg.png

The amplitude of an ERP is clearly related to the number of neurons activated in a region at the same time. As their name suggests, ERPs are time-locked, with the event defining time 0. Components of ERPs are defined by their relative place from this time 0, their polarity and their magnitude. ERPs inform us about when there was a greater change in voltage in a specific region. On the ERP plot we can find time on the x-axis and voltage on the y-axis. ERP analysis usually consists of analysing ERP peaks (i.e. the difference between maximum peaks) or analysing components (i.e. the average voltage of an interval of the ERP). Although it has been questioned whether these attributes of ERPs are meaningful (Hoffman & Richards, 1984; Nathan et al., 2012), it is still common practice to analyse brain responses in potentials measured from single electrodes, regions of interest (ROIs) or global averages of all electrodes by their peaks or components (Ronga et al., 2013; Jackson & Bolger, 2014; Wieser et al., 2014; Valentini & Gyimes, 2018). ERPs components vary based on the area where they were recorded and on the stimulus that triggered them.

4.2.6.2.2.1 Somatosensory evoked potentials SEPs

Somatosensory evoked potentials (SEPs) are mainly induced by the stimulation of the peripheral nerves wither the median nerve around the wrist or *tibial nerve* around the ankle (Nathan et al., 2012), thus activating the dorsal column/medial lemniscus system. In our studies, we used electrical stimulation of the left median nerve. The early components of SEPs, such as P14, N20 and P22 on the contralateral side (C4 electrode) or P30, N33, P39, N50 and P60 on the vertex (Cz electrode) are well established (Nathan et al., 2012). N19/20 has been linked to thalamocortical activation (Gugino & Chabot, 1990) while P22 has been assumed to signal a cortical activation in response to the median nerve stimulation. However, these early components have been proven to be hard to replicate in studies investigating pain alterations (Eimer & Forster, 2003). Later components, like N120/140 or P200 are proven to be more reliable in ERP studies. N120/140 has been shown to be sensitive to attention and processing negativity (Michie, 1984; Porro et al., 2002; Eimer & Forster, 2003; Porro, 2003). N120 peaks in Fz and FCz, while N140 is more of a bilateral component. However, both of them has been linked with anticipation of pain (Porro et al., 2002; Porro, 2003) and attention (Eimer & Forster, 2003) and assumed to be generated in the secondary somatosensory cortex located right behind the somatosensory cortex. P200 showed to be affected by attention (Kida et al., 2006; Forster & Gillmeister, 2011; Fiorio et al., 2012), anticipation or general arousal (Clauwaert et al., 2020).

4.2.6.2.2.2 Time-frequency representation of the EEG

ERPs and analysis of its components has been dominant for years (Nathan et al., 2012). However, it is becoming more and more accepted that oscillator activities describe brain activity better (Cohen & Gulbinaite, 2013). Neurophysiological and neuroanatomical studies showed that while the population of inhibitory neurons in the brain is small, they are responsible for organising the neural oscillation (Buzsáki et al., 2007). These neural oscillations act as reference for the firing of neurons (Jones & Wilson, 2005). Thus, the investigation of oscillatory activity in the brain can reveal more information about the neural activities under cognitive processes. György Buzsáki in his book *Rhythms of the brain* (2011, p. 104) states "[…] the most appropriate method for analysing brain signals would be a "time-frequency analysis" algorithm that would provide perfect description of changes in all frequencies as a function of time.". However, as Buzsáki describes in length, time and frequency are orthogonal to each other. Meaning, there is no frequency as a function of time or vice versa. Thus, there are two ways of analysing brain activity: the aforementioned ERPs which are in the time-domain; and the currently discussed frequency domain. However, one can feel confused about the title of this section. If time and frequency are orthogonal to each other, how can there be a time-frequency analysis? ERPs are the change in potential over time. Describing changes in frequency over time on the other hand, is a more complex issue.

The key to apply frequency as a function of time is the transformation named after Jean Baptiste Fourier. The Fourier transformation allows us to decompose a signal into sine waves. These waves can have amplitude or power (amplitude squared) as their function, describing the original signal by its components. This ingenious transformation opened the door for two important methods in understanding waves: filtering and time-frequency analysis. As the Fourier transformation is reversible, filtering given frequencies out from a signal became possible. But more importantly, by applying this transformation on short time-windows, it was able to describe frequency as a function of time. This way, we could dissect a window of a signal into its frequency components and create a spectrogram, where the x axis showed time, the y axis showed frequency and the z axis showed amplitude or power. Despite the trade-offs of this method (i.e. lower time resolution can create greater frequency resolution and vice versa), it allowed scientists to study the changes in oscillatory brain activity over time.

In order to truly appreciate the value of time-frequency analysis, we have to define *phase-locked* and *non-phase-locked* responses. Event-related activities are by definition time-locked, meaning we have a zero point in time corresponding to the onset of the event evoking the potential. As such, every change is locked to the aforementioned zero time point. However, by averaging the single trial ERPs, we lose the information about oscillations of the signal that are not in phase with e.g. an experimental sensory event. As the oscillations are not phase-locked (meaning the phase angles of the waves in the oscillation are not synchronised to each other) the averaging results in a loss of phase-dependent information. Imagine for example, that an event triggers an increase in the amplitude, and thus the power, of a brain activity at 15 Hz. There is no insurance that this activity will be at the exact same phase angle throughout all trials. Thus, by the end of averaging several ERPs, the oscillation following the signal will average itself out. By calculating a time-frequency representation of the data, we can tackle this issue. However, as power is calculated by squaring the amplitude, it is clear that the power output of lower frequencies will be higher than the higher frequencies. Thus the brain activity follows a ‘1/f’ or scale-free structure, where lower frequencies have high power and high frequencies have lower power. While this ‘1/f’ power distribution is not an artefact and holds valuable information (Voytek et al., 2015; Pertermann et al., 2019), it prevents the measurement of short-time changes. In experiments such as the ones discussed later in this thesis (Sections 5 & 6), we are focusing on quick changes in time, thus we have to remove the ‘1/f’ dynamics from the signal. Alexander Graham Bell provided us with a transformation exactly for this purpose. This transformation calculates a ratio between a ‘baseline’ and ‘activity’. We take the log10 of the signal divided by its baseline activity. Then we multiply it by 10 to use dB (decibel) instead of B (bel). This last part is only due to the more frequent use of dB over B. The baseline is defined as the part of the signal where we do not expect to see any event-related activity. By using this transformation, we normalise our power output making it comparable in every frequency.

While TF components correlate with ERP components (Elben et al., 2018), the TF components are less clearly defined (Cohen & Gulbinaite, 2013). Furthermore, the meaning behind neural oscillations in the different parts of the brain is yet to be mapped out (Cohen, 2017). However, there is a growing bulk of literature investigating correlations between cognitive processes and oscillatory activities (for example Singh, 2012; Buzsáki & Wang, 2012; Cohen & Donner, 2013; Cohen, 2014). Oscillatory activities are divided into frequency bands, like delta (<4Hz), theta (4-8Hz), alpha (8-14Hz), beta (14-35Hz) and gamma (>35Hz) associated with different cognitive functions. Recent research shows that changes in these oscillatory activities predict cognitive functions better than firing rates (see discussed in Singh, 2012). Hence, there are strong indications that oscillatory brain activities describe cognitive processes more accurately than event-related potentials. In our studies, we focused on the alpha and theta frequency bands, so I will discuss these two bands in greater depth. First, I will discuss the frequency bands which are less relevant for our studies. Delta activity, originating from the frontal and cingulate cortex, is associated with go-no go stimulus detection and corresponds with the P3 ERP component (Herrmann et al., 2016), as well as it has been assumed to show basic processes such as motivation (Knyazev, 2012) and concentration (Harmony, 2013) and language decoding (Giraud & Poeppel, 2012). However, the function of the delta oscillation is still not clear (Klimesch, 2018). Beta activity has been linked to tasks involving motor tasks or sensorimotor interactions (Neuper & Pfurtscheller, 2001; Kilavik et al., 2013). Gamma activity is mostly associated with general cortical activation, information processing, archiving, recalling and with cognitive performance (Herrmann et al., 2016). Theta activity is mostly associated with memory processes due to its connection with the hippocampus (Klimesch, 1999; Mitchell et al., 2008), especially with the working memory (Klimesch et al., 1994; Kahana et al., 1999; Kahana, 2006). This association with memory is further supported by studies done in rodent models, showing how hippocampal theta rhythm regulates neural activity (discussed in Klimesch, 2018). Furthermore, theta activity is linked to spatial working memory, too (Jones & Wilson, 2005; Zielinski et al., 2019). However there has been studies linking theta amplitudes to sensory stimuli as it overlaps with the classical vertex N2 and P2 SEP components (Valentini et al., 2014, 2015). The interpretations of theta activity discussed in length by Colgin (2013). The alpha activity is the oldest known brain oscillation (Berger, 1929). Alpha activity is associated with memory (Klimesch, 1997), attention (Hanslmayr et al., 2011) and somatosensory stimulation (Schürmann & Başar, 2001). Klimesch (2018) discusses the alpha frequency band in two parts: the upper and the lower alpha bands. While the upper alpha is mostly associated with visual cognitive tasks (e.g. Wolff et al., 2017; Nelli et al., 2017; Staudigl et al., 2017; Rominger et al., 2018; cited in Klimesch, 2018) and semantic memory

(Klimesch, 1999, 2012), the lower alpha seems to represent more general attention and acoustic stimuli (Klimesch, 2018). Furthermore, alpha activity was associated with the inhibition of the task-irrelevant parts of the brain (Herrmann et al., 2016), thus, increased alpha activity can signal cortical inhibition, while decreased alpha activity (lack of inhibition) can signal cortical activation (Yordanova et al., 2001; Mouraux et al., 2003). As such, we chose to investigate the changes in theta and alpha amplitudes after somatosensory stimuli. Low frequency bands (such as delta, theta, alpha and beta) assumed to play a significant role in top-down cognitive control (Klimesch, 2012).

For this thesis, we will focus on the theta and alpha frequency bands. The rationale for this choice is that changes in nociceptive theta amplitude were previously linked with MS (Valentini et al., 2014), while the alpha frequency band has been linked to somatosensory processes in general (Schürmann & Başar, 2001). Furthermore, as alpha activity signals inhibition of cortical activity (Klimesch, 2012) and attention (Hanslmayr et al., 2011), and nociceptive theta, as a slow wave response, is assumed to be affected by top-down modulation (Valentini et al., 2014). Additionally, both of these frequency bands are easy to detect and study and are independent from sensory modality. Thus, they can potentially assist us in understanding the underlying neural processes of TMT and the interactions between MS and personality traits as well as between MS and experience in meditation.

4.2.7 Neuroscientific testing of TMT hypotheses

Due to its roots in social psychology, the majority of research involving TMT has been conducted within the methodological traditions of social psychology. However, every cognitive process has an underlying neurological aspect as well. Thus, investigation of TMT in neuropsychological and psychophysiological experiments is crucial. Studies using EEG and fMRI attempted to shed light on how human brains process reminders of mortality and how these reminders can alter brain responses (Quirin et al., 2012; Jonas et al., 2014). As we used EEG in our research, we will focus on EEG-based studies mostly. However, it is important to talk about the studies using fMRI as painting a whole picture of the effects of MS on neural activity requires more than just one technique. The anterior cingulate cortex, cingulate, anterior insula, amygdala, ventrolateral prefrontal cortex areas, namely the salience network, are assumed to be functionally linked to the processing of salient environmental stimuli (Wiech et al., 2010; Harlé et al., 2012; Corradi-Dell'Acqua et al., 2016; Feng et al., 2017). This network is connected to the medial prefrontal cortex (Bressler & Menon, 2010) which is associated with reactions to norm violations (Buckholtz & Marois, 2012; Krueger & Hoffman, 2016). Both salient stimuli from the environment and the violation of norms are linked to MS. MS is a salient stimulus causing increased reactions towards violation of one's norms. And, as expected, parts of this network are shown to be influenced by MS (Han et al., 2010; Quirin et al., 2012; Yanagisawa et al., 2013; Feng et al., 2017). Studies using fMRI showed that self-esteem levels moderated the amygdala-ventrolateral prefrontal cortex connectivity after MS induction (Yanagisawa et al., 2016). This moderating effect of self-esteem on MS not only aligns with the framework of TMT, but also fits the classification of the amygdala-ventrolateral prefrontal cortex as part of the salience network.

Several studies showed how MS can affect ERP amplitudes (Klackl et al., 2013; Valentini et al., 2014; Wang & Tian, 2018; Valentini & Gyimes, 2018). These studies showed that death-related words can predict a greater late positive potential (Klackl et al., 2013) and increased N2 amplitude and P2 latency in response to threat from outgroup compared to ingroup after MS-induction (Henry et al., 2010) as well as greater P2 amplitude in response to somatosensory stimulation (Valentini et al., 2017), however MS predicted smaller N2 amplitude in Chinese participants in response to nociceptive stimuli (Wang & Tian, 2018).

Furthermore, MS-related images elicited smaller positive potential compared to more generic threat-related images (Valentini & Gyimes, 2018). While some studies showed that ERP amplitudes are dependent on novelty (Legrain et al., 2003, 2009) and salience (Ronga et al., 2013), there have been suggestions that top-down modulations also play a role (Valentini et al., 2017). Thus, it is a challenge to distinguish between differences due to bottom up salience and top-down cognitive modulations in MS experiments. It is important to point out that application of more powerful statistical approaches showed that some of the changes in ERP components were the result of error variance (Valentini et al., 2017). The sporadic findings of MS-related differences in brain responses and the indication that individual differences can lead to false-positive findings imply that more robust statistical methods are necessary for the investigation of the effect of MS. Furthermore, there are only few investigations on the effects of MS in the time-frequency representation of the EEG (Valentini et al., 2014, 2015; Liu et al., 2015). In a previous study, it has been shown that MS-induction predicted a lack of habituation of the second stimulus in a repetition-suppression method compared to exam failure (Valentini et al., 2014). However, more research is needed to explore how MS affects the cognitive processes.

4.3 Aim of the thesis

In this thesis, I will present two studies. Study 1 (Section 5) consists of two experiments and Study 2 (Section 6) consists of one experiment. In Study 1, we investigated the modulatory effects of seven personality traits on the expected effects of MS on somatosensory perception and brain activity. We aimed to expand our understanding on the importance of personality traits for measuring the effects of MS. Following this line in Study 2 (Section 6), we investigated the modulatory effects of experience in meditation experience on the expected effects of MS using the same experimental method. These studies offer a potential explanation for the sporadic findings and replication issues of TMT (Klein et al., 2019), as well as they test potential buffers against the changes predicted by MS induction (Park & Pyszczynski, 2019).

4.3.1 Noxious stimuli as a probe

In both studies, we expanded on previous methodology (Valentini et al., 2014). We utilised the threatening nature of nociceptive stimuli to investigate the effects of MS. Our aim was to disclose important factors influencing the perception and neural effects of reminders of death. There is a bi-directional relationship between anxiety and pain (Asmundson & Katz, 2009; van Wijk & Hoogstraten, 2009; Gonzalez et al., 2011). For an organism, noxious stimuli convey homeostatic and motivational value (Porreca & Navratilova, 2017). As these noxious stimuli signal threat to the body, they are a great tool for measuring the effects of existential threat. Based on this relationship between anxiety and pain, previous studies used nociceptive somatosensory stimuli to investigate the effects of MS (Valentini et al., 2014, 2015). Hence, we also used unpleasant/painful stimuli in our experiments. Pain is defined as “An unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.” (Merskey & Bogduk, 1994). MS has been shown to affect areas associated with emotional regulation (e.g. amygdala and anterior cingulate cortex) (Quirin et al., 2012). Thus, we assumed that a threatening stimuli would enhance the changes after MS-induction previously observed (Valentini et al., 2014, 2015). This assumption was further supported by previous studies showing that threatening stimuli are harder to ignore (Van Damme et al., 2004) and they elicit a greater cortical response compared to other sensory stimuli (Schrooten et al., 2012).

4.3.2 Experimental manipulations

Somatosensory stimuli can be modulated by expectation (Loeser & Melzack, 1999; Wiech et al., 2010; Tracey, 2010; Kokonyei et al., 2019), thus we introduced a manipulation of expectation into our method (see in Methods and materials of Section 5). As mentioned previously (Section 4.3.1), noxious stimuli already signals threat towards the body. We assumed that by increasing this threat level we can enhance the effects of MS resulting in greater effect sizes in both pain perception and neural responses.

As a control condition, we followed the approach used in Valentini et al. (2014, 2015) a similarly negative and arousing condition. We asked students to think about failing an important exam while we asked non-student participants to think about losing their job. Previous research showed that there was no significant difference between the control and experimental conditions in their level of arousal, valence, threat- only their context (i.e. death or exam-related; Valentini et al., 2014).

In Experiment 2 and Study 2, we expanded the classical MS by using the idea of the death of one's romantic partner (Sections 5.3 & 6). We replaced the classical reminder of mortality aiming at the participant (i.e. "Please briefly describe the emotions that your death arouses in you") to one aimed at the participant's romantic partner (i.e. "Please briefly describe the emotions that your romantic partner's death arouses in you"). The rationale for this was twofold: on one hand, TMT claims that even the word 'death' can trigger the defence mechanisms (Pyszczynski et al., 2015); on the other hand, it has been suggested that romantic relationship and relationship with others in general acts as a buffer against existential anxiety (Florian et al., 2002; Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018). As such, we assumed that regardless of whether the participant is reminded of their own mortality or the mortality of their loved one, the question will trigger the distal defences prescribed by TMT. Furthermore, as there is evidence linking relationship, intimate relationship, and MS, we believed that this reminder might even further increase the MS effects.

4.3.3 Potential buffers against MS

Relationships or attachments are not the only factor that can act as a defence against existential threats. Just to reiterate a previous example (Section 4.2.1), TMT states that participants with already high self-esteem levels show no changes in their behaviour after MS induction (Greenberg et al., 1992; Harmon-Jones et al., 1997; Pyszczynski et al., 2015). Several personality traits have been studied as moderators of MS induced effects (Greenberg et al., 2000; Goldenberg & Arndt, 2008; Cox & Arndt, 2012; Caspi-Berkowitz et al., 2019). Despite all the research carried out in this area, there has been no clear description on how personality can interact with the effects of MS. As I highlighted in Section 4.2.3 TMT faced substantial criticism in the recent past on both theoretical (Landau et al., 2007) and experimental grounds (Klein et al., 2019). We surmised that some of the unexplained observed variability might be coupled to individual differences in personality traits.

In Study 1 (Section 5), we aimed to shed light on the role of personality traits in the framework of TMT. We selected seven personality traits that could be reasonably argued to play a role in the defence against existential fear. Firstly, and most obviously, we selected self-esteem, measured by the widely used Rosenberg's Self-Esteem Scale (Rosenberg et al., 1995; Sarı et al., 2018; Pérez-Fuentes et al., 2019; Ogihara & Kusumi, 2020; Kielkiewicz et al., 2020; Kourakou et al., 2021; Syropoulou et al., 2021; Šagát et al., 2021), as it has been established as one of the core tenets of TMT (Pyszczynski et al., 2015). Second, we measured the participants’ trait anxiety and depression levels. We measured the anxiety trait (and state) levels of the participants by the State-Trait Anxiety Inventory Y (STAI) (Spielberger et al., 1983). This inventory is also widely used in multiple contexts to measure state and trait anxiety levels (Guillén-Riquelme & Buela-Casal, 2014; Han et al., 2020; Abdoli et al., 2020; Shah et al., 2021). STAI was used in a wide variety of experiments, from EEG experiments (Imperatori et al., 2019; Shadli et al., 2021), to studies investigating correlations between anxiety and amyotrophic lateral sclerosis (Siciliano et al., 2019). STAI is used in many studies across many disciplines proving itself to be a reliable measurement of anxiety state and trait levels. Depression trait scores were measured by the Patient Health Questionnaire 4 (Kroenke et al., 2009; Stanhope, 2016). PHQ-4 was used in studies screening depression levels of pregnant women (Rodríguez-Muñoz et al., 2020; Barrera et al., 2021), adolescents (Materu et al., 2020) and health care workers during the COVID-19 pandemic (Zhang et al., 2020), proving itself to be a reliable tool for quickly and efficiently measuring depression trait levels. It is common practice that participants with too high or too low scores on these personality traits should be excluded from the participant pool (Valentini et al., 2014, 2015). We reasoned that both traits can explain the efficacy of MS on an individual. We also included a measurement of fear of death, and fear of other’s death, two subscales from the Collett-Lester Fear of Death and Dying Scale (Collett & Lester, 1969; Lester & Abdel-Khalek, 2003; Lester, 2004). Previously, death anxiety was investigated in relationship with MS (Sliter et al., 2014). Thus, we assumed that besides anxiety, fear may play a major role in dealing with reminders of mortality. Based on the findings of previous studies, we included measurements of adult attachment types as predictors (Taubman-Ben-Ari et al., 2002). The Adult Attachment Scale (Collins & Read, 1990) is a reliable measurement tool (Collins et al., 2006) to help us quantifying attachment types which can moderate the effects of MS.

To answer the question of Study 1 (whether personality traits moderate the effects of MS), we used Rosenberg's Self-Esteem Scale to measure self-esteem reflecting the classical TMT studies (Pyszczynski et al., 2015); the State Trait Anxiety Inventory to measure both state and trait anxiety levels, similarly to previous studies of our lab group (Valentini et al., 2014) and other studies investigating the relationship between anxiety and neural activity (Imperatori et al., 2019); the Patient Health Questionnaire-4 for measuring depression levels as other studies did before (Zhang et al., 2020; Materu et al., 2020); the Collet-Lester Fear of Death and Dying Scale to measure fear of death and fear of other's death based on previous studies (Tomás-Sábado et al., 2007; Pérez-de la Cruz, 2021); and the Adult Attachment Scale to measure close, dependent and anxious attachment type scores based on the established link between existential threat and whish for intimate relationship (Taubman-Ben-Ari et al., 2002).

We expected to find fear of death (for Study 1, Experiment 1; Section 5.2) and fear of other's death (for Study 1, Experiment 2; Section 5.3) would predict greater MS induced effects on both the somatosensory perception and brain responses. Similarly, anxiety was expected to predict greater efficacy of MS, while depression was assumed to have the opposite effect – resulting in a decreased efficacy of MS. The rationale for this was the established, opposite effects of anxiety and depression on the central nervous system arousal (Hayes et al., 2010; Pyszczynski et al., 2015). As discussed above, we expected to see self-esteem as a buffer against MS (Pyszczynski, 2004; Pyszczynski et al., 2015). Out of the three adult attachment types (close, dependent, anxious) we assumed close attachment type to act as a defence against existential anxiety (Florian et al., 2002; Taubman-Ben-Ari et al., 2002).

Thus, Study 1 (Section 5) aimed to investigate the moderating effects of these aforementioned personality traits on the effects of MS directed towards the participant

(Experiment 1, Section 5.2), and the effects of MS directed towards the romantic partner of the participant (Experiment 2, Section 5.3). We aimed to enhance the MS-related changes by introducing a manipulation on the expectation of the stimuli, thus investigating the top-down modulation of nociception and pain sensation.

However, personality traits are not the only potential factors able to moderate MS-related changes in the behaviour. Recently, more and more studies aimed to investigate the effects of meditation practice on the body and mind (Baer, 2003; Ospina et al., 2007; Hauswald et al., 2015; Hashemi et al., 2016). Furthermore, the effects of meditation experience were tested in the framework of TMT (Niemiec et al., 2010; Park & Pyszczynski, 2019). Among other effects, experience in meditation predicted better performance in cognitive tasks, reduced symptoms of psychological disorders and in general a higher level of well-being (Kabat-Zinn, 2003; Bitner et al., 2003; Pagnoni & Cekic, 2007; Park & Pyszczynski, 2019).

Based on these promising results, we aimed to investigate the buffering potential of experience in meditation against MS induced changes in the behaviour and neural responses. We implemented the same methodology as Study 1, Experiment 2 in Study 2 (Section 6), using the previous pool of participants as control population for the meditation practitioners. We expected to see the dampening, buffering or reversing of the MS-related changes in pain perception and somatosensory brain responses.

4.3.4 Statistical analysis

We aimed to improve our statistical approach by applying mixed-effects models. Mixed-effects models, or random effects models, were first introduced at the beginning of the last century (Fisher, 1919). By the end of the 20th century, mixed-effects modelling became a major area in statistics (McLean et al., 1991; Robinson, 1991). However, due to the complexity of calculating mixed-effects models, it is only recently gaining true recognition (Austin, 2017; Collins et al., 2021; Comets & Mentré, 2021; Mattos et al., 2021). Data structures with multiple levels are frequent in science. Due to data collection, or other external factors, we may end up introducing effects that would influence our analysis. For example, inter-individual variation of responses can cause false positive findings (see Valentini et al., 2014). Mixed-effects models are capable of counteracting such issues by introducing random intercepts and slopes. First, we should explain the terminology. Mixed-effects models are formulas describing a line (linear, exponential, logarithmic, etc.) which best explains the variability of the data. As in this thesis I am using linear mixed-effects models, I will discuss the models in terms of fitting linear lines onto the data. The formula of a line is $y = m * x + b$, where m is the slope of the line b is the value where the line crosses (intercepts) the y axis, namely the intercept, y and x are coordinates of each point of the line. By adding extra terms to this basic formula, we are able to describe complex, multi-levelled datasets accounting for randomness embedded in the data structure. Relevant to psychology and neuroscience, individuals can differ significantly in their baselines. Despite the harnessing provided by the experimental instructions, people can interpret the experimental measurements differently. The easiest way to visualise differences in baselines is to use an example from biology. If we want to measure differences in growth of fish populations due to different foods, the fishes will most likely live in several ponds (regardless of which experimental group they are). These ponds might have innate differences, such as amount of sunlight to them, the surrounding vegetation or even shape. While these are meaningful ‘inter-pond’ differences, they could skew the results of the study. In such cases, mixed-effects models can include a so-called *random intercept*. With such a random intercept the model, essentially, allows variability within a level, such as ponds or participants. If we visualise the pond example from before, our model would try to fit a line on the fish population size before and after the experiment. If there is no free variability on the level of pond, the variance of their baseline, essentially noise, can affect the output of the model. However, by adding a random intercept for the level of participants, our model can take tackle this noise (Schaalje, 2008). Thus the inherent inter-individual differences do not affect the model's output, as each individual has their own intercept.

Furthermore, in some experiments (such as the studies of this thesis), individuals may attend a study for two sessions (e.g., for an experimental and a control condition) without the study being longitudinal. In such cases, there may be an unintended difference between the experimental sessions due to external circumstances. Such as, a participant may happen to have a good or a bad day; they are more or less perceptive of the experiment. In this type of design, where the difference between the two experimental sessions is not part of the experimental question, mixed-effects models can include *random slopes*. Random slopes, or random effects, allow the slopes of the fitted lines to vary within the specified level, like the level of experimental session in this example. In this example, it is possible that the baseline data collected on the two experimental sessions are different regardless of the experimental manipulation. By introducing a random slope to the level of experimental session, the output is not going to be skewed. To sum it up, mixed-effects models can allow variance of the intercept and/or slopes of fitted lines thus minimising the noise in the data. Variance of baseline (such as inter-individual differences) is tackled by adding random intercepts and unintended variance of factors (such as differences between experimental session days) is accounted by random slopes.

It is a valid question to ask if repeated measure analysis of variance (ANOVA) could account for the aforementioned problems. While it is true that for perfect data (i.e. a dataset with normal distribution, without missing data) a repeated measure ANOVA and a mixed-effects model would give the same output, mixed-effects models are more flexible, than ANOVAs. For example, and most importantly for the field of psychology, mixed-effects models (unlike ANOVAs) are capable of using unequal-sized groups (Krueger & Tian, 2004). This advantage is very useful when analysing EEG data, where rejection of single trials is frequent, thus leading to unequal size of each dataset. Furthermore, mixed-effects models are capable of analysing different types of measurement levels (nominal, ordinal, scale) within the same model. These aforementioned abilities make mixed-effects modelling a more robust method compared to ANOVAs.

Here, we implemented linear mixed-effects models on both the behavioural and the neural data we collected. We have included a random intercept by participants. Thus, we aimed to account for the individual differences. Furthermore, as participants attended two experimental sessions on different days, we added a random slope for accounting the difference between days. This random slope, random effect, was meant to account for differences between the experimental sessions caused by other factors besides our own experimental manipulations. We aimed to strengthen our findings by implementing a more robust and flexible statistical approach to not only analyse behavioural data, but to identify areas and intervals of neural data where our predictors would show significant effects. We believe that such robust methods can lead to a better understanding of neural processes and in the long term to a better methodology to analyse neural activities.

5 Study 1 – The moderating effects of personality traits on the effects of mortality salience

“O Cleopatra, I am not distressed to have lost you, for I shall straightaway join you; but I am grieved that a commander as great as I should be found to be inferior to a woman in courage.” Mark Antony (Cite Cleopatra: a life)

5.1 Prologue for Study 1

In this chapter I will report on two experiments. In this study (Study 1), we conducted two experiments investigating the moderating effects of personality traits on neural and behavioural changes following MS induction. We applied noxious somatosensory stimulation to the participants’ left hand to measure how the perception of unpleasant/painful stimuli and associated neural responses is affected by MS. We analysed changes in pain perception, and SEPs following MS induction and how this change is modulated by personality traits.

First, I will lay out the foundation for both experiments, finishing with the rationale for Experiment 1. These results are currently under revision in the Journal Psychophysiology while I am submitting this thesis. Experiment 2 serves as a follow-up for Experiment 1 and a preliminary experiment for Study 2 (Section 6). The rationale for Experiment 2 will be discussed in a separate, shorter introduction in the second half of the chapter. I am going to present the results of Experiment 2 in the same way as Experiment 1. At the end of the chapter, I will discuss the similarities and differences between the two studies and I will attempt to fit our findings into the wider framework of TMT literature.

5.2 Experiment 1

5.2.1 Abstract

Terror management theory (TMT) offered a great deal of generative hypotheses that have been tested in a plethora of studies. However, there is still substantive lack of clarity about the interpretation of TMT-driven effects and their underlying neurological mechanisms.

Here, we aimed to expand upon previous research by addressing the role of individual differences in personality on the purported aversive effects of reminders of death on perception and brain activity. We combined a manipulation of threat of iso-intense painful somatosensory stimuli with the classical mortality salience (MS) manipulation (contrasted with an equally negative control mind-set).

Linear mixed modelling disclosed the moderating role of individual differences in personality on the mortality salience effects on pain perception somatosensory evoked potentials (SEPs) and time-frequency (TF) electroencephalography responses. Self-reported individual differences in anxiety predicted greater pain when individuals were facing reminders of death. In a complementary fashion, participants with greater trait depression reported less pain. The moderating effects of anxiety and depression traits were found in the low alpha TF power. We observed a similar effect associated with close attachment, predicting a substantial increase after MS. Greater disposition to anxious attachment predicted a significant N2 SEP amplitude increase after MS. In a similar fashion, greater disposition to dependent attachment predicted a significant P2 SEP amplitude increase from pre- to post-MS.

We suggest that personality differences have a critical impact on the likelihood of replicating TMT predictions on behavioural and physiological variables.

5.2.2 Introduction

Ernest Becker argued the fear of death is the engine of an unlimited well of anxiety that humans buffered by developing symbolic systems of meaning, such as cultures, religions, and belief systems. By subscribing to these systems humans have an escape from mortality granted and thus find relief from the emotional taxing existential anxiety (Becker, 1973). Following up on Becker's ideas, Terror Management Theory (TMT) posits that humans are keener to defend their cultural views and increase their self-esteem when faced with the idea of mortality (Pyszczynski et al., 2004). In two companion landmark papers (Rosenblatt et al., 1989; Greenberg et al., 1990), researchers developed the empirical approach to test TMT hypotheses that reminders of mortality would lead participants to praise or punish individuals that uphold or violate cultural values. The core experimental manipulation entailed simply submitting the participants to the Mortality Attitudes Personality Survey, which consisted a brief ad-hoc two-item, open-ended questionnaire whereby they were asked to write about (a) what will happen to them as they physically die, and (b) the emotions that the thought of their own death arouses in them. As this methodology was intended to make mortality salient, it has been referred to as mortality-salience (MS) manipulation. The concept of MS can be braided into Heidegger's reasoning (1962) by classifying MS as a sudden, unexpected event that pulls us out from our "forgetfulness" state into a "mindfulness" state. In the latter state the mind's buffer systems are activated and the existential anxiety is consciously suppressed or denied. Importantly, TMT posits that MS effects take place only if participants are distracted from conscious reminders of death (Greenberg et al., 1994).

Since then, MS has been used in over 200 studies and the effects of mortality/death reminders, as operationalised according to TMT, have been replicated over five-thousand times (Burke et al., 2010; Hayes et al., 2010). However, TMT has seen rising criticism in the last years (Pyszczynski et al., 2015; Chatard et al., 2020) and more recent attempts to replicate core findings failed (Klein et al., 2019; Rodríguez-Ferreiro et al., 2019).

Despite criticism, there has been a growing effort to investigate the neurological underpinnings of some of these effects spanning from studies using the MS manipulation to studies implementing death-related cues without a reflective/contemplative and distraction procedure (e.g. Han et al., 2010; Quirin et al., 2012; Klackl et al., 2013; Valentini et al., 2017; Valentini & Gyimes, 2018). Notwithstanding the methodological variability, most of the findings supported the notion that reminders of death have specific effects on participants' behaviour and neural activity. However, there is still substantial confusion on the direction of these effects and their interpretation (Tritt et al., 2012; Jonas et al., 2014; Valentini et al., 2015).

Relevant to the current study is the TMT tenet that cultural and personality factors may act as mediators of the anxiogenic effects caused by awareness of death. A series of studies documented the role of personality as a moderator of MS effects, such as self-esteem, neuroticism, depression and attachment style (Solomon & Greenberg, 2000; Goldenberg & Arndt, 2008; Cox & Arndt, 2012; Caspi-Berkowitz et al., 2019). And yet, neither consistency across findings nor a clear characterization of the implied mechanisms is currently available.

Here, we expand on our previous research involving somatosensory painful stimuli and the MS manipulation (Valentini et al., 2014, 2015) aiming to further substantiate the MS effects previously observed and investigate the predictive role of personality traits in the changes expected both at perceptual and neural level. Our previous work, although confirming an effect of MS at both perceptual and neural level, revealed only a significant modulation of very late nociceptive evoked potentials triggered in the context of fast stimulus repetition (2015).

Therefore, to enhance the threat associated with the somatosensory stimulation (cf. Wiech et al., 2010 for a similar approach) we designed a sham manipulation aimed to interact with the MS mind-set. In other words, we assumed that increasing the threat of the noxious stimuli would strengthen the effects of MS. More importantly, we sought to investigate how this novel experimental manipulation in interaction with reminders of death would be altered by several personality traits that were previously reported as effective MS modulators (Pyszczynski et al., 2015).

According to the literature, we expected to find an increase of pain compared to an equally negative control mind-set condition (Valentini et al., 2014). The threat manipulation of sensory stimulation was expected to enhance this effect. Despite the differences in methodology, all across our previous work (Valentini et al., 2014, 2015, 2017; Valentini & Gyimes, 2018) we hypothesised to observe a greater amplitude of brain responses following reminders of death. However, the size of this neural effect can be significantly impacted by individual differences in personality due to their arguably important role in TMT-related effects. We identified the following dimensions as the most influential for psychophysiological moderation: fear of death, anxiety, depression, self-esteem, attachment. The selected traits have been shown to have important implications for the validation of TMT (Solomon & Greenberg, 2000; Taubman-Ben-Ari et al., 2002; Iverach et al., 2014; Pyszczynski et al., 2015; McCabe & Daly, 2018).

According to previous findings, we expected the heightened response to MS manipulation being enhanced by higher disposition to anxiety and buffered by higher disposition to depression (Hayes et al., 2010; Pyszczynski et al., 2015) due to a general alteration of central nervous system arousal. Furthermore, we expected a buffering effect of self-esteem, in that higher self-esteem was expected to reduce the MS effects (Pyszczynski et al., 2004, 2015). Similarly, we expected to find a modulation of adult attachment style on MS effects as previous findings suggested a buffering role of close romantic relationship (Collins & Read, 1990; Mikulincer et al., 2003; McCabe & Daly, 2018). We also introduced the measurement of fear of death measured by the Collet-Lester Fear of Death Scale (Collett & Lester, 1969; Lester, 2004) as a predictor of MS effects, based on the notion that a greater emotional sensitivity to the idea of one's own death could have bolstered MS perceptual and neural effects, particularly when the sensory stimuli were associated with greater bodily threat.

In sum, we expected the classical MS to exert an increase in perception and magnitude of brain responses, particularly during the threatening stimulation condition. In addition, we expected to observe further increase to be determined by greater disposition to anxiety, fear of death, and anxious attachment whereas greater self-esteem depression and close attachment type were expected to dampen the effects associated with MS manipulation (Mikulincer et al., 2003; Finch et al., 2016).

5.2.3 Methods and Materials

5.2.3.1 Participants

Twenty-five healthy participants (11 females, mean age 22.16 ± 2.79, ranging from 19 to 31, all students at the University of Essex) were screened and entered the study. The screening intended to filter out individuals with neurological, psychiatric, and other medical conditions that could interfere with the experiment. All participants had normal or corrected-to-normal vision. The experimental procedures were approved by the University of Essex ethics committee (1701) and were in accordance with the standards of the Declaration of Helsinki. Our sample size was based on the sample size in previous studies using similar techniques, methods or investigating similar effects. Studies investigating the effects of mortality salience on brain responses using EEG or magnetoencephalography (MEG) collected similar number of participants (≈20; Henry et al., 2010; Li et al., 2015; Fan & Han, 2018; Wang & Tian, 2018; Dor-Ziderman et al., 2019; Gao et al., 2020; Chen et al., 2020). Additionally, simulation statistical power for studies using TMT is difficult, as there is no clear estimation of expected effect sizes (Klackl & Jonas, 2019). Thus, we justified our sample size by considering previous similar studies.

5.2.3.2 Preliminary questionnaires

Participants who passed the screening procedure completed a set of online questionnaires using Qualtrics (Qualtrics, Provo, UT). Previous research showed potential impact on the effect of mortality salience by self-esteem, anxiety, and depression (Jonas et al., 2014; Pyszczynski et al., 2015). We used the Rosenberg's Self-Esteem Scale, the State-Trait Anxiety Inventory Y (STAI) and Patient Health Questionnaire 4 (PHQ-4). Additionally, we collected personality traits that could interact with the effects of the idea of one's own mortality. We used the Collett-Lester Fear of Death Scale which measures four types of fear: fear of death, fear of dying, fear of other's death and fear of other's dying (Lester & Abdel-Khalek, 2003; Tomás-Sábado et al., 2007). For this study, we only used the Fear of Death subscale. We also measured the attachment style of each participant using the original Adult Attachment Scale (Collins & Read, 1990; Taubman-Ben-Ari et al., 2002). This measurement allowed us to calculate the attachment style of each participant according to the three attachment styles anxious (i.e. extent to which a person is worried about being abandoned or unloved), depend (i.e. extent to which a person feels he/she can depend on others to be available when needed) and close (i.e. extent to which a person is comfortable with closeness and intimacy).

Importantly, we excluded participants with severe depression (>8 score on PHQ-4); and outside of ± 2 standard deviations (SDs) from the mean of the anxiety scores within an experimental group. We took this action to avoid outliers associated with the prevalence of mental health issues in UK students (Pereira et al., 2019). No participant was excluded based on these criteria.

5.2.3.3 EEG recording, pre-processing, and analysis

Sixty-two Ag/AgCl electrodes (Easycap, BrainProducts GmbH, Gilching, Germany) were used to record electroencephalography (EEG) (Synamps RT, Neuroscan, Compumedics). The ground was at AFz. The left earlobe was used as active reference and the right earlobe was used as an additional recording site for off-line re-reference of scalp electrodes. The electrodes were placed according to the positions of the 10-20 International System. All the electrodes had impedance lower than 10 kΩ and the signal was amplified and digitised at 1,000 Hz.

5.2.3.4 Somatosensory painful stimulation

BioPack® STMISOLA Constant Current and Constant Voltage Isolated Linear Stimulator were used to produce the electrical stimuli. The stimulator was controlled by E-Prime® 2 software and was monitored by AcqKnowledge® provided by BioPack®. STMISOLA was used in Current mode and sent 3 square-wave pulses at 150 Hz. The amplitude of the stimuli was adjusted to the participants' individual pain threshold (that could not overcome the stimulator's default maximum amplitude of 85 mA). The radiation of the left-hand median nerve was stimulated. The electrodes were placed on the second metacarpal bone the furthest possible place from the *flexor pollicis brevis* and the *lateral lumbrical* muscle of the left index finger to minimise direct muscle stimulation over the stimulation of nociceptors in the epidermis. Participants reported a painful, sharp, needle-like sensation. To prevent participant's distraction with the observation of their own hand being stimulated and reduce the electrical interference with the EEG recording, the left hand of the participant was shielded from view with a cardboard baffle.

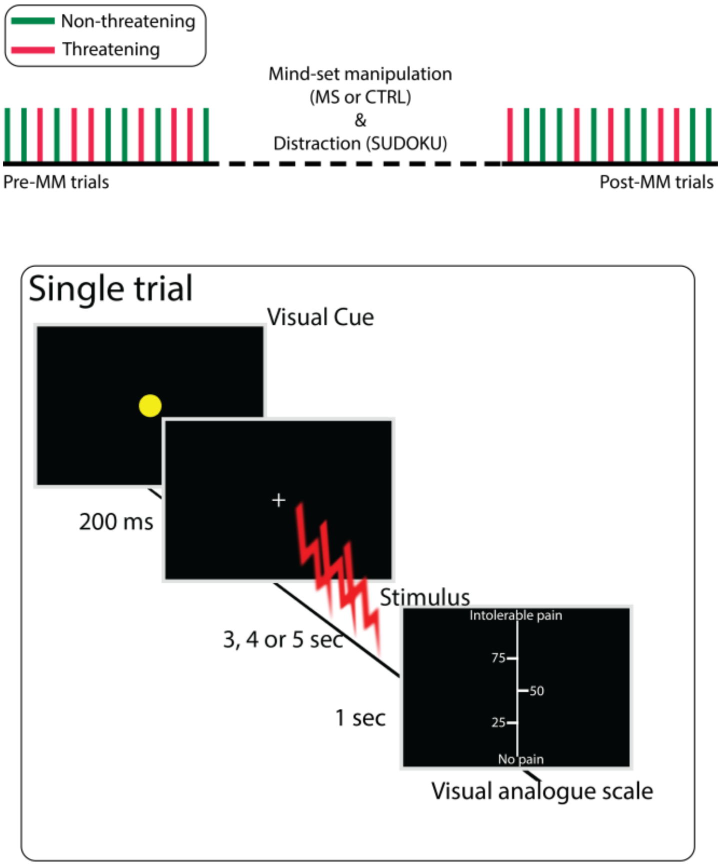

Figure 5-1. Experimental design and procedure. Participants received 60 painful electrical stimuli on the dorsum of their left hand before and 60 stimuli after being submitted to one of the questionnaires used to induce the mind-set manipulation. This phase was followed by a distraction task. Each trial was foreshadowed by a coloured circle indicating the level of threat (Threatening, Non-threatening; top left inset) associated with the upcoming painful electrical stimuli (cf. methods for details). The stimulus followed the coloured circle with a random interval (3, 4 or 5 s). Participants rated the pain associated with each stimulus on a visual analogue scale (0, no pain; 100, intolerable pain). Participants were asked to fill the STAI state and the PANAS questionnaires at four points of the experiment: before the experiment and before the mind-set manipulation (pre-MM), after the mind-set manipulation and after the experiment (post-MM).

5.2.3.5 Mind-set manipulation

Participants were asked to answer two open ended questions. In the mortality salience (MS) condition, they were asked to "Please briefly describe the emotions that your death arouses in you" and "Jot down, as specifically as you can, what will happen to you when you physically die and once you are dead" (Greenberg et al., 1986; Pyszczynski et al., 2015). In the control condition (CTRL) they were asked the same questions however framed around the failure on a very important exam (as in Valentini et al., 2014). This control condition was considered a valid and reliable control based on the assumption that the age and employment condition was like the seminal study. There was at least 48 hours lag between the two sessions and their order was pseudo-randomized between participants (Figure 5-1, top).

5.2.3.6 Threat manipulation

Participants were told that during the experiment each stimulus will be foreshadowed by a coloured circle (yellow or blue) (Figure 5-1, bottom). The colours were to signal whether the following stimulus was expected to be either a "normal, square-waved" or a "special, sigmoid-shaped" stimulus. Participants were told that the "sigmoid-shaped" can cause more inflammation in the skin ("Threatening" condition) while the "square-waved" are the normal stimuli used in every other research study ("Non-threatening" condition). Note that this was a cover story aimed to induce expectation of heightened pain for the Threatening condition and potentiate the effects associated with the existential mind-set manipulation. Crucially, stimulus intensity remained the same across the entire experimental session. The association between the actual colour and its meaning was pseudo-randomised between participants and their order of assignment to participants was pseudo-randomised.

5.2.3.7 Anxiety state and mood measures

According to the classical MS design (Valentini et al., 2014; Schultz & Arnau, 2017; Park & Pyszczynski, 2019), we have collected measurements of state anxiety, positive and negative mood at four points of the experiment, namely before the experiment, before the mind-set manipulation, after the mind-set manipulation and after the experiment. We used the state version of the State Trait Anxiety Inventory Y (Charles D Spielberger, 1987), and we used the Positive and Negative Affect Schedule (PANAS) (Crawford & Henry, 2004).

5.2.4 Study design and procedure

In summary, our design entailed assessing pain ratings and brain responses associated with the somatosensory painful stimulation before and after mind-set manipulation. The dependent variables are expressed as a change from baseline (pre-mind-set induction) across Mind-sets (MS, CTRL) and Threats (Threatening, Non-threatening). Significant difference between Mind-set and Threat conditions were defined based on their 95% confidence intervals (CIs). A difference between factor levels was considered significant if the 95% CIs did not overlap.

Participants were seated in a comfortable chair in front of a screen and controlled the computer mouse with their right hand. They could rest their left arm on the table and have the electrodes applied to the left hand for the transcutaneous electrical stimulation. After we ensured the optimal quality of the EEG cap montage and signal, participants started the experimental session. They were first asked to rate electrical stimuli of different intensities according to a pain calibration procedure. This consisted of sensory and pain threshold assessment followed by the identification of an individual pain criterion for the experiment while allowing participants to familiarise with the rating task. Participants were asked to rate their sensation on a visual analogue scale (VAS) from 0 to 100 (from 'No pain' to

‘Intolerable pain’). The adaptive staircase procedure started with a current intensity of 1 mA, which increased or decreased according to their ratings (VAS 0-9: +1 mA; 10-19: +0.5 mA; 30-39: +0.25 mA; 40-49: +0.125 mA; 50-59: no change; 60-69: -0.125 mA; 70-89: -0.25 mA; 90-100: -1 mA). We informed the participants that the experiment would have required a tolerable and consistent “moderately painful” sensation, expected to be located between 50 and 60 numerical anchors of the VAS scale and roughly within the first half of the third quartile of the VAS bar.

The current intensity which elicited a VAS rating consistently within a 50-60 range was selected and increased by 0.25 mA to reduce the impact of sensory habituation during the experiment. Once terminated the pain calibration phase, participants were submitted to two stimulation blocks separated by the Mind-set manipulation phase (Figure 5-1). They rated 60 stimuli before and 60 stimuli after the Mind-set manipulation (pre- and post-MM). They then answered the MM open ended questions followed by 10 minutes play with SUDOKU as a distraction task (aimed to trigger distal defences, see Pyszczynski et al., 2015 for a review). Each trial (Figure 5-1, main inset) started with a coloured cue (either yellow or blue circle) displayed at the centre of the screen for 200ms. The participants were instructed on the association between the cue colours and the purported properties of the upcoming stimulus at the beginning of the experimental session (cf. Threat manipulation). The coloured cue was then followed by a white fixation cross on a black background that was displayed for a variable time interval of 3 to 5 s (Figure 5-1, main inset). The electrical stimulus was jittered during this time-interval. The VAS appeared one second after the electrical stimulus to allow participants to rate the level of their pain before a new trial.

5.2.5 Data preparation and statistical analysis

5.2.5.1 Personality traits

We centred the personality trait scores by z-scoring them. We calculated the difference between the mean or each trait and the individual personality scores and divided them by the standard deviation of said trait. This method allowed us to assess the best fitting for linear regressions as well as ensuring a normal distribution of the values.

5.2.5.2 Anxiety state and mood

To reduce complexity and facilitate a consistent approach to data analysis, we averaged the results of the two measurements pre-Mind-set manipulation (pre-MM) and post-Mind-set manipulation (post-MM). Thus, the data structure was similar to the VAS ratings and the brain responses. We applied 2 x 2 repeated measure ANOVA to the state measurements using JASP (JASP Team, 2020). Significant interactions were further assessed with Bonferroni post-hoc tests (p_b).

5.2.5.3 Pain ratings

The ratings were normalised by min-max normalisation within-participant and within-session. The transformation was $x_{i\_norm} = \frac{x_i - x_{min}}{(x_{max} - x_{min})}$, where x_i is the individual rating of a participant in one of the experimental conditions (MS or CTRL); x_{min} is the lowest rating of the participant in the same condition (MS or CTRL) and x_{max} is the highest rating of the participant in the same condition. Thus, all ratings represented a percentage of the range by participant, by Mind-set condition. This method allowed us to avoid false positives due to the MS and CTRL being on different days, and meant that the results were easier to interpret. 8 points increase in a condition can mean a very large or a small increase in terms of individual participants. Some people utilise wider range of the VAS scale than others. As such, a normalisation method can provide us with a more comparable output. Using min-max transformation, we can say that the average rating in a condition increased by 10 % instead of 8 points. Thus, our results are more meaningful for both the individual and the group level at the same time. We fitted our *a priori* models to this dataset using the *lmer()* function of the *lme4* and *lmerTest* R packages. We calculated the χ^2 values for each effect using the *drop1()* function, the 95% confidence intervals (95% CI) by the *confint()* function and the βs, standard errors (SE), t- and *p*-values by the *summary()* function. To calculate the marginal and conditional R^2 values, we used the *r.squaredGLMM()* function from the *MuMIn* package.

Our models tested the following different effects:

<u>Model 1: The effect of Threat.</u>

As we applied the manipulation of threat for the first time in the context of the mortality salience manipulation, we performed a control analysis to assess the main effect of Threat regardless of Mind-set or Time or personality traits, using a simple model:

Normalised ratings ~ Threat + (1+Mind-set|Participants)

This model allowed us to investigate how effective our psychological manipulation was regardless of the other factors.

<u>Model 2. The modulatory role of Personality on the effect of Mind-set.</u>

Normalised ratings ~ Time * Mind-set + Time * Mind-set * Personality trait …+ (1+ Mind-set|Participant)

Time indicates pre- and post-MM; Mind-set indicates MS and CTRL. The model tested the pre- to post-MM change in each mind-set and the effect of the personality traits on the interaction between Time and Mind-set. We calculated the z-scores of each trait within the group they were measured. These centred values were added into our models.

<u>Model 3. The modulatory role of Personality on the interaction between Mind-set and Threat.</u>

Normalised ratings ~ Time * Mind-set * Threat + Time * Mind-set * Threat * Personality trait … + (1+ Mind-set|Participant)

We investigated how personality traits can predict changes from pre- to post-MM in the different Threat conditions.

Both Mind-set and Threat were added *as.factor()* into our models to test the differences between pre- and post-MM in all the different conditions. We added Mind-set as a random slope to counter the potential difference caused by the experimental sessions being on different days. It is worth noting that the main effect of Time in Model 2 and 3 is by default calculated on participants with a 0 z-score on all personality traits. This analytic strategy allows to how a unit-change in each personality trait (e.g. +1 z-score in anxiety) would affect the main effect of Time. For example, if the model would output a β of -3.443 for MS and a β of 5.345 for the anxiety trait in the MS condition, then a participant who is 1 z-score more anxious would rate 1.902 higher in post-MS compared to pre-MM.

5.2.5.4 Brain activity

5.2.5.4.1 EEG pre-processing

The acquired EEG data were resampled to 500 Hz and bandpass filtered (FIR filter, 0.1 – 45 Hz, 4080 filter order) using EEGLAB. The filtered files were further cleaned from artifacts by Independent Component Analysis (ICA) and the identified components were manually selected by using Multiple Artifact Rejection Algorithm (MARA). The post-ICA files were cut into pre- and post-mind-set manipulation (MM) files. These files were imported into Letswave 7 MATLAB plugin, where they were segmented into epochs based on the event markers. The signal was re-referenced to the average signal of all the channels. We have baseline corrected the event-related potentials (ERPs) by subtracting the average activity from -500 to 0ms. These files were used in the ERP analysis. The re-referenced, but not yet baseline corrected, files were used to calculate the time-frequency (TF) representation of the data. We calculated the power of frequencies from 1 Hz to 15 Hz in 0.1 Hz steps. We used the continuous wavelet transform function in Letswave 7. The values were divided by the mean of pre-stimulus activity from -1000ms to -200ms. To transform power from μV^2 to dB, we calculated the log10 of the baseline corrected values and multiplied them by 10. . Based on prior knowledge about the maximal activity associated with event-related responses to somatosensory stimuli, we selected an already established region of interest (ROI) for all the statistical analyses: a vertex ROI (VROI: FC1, FCz, FC2, C1, Cz, C2, CP1, CPz, and CP2) (Lagos, 2015).

We applied the models detailed for the analysis of pain ratings to the EEG data too. First, we identified intervals of interest (IOIs) for the somatosensory evoked potentials (SEPs). We applied our Model 2 and 3 on each timepoint of the SEP epochs. The IOIs were considered as significant if at least 10 consecutive models showed the same effect as significant (i.e. an interval of at least 20ms). Likewise, we identified time-frequency areas of interest (AOIs) with the minimum of 50 consecutive models with consistently significant effects (an interval of at least 100ms). We deemed the models statistically relevant only if they consecutively showed differences at 97.5 % CI, thus indicating non-overlapping MS and CTRL estimates.

The activity extracted from the SEP IOIs and the TF AOIs was then averaged. We have applied all three of our models on these average values to report our findings.

Following the identification of the IOIs and AOIs, we tested two experimental questions: 1) *Does the manipulation of sensory threat (Threat) influence brain responses? (i.e. Model 1)* and 2) *Does Threat interact with Mind-set and personality traits in exerting an effect on the change from pre- to post-MM? (i.e. Model 2 and 3).*

5.2.6 Results

5.2.6.1 STAI and PANAS results

The differences between pre- and post-MM are represented in the Appendix Figure 9-1.

5.2.6.1.1 Anxiety state

We found no significant main effect of Mind-set or Time. We also found no significant interaction between Mind-set and Time (Appendix Table 9-1 & Figure 9-2).

5.2.6.1.2 Positive mood

We found a significant main effect of Mind-set (Table 5-1) that was accounted for by lower values during the MS than CTRL session (Δ_{mean} = 3.140 ± 1.391, t = 2.257, 95% CI: [0.268; 6.012], p_b = 0.033).

	Sum of Squares	df	Mean Square	F	p	ω²
Mind-set	246.490	1	246.49	5.092	0.033	0.027
Residuals	1161.760	24	48.407	-	-	-
Time	193.210	1	193.210	8.748	0.007	0.026
Residuals	530.04	24	22.085	-	-	-
Mind-set x Time	10.890	1	10.890	1.849	0.187	< 0.001
Residuals	141.360	24	5.890	-	-	-

Table 5-1. Repeated measure ANOVA of the positive mood scores. We found significant main effects of Mind-set and Time, but no interaction between them.

Crucially though, this reduction in positive mood was not linked to the interaction between Mind-set and Time (Table 5-1 & Figure 5-2) whereas likely driven by an overall decrease of positive mood in Time (Δ_{mean} = 2.780 ± 0.940, t = 2.958, 95% CI: [0.840; 4.720], p_b = 0.007).

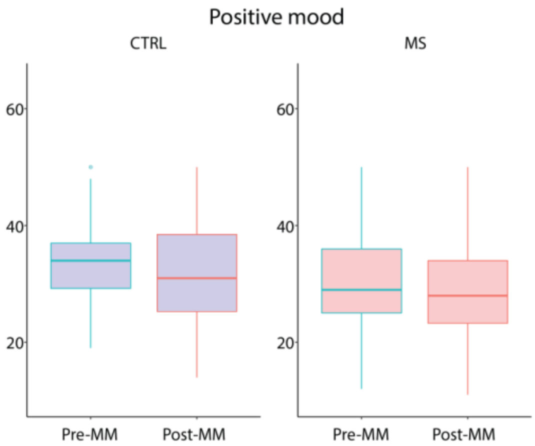

Figure 5-2. Pre- and post-MM positive mood scores during both Mind-set sessions. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue fill– CTRL, red fill – MS, green contour – pre-MM, orange contour – post-MM. Note the reduction of mood over time.

5.2.6.1.3 Negative mood

We found no significant main effect of Mind-set or Time. We also found no significant interaction between Mind-set and Time (Appendix Table 9-2 & Figure 9-3).

5.2.6.2 Pain ratings

5.2.6.2.1 Assessment of the effect of Threat (Model 1)

We found that the random slope significantly improved our model ($\chi^2(2) = 295.484$, $p <$ 0.001). We found a significant effect of Threat ($\chi^2(1) = 8.630$, $p = 0.003$). The model showed the intercept at 55.379 ± 1.511 % (t = 36.659, 95% CI: [52.418; 58.339], $p < 0.001$, R^2 marginal = 0.001, R^2 conditional = 0.178). The Threatening stimuli were rated higher than the Non-threatening stimuli (β_1 = 1.638 ± 0.557 %, t = 2.939, 95% CI: [0.545; 2.730], p = 0.003). Importantly, the same model applied to the non-normalised ratings led to statistically comparable results (Appendix Figure 9-4).

5.2.6.2.2 The modulatory role of Personality on the effect of Mind-set (Model 2)

The random slope improved the model fit ($\chi^2(2) = 272.539$, $p < 0.001$; R^2 marginal = 0.058, R^2 conditional = 0.243). The main effect of Time for a participant with average score of all personality traits (0 z-score) was ($\beta_{1\text{-MS}} = -3.443 \pm 0.762$ %, t = -4.511, 95% CI: [-4.939; -1.947], $p = 0.001$) and ($\beta_{1\text{-CTRL}} = -4.042 \pm 0.763$ %, t = -5.296, 95% CI: [-5.537; -2.546], $p < 0.001$). Table 5-2 & Figure 5-3 provides the detailed summary of these results.

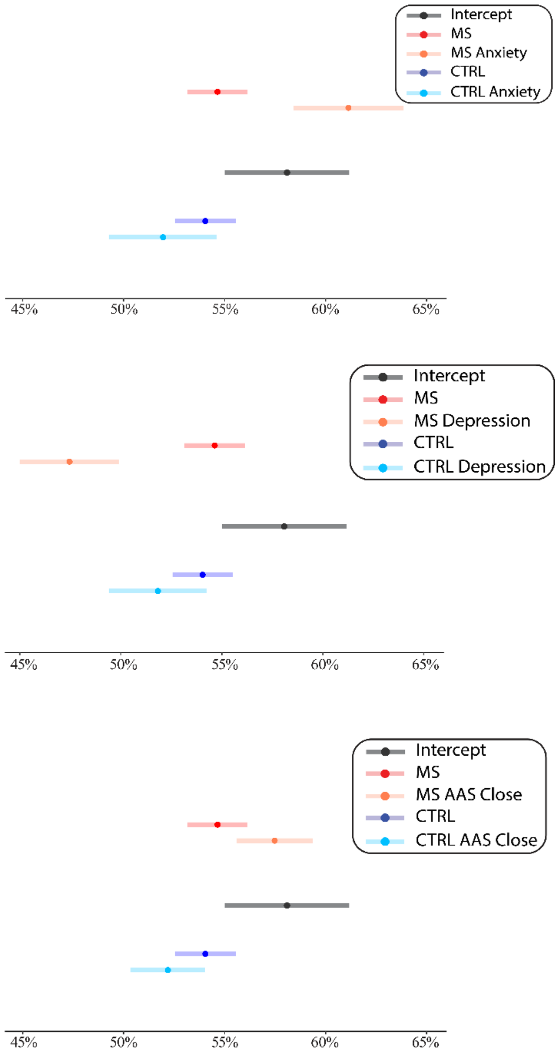

Figure 5-3. Model 2 applied to pain ratings. Dots represent the βs and the matted lines represent the 95% CIs calculated by the Wald method. We considered effects to be significantly different when their CIs did not overlap. Dots represent the βs and the matted lines represent the 95% CIs. The x axis represents the post-MM ratings ($\beta 0 + \beta 1$) in percentage (according to the min-max transformation). Top– Anxiety, Middle – Depression, Bottom – Adult Attachment Scale – Close.

Anxiety scores predicted an increase in ratings post-MS manipulation (Figure 5-3, top) but no substantial change post-CTRL. That is, the model indicates that higher levels of trait anxiety predict increase in pain during MS but not CTRL. Higher depression scores on the other hand, predicted a greater decrease in post-MS manipulation compared with post-CTRL (Figure 5-3, middle). Out of the three scores of the AAS, only the close attachment style showed a Mind-set specific effect (Figure 5-3, bottom). While higher scores in close attachment predicted a substantial increase in ratings post-MS, it predicted a significant decrease post-CTRL. At variance with these findings, higher fear of death and self-esteem scores predicted higher ratings post-MM regardless of the Mind-set.

		β	**SE**	**t**	**95% CI**	***p***	**χ^2(npar)**	**χ^2 *p***
Intercept		58.091	1.568	37.058	55.019; 61.163	< 0.001	-	-
MS		-3.443	0.763	-4.511	-4.939; -1.947	< 0.001	47.143(2)	< 0.001
CTRL		-4.042	0.763	-5.296	-5.537; -2.546	< 0.001		
Fear of Death	MS	5.969	0.888	6.725	4.230; 7.709	< 0.001	84.028(2)	< 0.001
	CTRL	5.588	0.869	6.433	3.885; 7.290	< 0.001		
Anxiety	MS	6.487	1.391	4.663	3.760; 9.213	< 0.001	23.998(2)	< 0.001
	CTRL	-2.098	1.361	-1.541	-4.765; 0.570	0.123		
Depression	MS	-7.191	1.257	-5.723	-9.654; -4.728	< 0.001	35.327(2)	< 0.001
	CTRL	-2.214	1.230	-1.800	-4.624; 0.196	0.072		
Self-esteem	MS	5.151	1.053	4.891	3.087; 7.215	< 0.001	36.871(2)	< 0.001
	CTRL	3.803	1.031	3.690	1.783; 5.822	< 0.001		
AAS Anxious	MS	3.969	1.058	3.752	1.896; 6.042	< 0.001	33.688(2)	< 0.001
	CTRL	4.647	1.035	4.490	2.619; 6.676	< 0.001		
AAS Close	MS	2.832	0.958	2.958	0.956; 4.709	0.003	12.864(2)	0.002
	CTRL	-1.861	0.937	-1.986	-3.698; -0.025	0.047		
AAS Dependent	MS	1.254	1.015	1.236	-0.735; 3.243	0.217	2.680(2)	0.262
	CTRL	1.077	0.993	1.084	-0.869; 3.023	0.278		

Table 5-2. Pre- to post-MM changes in pain ratings associated with Mind-set and personality traits. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

5.2.6.2.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

The random slope significantly improved our model ($\chi^2(2) = 273.648$, $p < 0.001$). β_0 was at 58.091 ± 1. 568 % (t = 37.059, 95% CI: [55.019; 61.163], $p < 0.001$, R^2 marginal = 0.061, R^2 conditional = 0.245). Our model did not reveal any difference driven by the interaction with Threat (Appendix Table 9-3).

5.2.6.3 Brain responses

5.2.6.3.1 Somatosensory evoked potentials

By applying Model 2 we identified two IOIs corresponding to an early negative (138 – 162ms) and late positive wave (406 – 428ms), consistently within the latency range of the classical N2-Ps vertex SEPs. The N2 IOI emerged from the interaction between Mind-set and the effects of anxious and close attachment types. The P2 IOI emerged from the interaction between Mind-set and dependent attachment type. We have applied our models on the average amplitude extracted from these IOIs to report our findings (Figure 5-4). Single-subject SEP plots representing the variance of the data are in the Appendix Figure 9-5.

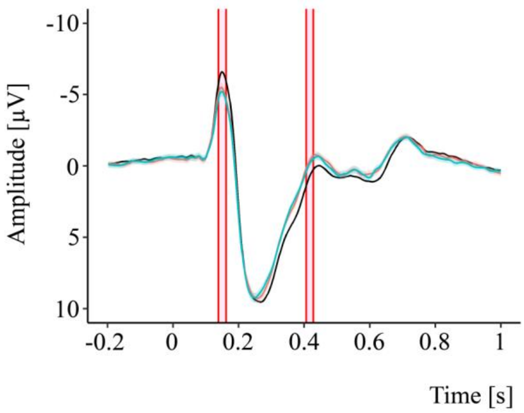

Figure 5-4. The IOIs identified by the LMM method (pink). The lines represent the pre-MM (β_0, black), post-MS (β_{MS}, red) and post-CTRL (β_{CTRL}, green) SEPs.

In summary, we found that Threat significantly modulated the N2 amplitude. Moreover, the change in Time was differently affected by anxious attachment type scores (N2) and dependent attachment scores (P2) across Mind-sets, particularly in the Threatening condition.

<u>5.2.6.3.1.1</u> <u>Assessment of the effect of Threat</u>

5.2.6.3.1.1.1 N2

The random slope improved the model fit ($\chi^2(2) = 237.228$, $p < 0.001$). β_0 was at -5.478 ± 1.218 µV (t = -4.497, 95% CI: [-7.866; -3.090], $p < 0.001$, R^2 marginal < 0.001, R^2 conditional = 0.640). We found that the negative amplitudes in Threatening condition was significantly greater than in Non-threatening condition ($\chi^2(1) = 5.801$, $p = 0.016$; $\beta_1 = -0.291$ ± 0.121 µV, t = -2.409, 95% CI: [-0.528; -0.054], $p = 0.016$).

5.2.6.3.1.1.2 P2

The random slope improved the model fit ($\chi^2(2) = 130.880$, $p < 0.001$). The intercept was at 0.275 ± 0.381 µV (t = 0.721, 95% CI: [-0.471; 1.021], $p = 0.477$, R^2 marginal < 0.001, R^2 conditional = 0.205). The model indicated no difference in amplitude associated with Threat ($\chi^2(1) = 0.490$, $p = 0.484$; $\beta_1 = -0.071$ ± 0.101 µV, t = -0.700, 95% CI: [-0.270; 0.128], p = 0.484).

<u>5.2.6.3.1.2</u> <u>The modulatory role of Personality on the effect of Mind-set (Model 2)</u>

5.2.6.3.1.2.1 N2

The random slope improved the model fit ($\chi^2(2) = 177.632$, $p < 0.001$). The intercept was at -6.809 ± 1. 325 µV (t = -5.138, 95% CI: [-9.406; -4.211], $p < 0.001$, R^2 marginal = 0.013, R^2 conditional = 0.650). Participants showed a general decrease of amplitude from pre- to post-MM (Appendix Table 9-4). Higher scores of anxious attachment predicted a significant amplitude increase/lack of decrease from pre- to post-MS (Figure 5-5).

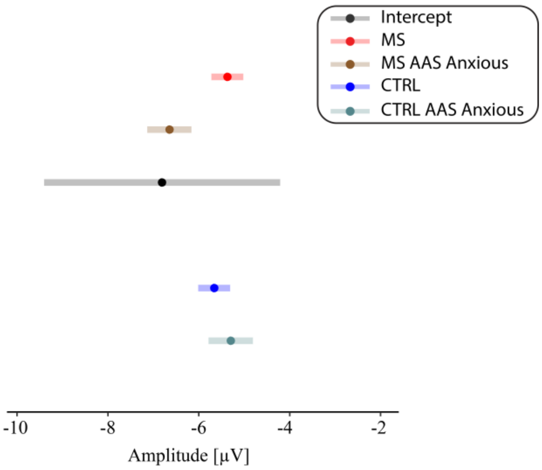

Figure 5-5. N2 amplitude change in Time as function of the interaction between anxious attachment type and Mind-set. Red – MS; Blue – CTRL; Brown – MS x AAS Anxious; Turquoise – CTRL x AAS Anxious. Dots represent βs, matted lines represent 95% confidence intervals calculated by Wald method. The higher scores of anxious attachment predicted greater N2 amplitude in the MS condition.

5.2.6.3.1.2.2 P2

The random slope improved the model fit ($\chi^2(2) = 101.478$, $p < 0.001$). The intercept was at 0.803 ± 0.422 µV (t = 1.902, 95% CI: [-0.025; 1.630], $p = 0.069$, R^2 marginal = 0.019, R^2 conditional = 0.228). Participants showed a general decrease in amplitude from pre- to post-MM (Appendix Table 9-5). Higher scores of dependent attachment predicted a significant amplitude increase from pre- to post-MS (Figure 5-6).

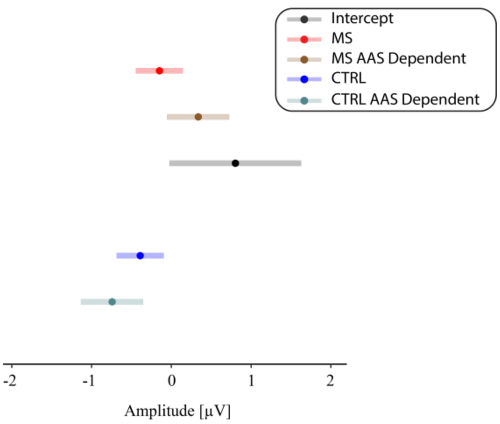

Figure 5-6. P2 amplitude change in Time as function of the interaction between dependent attachment and Mind-set. Red – MS; Blue – CTRL; Brown – MS x AAS Dependent; Turquoise – CTRL x AAS Dependent. Dots represent βs, matted lines represent 95% confidence intervals calculated by Wald method. The higher scores of dependent attachment types predicted greater P2 amplitude in the MS condition.

5.2.6.3.1.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

5.2.6.3.1.3.1 N2

The random slope improved the model fit ($\chi^2(2) = 178.145$, $p < 0.001$). The intercept was at -6.809 ± 1.325 µV (t = -5.138, 95% CI: [-9.406; -4.211], $p < 0.001$, R^2 marginal = 0.014, R^2 conditional = 0.651). We found no triple interaction on the N2 amplitudes (Appendix Table 9-6).

5.2.6.3.1.3.2 P2

The random slope improved the model fit ($\chi^2(2) = 101.861$, $p < 0.001$). The intercept was at 0.803 ± 0.422 µV (t = 1.902, 95% CI: [-0.024; 1.630], $p = 0.069$, R^2 marginal = 0.020, R^2 conditional = 0.230).The model indicated that the difference between the Mind-set conditions predicted by dependent attachment scores was only present in the Threatening condition (Appendix Table 9-7).

5.2.6.3.2 Time-frequency analysis

By applying Model 2 we identified an early alpha AOI (9.2 – 10.7Hz, 191.2 – 301.4ms), a low alpha/high theta AOI (7 – 8.3Hz, 277 – 352.3ms), a late alpha AOI (9.4– 11 Hz, 679.5– 734.1ms) and a late theta AOI (6.3– 7 Hz, 704.4– 796.5ms). The early alpha AOI emerged from the interaction between Mind-set and the effect of anxiety scores (Figure 5-7, left). The low alpha/high theta and late alpha AOI emerged from the interaction between Mind-set and the effect of depression scores (Figure 5-7, middle). The late theta AOIs emerged from the interaction between Mind-set and the effect of fear of death scores (Figure 5-7, right).

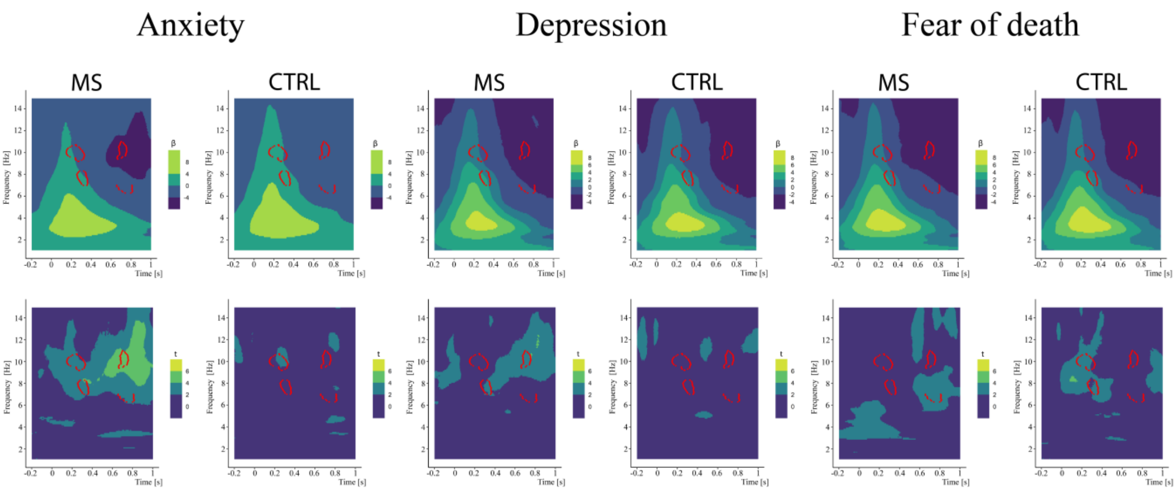

Figure 5-7. Time-frequency EEG areas of interest (AOIs) in MS and CTRL mind-sets predicted by individual differences in personality. The top panel shows the spectrograms of the post-MM effects (betas) predicted by the Mind-set conditions and the personality traits. The lower panel shows spectrograms of the difference (t-values) exerted by personality traits on the change in Time in each Mind-set. Anxiety predicted a significant difference between MS and CTRL in the early alpha activity (left). Depression scores predicted significant differences between Mind-set conditions in the late alpha and the low alpha/high theta areas (middle). Fear of death scores predicted significant differences between Mind-set conditions in the late theta activity (right).

In summary, we found significantly greater late alpha power following Threatening stimuli. Fear of death scores predicted lower early alpha during Non-threatening stimuli and lower alpha/high theta power after CTRL as well as significantly lower theta after MS. Anxiety trait scores predicted lower early and late alpha as well lower alpha/high theta power after MS. Furthermore, anxiety trait scores predicted lower late theta power after MS. In contrast, depression scores showed the opposite pattern. However, depression only predicted higher theta power during Threatening stimuli.

5.2.6.3.2.1 Assessment of the effect of Threat

5.2.6.3.2.1.1 Early alpha activity

The random slope improved the model fit ($\chi^2(2) = 363.729$, $p < 0.001$). The intercept was at 0.452 ± 0.405 dB (t = 1.117, 95% CI: [-0.341; 1.246], $p = 0.275$, R^2 marginal < 0.001, R^2 conditional = 0.459). The early alpha activity in the Threatening condition was not significantly different from Non-threatening condition ($\chi^2(1) = 0.244$, $p = 0.621$; $\beta_1 = 0.029 \pm 0.059$ dB, t = 0.494, 95% CI: [-0.087; 0.146], $p = 0.621$).

5.2.6.3.2.1.2 Low alpha/high theta activity

The random slope improved the model fit ($\chi^2(2) = 137.764$, $p < 0.001$). The intercept was at 1.820 ± 0.541 dB (t = 3.362, 95% CI: [0.759; 2.881], $p = 0.003$, R^2 marginal < 0.001, R^2 conditional = 0.511). The low alpha/high-theta activity in the Threatening condition was not significantly different from Non-threatening condition ($\chi^2(1) = 1.970$, $p = 0.160$; $\beta_1 = -0.099 \pm 0.070$ dB, t = -1.404, 95% CI: [-0.237; 0.039], $p = 0.160$).

5.2.6.3.2.1.3 Late alpha activity

The random slope improved the model fit ($\chi^2(2) = 154.005$, $p < 0.001$). The intercept was at -3.124 ± 0.304 dB (t = -10.293, 95% CI: [-3.719; -2.530], $p < 0.001$, R^2 marginal = 0.001, R^2 conditional = 0.302). The alpha activity in the Threatening condition was significantly lower than in Non-threatening condition ($\chi^2(1) = 11.612$, $p = 0.001$; $\beta_1 = -0.227 \pm 0.067$ dB, t = -3.409, 95% CI: [-0.358; -0.096], $p = 0.001$).

5.2.6.3.2.1.4 Late theta activity

The random slope improved the model fit ($\chi^2(2) = 12.057$, $p = 0.002$). The intercept was at -1.637 ± 0.208 dB (t = -7.888, 95% CI: [-2.044; -1.231], $p < 0.001$, R^2 marginal < 0.001, R^2 conditional = 0.081). The theta activity in the Threatening condition was not significantly different from Non-threatening condition ($\chi^2(1) = 0.346$, $p = 0.556$; $\beta_1 = 0.053 \pm 0.089$ dB, t = 0.589, 95% CI: [-0.122; 0.227], p = 0. 556).

<u>5.2.6.3.2.2 The modulatory role of Personality on the effect of Mind-set (Model 2)</u>

5.2.6.3.2.2.1 Early alpha activity

The random slope improved the model fit ($\chi^2(2) = 329.307$, $p < 0.001$). The intercept was at 0.687 ± 0.419 dB (t = 1.640, 95% CI: [-0.134; 1.508], $p = 0.114$, R^2 marginal = 0.023, R^2

conditional = 0.494). We found decreased power regardless of the Mind-set condition (Appendix Table 9-8). Higher scores of fear of death predicted lower power after CTRL (Appendix Table 9-8). On the other hand, anxiety trait scores predicted lower power after MS and greater power after CTRL (Appendix Table 9-8). Notably, self-esteem scores only predicted a significant decrease in alpha power in MS, but not in CTRL, however we found no significant difference between the Mind-sets (Appendix Table 9-8).

5.2.6.3.2.2.2 Low alpha/high theta activity

The random slope improved the model fit ($\chi^2(2) = 129.262$, $p < 0.001$). The model showed the intercept at 2.014 ± 0.537 dB (t = 3.749, 95% CI: [0.961; 3.067], $p = 0.001$, R^2 marginal = 0.018, R^2 conditional = 0.541). Higher scores of fear of death predicted lower power after CTRL (Table 5-3, Figure 5-8).

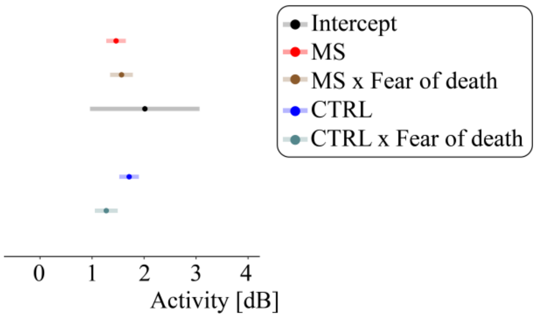

Figure 5-8. Fear of death scores effects on the change of low alpha/high theta activity from pre- to post-MM. Red – MS; Blue – CTRL; Brown – MS x Fear of death; Turquoise – CTRL x Fear of death. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method. Higher disposition to fear of death predicted lower alpha/high theta activity after CTRL.

While higher anxiety scores predicted lower power after MS (Table 5-3, Figure 5-9), higher depression scores predicted greater power after MS condition (Table 5-3, Figure 5-10). Moreover, higher scores of anxious attachment predicted greater power after CTRL.

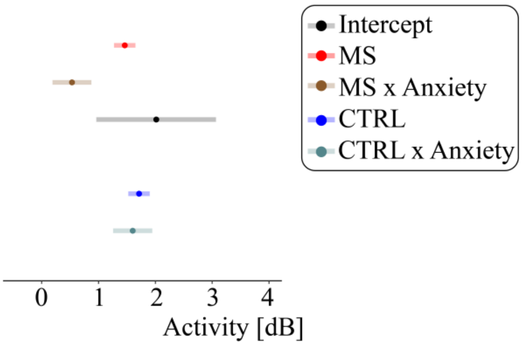

Figure 5-9. Anxiety trait scores effect on the change of low alpha/high theta activity from pre- to post-MM. Red – MS; Blue – CTRL; Brown – MS x Anxiety; Turquoise – CTRL x Anxiety. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method. Greater disposition to anxiety predicted lower alpha/high theta power after MS.

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		2.014	0.537	3.749	0.961; 3.067	0.001	-	-
MS		-0.552	0.096	-5.733	-0.741; -0.363	< 0.001	78.224(2)	< 0.001
CTRL		-0.301	0.096	-3.126	-0.490; -0.112	0.002		
Fear of Death	MS	0.104	0.111	0.936	-0.114; 0.322	0.349	16.191(2)	< 0.001
	CTRL	-0.439	0.112	-3.922	-0.659; -0.220	< 0.001		
Anxiety	MS	-0.928	0.174	-5.324	-1.270; -0.586	< 0.001	28.456(2)	< 0.001
	CTRL	-0.111	0.176	-0.635	-0.456; 0.233	0.525		
Depression	MS	0.472	0.157	2.995	0.163; 0.780	0.003	13.354(2)	0.001
	CTRL	-0.308	0.159	-1.941	-0.619; 0.003	0.052		
Self-esteem	MS	-0.235	0.132	-1.777	-0.493; 0.024	0.076	3.157(2)	0.206
	CTRL	-0.005	0.133	-0.038	-0.266; 0.256	0.970		
AAS Anxious	MS	-0.189	0.133	-1.426	-0.449; 0.071	0.154	15.375(2)	< 0.001
	CTRL	0.478	0.134	3.584	0.217; 0.740	< 0.001		
AAS Close	MS	0.049	0.120	0.404	-0.187; 0.284	0.686	0.830(2)	0.660
	CTRL	0.101	0.121	0.836	-0.136; 0.338	0.403		
AAS Depend	MS	-0.381	0.127	-2.996	-0.630; -0.132	0.003	8.968(2)	0.011
	CTRL	-0.029	0.128	-0.229	-0.280; 0.222	0.819		

Table 5-3. Pre- to post-MM changes in low alpha/high theta power associated with Mind-set and personality traits. 95 % CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

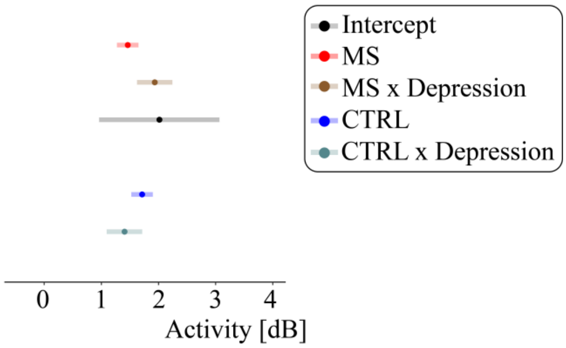

Figure 5-10. Depression trait scores effect on the change of low alpha/high theta activity from pre- to post-MM. Red – MS; Blue – CLRE; Brown – MS x Depression; Turquoise – CTRL x Depression. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method. Greater disposition to depression predicted greater alpha/high theta power after MS.

5.2.6.3.2.2.3 *Late alpha activity*

The random slope improved the model fit ($\chi^2(2) = 83.252$, $p < 0.001$). The model showed the intercept at -3.396 ± 0.315 dB (t = -10.780, $p < 0.001$, 95% CI: [-4.014; -2.779], R^2 marginal = 0.027, R^2 conditional = 0.331). Higher anxiety scores predicted lower power after MS while higher depression scores predicted greater power after MS (Appendix Table 9-9).

5.2.6.3.2.2.4 *Late theta activity*

The random slope did not improve the model fit ($\chi^2(2) = 3.048$, $p = 0.218$). Thus, we applied a model without random slopes. The model showed the intercept at -1.414 ± 0.211 dB (t = -6.404, 95% CI: [-1.847; -0.981], $p < 0.001$, R^2 marginal = 0.017, R^2 conditional = 0.102). Higher fear of death scores predicted lower power after MS. On the contrary, higher anxiety scores predicted lower theta power after MS (Appendix Table 9-10).

5.2.6.3.2.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

5.2.6.3.2.3.1 Early alpha activity

The random slope improved the model fit ($\chi^2(2) = 333.948$, $p < 0.001$). The intercept was at 0.687 ± 0.419 dB (t = 1.640, 95% CI: [-0.134; 1.508], $p = 0.114$, R^2 marginal = 0.028, R^2 conditional = 0.499). The effect of fear of death scores, shown by Model 2, was significant in the Non-threatening condition only (Appendix Table 9-11). Additionally, while depression scores predicted lower power for both Mind-sets during Non-threatening stimuli, they predicted greater power after MS during Threatening stimuli (Appendix Table 9-11). However, there was no significant difference between MS and CTRL in any Threat condition (Appendix Table 9-11).

5.2.6.3.2.3.2 Low alpha/high theta activity

The random slope improved the model fit ($\chi^2(2) = 130.912$, $p < 0.001$). The intercept was at 2.014 ± 0.537 dB (t = 3.749, 95% CI: [0.961; 3.066], $p = 0.001$, R^2 marginal = 0.022, R^2 conditional = 0.545). The significant increase in power predicted by depression scores following MS shown by Model 2 was significant only in the Threatening condition (Appendix Table 9-12).

5.2.6.3.2.3.3 Late alpha activity

The random slope improved the model fit ($\chi^2(2) = 111.903$, $p < 0.001$). The intercept was at -3.396 ± 0.315 dB (t = -10.780, $p < 0.001$, 95% CI: [-4.014; -2.779], R^2 marginal = 0.032, R^2 conditional = 0.336). Anxiety scores predicted lower power and depression scores predicted higher power post-MS regardless of the Threat condition (Appendix Table 9-13).

5.2.6.3.2.3.4 Late theta activity

The random slope did not improve the model fit ($\chi^2(2) = 3.144$, $p = 0.208$). Hence, we applied a model without random slope. The intercept was at -1.428 ± 0.211 dB ($t = -6.778$, $p < 0.001$, 95% CI: [-1.841; -1.015], R^2 marginal = 0.022, R^2 conditional = 0.107). We found that the lower power predicted by fear of death scores was only significant in Threatening conditions (Appendix Table 9-14). Surprisingly, by the introduction of Threat conditions, the significant decrease of power predicted by anxiety in Model 2 was not present in Model 3 (Appendix Table 9-14).

5.2.7 Discussion

Our study tested whether young adults submitted to reminders of death revealed a change in their perception and brain responses to noxious electrical stimuli, and whether these changes were also dependent on their expectations on the threat value of the sensory stimulation (Figure 5-1). According to the main tenet of TMT, we expected the classical MS manipulation to induce an increase in perception and magnitude of brain responses, particularly when a more painful stimulus was expected (i.e. during the threatening condition). In addition, we expected to observe further increase resulting from greater disposition to anxiety, fear of death, and anxious attachment whereas greater self-esteem and depression were expected to dampen the effects associated with MS manipulation.

5.2.7.1 Anxiety state and Mood

As TMT establishes that no explicit changes in mood and anxiety should be observed following mortality salience induction, we did not expect a significant difference between mind-set sessions in these ratings. There was indeed no difference in state anxiety, negative, and positive mood between mind-sets (Table 9-1 & Table 9-2; Figure 9-2, Figure 9-3), thus confirming our previous findings (Valentini et al., 2014, 2015). However, we found a significant reduction in positive mood that was independent from the type of Mind-set (Table 5-1; Figure 5-2). This difference may simply be explained by aware reduction in positive affect due to the exposure to negative valence mind-sets. Nevertheless, according to TMT, no consciously accessible changes of affect should take place whatsoever in the experimental participants (as measured by e.g. PANAS). According to the anxiety-buffer hypothesis MS effects are generated from the potential for anxiety triggered by the awareness of death (Greenberg et al., 2003). However, this hypothesis has been challenged and remains difficult to integrate with parsimonious models of biological responses to psychological threats (Jonas et al., 2014).

It begs the question of what the underlying mechanism from which MS effects stem is. It is more likely that the effects generated by reminders of death would act through the neural paths of an overarching anxiety biological system, common to other types of symbolic and sensory threats (Mcgregor et al., 2010; Tritt et al., 2012). This account would be able to explain mind-set effects that are not specific to mortality salience. This theoretical and methodological conundrum has already been spelled out (Lambert et al., 2014) and leaves researchers wondering whether both TMT and the devices traditionally used to measure affect are not equipped to account for the hypothesised effects. However, we previously showed that self-report measures correlate with EEG changes post-MS (Valentini et al., 2015), thus suggesting that while the differences in anxiety and mood between two negative mind-sets may be small to be detected with current available self-report measures, the latter could still be able to index ongoing changes associated with the experimental manipulation. If so, the ball would eventually be in the TMT field: a better explanation of MS mechanisms is required.

5.2.7.2 Pain ratings

Pain intensity decreased from pre- to post-MM regardless of the mind-set, according to a general habituation phenomenon (Figure 5-3). Habituation is a widely observed phenomenon in perception (and pain) experiments, especially when using single stimuli with relatively long inter-stimulus intervals (Hollins et al., 2011). However, despite the general reduction in perception, participants with greater trait anxiety rated post-MS stimuli as more painful (Figure 5-3, top; Table 5-3). On the contrary, Participants with greater trait depression rated post-MS stimuli as less painful (Figure 5-3, middle; Table 5-3). In addition, we found that individuals scoring higher in close attachment style reported an increase in pain following MS manipulation (Figure 5-3, bottom; Table 5-3). At variance with our expectations however, greater disposition to fearing death did not predict increased pain following MS (Table 5-3). Equally, greater self-esteem did not act as a buffer against MS effects. We instead found a general increase of pain ratings in people reporting greater fear of death and greater self-esteem regardless of the mind-set (Table 5-3).

It is worth noting that we introduced an element of novelty in this study compared to our past research where we also took advantage of inducing pain as a means to enhance our ability to detect MS effects (Valentini et al., 2014, 2015, 2017): the manipulation of threat associated with the sensory stimuli. The rationale of this choice is based on well-known notion that expectation can increase perception (Loeser & Melzack, 1999; Tracey, 2010; Kokonyei et al., 2019), and particularly on past empirical evidence (Wiech et al., 2010) showing how the manipulation of the perceived threat value of otherwise physically identical nociceptive stimuli does impact pain perception (i.e. threatening stimuli perceived as more painful). Our results confirm this manipulation was effective but do not support the hypothesis of an interaction between the threat manipulation and mind-set type. Out of the seven individual traits, only close attachment type predicted significant difference between Mind-set conditions only in Non-threatening condition (Appendix Table 9-3).

5.2.7.3 Somatosensory evoked potentials

The N2 wave proved sensitive to Threat manipulation. This finding is in keeping with the sensitiveness of the N2 wave to bottom-up and top-down attentional modulations in the visual (Hillyard et al., 1998), auditory (Wu et al., 2010; Tomé et al., 2015), and somatosensory (Michie, 1984; Eimer & Forster, 2003) domain, implying a functional role in homeostatic processing of bodily and environmentally relevant changes. The N2 also showed a significant amplitude reduction in Time, conforming to the general habituation phenomenon, akin to the pain ratings. While we could not find an effect of MS on N2 and P2 waves in a previous study with a different design (Valentini et al., 2014), others have reported a greater amplitude for the negative wave and a lower amplitude for the positive wave elicited by electrical painful stimuli after presenting participants with a series of statements related to death vs. a negative control condition (Wang & Tian, 2018).

Interestingly, while we could not detect a main effect of Mind-set on the N2 and P2 components we identified its interaction with individual differences in personality. Higher level of anxious attachment predicted lack of habituation or even increase of the N2 component in the MS condition. Notably, fear of death scores predicted a similar effect on the N2 amplitude during MS, though not satisfying the statistical threshold (Appendix Table 9-4). Similarly, greater dependent attachment predicted increase of the P2 amplitude (lack of habituation thereof) in MS condition (Appendix Table 9-5). Furthermore, this interaction was only significant in the Threatening condition, showing not only the interaction with mind-set but also with a further psychological manipulation created ad-hoc to potentiate the effects induced by MS (Appendix Table 9-7).

These results indicate that classical ERPs effects observed following reminders of death may be importantly impacted by individual differences in personality traits. We speculate that personality factors and their interaction with reminders of death may influence our ability to estimate the already small effects associated with the MS manipulation (see also Valentini et al., 2014).

5.2.7.4 Time-frequency analysis

At variance with our previous work where we established *a priori* arbitrary frequencies of interest and used single electrodes for measuring the experimental responses (Valentini et al., 2014, 2015), here we opted for a data-driven identification of significant spectral modulations across the scalp and relied on stringent statistical criteria for significance. Our approach revealed four time-frequency AOIs: an early alpha AOI (9.2 – 10.7Hz, 191.2 – 301.4ms); a low alpha AOI (7 – 8.3Hz, 277 – 352.3ms); a late alpha AOI (9.4– 11 Hz, 679.5– 734.1ms); and a late theta AOI (6.3– 7 Hz, 704.4– 796.5ms) (Figure 5-7). The early alpha AOI emerged from the significant interaction between anxiety trait scores and Mind-set conditions (Figure 5-7, left). The low alpha and the late alpha AOIs emerged from the interaction between depression trait scores and Mind-set (Figure 5-7, middle). Lastly, the late theta AOI emerged from the interaction between fear of death scores and Mind-set (Figure 5-7, right). We found that the event-related desynchronization (ERD) (i.e. the transient suppression of oscillatory magnitude compared to pre-stimulus, Neuper & Pfurtscheller, 2001) in the late alpha AOI was significantly greater when Threatening stimuli were delivered. Alpha desynchronization is thought to be a reliable correlate of the increased thalamocortical excitability (Pfurtscheller et al., 2008), reflecting both sensory and cognitive modulations (Hu, Peng, et al., 2013). In the context of the current study, we surmise alpha ERD reflected increased cognitive/affective load during the experimental condition participants expected to feel greater pain. This interpretation would also account for the effects exerted by the anxiety trait in predicting greater early and late alpha (Appendix Table 9-8 & Table 9-9) as well as low alpha ERD in the MS condition (Table 5-3). In a mirroring fashion, the depression trait counteracted the desynchronization trend in the low alpha activity (Figure 5-9 & Figure 5-10, Table 5-3), especially in the Threatening condition (Appendix Table 9-12). This combined effect of anxiety and depression in increasing vs. reducing excitability of brain activity is in keeping with a large bulk of literature (Clark et al., 2009).

Unexpectedly, we found that fear of death scores predicted a significantly greater early alpha desynchronization following CTRL mind-set instead of MS (Appendix Table 9-8). Both attachment style and fear of death have been implicated as independent or dependent variables in TMT research (Mikulincer et al., 2003; Cox & Arndt, 2012; Yanagisawa et al., 2016). We assumed that both stable dispositions in anxious attachment and fear of death could interact with MS in triggering changes in pain perception and neural activity. However, our findings do not support this hypothesis. Likewise, that self-esteem was not associated with a reduction of pain after MS induction is in contrast with evidence supportive of TMT (Solomon et al., 1991; Solomon & Greenberg, 2000; Routledge et al., 2004; Niemiec et al., 2010; Wisman et al., 2015).

5.2.7.5 Limitations and future directions

Our study introduces a few elements of novelty. First, we capitalised on individual differences in relevant personality traits to account for differences between reminders of death and the control mind-set. In previous research, we used trait anxiety and depression only as a screening tool to test the effects of the classical TMT MS paradigm, thus treating individual differences in anxiety and depression as confounding variables. In the current study, besides screening individuals for extreme scores in both variables, we considered anxiety and depression as explanatory rather than interfering variables in the statistical analysis. The current approach allowed us to detect a complementary finding of increased and decreased pain following reminders of mortality when the individuals displayed either an anxious or depressive trait respectively. While anxiety scores predicted a significantly greater increase in pain, depression scores predicted a significant decrease in pain following MS induction. This finding supports the idea that self-reported individual differences in anxiety and depression do alter the outcome of MS manipulation and that individuals reporting greater anxious/depressive disposition are affected more by reminders of death. This finding, when combined with lack of Mind-set-related differences in state mood and anxiety during the experiment, seems in agreement with previous literature reporting the role of related personality traits, such as neuroticism (Goldenberg et al., 2006; Goldenberg & Arndt, 2008; Pyszczynski et al., 2015). Undoubtedly, trait anxiety had the greater impact on the EEG measures. It predicted a greater desynchronization following MS in the low alpha AOI (Table 5-3, Appendix Table 9-8 & Table 9-9). This finding is in keeping with previous research indicating a role of the anxiety trait in the context of behavioural response to existential threats (Solomon et al., 1991; Pyszczynski, 2004).

Although counterintuitively, there is evidence that more intensive reminders of death can eliminate the expected MS effects, compared to milder MS manipulation (for a review see Pyszczynski et al., 2015). Hence, we surmise that the combination of both MS and the higher sensory threat while enhancing our abilities to observe the effect of individual differences in other personality traits (e.g. anxiety) may be less sensitive when measuring other, less unequivocal personality measures. In fact, the interpretation of findings on the interaction between MS and self-esteem is also particularly challenging. For example, individuals who value driving ability as a means of self-worth were more likely to engage in risky driving following MS induction (Jessop et al., 2008). Likewise, research has shown that individuals with high self-esteem may be more willing to take risks whereas those with low self-esteem may be risk aversive (Goldenberg et al., 2006). Nonetheless, the opposite has been shown as well (Miller & Taubman-Ben-Ari, 2004). This ambiguity and the counterintuitive results jeopardise a simple interpretation of the interaction between mortality awareness and self-esteem. Interestingly, as reviewed by Schmeichel et al. (2009) there are several findings contradicting TMT predictions, especially when explicit self-esteem was measured (as in the current study).

Considering the criticism conveyed by alternative theories (McGregor et al., 2001; Heine et al., 2006; Carleton, 2016a) and the recent failure to replicate classical TMT findings (Mcgregor et al., 2010; Jonas et al., 2014; Rodríguez-Ferreiro et al., 2019) we are cautious in the interpretation of our current results. Nonetheless, they suggest that individual differences in personality may act as moderators and account for a substantive amount of variance otherwise linked to reminders of death. Their latent influence may mask or explain the purported effects of mortality salience in healthy adults.

5.3 Experiment 2

5.3.1 Introduction

Experiment 2 utilised the same design as Experiment 1 with only one significant expansion: We aimed to test how an MS aimed at one's romantic partner instead of one's own mortality would predict changes in behaviour and brain responses. Previous research linked wishes for interactions and relationships to MS (Florian et al., 2002; Taubman-Ben-Ari et al., 2002). However, there is no substantial investigation on how the reminder of one's romantic partner's death would affect behaviour and neural responses.

Here we attempted to utilise our previous experimental design to investigate participants in exclusive romantic relationships. Similarly to Experiment 1, we collected personality trait measurements before the experiment. Instead of using the fear of death subscale of the Collett-Lester Fear of Death scale, we used the fear of other's death subscale to measure a better aligned fear to losing one's loved one. It is assumed that even indirect reminders of mortality, such as an image (Valentini & Gyimes, 2018) or even the word 'death' (Pyszczynski et al., 2015) can trigger the changes described in TMT. We expected that the effects of MS in Experiment 1 and Experiment 2 will be similar compared to the CTRL, showing that they trigger a similar reaction.

5.3.2 Methods and Materials

We followed the same methods as in Experiment 1, except the participant pool and the experimental mind-set manipulation. For experiment 2, we only recruited participants who were in exclusive romantic relationship and we used a MS aimed towards said romantic partner: "Please briefly describe the emotions that your romantic partner's death arouses in you” and “Jot down, as specifically as you can, what will happen when they physically die and once they are dead”.

5.3.2.1 Participants

Twenty-nine healthy participants (17 females, mean age 25.21 ± 9.28, ranged from 19 to 66) were screened and entered the study. The screening intended to filter out individuals with neurological, psychiatric, and other medical conditions that could interfere with the experiment. All participants had normal or corrected-to-normal vision. The experimental procedures were approved by the University of Essex ethics committee (1701) and were in accordance with the standards of the Declaration of Helsinki. No participant was excluded based on the criteria outlined in Experiment 1 (Section 5.2).

5.3.3 Results

5.3.3.1 STAI and PANAS results

We analysed the change in anxiety state, positive and negative mood. The differences between pre- and post-MM are represented in Appendix Figure 8. There was a significant main effect of Time and interaction between Time and Mind-set on positive mood scores. We found that it was driven by the significantly higher pre-CTRL scores (Table 5-4, Table 5-5 & Figure 5-11).

5.3.3.1.1 Anxiety state

We found no significant main effect of Time or Mind-set or significant interaction between them (Appendix Figure 9-9, Table 9-15).

5.3.3.1.2 Positive mood

There was a significant main effect of Time and interaction between Time and Mind-set (Figure 5-11, Table 5-4). *Post-hoc* tests revealed significant decrease from pre- to post-MM (Δ_{mean} = 1.345 ± 0.491, t = 2.738, 95% CI: [0.339; 2.351], p_b = 0.011). Follow up test on the interaction showed that this change was only significant in CTRL condition (Table 5-5).

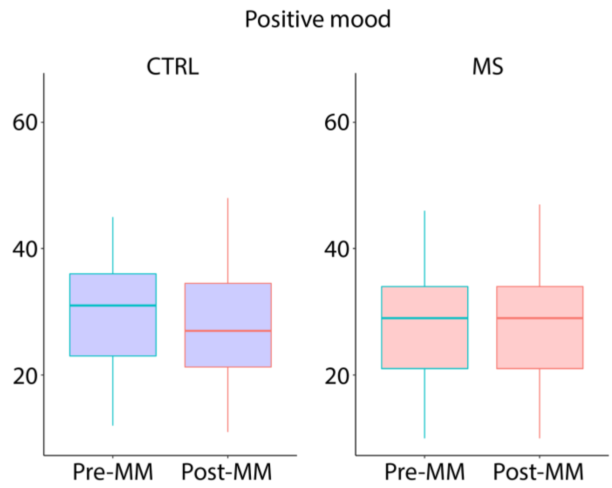

Figure 5-11. Difference between pre- and post-MM positive mood scores in both Mind-set conditions in Experiment 2. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue – CTRL, red – MS, green – pre-MM, orange – post-MM.

	Sum of Squares	df	Mean Square	F	p	ω²
Mind-set	13.793	1	13.793	0.675	0.418	0.000
Residuals	572.082	28	20.431	-	-	-
Time	52.448	1	52.448	7.495	0.011	0.006
Residuals	195.927	28	6.997	-	-	-
Mind-set x Time	18.241	1	18.241	4.790	0.037	0.002
Residuals	106.634	28	3.808	-	-	-

Table 5-4. Results of the repeated measure ANOVA on the positive mood scores in Experiment 2. Note the significant main effect of Time and interaction between Time and Mind-set.

		Mean Difference	SE	t	P_b	95% CI
Pre-CTRL	Pre-MS	1.483	0.914	1.622	0.679	-1.062; 4.027
	Post-CTRL	2.138	0.610	3.502	0.006	0.463; 3.813
	Post-MS	2.034	0.973	2.092	0.253	-0.649; 4.718
Pre-MS	Post-CTRL	0.655	0.973	0.674	1.000	-2.029; 3.339
	Post-MS	0.552	0.610	0.904	1.000	-1.123; 2.227
Post-CTRL	Post-MS	-0.103	0.914	-0.113	1.000	-2.648; 2.441

Table 5-5. *Post hoc* tests of the Mind-set x Time interaction on the positive mood scores in Experiment 2. P values are Bonferroni corrected.

5.3.3.1.3 Negative mood

We found no significant main effect of Time or Mind-set or significant interaction between them (Appendix Figure 9-10, Table 9-16).

5.3.3.2 Pain ratings

Our models revealed the main effects of Threat and Mind-set on the pain ratings. Participants rated the Threatening stimuli significantly higher than the Non-threatening ones (Appendix Figure 9-11). In terms of Mind-set, we found the expected habituation in the CTRL condition and a significant increase in the MS condition from pre- to post-MM (Figure 5-12). Out of the seven personality traits, depression and anxiety trait scores predicted similar tendencies as in Experiment 1; however, they did not predict significant changes exclusively in MS (Figure 5-12). The effect of anxiety was only significantly different between Mind-set conditions in the Non-threatening, while the effect of depression was only significantly different between Mind-set conditions in the Threatening condition (Appendix Table 9-7).

5.3.3.2.1 Assessment of the effect of Threat (Model 1)

The random slopes significantly improved our model's fit ($\chi^2(2) = 566.361$, $p < 0.001$). Model 1 revealed a significant effect of Threat ($\chi^2(1) = 36.493$, $p < 0.001$). The model showed the β_0 at 51.904 ± 1.540 % (t = 33.712, 95% CI: [48.887; 54.922], $p < 0.001$, R^2 marginal = 0.004, R^2 conditional = 0.120). Threatening stimuli were rated higher than the Non-threatening (β_1 = 3.237 ± 0.535 %, t = 6.048, 95% CI: [2.188; 4.286], $p < 0.001$) (Appendix Figure 9-11). Importantly, the same model applied to the non-normalised ratings led to statistically comparable results (Appendix Figure 9-11).

5.3.3.2.2 The modulatory role of Personality on Mind-set (Model 2)

The random slope significantly improved our model's fit ($\chi^2(2) = 521.445$, $p < 0.001$). The model showed β_0 at 53.091 ± 1.530 % (t = 34.703, 95% CI: [50.093; 56.090], $p < 0.001$, R^2 marginal = 0.053, R^2 conditional = 0.246). A participant with average score (0 z-score) showed increased ratings to post-MS ($\beta_{1\text{-MS}}$ = 5.072 ± 0.740 %, t = 6.855, 95% CI: [3.622; 6.522], $p < 0.001$) and a decreased ratings to post-CTRL ($\beta_{1\text{-CTRL}}$ = -3.687 ± 0.740 %, t = -4.984, 95% CI: [-5.138; -2.237], $p < 0.001$). Anxiety level predicted an increase in perceived pain in both conditions; however, it affected CTRL significantly more (Figure 5-12, Table 5-6). Higher levels of depression predicted a decrease in pain perception, and a significantly greater level in MS condition (Figure 5-12, Table 5-6).

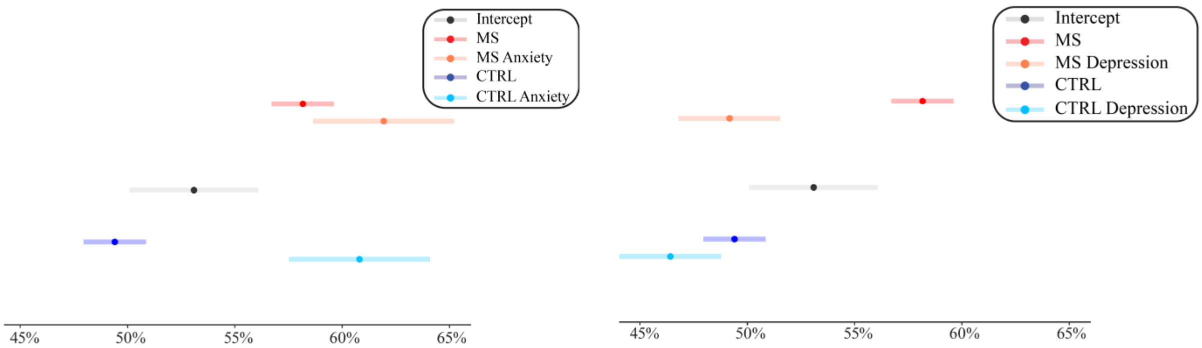

Figure 5-12. Model 2 applied to pain ratings in Experiment 2. Dots represent the βs and the matted lines represent the 95% CIs calculated by the Wald method. We considered effects to be significantly different when their CIs did not overlap. Dots represent the βs and the matted lines represent the 95% CIs. The x axis represents the post-MM ratings (β0 + β1) in percentage (according to the min-max transformation). Differences between two β1s defined as not overlapping CIs. Left – Anxiety, Right – Depression

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		53.091	1.530	34.703	50.093; 56.090	< 0.001	-	-
MS		5.072	0.740	6.855	3.622; 6.522	< 0.001	72.339(2)	< 0.001
CTRL		-3.687	0.740	-4.984	-5.138; -2.237	< 0.001		
Fear of other's Death	MS	0.561	1.171	0.479	-1.735; 2.857	0.632	5.058(2)	< 0.001
	CTRL	-2.576	1.172	-2.198	-4.873; -0.279	0.028		
Anxiety	MS	3.769	1.678	2.246	0.481; 7.058	0.025	50.932(2)	< 0.001
	CTRL	11.400	1.679	6.791	8.110; 14.690	< 0.001		
Depression	MS	-8.993	1.210	-7.435	-11.364; -6.622	< 0.001	61.150(2)	< 0.001
	CTRL	-2.991	1.210	-2.471	-5.362; -0.619	0.013		
Self-esteem	MS	0.086	1.073	0.080	-2.018; 2.189	0.937	12.786(2)	< 0.001
	CTRL	3.842	1.074	3.577	1.737; 5.947	< 0.001		
AAS Anxious	MS	3.013	1.559	1.932	-0.043; 6.069	0.053	5.196(2)	< 0.001
	CTRL	1.891	1.560	1.212	-1.167; 4.948	0.226		
AAS Close	MS	3.008	1.174	2.561	0.706; 5.309	0.010	17.601(2)	0.002
	CTRL	3.932	1.175	3.347	1.630; 6.235	0.001		
AAS Dependent	MS	0.450	1.354	0.332	-2.204; 3.104	0.740	1.911(2)	0.262
	CTRL	-1.823	1.355	-1.345	-4.478; 0.833	0.179		

Table 5-6. Pre- to post-MM changes in pain ratings associated with Mind-set and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

5.3.3.2.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

The random slope significantly improved our model's fit ($\chi^2(2) = 523.655$, $p < 0.001$). The model showed β_0 at 53.091 ± 1.530 % (t = 34.704, 95% CI: [50.093; 56.089], $p < 0.001$, R^2 marginal = 0.056, R^2 conditional = 0.249). The increase in ratings in MS condition predicted by anxiety trait scores was only significantly greater from the increase in CTRL in the Non-threatening condition. On the contrary, the decrease in ratings in MS predicted by depression scores was only significantly different from the decrease in CTRL in the Threatening condition (Appendix Table 9-17).

5.3.3.3 Brain responses

5.3.3.3.1 Event-related potentials

By applying Model 2 and 3 we identified three IOIs corresponding to A very early one (-4 – 16ms, N1), an early negative component (138 – 162ms, N2), a positive component (200 – 230ms, P2) (Figure 5-13), consistently within the latency range of the classical N2-Ps vertex SEPs. The N1 IOI emerged from the interaction between Mind-set and anxiety trait. The N2 IOI emerged from the interaction between Mind-set and the effects of and close attachment types in the Threatening condition. The P2 IOI emerged from the interaction between Mind-set and close attachment type. We applied our models on the average amplitude extracted from these IOIs to report our findings (Figure 5-13). Single-subject SEP plots representing the variance of the data as well as the topographies of the components are in the Appendix Figure 9-12 & Figure 9-13.

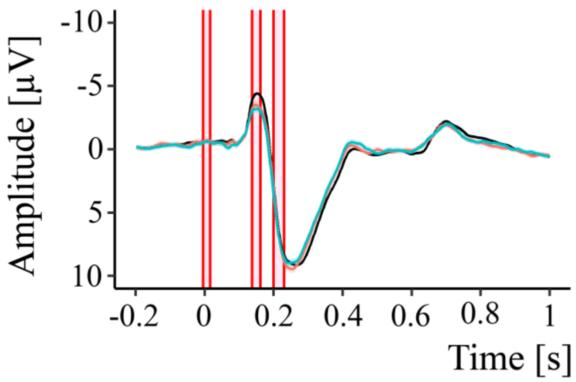

Figure 5-13. The IOIs identified by the the LMM method (pink) in Experiment 2. The lines represent the pre-MM (β0, black), post-MS (βMS, red) and post-CTRL (βCTRL, green) SEPs. Note that the LMM IOIs are overlapping with the ANOVA IOIs.

We found that Threat predicted no difference in any components. The N1 amplitude change from pre- to post-MM was significantly greater in the MS condition predicted by anxiety trait and close attachment type scores (Appendix Table 9-18). However, both of these personality traits predicted significant differences between MS and CTRL in the Non-threatening condition (Appendix Table 9-21). Close attachment type scores also predicted a significantly lesser increase of P2 amplitude from pre- to post-CTRL compared to MS (Appendix Table 9-20). This effect of the close attachment type on the P2 amplitude was only significant in the Non-threatening condition (Appendix Table 9-23). Surprisingly, close attachment type only showed a significant effect on the change of N2 component from pre- to post-CTRL in the Threatening condition (Appendix Table 9-22).

<u>5.3.3.3.1.1</u> <u>Assessment of the effect of Threat (Model 1)</u>

5.3.3.3.1.1.1 N1

The model fit did not improve by the random slope ($\chi^2(2) = 3.919$, $p = 0.141$). Hence we used a model without random slope. β_0 was at -0.661 ± 0.081 µV (t = -8.189, 95% CI: [-0.819; -0.503], $p < 0.001$, R^2 marginal < 0.001, R^2 conditional = 0.008). We found that the negative amplitudes in Threatening condition were non-significantly different than in Non-threatening condition ($\chi^2(1) = 0.788$, $p = 0.375$; $\beta_1 = 0.079 \pm 0.089$ µV, t = 0.888, 95% CI: [-0.096; 0.254], $p = 0.375$).

5.3.3.3.1.1.2 N2

The model fit has improved by the random slopes ($\chi^2(2) = 384.947$, $p < 0.001$). β_0 was at -3.731 ± 0.793 µV (t = -4.707, 95% CI: [-5.284; -2.177], $p < 0.001$, R^2 marginal < 0.001, R^2 conditional = 0.494). The negative amplitudes in Threatening condition were non-significantly greater than in Non-threatening condition ($\chi^2(1) = 0.070$, $p = 0.791$; $\beta_1 = -0.029$ ± 0.107 µV, t = -0.265, 95% CI: [-0.239; 0.182], $p = 0.791$).

5.3.3.3.1.1.3 P2

The model fit has improved by the random slope ($\chi^2(2) = 376.959$, $p < 0.001$). β_0 was at 6.244 ± 0.719 µV (t = 8.690, 95% CI: [4.836; 7.653], $p < 0.001$, R^2 marginal < 0.001, R^2 conditional = 0.460). We found that the negative amplitudes in Threatening condition were non-significantly different compared to the ones in Non-threatening condition ($\chi^2(1) = 0.047$, $p = 0.828$; $\beta_1 = 0.024 \pm 0.111$ µV, t = 0.218, 95% CI: [-0.193; 0.241], $p = 0.828$).

5.3.3.3.1.2 The modulatory role of Personality on Mind-set (Model 2)

5.3.3.3.1.2.1 N1

Adding the random slope did not improve our model significantly ($\chi^2(2) = 0.252$, $p = 0.881$). Hence, we used a model without the random slope. β_0 was found at -0.608 ± 0.082 µV (t = -7.379, $p < 0.001$, 95% CIs: [-0.770; -0.447], R^2 marginal = 0.004, R^2 conditional = 0.010). There was no significant change from pre to post-MM. However, we found that higher levels of anxiety predicted significantly greater negative amplitudes post-MS compared to post-CTRL (Figure 5-14). Similarly close attachment type scores predicted significantly greater negative amplitude in MS condition compared to CTRL (Appendix Table 9-18).

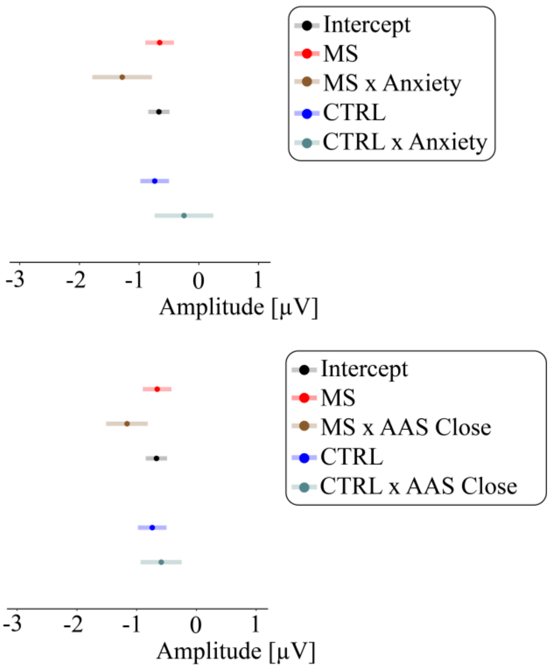

Figure 5-14. Effects of anxiety trait (top) and close attachment type (bottom) scores on the change of N1 amplitude from pre-, to post-MS and post-CTRL in Experiment 2. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method.

5.3.3.3.1.2.2 N2

Adding the random slope improved our model significantly ($\chi^2(2) = 307.753$, $p < 0.001$). β_0 was found at -4.639 ± 0.862 µV (t = -5.383, $p < 0.001$, 95% CIs: [-6.328; -2.950], R^2 marginal = 0.012, R^2 conditional = 0.504). There was a decrease of the negative amplitude from pre- to post-MM regardless of the Mind-set type (Appendix Table 9-19). While we found significant interactions between Mind-set and personality traits, none of them showed significant differences between Mind-set conditions (Appendix Table 9-19).

5.3.3.3.1.2.3 P2

Adding the random slope improved our model significantly ($\chi^2(2) = 331.551$, $p < 0.001$). β_0 was found at -6.560 ± 0.782 µV (t = 8.392, $p < 0.001$, 95% CIs: [5.028; 8.092], R^2 marginal = 0.007, R^2 conditional = 0.461). The amplitude increased from pre to post-MM regardless of the Mind-set. Close attachment type predicted a decrease in amplitude in post-CTRL and no change to post-MS (Figure 5-15, Appendix Table 9-20).

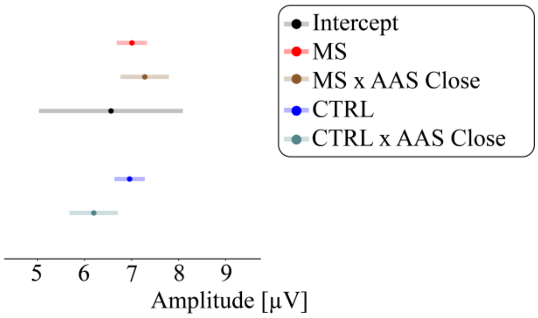

Figure 5-15. Effects of close attachment type scores on the change of P2 amplitude from pre-, to post-MS and post-CTRL in Experiment 2. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method.

5.3.3.3.1.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

5.3.3.3.1.3.1 N1

Adding the random slope did not improve our model significantly ($\chi^2(2) = 0.263$, $p = 0.877$). Hence, we used a model without the random slopes. β_0 was found at -0.608 ± 0.082 µV (t = -7.379, $p < 0.001$, 95% CIs: [-0.770; -0.447], R^2 marginal = 0.007, R^2 conditional = 0.013). We found that the effect of anxiety was only present in Non-threatening conditions. Close attachment type predicted a greater negative amplitude post-MS only in the Non-threatening condition (Appendix Table 9-21).

5.3.3.3.1.3.2 N2

Adding the random slope significantly improved our model's fit ($\chi^2(2) = 309.466$, $p < 0.001$). β_0 was found at -4.639 ± 0.862 µV (t = -5.383, $p < 0.001$, 95% CIs: [-6.328; -2.950], R^2 marginal = 0.014, R^2 conditional = 0.506). Close attachment type scores predicted greater reduction in CTRL condition compared to MS in the Threatening condition (Appendix Table 9-22).

5.3.3.3.1.3.3 P2

Adding the random slope improved our model significantly ($\chi^2(2) = 332.435$, $p < 0.001$). β_0 was found at -6.560 ± 0.782 µV (t = 8.392, $p < 0.001$, 95% CIs: [5.028; 8.092], R^2 marginal = 0.009, R^2 conditional = 0.461). We only found the significant effect of close attachment type in the Non-threatening condition (Appendix Table 9-23).

5.3.3.3.2 Time frequency

We identified an AOI in the theta frequency band (5.4 – 6 Hz, 109.333 – 264ms) as we found consecutively significant effects of close attachment type scores (Figure 5-16). Close attachment type scores predicted lower theta activity post-MS compared to CTRL, however, only in the Non-threatening condition. Topography of the AOI is represented in the Appendix Figure 9-14.

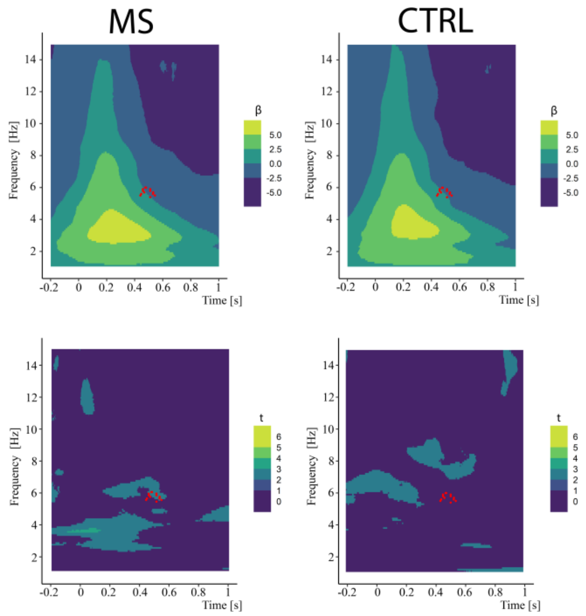

Figure 5-16. Time-frequency brain activities in MS and CTRL conditions predicted by close attachment type scores in Experiment 2. The upper spectrograms show the post-MM activities predicted by the Mind-set conditions and the close attachment type scores. The lower plots show the absolute t-values of the effect of the close attachment type scores on the change in Time in the Mind-set conditions. The significant AOI has been found in the theta frequency band.

5.3.3.3.2.1 Assessing the effects of Threat (Model 1)

Adding the random slope significantly improved our model's fit ($\chi^2(2) = 148.369$, $p < 0.001$). β_0 was found at 0.342 ± 0.313 dB (t = 1.093, 95% CIs: [-0.271; 0.954], $p = 0.284$, R^2 marginal < 0.001, R^2 conditional = 0.275). There was no significant main effect of Threat ($\chi^2(1) = 0.714$, $p = 0.398$). Theta activity after Threatening stimuli was not significantly different from the activity following Non-threatening stimuli (β = 0.057 ± 0.068 dB, t = 0.845, 95% CI: [-0.075; 0.190], $p = 0.398$).

5.3.3.3.2.2 The modulatory role of Personality on Mind-set (Model 2)

Adding the random slope significantly improved our model's fit ($\chi^2(2) = 118.344$, $p < 0.001$). β_0 was found at 0.424 ± 0.311 dB (t = 1.365, 95% CIs: [-0.185; 1.033], $p = 0.183$, R^2

marginal = 0.016, R^2 conditional = 0.288). We found that close attachment type predicted decreased activity post-MS, significantly different from the non-significant change in CTRL condition (Figure 5-17, Appendix Table 9-24). Additionally, higher levels of depression predicted significantly less theta activity post-MM, regardless of the Mind-set (Appendix Table 9-24).

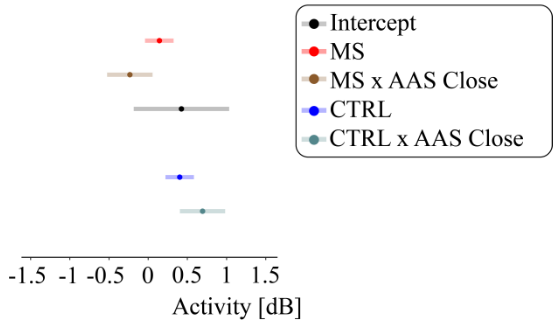

Figure 5-17. Effects of close attachment type scores on the change of theta activity from pre-, to post-MS and post-CTRL in Experiment 2. Dots represent the βs; the matted lines represent the 95% CIs calculated by Wald method.

5.3.3.3.2.3 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

Adding the random slope significantly improved our model's fit ($\chi^2(2) = 119.279$, $p < 0.001$). β_0 was found at 0.424 ± 0.311 dB (t = 1.365, 95% CIs: [-0.185; 1.033], p = 0.183, R^2 marginal = 0.020, R^2 conditional = 0.292). The significant interaction between close attachment and Mind-set was only significant in the Non-threatening condition (Appendix Table 9-25). Additionally, a significantly lower theta activity predicted by anxiety scores in MS condition compared to CTRL.

5.3.4 Discussion of Study 1 Experiment 2

Here we investigated the effects of a MS aimed at one's exclusive romantic partner. We hypothesised that we will find similar effects of MS as we did in Experiment 1. Previous studies showed that even indirect MS can trigger the changes in neural activity (Valentini et al., 2015; Wang & Tian, 2018) exclusive to mortality. Surprisingly, we found that the reminder of one's romantic partner's death triggered different changes in both behaviour and brain responses compared to the reminder of one's own death. We showed that the perceived intensity of pain increased after reminder of the romantic partner's death which increase was not present after reminders of one's own mortality. Moreover, we showed results in support of the notion that close attachment interacts with the MS effects (Mikulincer et al., 2003; Cox & Arndt, 2012; McCabe & Daly, 2018).

5.3.4.1 Anxiety and mood

Similar to Experiment 1, we found that the positive mood has decreased from pre- to post-MM (Figure 5-11 & Table 5-4). However, unlike in Experiment 1, here we found that the reason behind this decrease was the significant decrease in positive mood from pre- to post-CTRL, while there was no significant change in the MS condition (Table 5-5). Thus, we could not support our theory that the experimental methodology used in our study could influence the participant's positive mood. In accordance with previous studies, we found no change in anxiety state or negative mood scores (Valentini et al., 2014, 2015). However, it cannot be ignored that the changes in positive mood here were exclusive to our CTRL condition. This inadvertently questions the uniqueness of MS in comparison with exam failure. As our study was not designed to investigate this hypothesis, we could not explain this finding using the framework of TMT. Whether the experimental manipulation or the idea of exam failure can influence participants' mood is a question worth exploring in further studies.

5.3.4.2 Pain ratings

We found that the perceived intensity of pain decreased from pre- to post-CTRL, in accordance with the habituation phenomenon and Experiment 1 (Figure 5-12) (Hollins et al., 2011). However, perceived pain increased from pre- to post-MS (Figure 5-12). This finding proposes that the idea of the death of one's romantic partner predicts significant changes in pain perception. While this finding is in accordance with our hypothesis, it is worth noting that there was no such effect of the MS aimed at the participant (Figure 5-3). However, the interactions between pain ratings and anxiety trait and depression scores were similar to Experiment 1. Higher levels of anxiety predicted a significant increase of post-MM pain perception in both Mind-set conditions, however significantly more in the CTRL condition. Similarly, depression scores predicted a decrease in VAS ratings from pre- to post-MM in both Mind-set conditions, however significantly more in the MS condition (Figure 5-12). These interactions with anxiety and depression scores seem to counterbalance the main effect of Mind-set as they seem to affect more the Mind-set condition which predicts an opposite direction to the anxiety's increase or the depression's decrease. Furthermore, anxiety predicted significantly different changes between MS and CTRL conditions in Non-threatening, while depression did in the Threatening condition (Appendix Table 9-17).

Similarly to Experiment 1, while our novel approach to manipulate the perception of the threat level of a stimulus worked (Appendix Figure 9-11), it showed no interaction with the Mind-set conditions (Appendix Table 9-17).

5.3.4.3 Somatosensory-evoked potentials

In this experiment, we identified three intervals of interest (IOIs) in the SEP data. Two of them, the N2 and P2 components, were expected, however, the third, the N1 component, starting from before the stimulus onset was unexpected. Even more surprising, we found that the random slope did not improve the models applied on the N1 component, thus the model with only random intercept by participants was applied. The investigation of the SEP components revealed that the most frequent predictor was the close attachment type (Figure 5-14 & Figure 5-15). The change in the N1 component from pre- to post-MS was affected by anxiety scores predicting a significant increase in amplitude, however, by adding Threat to the model, we found that there was only significant difference in the Non-threatening condition. Close attachment type scores predicted significantly greater N1 amplitude post-MS compared to CTRL (Figure 5-14). The same attachment type predicted significantly less increase of P2 component and more decrease of N2 component from pre- to post-CTRL compared to MS. Most interestingly, the close attachment type scores only predicted significantly different changes between Mind-set conditions on the N1 and P2 component in the Non-threatening and for N2 in the Threatening condition. The latter finding fits into the notion that N2 is sensitive to attention and negative valence (Michie, 1984; Hillyard et al., 1998; Eimer & Forster, 2003; Wu et al., 2010). We were expecting such significant effects of close attachment type, as it has been shown that romantic attachment can act as a buffer against MS (Mikulincer & Florian, 2000; Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018). Thus, we assessed the significant predictive ability of close attachment type in this study as in line with the literature.

5.3.4.4 Time-frequency analysis

Unlike in Experiment 1, here we only found one area of interest (AOI) in the theta frequency band. Similarly to the SEP findings, close attachment type had the greatest effect on the time-frequency data. Close attachment type scores were predicted as significantly lower theta activity post-MS compared to CTRL (Appendix Table 9-24). This again alludes to the significant interaction between close attachment type and MS. Threat manipulation showed that the effect of close attachment type was only present in the Non-threatening condition. Furthermore, we found a significant decrease in theta power predicted by anxiety trait scores in MS condition compared to CTRL (Appendix Table 9-24). Additionally, depression scores predicted significant decrease in theta activity regardless of the Mind-set type. Such effect is in agreement with the notion that depressive states can reduce brain excitability (Clark et al., 2009).

5.4 Conclusion of Study 1

Here, we investigated the effects of two types of MS in two experiments. We further improved on previous experimental designs (Valentini et al., 2014, 2015) and included an additional manipulation to further distinguish the effects of MS from an equally negative CTRL. In Experiment 1, we investigated the changes in mood, anxiety state, perception of and responses to threatening somatosensory stimuli predicted by reminders of mortality. In Experiment 2, we tested the effects of a special indirect MS aimed at the participants' romantic partner compared to a similarly negative control condition with the same methodology as in Experiment 1. More importantly, we investigated if individual differences in personality traits can explain the lack of consistency in MS-related findings in the literature. In this conclusion, we will discuss the findings of the two experiments, aiming to draw conclusions about our independent variables, experimental design and predictors.

5.4.1.1 Anxiety state, positive and negative mood

We found no Mind-set specific change in anxiety state or mood scores. This was expected, as TMT clearly establishes that there should be no change in these variables (Valentini et al., 2014, 2015). However, despite our expectations, we found a significant reduction in positive mood from pre- to post-MM in both experiments. This reduction in positive mood was explained in Experiment 2 by the significantly higher scores pre-CTRL compared to all others. However, there was no such clear explanation for the same effect in Experiment 1. As already stated in the discussion of Experiment 1, it seems possible that our experimental design can have unintentional effects on the participants' mood. Nonetheless, with the additional findings of Experiment 2, we cannot state this without reasonable doubt. In Experiment 2, we found that positive mood only changed in one condition (from pre- to post-

CTRL). However, the pre-CTRL scores of positive mood were significantly higher than all other conditions (i.e. post-CTRL, pre-MS, post-MS). It is possible, that the experiment only affected people with already higher positive scores, but our experimental methodology was not designed to confirm or reject this idea.

5.4.1.2 Assessing the effects of Mind-set and Threat conditions

Reminder of the death of one's romantic partner predicted a significant increase in pain perception, but there was no such change after the classical MS induction. While the manipulation of threat expectation on pain perception worked in both Experiment 1 and 2, we failed to utilise this additional manipulation in enhancing the effects of MS. Experiment 1 showed a clear main effect of Threat on both the N2 amplitude and on the late alpha activity. Contrary to this, Experiment 2 showed no significant main effect of Threat on either the SEPs of the time-frequency responses. The N2 component was clearly affected by Threat in Experiment 1; however Experiment 2 failed to replicate this effect. Thus, we can conclude that while the psychological manipulation did work and in Experiment 1 even manifested in differences in brain responses, we failed to enhance the effects of Mind-set by using Threat in both experiments.

5.4.1.3 Personality traits

Besides Threat manipulation, we investigated seven personality traits. We tested how anxiety, depression, self-esteem, attachment types and fear of death and fear of other's death (respectively in Experiment 1 and 2) can influence the effects of Mind-set and Threat. Differences in personality traits can potentially explain the sporadic findings of TMT research in neuroscience. The difference between N2 amplitude following MS and CTRL conditions disappeared when individual variability was taken into account (Valentini et al., 2014). Here, we sought to improve the analysis of individual differences in two ways. We used linear mixed-effects models to analyse behavioural results. Furthermore, we applied these models to identify IOIs and AOIs in the brain responses and report on how these IOIs and AOIs were affected by Mind-set, Threat and personality traits. We aimed to test the sporadic results obtained with experimental design using personality traits as independent variables.

5.4.1.3.1 Fear of death and fear of other's death

We assumed that changes following MS can be explained by the fear fitting to the MS (fear of death or fear of other's death in Experiment 1 and 2 respectively). Surprisingly, we found little to no significant interactions between fear scores and Mind-set. It predicted a general increase in post-MM VAS ratings in Experiment 1 and a non-significant change to post-MS and a small, significant decrease to post-CTRL without a significant difference between Mind-set conditions in Experiment 2. Fear of death scores did predict significantly lower post-CTRL early alpha, low alpha and late theta activity compared to MS in Experiment 1. Fear of other's death showed a possible tendency to predict greater post-MS theta activity in Non-threatening condition in Experiment 2, however, this was not significant. It is worth noting, that fear of death scores were only interacting with Threat on the late theta activity in Experiment 1. Thus, we can conclude that the fear of death and fear of other's death scores measured by the Collett-Lester Fear of Death and Dying Scale (Collett & Lester, 1969; Lester & Abdel-Khalek, 2003; Lester, 2004) did not predict changes in pain perception or brain responses following MS induction.

5.4.1.3.2 Anxiety

Unlike fear of death and fear of other's death scores, the anxiety trait scores, measured by the State-Trait Anxiety Inventory Y (Charles D Spielberger, 1987) showed important results. Trait anxiety acts at most as mere exclusion criteria in neuropsychological studies (for example Valentini et al., 2014, 2015), it is not used frequently as a predictor for neural changes following MS-induction. In Experiment 1, we found that anxiety generally predicted higher VAS ratings and higher level of brain excitability following MS. Anxiety scores predicted lower early alpha activity, low alpha activity, late alpha activity and higher late theta activity. Experiment 2 showed a significant increase in perceived pain in both conditions, significantly more in CTRL compared to MS. Anxiety trait scores predicted greater N1 component, but the difference was only significant in the Non-threatening condition in Experiment 2 (Appendix Table 9-21). Furthermore, we found that in the Non-threatening condition anxiety trait scores predicted significantly lower theta power following MS induction compared to CTRL. These numerous effects of anxiety trait scores can be an indication that personal disposition to anxiety is an important predictor in TMT research.

5.4.1.3.3 Depression

Depression scores, akin to anxiety proved to be important predictors of MS effects. Depression and anxiety trait effects mirrored each other in directions. This is in agreement with the notion that anxiety predicts increase, depression predicted decrease of brain excitability (Clark et al., 2009) as well as in pain perception. Notably, we found that the effects of depression tended to be significant in Threatening conditions. This was an unintended finding in that people with higher levels of depression were more susceptible to MS or to threat in general (Experiment 2).

5.4.1.3.4 Self-esteem

Self-esteem was probably our most surprising null-finding. It had no exclusive effect on the changes after MS induction, even though self-esteem is regarded as one of the main buffers against existential threat investigated in numerous studies (Taubman-Ben-Ari et al., 1999; Pyszczynski et al., 1999; Niemiec et al., 2010; Pyszczynski et al., 2015; Rodríguez-Ferreiro et al., 2019). Here, we either failed to find a single case where self-esteem interacted exclusively with MS. In Experiment 1, it predicted a general increase in perceived pain from pre- to post-MM regardless of Mind-set condition (Table 5-2). While we did find cases where self-esteem scores only interacted significantly with MS, the effects were not significantly different from CTRL (Experiment 1, early alpha and late theta AOIs). Furthermore, in Experiment 2, self-esteem scores interacted more with CTRL than MS (VAS ratings, N2 component especially in Threatening condition). However, we failed to detect any significant role of self-esteem in buffering changes after MS induction.

5.4.1.3.5 Attachment types

As the literature points out, relationships can act as a buffer against MS (Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018; Caspi-Berkowitz et al., 2019). To investigate how different attachment types can influence the changes after MS induction, we measured anxious, close and dependent attachment type scores. We found that close attachment type predicted several significant MS-related changes in brain responses. Close attachment type had effects on both the SEP and TF brain responses, predicting greater N1 amplitude, while it interacted more with CTRL condition on the N2 and P2 amplitudes in Experiment 2. We also found significantly lower theta activity predicted by close attachment type scores. Experiment 1 showed less significant effects of attachment types. Anxious attachment type predicted less reduction of the N2 component compared to CTRL and dependent attachment type scores predicted less reduction of P2 amplitude similarly. Notable, the latter was only significant in the Threatening condition. In terms of time-frequency brain responses, we found that anxious attachment type predicted higher low alpha activity in CTRL condition compared to MS in the Threatening condition. We concluded that while anxious and dependent attachment types interacted generally with reminders of mortality, the close attachment type had a stronger link to the MS aimed at one's romantic partner as well acted as a more generic predictor in participants with relationship.

To sum it up, this study shed light on the importance of individual differences in personality traits for experiments investigating the effects of MS. Anxiety and depression trait scores are seemingly the most dominant personality factors as measured through established questionnaires, however, attachment types seem to play a more significant role when the participant is in a relationship.

6 Study 2 – The buffering effects of meditation experience on the effects of mortality salience

“Whatever you can do or dream you can, begin it. Boldness has genius, power and magic in it!” John Anster, The First Part of Goethe's Faust

6.1 Prologue to Study 2

We investigated the potential buffering effects of practice in meditation techniques on the behavioural and neural changes induced by MS. We recruited participants who are actively practicing meditation techniques and tested them using the same methodology as in Study 1 Experiment 2 (Section 5.3). We compared the results of the meditation practitioners to the results of the non-practitioners from Study 1 Experiment 2. The same analysis method was used, applying linear mixed-effects models on both the behavioural and the neural data. Thus, we showed how experience in meditation techniques can buffer the effects of MS. Additionally, we analysed the event-related potentials as an addition to this study and reported our results in the Appendix (Section 10.4). However, as our focus was the time-frequency domain, we did not include the ERP results in the submitted manuscript.

6.2 Abstract

The awareness of mortality led to the evolution of a complex defence system buffering fear of death in humans. Terror Management Theory (TMT) attempts to explain how this defence system operates, and predicts changes in behaviour. However, individuals do not always show these changes because other variables interfere by heightening or weakening them. For example, personality traits (e.g. self-esteem), personal circumstances (e.g. age) and cognitive operations (e.g. meditation) may interact with the defences against existential anxiety described in TMT.

Here, we investigated the latent effects of meditation practice against changes in pain perception of, and neural responses to somatosensory stimuli after induction of reminders of the mortality of one's romantic partner. Linear mixed-effects modelling helped us identify the effects of mortality salience (MS) and the interaction between MS and meditation experience on pain ratings and time-frequency EEG responses. We found that while non-practitioners experienced increased sensation of pain after MS induction, meditation practitioners did not show such a tendency. However, practitioners showed significantly greater EEG alpha power after control mind-set and lower alpha power after MS mind-set. These findings demonstrate that meditation experience can buffer the effects of reminders of death on perception while suggesting a central role of alpha oscillations in explaining this mechanism.

6.3 Introduction

We all have experienced a sudden sense of panic at least once in our life when thinking of our own inevitable death. However, such an insight is surprisingly rare when considering the amount of potential threats to life we may be exposed to. Terror Management Theory (TMT) offers an explanation on how the human mind defends itself against the threat of mortality (Pyszczynski et al., 2015). Research within the framework of TMT showed that reminders of mortality predicts increase in stereotypical thinking (Schimel et al., 1999), bolster defensive behaviour for one's worldview and values (Greenberg et al., 2008) and enhances phobic reactions (Strachan et al., 2007). TMT posits that the changes in behaviour reflect a defence mechanism against existential anxiety. Such changes, as listed above, reflect the increased need of the individual to subscribe their cultural values, to get closer to their 'own group'. This defence is explained by the concept of "symbolic self" as described by Ernst Becker (1973). This "symbolic self" is an idealised version of people, based on their culture, worldview and ingroup. By holding up cultural values and being more hostile against the values of others, the individual quasi 'immortalises' themselves via being part of a collective. TMT attempts to explain how humans deal with the looming presence of mortality without a constant existential threat. Several behavioural changes, such as the ones mentioned above were studied; however, understanding the effects of reminders of mortality on human consciousness is a long process. TMT was originally built to explain the importance of self-esteem (Pyszczynski et al., 2015) but, as time passed, several other traits have been linked to the defence mechanisms against fear of mortality. TMT establishes a link between reminders of mortality and anxiety (Pyszczynski et al., 2015), or more specifically, the potential for anxiety (Greenberg et al., 2003). This link is supported by previous studies claiming that reminders of mortality (mortality salience, MS) predict anxiety and increase in avoidance of the self-focused state (Arndt et al., 1998). More recent neuroscientific research has linked larger late positive brain potential amplitudes recorded during observation of death-related words (Klackl et al. 2013). A finding the authors interpreted as indexing preferential MS effects on emotion regulation. Although a relationship between MS effects and implicit anxiogenic mechanisms has been acknowledged in previous studies, there was no evidence linking the effects of MS to representation of threatening sensory information within the central nervous system. This evidence has been more recently provided by our group, showing that MS predicted larger delta and theta event-related oscillations and slow negative event-related potential (ERP) compared with an equally negative control condition (Valentini et al., 2014, 2015). In accordance with the tenants of TMT (Pyszczynski et al., 1999; Pyszczynski et al., 2015), we found that self-esteem moderated the MS effects (Valentini et al., 2015), and that participants with higher level of trait anxiety reported greater pain whereas participants with higher level of trait depression reported lower pain following reminders of mortality (Gyimes & Valentini, 2021, under review; Supplementary material A[1]).

We have recently established that personality traits, such as trait anxiety and depression can predict the MS efficacy on both the behaviour and the brain activity (Gyimes & Valentini, 2021, under review). This finding agrees with previous research showing anxiety and depression as important factors in MS research (Solomon & Greenberg, 2000; Goldenberg & Arndt, 2008). Previous studies established links between MS and depression (Menzies et al., 2021). Similarly, anxiety has been linked to the MS effects (Pyszczynski et al., 2004; Hu et

[1] The manuscript titled "*Meditation in the face of death: Experience in meditation as a buffer of mortality salience effects on perception and brain activity*" has been submitted with 2 supplementary materials. Supplementary material A referred to the in-review manuscript titled "*The modulatory role of individual differences in personality on mortality salience: effects on pain perception and somatosensory related brain activity*" (Section 5.2) due to the similarities in methodology. In this thesis, the referred material is the section 5.2. Supplementary material B is referred to as Appendix.

al., 2020). However, if certain personality trait scores can predict the efficacy of MS, it is reasonable to assume that practices aiming to affect said traits can interfere with reminders of mortality. Meditation practice has been linked to reduced anxiety and depression (Shapiro et al., 1998; Ospina et al., 2007) as such, it could act as a potential buffer against the effects of MS.

In fact, researchers have not only been interested in basic MS effects and mechanisms, they also investigated cognitive and affective processes that could counteract the effects of MS. One important field of investigation is indeed the study of relaxation practices and psychosocial interventions, like mindfulness meditation, as a tool to alleviate the MS anxiogenic effects. Studies in this field showed that meditation practice can act as a buffer against MS-induced behavioural changes (Niemiec et al., 2010; Schultz & Arnau, 2017; Park & Pyszczynski, 2019). Meditation practice helps reducing anxiety (Shapiro et al., 1998) and depression (Shapiro et al., 1998; Bitner et al., 2003), increasing psychological well-being (Ospina et al., 2007), compassion (Lutz et al., 2008), attention, self-regulation (Jha et al., 2007; Brefczynski-Lewis et al., 2007; Tang et al., 2007; Chambers et al., 2009; Goldin & Gross, 2010; Malinowski, 2013; Farb et al., 2013; Lutz et al., 2013; Morrison & Jha, 2015), and improves pain management (Bushnell et al., 2013).

In light of previous findings, it can be assumed that meditation practice can act as a buffer against negative mental state induced by reminders of death. Relevant to the neural mechanisms of this interaction is the evidence that people experienced in relaxation techniques show enhanced emotional regulation ability (Basso et al., 2019). Despite the growing number of studies, little is known about the neural processes underlying the effects of reminders of mortality on human behaviour. Evidence of increase in activation of the salience network (i.e. anterior cingulate cortex, cingulate, anterior insula, amygdala, ventrolateral prefrontal cortex; Wiech et al., 2010; Harlé et al., 2012) following MS induction has been reported (Quirin et al., 2012). The salience network is in turn associated with emotional regulation (Bressler & Menon, 2010), thus supporting the hypothesis of an interaction between MS and meditation practice. Thus, one would expect to witness a wealth of research on cognitive operations aimed to mitigate death anxiety. And yet, there currently is a lack of knowledge on how existential anxiety (i.e. anxiety originating from the awareness of death) can be modulated by psychosocial interventions such as meditation. While MS interacts with personality traits such as anxiety, self-esteem and depression (see Pyszczynski et al., 2015 for a review), experience in meditation techniques affects these traits (Shapiro et al., 1998; Bitner et al., 2003; Ospina et al., 2007). Furthermore, both MS (Quirin et al., 2012) and experience in meditation (Basso et al., 2019) affects the emotional regulation and its associated brain structures. Thus, meditation is likely to interact with MS effects and lead to a reduction of its anxiogenic effects. Research seems to support the notion of meditation, and personality factors linked to emotional regulation such as the mindfulness trait, as a cognitive tool to decrease defensive responses to MS (Niemiec et al., 2010; Park & Pyszczynski, 2019).

Here, we aimed to investigate the buffering effects of meditation practice on the changes induced by MS. We recruited participants with and without practice in meditation who were in an exclusive relationship and exposed them to the idea of the death of their romantic partner. We assumed that the idea of the death of one’s romantic partner would increase the perceived intensity of the somatosensory stimuli akin to what observed with the classical MS. TMT posits that even the word ‘death’ is sufficient to trigger the behavioural changes associated with reminders of mortality (Pyszczynski et al., 2015). Importantly, research showed that having participants imagine a separation from a romantic partner (i.e. "separation salience") increases the accessibility of death-related thoughts and instigates cultural defensive behaviours (Florian et al., 2002). Equally, reminders of death lead people to initiate interactions with other and feel greater wish for intimacy (Taubman-Ben-Ari et al., 2002).

As meditation practitioners seem to regulate their perception and emotions better (Goyal et al., 2014; Zeidan et al., 2015; Kral et al., 2018; Basso et al., 2019), we expected reduced MS effects compared with non-practitioners. We expected lower negative mood (as well as higher positive mood) and anxiety, a reduced enhancement of pain ratings due to MS, and the modulation of the stimulus-induced EEG alpha power in meditation practitioners. In particular, we expected a significant decrease in alpha power following MS induction, signalling the increase in attention to the somatosensory stimuli (Ploner et al., 2017) but had no specific expectation on whether this pattern would have been increased or decreased in meditators.

6.4 Methods and materials

6.4.1 Participants

Fifty-three healthy participants (27 females, mean age 29.642 ± 13.862, ranged from 19 to 72, 24 meditation practitioners: 10 females, mean age 35.083 ± 16.516, from 19 to 72; 29 non-practitioners: 17 females, mean age 25.138 ± 9.296, from 19 to 66) were screened and entered the study. The screening intended to filter out individuals with neurological, psychiatric, and other medical conditions that could interfere with the experiment. All participants had normal or corrected-to-normal vision. The experimental procedures were approved by the University of Essex ethics committee (1701) and were in accordance with the standards of the Declaration of Helsinki.

6.4.2 EEG recording, pre-processing, and analysis

We used sixty-two Ag/AgCl electrodes (Easycap, BrainProducts GmbH, Gilching, Germany) to record electroencephalography (EEG) (Synamps RT, Neuroscan, Compumedics). We utilised AFz as ground, the left earlobe as active and the right earlobe as off-line re-reference. The electrodes were placed according to the positions of the 10-20 International System. All the electrodes had impedance lower than 10 kΩ and the signal was amplified and digitised at 1,000 Hz.

6.4.3 Somatosensory painful stimulation

We adopted the same stimulation and materials detailed in a previous study (Gyimes & Valentini, 2021, under revision). The BioPack® STMISOLA Constant Current and Constant Voltage Isolated Linear Stimulator were used to produce the electrical stimuli and controlled by E-Prime® 2 software. We stimulated the radiation of the left-hand median nerve. The electrodes were placed on the left had as outlined in Gyimes & Valentini (2021).

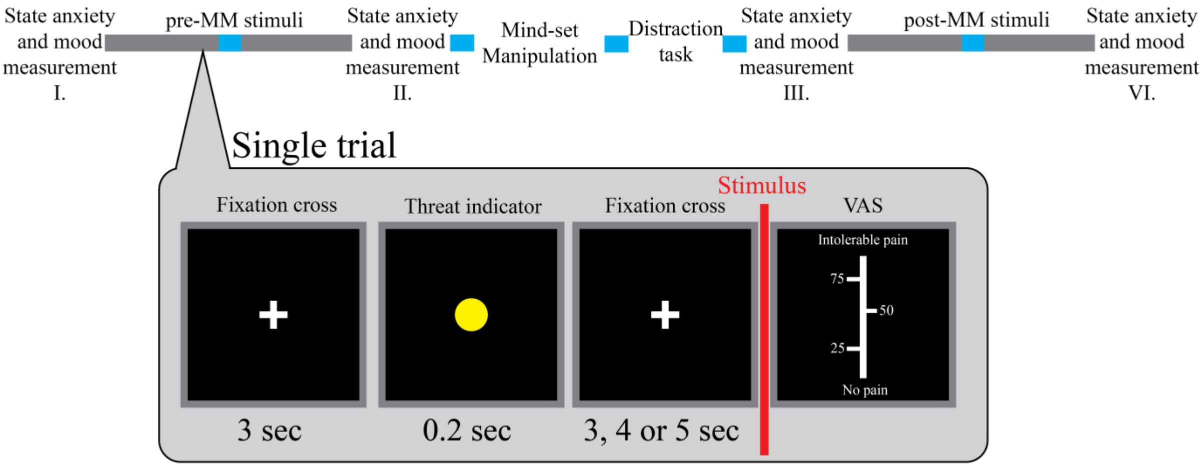

Figure 6-1. Experimental design and procedure. Participants received 120 painful electrical stimuli on the dorsum of their left hand before and after the mind-set manipulation. Participants were asked to fill the PANAS and STAI Y state questionnaires to measure state anxiety and mood scores at four times during the experiment. A distraction task (playing SUDOKU) followed the mind-set manipulation. Each trial (see inset) started with a screen displaying a fixation cross for 3 s, followed by a coloured circle indicating the level of threat (Threatening, Non-threatening, yellow or blue) associated with the upcoming painful electrical stimuli (cf. methods for details). The stimulus randomly followed the indicator within 3, 4 or 5 s. Participants rated the pain associated with each stimulus on a visual analogue scale (VAS; 0, no pain; 100, intolerable pain). Blue intervals show short breaks for the participants.

6.4.4 Mind-set manipulation

Participants were asked to answer two open ended questions. In the mortality salience (MS) condition, they were asked to “Please briefly describe the emotions that your romantic partner’s death arouses in you” and “Jot down, as specifically as you can, what will happen to you when your romantic partner physically die and once they are dead” (Greenberg et al., 1986; Pyszczynski et al., 2015). In the control condition (CTRL) they were asked the same questions however framed around the failure on a very important exam when participants were university students (Valentini et al., 2014) or losing their employment when participants were non-students (Yaakobi, 2015; McCabe & Daly, 2018). This control condition was considered a valid and reliable control based on the assumption that the effects of MS should be unique compared to any other negative controls (Hayes et al., 2010). There was at least 48 hours lag between the two sessions (MS and CTRL) and their order was pseudo-randomised between participants.

6.4.5 Threat manipulation

We created a cover story whereby participants were instructed that they will receive different type of electrical stimuli, a “sigmoid-shaped” stimulus meant to cause more inflammation in the skin (“Threatening” condition) as well as a “square-waved” stimulus meant to be the normal stimulus used in every other research study (“Non-threatening” condition). Crucially, stimulus intensity remained the same across the entire experimental session (see Gyimes & Valentini, 2021, under review, for more details). A coloured circle (yellow or blue) anticipated each electrical stimulus according to pseudo-random association (Figure 6-1, inset). This manipulation aimed to enhance the effects of MS.

6.4.6 Anxiety state and mood measures

According to the classical MS design (Valentini et al., 2014; Schultz & Arnau, 2017; Park & Pyszczynski, 2019) we asked participants to report state anxiety, positive and negative mood before the experiment, before the mind-set manipulation, after the mind-set manipulation and after the experiment (Figure 6-1, top). We used the state version of the State Trait Anxiety Inventory Y (Charles D Spielberger, 1987) and the Positive and Negative Affect Schedule (PANAS) (Crawford & Henry, 2004).

6.4.7 Study design and procedure

As in previous research (Gyimes & Valentini 2021), we collected pain ratings and EEG responses to the electrical stimuli. The dependent variables are expressed as a change from baseline (pre-mind-set induction) across Mind-sets (MS, CTRL), Threats (Threatening, Non-threatening), and Meditation experience (practitioners - MP, non-practitioners - NP).

Participants sat in front of a computer comfortably resting their left arm on the table. After the EEG cap montage, participants completed a staircase procedure in order to identify their individual pain threshold. With their pain threshold identified, participants rated 60 stimuli before and 60 stimuli after mind-set manipulation (30 for the Non-threatening and 30 for the Threatening condition in each half). They were asked to focus on the screen where the fixation cross was replaced by a coloured circle for 200ms on a black background followed by a stimulus (see Gyimes & Valentini, 2021, under review, for more details)

6.4.8 Data preparation and statistical analysis

6.4.8.1 Data preparation

We processed the state anxiety, positive and negative mood, and VAS ratings in the same fashion as in Gyimes & Valentini (2021). We have calculated the average state anxiety and mood scores in pre- and post-MM. The VAS scores were min-max normalised within participant per mind-set. We followed the same method detailed in Gyimes & Valentini (2021) for EEG pre-processing.

6.4.8.1.1 Data analysis

The pre- and post-MM state anxiety and mood values were analysed by a 2 x 2 x 2 repeated measure analysis of variance (ANOVA) in JASP (JASP Team, 2020). Time (pre/post) and Mind-set (CTRL/MS) were assessed as within-subject factors and Meditation experience (ME; non-practitioners: NP/meditation practitioners: MP) as between-subject factor. Significant interactions were further assessed with Bonferroni post-hoc tests (pb).

The normalised VAS ratings were analysed using the same R packages as detailed in Gyimes & Valentini (2021). We fitted our *a priori* models using the *lmer()* function. The χ^2 values for each effect were calculated by comparing our model to an alternative model without the effect of interest (e.g. $\text{Model}_{a\ priori}$: A ~ B + C vs $\text{Model}_{\text{alternative}}$: A ~ B) using the *anova()* function. The 95% Confidence Intervals (CIs), conditional and marginal R^2s and estimates were calculated following the methods outlined in Gyimes & Valentini (2021, under review). We have created three models with random intercept for each participants and random slope for the Mind-set level to answer our experimental questions:

Model 1: The effect of Threat:

To assess the interaction between Threat and Mind-set, first we have investigated the efficiency of Threat and the effect of ME on this manipulation:

Normalised ratings ~ Threat + Threat * Meditation experience (1+Mind-set|Participants)

Threat indicates Non-threatening and Threatening stimuli. This model allowed us to investigate how effective our psychological manipulation was on both MP and NP regardless of the other factors.

Model 2. The interaction between Time and Mind-set:

Here we investigated how the change from pre- to post-CTRL was different from the change in the MS condition.

Normalised ratings ~ Time + Time * Mind-set + Time * Meditation experience + Time * Mind-set * Meditation experience + (1+ Mind-set|Participant)

Time indicates pre- and post-MM; Mind-set indicates MS and CTRL. The model tested how the pre- to post-MM change was influenced by Mind-set (CTRL vs MS) and how this influence differed between MP and NP.

Model 3. The interaction between Time, Mind-set, and Threat:

Here, we assessed how Threat can interact with the Mind-set manipulations as a summary of Model 1 and 2.

Normalised ratings ~ Time + Time * Mind-set + Time * Mind-set * Threat + Time * Meditation experience + Time * Mind-set * Meditation experience + Time * Mind-set * Threat * Meditation experience + (1+ Mind-set|Participant)

We applied the models detailed for the analysis of pain ratings to the pre-processed EEG data. We identified time-frequency areas of interest (AOIs). AOIs were considered significant if our models showed the same effect as significant across at least 50 consecutive time-points (i.e. an interval of at least 100ms in the widest part of the AOI blob).

Following the identification of the AOIs, we tested three experimental questions: a) Does the manipulation of sensory threat (Threat) influence brain responses? (i.e. Model 1), b) Does Mind-set predict different post-MM values and is this prediction influenced by Threat? (i.e. Model 2 and 3) and c) Does experience in meditation practices predict a reduction of MS effects? (i.e. Model 1, 2 & 3). To answer these questions we extracted the average power from the significant AOIs and applied all three of our models on these average values to report our findings.

6.5 Results

6.5.1 Anxiety and mood

We have investigated how anxiety state, positive and negative mood changed during the experiment (Appendix, Figure 10-1). Regardless of the mind-set, MP scored significantly lower on anxiety state and higher on positive mood measurements compared with NP, as well as marginally non-significantly lower on negative mood measurement (Figure 6-2 A).Only positive mood changed significantly over time (Figure 6-2 B).

6.5.1.1 Anxiety state

We found no significant change in anxiety levels associated with Mind-set (Appendix, Table 10-1, Table 10-2 & Figure 10-2). Nevertheless, anxiety scores were different between MP and NP ($F_{(1,51)} = 14.993$, $p < 0.001$, $\omega^2 = 0.119$). *Post-hoc* test revealed that meditators were less anxious compared with non-meditators ($\Delta_{mean} = 7.109 \pm 1.836$, $t = 3.872$, 95% CI: [3.423; 10.795], $p_b < 0.001$) (Figure 6-2 A).

6.5.1.2 Negative mood

We found no significant change in negative mood scores associated with Mind-set (Appendix, Table 10-4, Table 10-5 & Figure 10-3). Negative mood scores were marginally non-significantly different between MP and NP ($F_{(1,51)} = 3.981$, $p = 0.051$, $\omega^2 = 0.028$). Nevertheless, we confirmed that MP have lower level of negative mood than the NP (Figure 6-2 A).

6.5.1.3 Positive mood

We found a main effect of Time ($F_{(1,51)} = 11.606$, $p = 0.001$, $\omega^2 = 0.006$) and main effect of ME ($F_{(1,51)} = 11.118$, $p = 0.002$, $\omega^2 = 0.089$) (Table 6-1, Figure 6-2 B & Appendix, Table 10-3). *Post hoc* tests showed that the positive mood decreased from pre- to post-MM (Δ_{mean} = 1.162 ± 0.341, t = 3.407, 95% CI: [0.477; 1.847], p_b = 0.001); and that NP had lower positive mood scores than MP (Δ_{mean} = -6.602 ± 1.980, t = -3.334, 95% CI: [-10.576; -2.627], p_b = 0.002) (Figure 6-2 A).

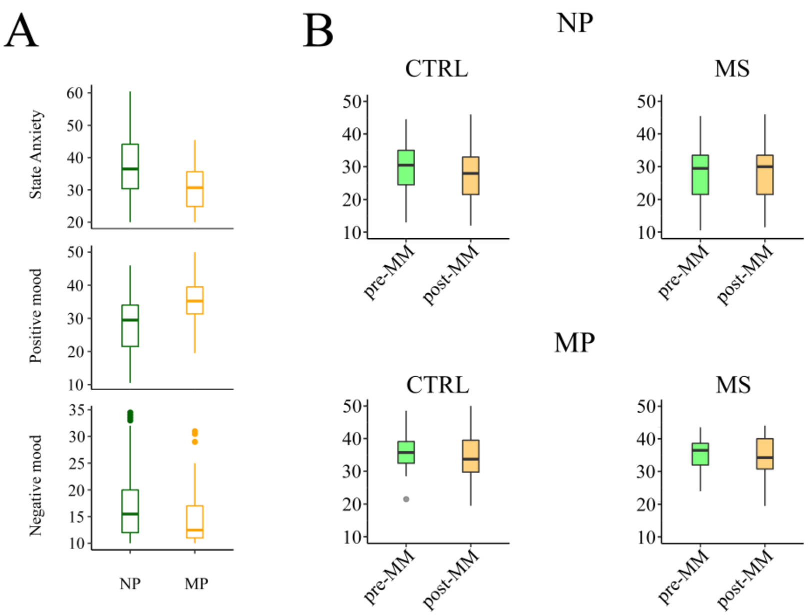

Figure 6-2. A represents the difference between NP (green) and MP (orange) in state anxiety (A top), positive (A middle) and negative (A bottom) mood scores. B represents the difference between pre- (green) and post-MM (orange) positive mood scores during mortality salience (MS) and control condition (CTRL) for non-practitioners (NP) (B top) and meditation practitioners (MP) (B bottom). The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers.

Cases	Sum of Squares	Df	Mean Square	F	p	ω²
Time	70.926	1	70.926	11.606	0.001	0.006
Time x ME	1.756	1	1.756	0.287	0.594	0.000
Residuals	311.666	51	6.111	-	-	-
Mind-set	39.363	1	39.363	2.388	0.128	0.002
Mind-set x ME	1.627	1	1.627	0.099	0.755	0.000
Residuals	840.540	51	16.481	-	-	-
Time x Mind-set	12.097	1	12.097	3.791	0.057	< 0.001
Time x Mind-set x ME	5.153	1	5.153	1.615	0.210	< 0.001
Residuals	162.717	51	3.191	-	-	-

Table 6-1. Within-subject results of the 2 x 2 x 2 repeated measure ANOVA on the positive mood scores. We investigated how positive mood scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels. Note the main effect of Time.

6.5.2 Pain ratings

The expectation of threat predicted higher VAS ratings (Appendix, Figure 10-4). Ratings in the CTRL condition decreased for both MP and NP. However, while the ratings increased for NP after MS induction, this effect was counteracted by ME (Figure 6-3, left). We found that MP rated the post-MM stimuli similarly in both Mind-set conditions. Furthermore, Threat predicted a stronger effect of MS (Figure 6-3, right). This effect of Threat on the interaction between Time and Mind-set was not buffered by ME (Figure 6-3, right).

6.5.2.1 Assessment of the effect of Threat (Model 1)

The random slope improved the model's fit ($\chi^2(2) = 816.436$, $p < 0.001$). Model 1 showed a main effect of Threat ($\chi^2(1) = 36.898$, $p < 0.001$). The interaction between Threat and ME did not improve our model's fit ($\chi^2(1) = 1.066$, $p = 0.302$). The model identified the intercept at 52.898 ± 1.224 % (t = 43.204, 95% CI: [50.498; 55.297], $p < 0.001$, $R^2_{marginal} = 0.003$, $R^2_{conditional} = 0.194$). Threatening stimuli were rated as more painful by 3.188 ± 0.524 (t = 6.080, 95% CI: [2.160; 4.215], $p < 0.001$) and MP rated Threatening stimuli non-significantly lower than NP ($\beta_1 = 0.801 \pm 0.774$, t = -1.035, 95% CI: [-2.317; 0.715], $p = 0.301$).

Importantly, the same effects were present on the non-normalised ratings too (Appendix, Figure 10-4).

6.5.2.2 Assessing the interaction between Time and Mind-set (Model 2)

The random slope significantly improved the model's fit ($\chi^2(2) = 865.584$, $p < 0.001$). Model 2 revealed a main effect of Time ($\chi^2(1) = 25.035$, $p < 0.001$) and interaction between Time and Mind-set ($\chi^2(1) = 69.682$, $p < 0.001$). There was no effect of ME on Time ($\chi^2(1) = 2.333$, $p = 0.127$), however we did find an effect of ME on the interaction between Time and Mind-set ($\chi^2(1) = 18.662$, $p < 0.001$). The model identified the intercept at 54.531 ± 1.227 % (t = 44.446, 95% CI: [52.126; 56.935], $p < 0.001$, $R^2_{marginal} = 0.009$, $R^2_{conditional} = 0.207$) (Figure 6-3, left). The ratings decreased in CTRL condition by 3.683 ± 0.735 % (t = -5.014, 95% CI: [-5.122; -2.243], $p < 0.001$) for the NP. For MP the decrease in CTRL condition was not significantly different (1.658 ± 1.087, t = 1.525, 95% CI: [-0.472; 3.788], $p = 0.127$) (Figure 6-3, left). NP rated post-MS stimuli 8.639 ± 1.031 % higher than post-CTRL stimuli (t = 8.378, 95% CI: [6.618; 10.660], $p < 0.001$). Finally, we found that the difference between CTRL and MS was lower for MP ($\beta_1 = -6.623$, t = -4.323, 95% [-9.626; -3.620], $p < 0.001$) (Figure 6-3, left).

6.5.2.3 Assessing the interaction between Time, Mind-set, and Threat (Model 3)

The random slope improved the model's fit ($\chi^2(2) = 866.360$, $p < 0.001$). Model 3 revealed a main effect of Time ($\chi^2(1) = 25.056$, $p < 0.001$) and interaction between Time and Mind-set ($\chi^2(1) = 37.682$, $p < 0.001$) as well as the interaction between Time, Mind-set and Threat ($\chi^2(1) = 8.244$, $p = 0.004$). Similarly to Model 2's findings, there was no significant interaction between ME and Time ($\chi^2(1) = 2.334$, $p = 0.127$), but a significant effect of ME on the interaction between Time and Mind-set ($\chi^2(1) = 11.605$, $p = 0.001$); whereas no interaction between Time, Mind-set, Threat, and ME ($\chi^2(1) = 0.948$, $p = 0.330$) was found. The model identified the intercept at 54.530 ± 1.227 % (t = 44.446, 95% CI: [52.126; 56.935], $p < 0.001$, $R^2_{marginal} = 0.010$, $R^2_{conditional} = 0.207$) (Figure 6-3, right). Upon the findings of Model 2, the difference between post-CTRL and post-MS ratings was greater in the Threatening condition ($\beta_1 = 3.024 \pm 1.053$, t = 2.871, 95% CI: [0.960; 5.088], $p = 0.001$) but there was no difference associated with ME (Appendix, Table s7) (Figure 6-3, right).

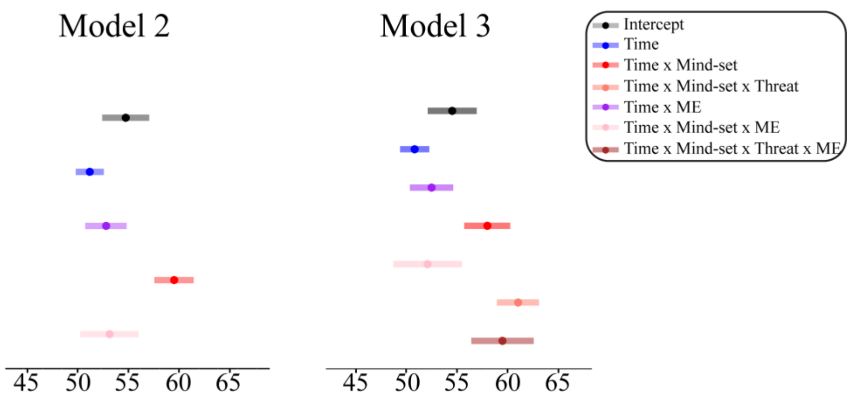

Figure 6-3. Results of Model 2 (left) and Model 3 (right) on the normalised VAS ratings (min-max transform, %). Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, orange – Time x Mind-set x Threat interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction, brown – Time x Mind-set x Threat x ME interaction.

6.5.3 Brain oscillations

By applying our models to the time-frequency (TF) data, we identified one theta and two alpha AOIs: a theta (6.6 – 7.2 Hz. 364.571 – 467.143ms) and alpha AOI (10.7 – 12.6 Hz, 251.2 – 348.3ms), and a late low alpha AOI (7.1 – 8.4 Hz, 682 – 909ms) by consecutive significant interactions between both Time, Mind-set and Threat as well as Time, Mind-set and ME (Figure 6-4). Topographies are presented in Figure 6-5.

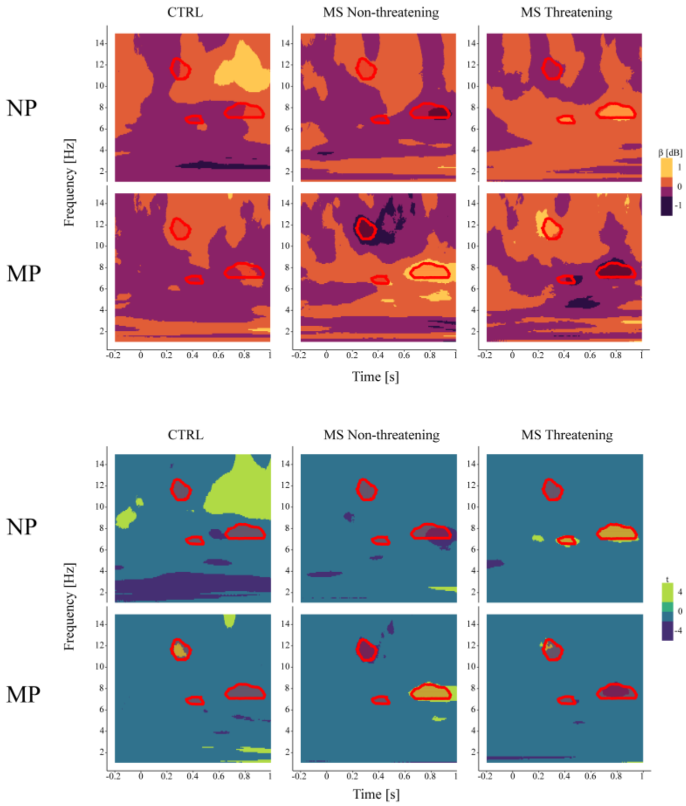

Figure 6-4. Time-frequency EEG areas of interest (AOIs, theta (6.6 – 7.2 Hz. 364.571 – 467.143ms), alpha (10.7 – 12.6 Hz, 251.2 – 348.3ms), and low alpha (7.1 – 8.4 Hz, 682 – 909ms)). The top six panels show the spectrograms of the post-CTRL (Threat conditions pooled) and post-MS (in Non-threatening and Threatening conditions) estimates. The bottom six panels show the t-values in the same conditions. Upper rows are the effects in NP and lower rows are the effects in MP. AOIs are circled. The plots are showing the difference between Non-threatening/Threatening MS and CTRL as well as NP and MP.

There was no significant main effect of Threat on the brain responses in any AOIs. The theta activity post-MS was greater compared with post-CTRL in the Threatening condition for the NP. Yet, MP did not display such an increase. MP had greater alpha power post-CTRL and lower post-MS. However, the decrease post-MS was only present in the Non-threatening condition as there was a lack of change in the Threatening condition from pre- to post-MS in the alpha activity. MP showed increased late low alpha post-MS, however, Model 3 revealed this increase only in the Non-threatening condition. MP showed a decrease in post-MS late low activity in the Threatening condition. On the contrary, NP showed a significantly decrease of post-MS late low alpha activity in the Non-threatening but increase in the Threatening condition.

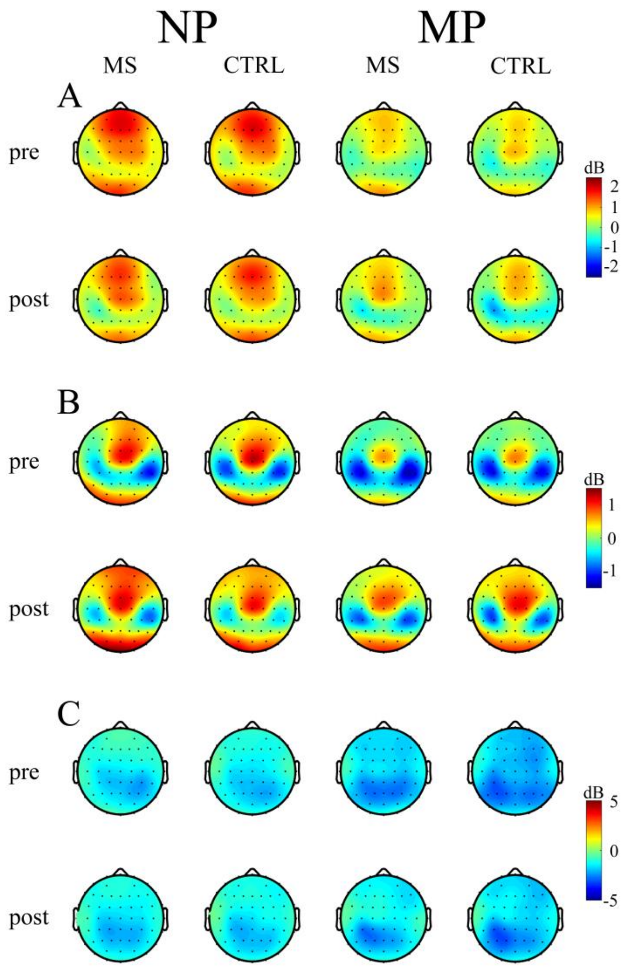

Figure 6-5. Topographies of the theta AOI (A), the alpha AOI (B), the late low alpha AOI (C) for NP (right) and MP (left) in pre- and post-MS and CTRL conditions. The changes in power from pre- to post-MM were affected by the interactions between Time, Mind-set and Threat as well between Time, Mind-set and Meditation experience (ME).

6.5.3.1 Assessment of the effect of Threat (Model 1)

6.5.3.1.1 Theta

The random slope improved the model's fit ($\chi^2(2) = 144.519$, $p < 0.001$). We found no effect of Threat on the theta power ($\chi^2(1) = 0.693$, $p = 0.405$) or interaction between Threat and ME ($\chi^2(1) = 0.494$, $p = 0.482$). The model estimated the intercept at –0.341 ± 0.231 dB (t = -1.476, 95% CI: [-0.794; 0.112], $p = 0.146$, $R^2_{marginal} < 0.001$, $R^2_{conditional} = 0.222$). The theta power following Threatening stimuli was non-significantly higher for NP ($\beta_1 = 0.064 \pm 0.077$ dB, t = 0.831, 95% CIs: [-0.087; 0.214], $p = 0.831$). ME predicted a non-significantly greater power for MP compared with NP (β_1 = 0.080 ± 0.114 dB, t = 0.706, 95% CIs: [-0.142; 0.303], p = 0.480).

6.5.3.1.2 Alpha

The random slope improved the model's fit ($\chi^2(2)$ = 78.025, p < 0.001). There was no effect of Threat on the alpha power ($\chi^2(1)$ = 1.597, p = 0.206), or interaction between Threat and ME ($\chi^2(1)$ = 3.699, p = 0.054). The model estimated the intercept at -1.126 ± 0.208 dB (t = -5.417, 95% CI: [-1.534; -0.719], p < 0.001, $R^2_{marginal}$ < 0.001, $R^2_{conditional}$ = 0.218). The alpha power following Threatening stimuli were non-significantly lower for NP (β_1 = -0.087 ± 0.069 dB, t = -1.265, 95% CIs: [-0.223; 0.048], p = 0.206). ME predicted a non-significantly greater power for MP compared with NP (β_1 = 0.197 ± 0.102 dB, t = 1.926, 95% CIs: [-0.003; 0.397], p = 0.054).

6.5.3.1.3 Late Low alpha

The random slope improved the model's fit ($\chi^2(2)$ = 71.828, p < 0.001). We found no effect of Threat on the low alpha power ($\chi^2(1)$ = 0.118, p = 0.731) or interaction between Threat and ME ($\chi^2(1)$ = 0.363, p = 0.547). The model estimated the intercept at –3.010 ± 0.210 dB (t = -14.300, 95% CI: [-3.422; -2.597], p < 0.001, $R^2_{marginal}$ < 0.001, $R^2_{conditional}$ = 0.249). The low alpha power following Threatening stimuli was not significantly different for the NP (β_1 = 0.022 ± 0.064 dB, t = 0.731, 95% CIs: [-0.103; 0.147], p = 0.731), or between the experimental groups (β_1 = 0.057 ± 0.095 dB, t = 0.602, 95% CIs: [-0.129; 0.242], p = 0.547).

6.5.3.2 Assessing the interaction between Time and Mind-set (Model 2)

6.5.3.2.1 Theta

The random slope improved the model's fit ($\chi^2(2) = 144.301$, $p < 0.001$). There was no effect of Time on the theta power ($\chi^2(1) = 2.187$, $p = 0.139$), nor interaction between Time and ME ($\chi^2(1) = 0.888$, $p = 0.346$), interaction between Time and Mind-set ($\chi^2(1) = 0.509$, $p = 0.476$) or interaction between Time, Mind-set and ME ($\chi^2(1) = 0.799$, $p = 0.372$). The model estimated the intercept at -0.221 ± 0.230 dB (t = -0.960, 95% CI: [-0.673; 0.230], $p = 0.342$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.222$). There were no significant effects of Mind-set or ME (Appendix, Table 10-8).

6.5.3.2.2 Alpha

The random slope improved the model's fit ($\chi^2(2) = 71.032$, $p < 0.001$). We found no effect of Time on the alpha power ($\chi^2(1) = 0.161$, $p = 0.689$) or interaction between Time and Mind-set ($\chi^2(1) = 0.999$, $p = 0.318$). There were significant interactions between Time and ME ($\chi^2(1) = 8.876$, $p = 0.003$) and between Time, Mind-set, and ME ($\chi^2(1) = 8.082$, $p = 0.004$). The model estimated the intercept at -1.184 ± 0.208 dB (t = -5.691, 95% CI: [-1.592; -0.776], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.218$). While there was no difference between the change in alpha power from pre- to post-MS and –CTRL for NP, there was a significantly lower alpha power post-MS compared with post-CTRL and higher alpha power from pre- to post-CTRL for the MP (Table 6-2 & Figure 6-6).

	β	SE	t-value	95% CIs	*p-value*
Intercept	-1.184	0.208	-5.691	-1.592; -0.776	< 0.001
Time	-0.037	0.092	-0.404	-0.219; 0.144	0.686
Time x Mind-set	0.123	0.123	1.001	-0.118; 0.365	0.316
Time x ME	0.408	0.137	2.983	0.140; 0.677	0.003
Time x Mind-set x ME	-0.521	0.183	-2.849	-0.879; -0.162	0.004

Table 6-2. Summary of Model 2 partitioning the effects of Time, Mind-set and Meditation experience (ME) on the alpha activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. Note the significant effects of ME in the CTRL and in the MS conditions.

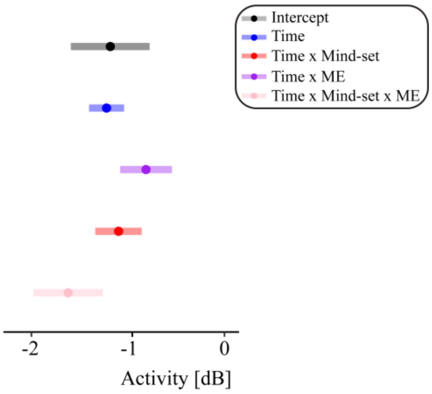

Figure 6-6. Alpha AOI Model 2 results. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction. Note the greater alpha power post-CTRL and its decrease post-MS for the MP.

6.5.3.2.3 Late Low alpha

The random slope improved the model's fit ($\chi^2(2) = 68.570$, $p < 0.001$). We found no effect of Time on the low alpha power ($\chi^2(1) < 0.001$, $p = 0.999$), interaction between Time and ME ($\chi^2(1) = 0.063$, $p = 0.802$), or interaction between Time and Mind-set ($\chi^2(1) = 2.967$, $p = 0.085$). However, we did find a significant interaction between Time, Mind-set and ME ($\chi^2(1) = 9.057$, $p = 0.003$) The model estimated the intercept at -2.988 ± 0.211 dB (t = -14.194, 95% CI: [-3.401; -2.576], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.250$). There was no effect of Mind-set on the NP, whereas MP showed higher late low alpha power post-MS compared with NP (Appendix, Table 10-9).

6.5.3.3 Assessing the interaction between Time, Mind-set, and Threat (Model 3)

6.5.3.3.1 Theta

The random slope improved the model's fit ($\chi^2(2) = 144.507$, $p < 0.001$). We found no effect of Time ($\chi^2(1) = 2.187$, $p = 0.139$), Time and ME ($\chi^2(1) = 0.888$, $p = 0.346$), interactions between Time and Mind-set ($\chi^2(1) = 0.509$, p = 0.476) or between Time, Mind-set and ME ($\chi^2(1) = 0.799$, $p = 0.372$) (Table 6-3). There were significant interactions between Time, Mind-set, and Threat ($\chi^2(1) = 11.189$, $p = 0.001$) and between Time, Mind-set, Threat and ME ($\chi^2(1) = 4.383$, $p = 0.036$). The model estimated the intercept at -0.221 ± 0.230 dB (t = -0.960, 95% CI: [-0.673; 0.230], $p = 0.342$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.222$). We found that the difference between post-MS and post-CTRL theta power was significant in the Threatening condition for NP (Table 6-3 & Figure 6-7). MP did not show this change (Table 6-3 & Figure 6-7).

	B	SE	t-value	95% CIs	*p-value*
Intercept	-0.221	0.230	-0.960	-0.673; 0.230	0.342
Time	-0.155	0.104	-1.481	-0.359; 0.050	0.139
Time x Mind-set	-0.156	0.161	-0.970	-0.472; 0.160	0.332
Time x Mind-set x Threat	0.515	0.154	3.345	0.213; 0.817	0.001
Time x ME	-0.146	0.155	-0.942	-0.449; 0.157	0.346
Time x Mind-set x ME	0.428	0.240	1.787	-0.041; 0.898	0.074
Time x Mind-set x Threat x ME	-0.479	0.229	-2.093	-0.927; -0.030	0.036

Table 6-3. Summary of Model 3 partitioning the effects of Time, Mind-set, Threat and Meditation experience (ME) on the theta activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. Note the significant effects of Threat in both NP and MP cases.

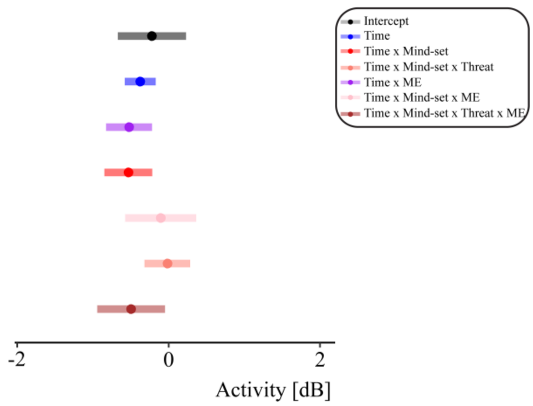

Figure 6-7. Model 3 results on the theta AOI. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, orange – Time x Mind-set x Threat interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction, brown – Time x Mind-set x Threat x ME interaction. ME predicted significantly lower post-MS theta activity in Non-threatening but not in Threatening condition.

6.5.3.3.2 Alpha

The random slope improved the model's fit ($\chi^2(2) = 71.111$, $p < 0.001$). No effect of Time on the alpha power ($\chi^2(1) = 0.161$, $p = 0.688$), interaction between Time and Mind-set ($\chi^2(1) = 2.577$, $p = 0.108$), or interaction between Time, Mind-set and Threat ($\chi^2(1) = 2.235$, $p = 0.135$) was revealed. We did find significant interactions between Time and ME ($\chi^2(1) = 8.881$, $p = 0.003$), Time, Mind-set and ME ($\chi^2(1) = 14.277$, $p < 0.001$) and between Time, Mind-set, Threat and ME ($\chi^2(1) = 7.044$, $p = 0.008$). The model estimated the intercept at -1.184 ± 0.208 dB (t = -5.691, 95% CI: [-1.592; -0.776], $p < 0.001$, $R^2_{marginal} = 0.002$, $R^2_{conditional} = 0.219$). Alpha power increased post-CTRL for MP. MP showed a lower post-MS alpha power in the Non-threatening condition while higher in the Threatening condition (Table 6-4 & Figure 6-8).

	β	SE	t-value	95% CIs	*p-value*
Intercept	-1.184	0.208	-5.691	-1.592; -0.776	< 0.001
Time	-0.037	0.092	-0.404	-0.219; 0.144	0.686
Time x Mind-set	0.227	0.141	1.609	-0.050; 0.504	0.108
Time x Mind-set x Threat	-0.207	0.139	-1.495	-0.479; 0.065	0.135
Time x ME	0.408	0.137	2.983	0.140; 0.677	0.003
Time x Mind-set x ME	-0.794	0.210	-3.785	-1.205; -0.383	< 0.001
Time x Mind-set x Threat x ME	0.547	0.206	2.654	0.143; 0.951	0.008

Table 6-4. Summary of Model 3 partitioning the effects of Time, Mind-set, Threat and Meditation experience (ME) on the alpha activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. Note the significant effects of ME.

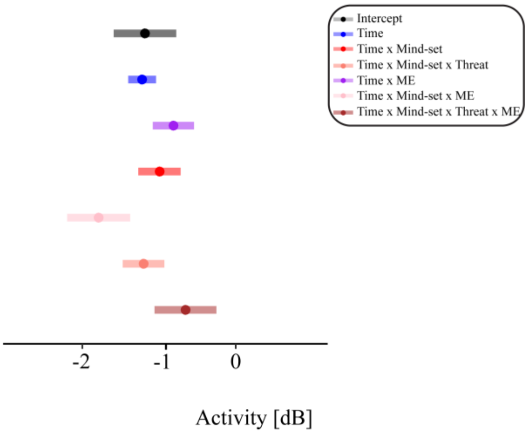

Figure 6-8. Model 3 results on the alpha AOI. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, orange – Time x Mind-set x Threat interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction, brown – Time x Mind-set x Threat x ME interaction. ME predicted lower post-MS alpha power in the Non-threatening condition and higher in the Threatening condition.

6.5.3.3.3 Late low alpha

The random slope improved the model's fit ($\chi^2(2) = 68.799$, $p < 0.001$). We found no effect of Time on the low alpha power ($\chi^2(1) < 0.001$, $p = 1.000$) or interaction between Time and ME ($\chi^2(1) = 0.063$, $p = 0.802$). Our model revealed significant interactions between Time and Mind-set ($\chi^2(1) = 13.777$, $p < 0.001$), between Time, Mind-set and ME ($\chi^2(1) = 20.359$, $p < 0.001$), between Time, Mind-set and Threat ($\chi^2(1) = 20.167$, $p < 0.001$) and between Time, Mind-set, Threat and ME ($\chi^2(1) = 14.800$, $p < 0.001$). The model estimated the intercept at -2.988 ± 0.211 dB (t = -14.196, 95% CI: [-3.401; -2.576], $p < 0.001$, $R^2_{marginal} = 0.003$, $R^2_{conditional} = 0.251$). There was no change in late low alpha power in the CTRL condition in either experimental group (Table 6-5 & Figure 6-9). Model 3 revealed that NP showed a decrease post-MS in late low alpha power in the Non-Threatening, but not in the Threatening condition. MP showed higher late low alpha power post-MS compared with NP in the Threatening and lower in the Threatening condition (Table 6-5 & Figure 6-9).

	β	SE	t-value	95% CIs	*p-value*
Intercept	-2.988	0.211	-14.196	-3.401; -2.576	< 0.001
Time	0.000	0.085	0.002	-0.167; 0.168	0.999
Time x Mind-set	-0.483	0.130	-3.713	-0.739; -0.228	< 0.001
Time x Mind-set x Threat	0.575	0.128	4.492	0.324; 0.826	< 0.001
Time x ME	-0.032	0.127	-0.252	-0.280; 0.216	0.801
Time x Mind-set x ME	0.873	0.193	4.514	0.494; 1.253	< 0.001
Time x Mind-set x Threat x ME	-0.732	0.190	-3.847	-1.105; -0.359	< 0.001

Table 6-5. Summary of Model 3 partitioning the effects of Time, Mind-set, Threat and Meditation experience (ME) on the late low alpha activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. Note the effects of MS and Threat on the NP and the inverse effects in the MP cases.

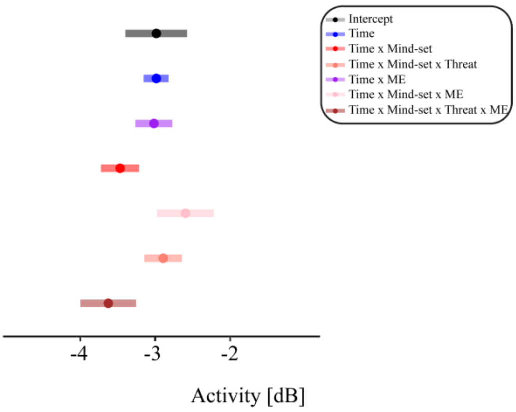

Figure 6-9. Model 3 results on the late low alpha AOI. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, orange – Time x Mind-set x Threat interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction, brown – Time x Mind-set x Threat x ME interaction. NP showed lower post-MS late low alpha power in the Non-threatening condition and no change in the Threatening condition, while MP showed significantly higher post-MS late low alpha power in the Non-threatening condition and lower in the Threatening condition.

6.6 Discussion

The present study aimed to quantify the impact of experience in meditation practice on MS effects over perception and neural responses. We followed a previously established methodology to measure the effects of MS on somatosensory brain responses and pain perception (Gyimes & Valentini, 2021, under review). Thus, we tested how meditators were differently affected by reminders of death in terms of somatosensory perception and brain activity. Moreover, we have introduced a psychological manipulation on the expectation of pain (Gyimes & Valentini, 2021 under review) aiming to enhance the effects of MS measured in previous studies (Valentini et al., 2014, 2015, 2017). According to TMT explanations, we expected to see increased pain after MS induction. Furthermore, we expected decrease in alpha frequency band power and increase in theta power compared with CTRL condition. Most importantly, we expected for the MS effects to be dampened, or even reversed in individuals with experience in meditation.

6.6.1 Anxiety state and mood

TMT claims that no explicit change in anxiety state level or mood should occur as a result of MS induction. Accordingly, we found no significant change in anxiety or negative mood (Appendix, Table 10-1, Table 10-4, Figure 10-2 & Figure 10-3) confirming our previous findings (Valentini et al., 2014, 2015, Gyimes & Valentini, 2021, under review). However, we also replicated a significant reduction in positive mood (Table 6-1, Figure 6-2). A finding we recently interpreted as due to the overall negative valence of the experimental mind-sets, leading to a general reduction in positive mood (Gyimes & Valentini, 2021, under review).

Concerning meditation practitioners, they showed lower anxiety and negative mood whilst higher positive mood scores than non-meditation practitioners (Figure 6-3). This is supportive of the notion that meditation practice can lead to anxiety and stress reduction (Shapiro et al., 1998) and well-being improvement (Kingston et al., 2007).

6.6.2 Pain ratings

As we expected, post-MS ratings of painful stimuli were significantly higher than post-CTRL (Figure 6-3). This is in agreement with previous findings using classical MS (Valentini et al., 2014). Furthermore, we were successful in increasing the MS effect by introducing the Threat factor, resulting in a significantly greater increase in perceived pain level post-MS (Figure 6-3, right). Our analysis also revealed a significant decrease in VAS ratings in the CTRL condition, likely explained by a general habituation phenomenon (Figure 6-3 left and right) (Hollins et al., 2011).

MP showed no difference from NP in CTRL condition, and they did not experience an increase in pain intensity post-MS. Thus, we confirmed our hypothesis that experience in meditation can act as a buffer against MS effects. Surprisingly, while meditation practitioners showed no change in their pain after MS induction, they were influenced by the Threat manipulation (Figure 6-3, right). One could argue that while MP can buffer abstract existential threats, they are not equally able to buffer concrete sensory threat. Nonetheless, a more logical explanation might ground in the effect of meditation practice on agreeableness. Indeed, meditation practice positively correlates with agreeableness (Thompson & Waltz, 2007; Barkan et al., 2016) and higher degree of agreeableness has been linked to greater susceptibility to placebo effects (Beedie et al., 2008; Kelley et al., 2009; Peciña et al., 2013). Thus, it is possible that MP are more vulnerable to psychological manipulations such as our Threat condition.

6.6.3 Brain oscillations

We have identified three AOIs: a theta (6.6 – 7.2 Hz. 364.571 – 467.143ms), an alpha (10.7 – 12.6 Hz, 251.200 – 348.300ms) and a late low alpha AOI (7.1 – 8.4 Hz, 682.000 – 909.000ms) (Figure 6-4 & Figure 6-5). These AOIs resulted from the consecutive significant interaction between Time, Mind-set and Threat or Time, Mind-set, and Meditation experience, or both.

Theta power increased significantly post-MS in the Threatening condition for the NP. This is reminiscent of the increased theta amplitudes in response to painful laser stimulation both with the classical MS manipulation and during observation of death-related images (Valentini et al., 2014, 2017). MP did not show this pattern, thus suggesting a top-down modulation on the standard somatosensory brain responses in this group. Interestingly, MP showed greater alpha power post-CTRL and greater power reduction post-MS relative to the pre-stimulus baseline (Figure 6-6). This is usually referred to as event-related desynchronization (ERD) and thought to index increased cortical excitability (Neuper & Pfurtscheller, 2001). Consequently, ERD can be a meaningful marker of sensory and cognitive modulations (Streltsova et al., 2010; Hu et al., 2013; Peng et al., 2015; Ricci et al., 2019). We posit that the increased alpha ERD may represent increased attentional gain of somatosensory stimuli after reminders of mortality. Surprisingly, MP showed alpha ERD after MS only in the Non-threatening condition (Figure 6-8). Despite the lack of a significant main effect of Threat, this finding suggests a significant interaction between MS and pain expectation. NP experienced significant late low alpha ERD post-MS in the Non-threatening but not in the Threatening condition (Figure 6-9). MP on the other hand showed a significant late low alpha ERS post-MS in the Non-Threatening condition and not in the Threatening condition (Figure 6-9). It is possible that the psychological threat of pain is differently processed between MP and NP.

However, our design was not conceived to disclose this difference as it was focused on enhancing and detecting the MS effects on the neural processes.

Alpha event-related synchronization (ERS) and ERD can both signal attention shifts. ERS has been theorised to show a suppression of attention towards non-relevant tasks (Klimesch, 2012). The alpha activity for MP increased significantly post-CTRL while decreased significantly post-MS, a pattern that may reflect selective attention differences between the mind-sets. We speculate that the alpha ERD following MS (Figure 6-6) signals an increase in somatosensory activity for meditators. However, the lack of alpha ERD when presented with an increased sensory threat may suggest a top-down inhibition of somatosensory activation in this group. This explanation is supported by the notion that alpha activity can signal attention to pain (Ploner et al., 2017).

6.6.4 Conclusive remarks

The novelty of the current study is twofold. First, we demonstrate that experience in meditation can act as a buffer against the MS induced changes in perceptual and neural responses. Second, we implemented a MS that is directed towards one's romantic partner instead of the participant's own mortality. Previous studies indicated that close relationships can act as a buffer against reminders of death (Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018). Crucially, ours is the first study to show that reminders of a romantic partner's death can indeed trigger similar MS effects.

Based on a previously developed methodology (Gyimes & Valentini, 2021, in review), we showed again that expectation of a more threatening stimulus can influence both the subjective experience of the electric stimulus and the brain responses supporting the top-down modulation of pain perception (Fiorio et al., 2012; Valentini et al., 2014; Torta et al., 2017). Nevertheless, this was a collateral finding associated with our design. Future research may determine the extent of the effects observed in our study by adopting different designs and techniques.

In conclusion, we confirmed our hypothesis that experience in meditation can buffer the effects exerted by reminders of death and that this modulation is associated with specific alteration of oscillatory brain activity.

7 General discussion

Throughout this thesis, I presented two studies (Sections 5 & 6). In this current chapter I will discuss our findings, the strengths and limitations of our studies, and lay out potential further directions for investigating the effects of MS on the brain responses. After a short recap below, I will first reiterate the most significant findings of Study 1 (Section 5) and Study 2 (Section 6) separately, explaining how they fit in the literature. Secondly, I will talk about the novelty of our experimental and statistical methods utilised in our studies. Finally, I will discuss the strengths and limitations of our study suggesting improvements for future experiments.

In Study 1, our aim was to test how certain personality traits linked to MS can act as moderators to the effects of MS. We expanded on previous methodologies (Valentini et al., 2014, 2015) by adding an additional manipulation, namely the manipulation of the expectation of pain. As expectation of pain has also been linked to pain perception, in that stimuli with higher expectation of pain is perceived as more painful (Fiorio et al., 2012). This manipulation was included to enhance the effects of MS on pain perception and somatosensory brain responses. While we failed to detect increase in perceived pain after classical reminders of participants' own mortality (Experiment 1, Section 5.2), reminders of mortality of one's romantic partner did predict a significant increase in perceived pain levels (Experiment 2, Section 5.3). However, more importantly, we showed the significant effects of anxiety and depression trait scores on both pain perception and somatosensory brain responses. Not only did we confirm the opposing effects of anxiety and depression (Dobson, 1985), we also showed how strongly these personality traits can predict the effectiveness of MS induction.

Following Study 1, we tested participants who had experience in meditation techniques in Study 2 (Section 6). By implementing the same MS as we used in Study 1 Experiment 2 (Section 5.3), we investigated how experience in meditation acts as a buffer against MS. There are numerous studies investigating the effects of meditation on the mind (e.g. Baer, 2003; Kingston et al., 2007; Ospina et al., 2007; Hashemi et al., 2016; Basso et al., 2019) and there is evidence for considering meditation practices as a potential buffer against MS (Park & Pyszczynski, 2019). Indeed, we found that there was no significant increase in pain after MS of the meditation practitioners. Furthermore, we also observed a greater alpha desynchronization following MS induction for the meditation practitioners. Thus, we showed how people with experience in meditation techniques are affected differently by MS.

7.1 The moderating effects of personality traits on the effects of mortality salience

In Study 1 (Section 5) we conducted 2 experiments. In Experiment 1 (Section 5.2) we investigated how the effects of MS on somatosensory perception and brain responses can be predicted by seven personality traits. These traits (i.e. self-esteem, anxiety, depression, fear of death trait scores as well as anxious, close and dependent attachment style scores) were all established as factors interacting with reminders of mortality. Self-esteem is one of the original personality traits believed to act as a buffer against existential threat (Greenberg et al., 1986; Harmon-Jones et al., 1997; Pyszczynski et al., 2004). Links between anxiety and existential threat have also been already established (Pyszczynski, 2004; Iverach et al., 2014). Following that, there is a connection between anxiety and depression (Dobson, 1985). Anxiety seems to occur in response to potential threats to self-esteem or happiness, and depression responds more to already occurring threats to self-esteem or happiness (Beck, 1976). Thus, self-esteem, anxiety and depression are linked to each other and potentially to the buffers and defences against existential anxiety. While fear of death seems to be intuitively linked to MS, there are studies investigating how perceptive one can be to reminders of mortality (Solomon & Greenberg, 2000). Relationships and attachments have also been named as potential buffers against death anxiety (Florian et al., 2002; Cox & Arndt, 2012). It has been shown that MS-induction resulted in increased wish for intimacy (Taubman-Ben-Ari et al., 2002). Thus, we chose the aforementioned personality traits to investigate how well they can explain the changes in perception of and brain responses to anxiogenic somatosensory stimuli. Furthermore, we expanded the previous method of using pain to measure the effects of MS (Valentini et al., 2014, 2015, 2017) by implementing a psychological threat manipulation. Participants were expecting "normal" (Non-threatening) and "sigmoid-shaped" (Threatening) stimuli. These were indicated by a coloured circle before each stimulus. It is widely accepted that expectation of pain can affect perception (Loeser & Melzack, 1999; Wager et al., 2004; Tracey, 2010; Atlas & Wager, 2012; Kokonyei et al., 2019). Thus, we built on this notion and the previous findings that perceived threat value can predict higher perceived pain (Wiech et al., 2010; Atlas & Wager, 2012) in order to enhance our ability to detect MS-related changes.

There were two significant differences between Study 1 Experiment 1 (Section 5.2) and Experiment 2 (Section 5.3). Firstly, while we only recruited people who were not in an exclusive romantic relationship for Experiment 1 and utilised the classical MS directed to the self (see in Study 1 Methods and Materials section, Section 5.2.3), we did investigate people who were in exclusive relationships in Experiment 2 and asked participants to think about the death of their romantic partner. This change was justified by the assumptions of TMT that any death-related reminder can trigger the changes in behaviour described by TMT (see Pyszczynski et al., 2015 for a review), as well as by the previously mentioned link between relationships and terror management (Florian et al., 2002; Taubman-Ben-Ari et al., 2002; Mikulincer et al., 2003; Cox & Arndt, 2012). Secondly, we used the measurement of fear of other's death instead of fear of death for our analysis to better fit the experimental design. The rationale behind this was the MS. We assumed that reminder of the mortality of one's romantic partner should be closer linked to fear of other's death than to fear of death.

7.1.1 Pain perception

Despite our assumptions, MS only predicted significant change in perceived pain levels in Experiment 2 (Figure 5-12). In the CTRL condition and in Experiment 1's MS condition we found that pain levels decreased over time (Figure 5-3), conforming to the general habituation effect (Hollins et al., 2011). Thus, we found that only the idea of losing one's romantic partner elicited higher perception of pain.

However, personality trait scores showed significant interactions with the changes of VAS ratings in the different Mind-set conditions. In both experiments anxiety and depression predicted opposing effects, showing that with higher anxiety trait level predicting an increase, higher level of depression trait predicted decrease in pain perception (Table 5-2, Table 5-6). These findings confirm both the importance of anxiety and depression traits for TMT research and their complementary opposite direction. While in some studies participants with extreme levels of anxiety or depression are excluded (Valentini et al., 2014, 2017), the effects of these personality traits on behaviour have not been addressed. In Study 1, we provided a strong case for taking personality traits into account to measure effects of MS also more generic threat in a more reliable fashion.

We found that this psychological threat manipulation predicted a significant increase in perceived pain; however, we failed to enhance the effects of MS in our experimental paradigm in Study 1. Sporadically, we succeeded in identifying Threat condition-specific interactions, such as the close attachment in Study 1 Experiment 1.

All other personality traits predicted sporadic increases and decreases in both Experiment 1 and 2. We found that while fear of death predicted an increase in perceived pain in both Mind-set conditions, fear of other's death only predicted decrease in CTRL condition. Similarly, self-esteem in Experiment 1 predicted increased pain perception in both conditions, but only in CTRL in Experiment 2. These findings questioned the buffering role of self-esteem against MS. Self-esteem is cardinal for TMT (Routledge et al., 2004; Pyszczynski et al., 2015). However, as the replication crisis reached TMT (Klein et al., 2019), it worth rethinking and retesting its core elements. As expected, close attachment type showed significant interaction with MS in Experiment 1 (Mikulincer et al., 2003), however, it was not exclusive to MS in Experiment 2. It is possible, that our control condition triggered similar cognitive mechanisms to the MS used in Experiment 2 as an "active placebo". However, this goes against the notion that the idea of mortality triggers a unique type of threat and consequently cognitive buffering mechanisms.

Overall, we showed that a lack of change after MS induction can be explained by anxiety and depression trait levels. The significant predictive power of personality traits in the framework of TMT was the most important finding of Study 1 (Section 5).

7.1.2 Brain responses

We investigated the somatosensory-evoked potentials as well as the brain oscillations between 1 and 15 Hz from -0.2 sec to 1 sec after stimulus onset. The N2 component was sensitive to threat manipulation in Experiment 1. This finding supports the assumption that N2 is affected by attention to somatosensory stimulation (Michie, 1984; Eimer & Forster, 2003). We found that the N2 component showed no habituation post-MS predicted by a higher level of anxious attachment style (Figure 5-5). Similarly, dependent attachment type predicted a lack of habituation of P2 component (Figure 5-6). The latter was notably only present in the Threatening condition. In Experiment 2, we found that the N2 amplitude interacted with the close attachment type (Figure 5-14, bottom). On one hand, this was expected, as N2 is assumed to reflect negative valence (Hillyard et al., 1998; Eimer & Forster, 2003; Wu et al., 2010). On the other hand, N2 interacted with the CTRL mind-set rather than the MS mind-set. This was surprising, as we expected an effect of the on the MS-buffering romantic relationship (Mikulincer & Florian, 2000; Taubman-Ben-Ari et al., 2002; Cox & Arndt, 2012; McCabe & Daly, 2018). However, our findings did not reveal MS-exclusive interaction of close attachment type. It is not impossible that relationships can act as a buffer against a wide variety of threats, making existential threats less outstanding. Alternatively, it is also possible that our control condition acted as an "active placebo" triggering anxiogenic processes on a similar level than reminders of mortality, akin to the effect we saw on the pain ratings.

Despite investigating a range of frequencies including delta, theta, alpha and low beta (1-15 Hz), we only found AOIs in the alpha and theta frequency bands.

We identified three alpha AOIs (early, late and low) in Experiment 1 (Figure 5-7). Alpha activity is a reliable indicator of thalamocortical excitability (Pfurtscheller et al., 2008; Hanslmayr et al., 2011). There was significantly greater late alpha desynchronization following Threatening stimuli compared to Non-threatening ones. This finding may be interpreted as reflecting attention towards more threatening stimulus. Higher level of anxiety predicted alpha desynchronization in all three AOIs, whereas depression predicted greater alpha synchronization, confirming that anxiety generally results in a higher excitability

(Dobson, 1985). In a similar way, depression showed an inverse effect to anxiety. Thus supporting the notion that anxiety increases and depression decreases brain excitability (Dobson, 1985; Clark et al., 2009).

A modulation in the theta band was observed in both Experiment 1 and Experiment 2 (Figure 5-7 & Figure 5-16). The theta activity in Experiment 2 showed a significant reduction in MS compared with CTRL predicted by close attachment style (Figure 5-17). Surprisingly, this effect was not present in the Threatening condition. This can be attributed to threat overload, that is the MS effects disappear when the level of threat conveyed is very high (see discussed in Pyszczynski et al., 2015). Anxiety predicted a significantly greater theta desynchronization in MS compared with CTRL. Depression trait scores also predicted greater theta desynchronization in both Mind-set conditions. This was surprising, as we were expecting anxiety trait scores to predict effects opposite in direction to depression. It is possible that while in terms of perception of pain and thalamocortical excitability anxiety and depression are predicting reciprocal effects (Dobson, 1985; Clark et al., 2009), this may not hold true for all frequency bands. Higher fear of death scores predicted greater synchronized theta activity (Figure 5-8). All these findings are in agreement with the notion that slow oscillatory activities such as delta, theta, alpha and beta can show cognitive top-down modulation (Klimesch, 2018).

Similarly to pain ratings, we found no significant effect of self-esteem on somatosensory-evoked potentials nor on brain oscillations as measured through explicit self-reports collected by a well-established questionnaire in the literature (Solomon et al., 1991; Solomon & Greenberg, 2000; Routledge et al., 2004; Niemiec et al., 2010; Wisman et al., 2015). We failed to identify substantial predictive capability of the fear of death and fear of other’s death scores.

To sum it up, here we presented an important finding about the overlooked importance of trait anxiety and depression in TMT research. Our results suggest that even small individual variance in these trait scores (i.e. < 2 standard deviations) can result in significant impact on MS effectiveness.

7.2 The buffering effects of meditation experience on the effects of mortality salience

In Study 2 (Section 6), we utilised the experimental design used in Study 1 Experiment 2 to investigate if experience in meditation can act as a buffer against the effects of MS. We used the data collected in Study 1 Experiment 2 as a control group for Study 2 and we followed a similar method to analyse the results. There are numerous studies showing how experience in meditation can lead to reduced anxiety (Shapiro et al., 1998) and depression levels (Bitner et al., 2003) as well as to an increased psychological well-being (Ospina et al., 2007), compassion level (Lutz et al., 2008), higher level of attention and self-regulation (Brefczynski-Lewis et al., 2007; Tang et al., 2007) among others. Considering how meditation practitioners are better at regulating their emotions (Basso et al., 2019), it is not hard to see why people would investigate the effects of meditation on existential threat (Park & Pyszczynski, 2019).

7.2.1 Pain perception

Akin to Study 1 (Section 5), we investigated the effect of pain expectation manipulation. Threat affected both participants with and without experience in meditation practices. Other studies showed similar results of meditation practitioners buffered pain measured on McGill Pain Questionnaire but not against thermal pain assessments (Mischkowski et al., 2021).

Furthermore, it is argued that the perception of pain expectation manipulation can strongly differ between individuals (Lim et al., 2020). A potential explanation can rest in the role of individual differences in agreeableness. Prior studies show, that even short term experience in meditation practices can lead to an increase in one's agreeableness scores (Thompson & Waltz, 2007; Barkan et al., 2016). People with higher scores of agreeableness are more prone to experience placebo effects (Beedie et al., 2008; Kelley et al., 2009; Peciña et al., 2013). It is noteworthy that our manipulation of expectation can be considered as nocebo. Participants were expecting a more painful stimulation while in fact they received stimuli with the same intensity. Therefore, individuals with higher disposition to nocebo might have responded to the threatening stimulus to the greater extent.

7.2.2 Brain activity

In Study 2, we focused only on the brain oscillatory activity, as it is a more accurate description of the brain activity than event-related potentials (Buzsáki, 2011). Neural oscillation are believed to be better suited to disclose the neural mechanisms underpinning several cognitive, sensory and motor functions (Cohen, 2017). Thus, we decided to work on this more meaningful form of neural data instead of the SEPs. Nevertheless, for the completeness of this thesis, we provided the SEP analysis in the Appendix for Study 2, Section 10.4. Similarly to Study 1, we identified alpha a theta AOIs.

NP showed an increase in theta synchronisation post-MS compared with CTRL only in the Threatening condition. Among other slow oscillations, theta is affected by top-down modulation (Klimesch, 2018). On one hand, this seems to confirm our hypothesis that by increasing the perceived threat value of our somatosensory stimuli, we can enhance the effects of MS. On the other hand, it begs the question if this psychological manipulation enhances the MS effects or competes for the same cognitive load required to process the MS manipulation, thus dampening the effects of MS (see in Pyszczynski et al., 2015). MP showed a greater alpha synchronization post-CTRL and desynchronization post-MS. This is in accordance with the idea that event-related synchronisations (ERSs) and event-related desynchronization (ERDs) in the alpha frequency band can indicate inhibition and activation in certain brain areas respectively (Klimesch, 2012). Furthermore, it is possible that alpha ERS indicates an inhibition of a certain area in the brain in response to a stimulus and not a general lack of focus (Klimesch, 2012). We found that Threat predicted a significantly greater late low alpha ERD for the MP but not for the NP who showed an increase in alpha synchronisation. Thus, it is possible that late alpha activity reflects the cognitive processes (e.g. emotion control (Ospina et al., 2007), self-regulation and attention (Jha et al., 2007; Brefczynski-Lewis et al., 2007; Tang et al., 2007)) that are affected by meditation experience. Previous studies already showed that people with experience in meditation can down-regulate pain perception (Zorn et al., 2020). MP showed a significantly greater alpha ERD in the Non-threatening condition, but not in the Threatening one. However, the NP showed no such pattern. This pattern was unexpected as we were expecting the same, but dampened effects in MP and in NP. It is possible that as MP have higher level of self-regulation (Tang et al., 2015), control over their attention (Jha et al., 2007; Malinowski, 2013; Farb et al., 2013; Morrison & Jha, 2015), ability to regulate their emotions (Chambers et al., 2009; Goldin & Gross, 2010; Lutz et al., 2013) as well as self-awareness (Hölzel et al., 2011; Berkovich-Ohana et al., 2012; Yair Dor-Ziderman et al., 2013) their neural response for anxiogenic stimuli may be different from NP. Previous studies showed that greater experience in meditation techniques can predict a greater ability to reduce the effects of pain (Bushnell et al., 2013; Zeidan et al., 2015; Zorn et al., 2020). Thus, our results seem to be in agreement with the notion that meditation practice can lead to greater emotional control (Chambers et al., 2009; Goldin & Gross, 2010; Lutz et al., 2013), pain regulation and even changes in neural responses (Davidson et al., 2003; Cahn & Polich, 2006; Hauswald et al., 2015).

7.3 General conclusions of Study 1 and Study 2

Our research aimed at shedding light on how neural responses are affected by MS and how personality traits (Study 1, Section 5) and experience in meditation (Study 2, Section 6) can act as moderators for the effects of MS. We implemented an experimental design using threatening somatosensory stimuli while measuring the level of perceived pain by visual analogue scale ratings and brain activity using EEG (Figure 5-1 & Figure 6-1). In Study 1, we presented a strong case for including personality traits as predictive factors into TMT research. Especially anxiety and depression trait scores can predict different levels of effectiveness of MS. Even though we identified significant AOIs in the theta range, we generally found that the alpha frequency band holds important information of how the brain's process of external stimuli is affected by MS. Study 2 provided us with results supporting the idea that experience in meditation techniques can act as buffers against existential threats. However, we also found that while experience in meditation results in greater attention and self-regulation levels (Brefczynski-Lewis et al., 2007; Tang et al., 2007), MP can be more perceptible to psychological manipulation. We considered this as the effect of a generally higher level of agreeableness observed in MP (Thompson & Waltz, 2007; Barkan et al., 2016) which positively correlates with the efficiency of the placebo effect and so by analogy of nocebo effect (Beedie et al., 2008; Kelley et al., 2009; Peciña et al., 2013). Our manipulation of the pain expectation is a nocebo effect (Požgain et al., 2014). Meaning, it is possible that the higher level of agreeableness also correlates with the efficiency of nocebo. It is also noteworthy, that our analysis revealed two significant effects in mood and anxiety scores: as expected, we found that MP had a significantly higher positive mood score, lower anxiety state and marginally non-significantly lower negative mood scores compared to NP; however, we also found that the positive mood scores decreased significantly in both studies, regardless of Mind-set condition. This is an important finding, as it can signal either that the experimental method affects the mood and/or that the threatening scenarios affect the mood scores. Although, our study was not designed to investigate this question, these effects will have to be addressed in future research.

7.4 Novel methods and limitations

In the two studies presented, we used the novel statistical approach of applying mixed-effects models to the analysis of neural data. We argued that the best method to investigate the effects of categorical (pre/post, CTRL/MS, Non-threatening/Threatening, NP/MP) together with continuous factors (personality traits) was mixed-effects modelling. Unlike analysis of variance (ANOVA), mixed-effects models can include random intercepts and random slopes. For example, in our experimental design the model intercept was random on the participant level. This operation allowed us to eliminate the statistical differences between participants. While in our case the linearity of the models were assumed (i.e. we always had two levels in the categorical factors and two points always defines a line) one of the main strengths of mixed-effects models is their ability to model non-linear relationships (Krueger & Tian, 2004). Mixed-effects models offer numerous additional benefits making them more suitable for neural data analysis compared to ANOVA. While repeated measures ANOVA cannot handle missing data or unequal sample sizes, generalised mixed-effects models can tackle this issue (Krueger & Tian, 2004). Frequently, EEG data points are lost due to noises or artifacts. By implementing mixed-effects models as the default analysis method, we improved our methods of understanding neural data. Lastly, mixed-effects models can take individual differences into account. These abilities make mixed-effects modelling a superior method compared to ANOVA for analysing brain activity. Even though mixed-effects models have been utilised on EEG components before (Huang et al., 2008; Davidson, 2009; Riha et al., 2020), there has been no attempt to use mixed-effects models as a method of whole trial analysis to our knowledge. We applied our models onto each point in our SEP and brain oscillation data.

However, there are some limitations that should be discussed. Firstly, due to the complexity of our studies, we could not establish false discovery rates (FDRs) for our method. Study 1 had three categorical factors (Mind-set, Threat and Time) with seven continuous predictors (personality traits). To establish a justifiable FDR for our methodology, a study with one factor and another study with two factors and one interaction are needed. In general, we can use bootstrapping or theoretical criteria to limit sporadic false positives. We used the latter, claiming that a meaningful SEP IOI should be at least 20 ms and brain oscillation at least 100 ms long. A more precise method would attempt measuring the required amount of consecutive time points with significant effects to the frequency, such as at least 2 or 3 cycles (i.e. this would mean 500 ms length of 4 Hz or 200 ms of 10 Hz). Furthermore, we found no clear indication in the literature about the range of frequencies required for a meaningful AOI. Our resolution in the frequency domain was 0.1 Hz, resulting in some very long (500 – 700 ms) effects in the lower frequencies (1 – 3 Hz) but only in a few frequency lines (e.g. from 2.7 to 2.1 Hz). We aim to further investigate this and to establish clear criteria to what considers as significant IOI and AOI.

In terms of our findings, we showed the importance of personality traits in predicting the effectiveness of MS (Section 5) and the buffering effect of experience in relaxation techniques against the effects of MS (Section 6). Although our effects were highly significant in both studies, our main limitation was the number of participants. To establish clear effects accounted by continuous variables, such as personality traits, a greater sample size is required. Thus, our studies cannot provide a conclusive statement on the role of individual differences in personality traits in the context of TMT research. Similarly, we could not recruit large number of MP to account for short and long-term effects of experience in meditation techniques. This was partially caused by the scarce availability of local meditators particularly those with longstanding and intense practice. Moreover, the COVID-19 pandemic prevented us to recruit more participants. Likewise, age is a clear unbalancing factor in experiments investigating the effects of experience in a given practice. Participants who were long-time practitioners of meditation techniques tend to be older compared to non-meditation practitioners. As every research conducted on university campuses, our primary pool of participants was university students. Thus, sampling participants from different age groups is unavoidable. Nevertheless, our findings on the efficacy of such experience against existential threat but not against other threat types (in our case the psychological manipulation of stimulus expectation) opened a new line of questions.

Power analysis was also an issue for all of our experiments. The effect sizes of MS are unclear, as pointed out by Klackl & Jonas (2019). As such, any power simulation is questionable. Yet, we have relied on the sample size of previous studies and the strengths of our within-subject design and mixed-effects analysis. Within-subject designs are less affected by failure to randomly assign participants to experimental conditions and decrease the effect of individual variance (Charness et al., 2012). A recent study recorded four participants three times with four different EEG systems. They reported that differences across participants accounted for 32% of the variance, the EEG systems for 9% of the variance, and the repeated sessions for the combination of each subject-system for 1% of the variance (Melnik et al., 2017). In statistical terms, within-subject designs allow to capitalise on the analysis of variance, within-subjects factors are included in the error-term notation whereas between-subjects factors are only included in the notation for the fixed-effects structure. Of course, both designs have advantages, but it is fair to claim that between-subjects designs have less power, especially in contexts (like ours) where mixed-effects models can compellingly tackle individual variance at trial level.

Unfortunately, during the past few years TMT has been heavily criticised (Klein et al., 2019). These criticisms raised several valid issues, worth considering. McCabe at al. (2018) found that the idea of losing one's job can lead to greater mortality cognition (compared to a control mind-set). This finding questions the basic idea of TMT that death is a unique concept for us. Such results open up a whole new line of questioning whether existential anxiety is only limited to the fear of death, or it includes other aspects of our existence such as job security. If, the assumption of TMT is true and death is a unique concept for the human consciousness, then using the idea of losing one's job, such as we did in Study 2 (Section 6) for people who were not students is an exceptionally well-established control. The threat to job security and financial stability is not directly linked to threats against one's existence. As such, the difference between these two concepts should only be the idea of mortality. However, if TMT is incorrect in its assumption of the fear of mortality being special, we will have to reconsider our approach to terror management.

The classical control condition for MS is dental pain (Greenberg et al., 1994; Pyszczynski et al., 2015). It is important to investigate the effects of MS using different control conditions, ones that are closer to be existential threats, but are not related directly to the idea of death. Such issues were addressed by proponents of TMT stating that certain conditions can logically lead to the idea of mortality (such as the idea of violence can invoke the idea of consequent death; Pyszczynski et al., 2006). However, such explanation cannot be applied to the idea of job security, which requires several steps and leaps to link with mortality (e.g. loss of employment leads to financial insecurity, which leads to insecurity of living place as well as food, which leads to a harsher life situation which leads to potential death). Similarly, the idea that certain threats can increase death thought accessibility goes against the theory of mortality salience being unique. The field of TMT would greatly benefit from extensive research involving a wider variety of threats to establish what humans perceive as existential threat.

Last, but not least, we used different colours to manipulate stimulus expectation. It can be argued that colours can affect pain perception, this is a weak point of our experimental design (Wiercioch-Kuzianik & Bąbel, 2019). While there is no data suggesting that yellow and blue colours would affect pain sensation significantly differently, there are indications that short- and long-wavelength colours have different psychological meanings (Adams & Osgood, 1973). Thus, we recommend that future research use a different method for manipulating stimulus expectations, such as arrows pointing right or left or other geometrical shapes in two different positions.

To summarise, we consider the statistical method used in our studies as a promising first step towards a more robust and precise analysis of brain responses. Further research is clearly needed to establish selection criteria and FDR. Replication of our studies using greater number of participants and not colour-based manipulation of stimulus expectation is important for testing our methodology. More importantly, expanding the scope of personality traits that can potentially interact with MS is a crucial step to test the validity of TMT.

7.5 Future research

Our two studies provided a greater understanding on the effects of mortality salience. However, it is important to push forward and expand on our findings. In the followings, I will list three potential research lines that can use our studies as their bases.

7.5.1 Personality traits

First and foremost, we investigated seven personality traits that were reported to be linked with MS by past literature. However, there are more trait measurements which can potentially act as significant moderators. Body-esteem has recently been linked to MS in tactile sensation (Beyrak-Lev et al., 2018). As we did not find any effect of self-esteem in our methodology, it would be beneficial to measure self-esteem and body-esteem in a similar methodology or to use implicit self-esteem, measures to address this issue. There is foundation for using Implicit Association Test (Greenwald et al., 1998) to measure implicit self-esteem (Greenwald & Farnham, 2000). By applying multiple methods of measuring self-esteem, we could narrow down which aspect of it buffers the effects of MS. Following this logic, it is beneficial to use different questionnaires and methods to investigate personality traits. Here we only used one per trait. While the questionnaires we utilised are all well-established and frequently used (see in Sections 4.2.4 and 4.3.3), future studies can expand on this by investigating the same personality traits using different measuring tools. Moreover, breaking down traits into subscales can also provide valuable information. In Study 2 (Section 6), we investigated experience in meditation. Mapping out the predictive capabilities of simpler traits, such as mindfulness traits or agreeableness, can be useful to understand the effects of meditation practice. Such experiments will provide convergent evidence about the role of personality traits in the framework of TMT. To sum up, investigating more personality traits, researching the same traits with using different tools and investigating subscales of said traits can provide better understanding on the effects of MS.

7.5.2 Other, non-death-related control conditions

The classical TMT research uses dental pain as control to mortality (Pyszczynski et al., 2015). However, the idea of pain in a research using somatosensory stimuli is biased, thus we followed a previously established control of failure on an important exam (Valentini et al., 2014) and added a similarly negative control of losing one’s employment. It is important to investigate the effects of further, non-death-related threats to show if reminders of death effects are truly unique. Researchers are using different control conditions ranging from watching television (Huang et al., 2021) through general negative statements (Feng et al., 2017) to failing on an exam (Valentini et al., 2014), but there is currently no comprehensive study investigating the perception and/or the effects of non-death-related, generic threats. It is crucial to investigate the effects of non-death-related existential threats, too (e.g. paralysis, abandonment, being lost, etc.). This is certainly a valid field of investigation that would require more attention from the research community. Implementation of linear mixed-effects models EEG data

Mixed-effects models handle unequal group sizes, great individual variance and different types of predictors better than ANOVA. These abilities make mixed-effects modelling well-suited for EEG studies, where trials are rejected due to artifacts and individual brain responses can vary. Although our studies implemented mixed-effects models in a novel way, there are several aspects of this new method that require investigation. Further analysis could use our studies as a foundation for consecutivity thresholding. By simulating data using a bootstrapping method we can establish a minimum time length for an effect to be considered significant. As neural data autocorrelates, using the length of consecutive significant findings can prove to be a faster, easier and less aggressive false discovery ratio correction than lowering the *p* value or cluster-based permutation tests. Adjusting the *p* value raises the issue with the amount of data we test in an EEG experiment, while cluster-based permutation tests are not equipped to provide valid information on ‘where’ or ‘when’ the difference between two condition occurs (Sassenhagen & Draschkow, 2019). Studies implementing permutation-based tests will lead to universally established consecutivity thresholding reducing FDR and the potential for overcorrecting EEG data.

7.6 Conclusions

This thesis details how individual differences in personality traits and experience in meditation techniques interact with the effects of MS on pain perception and somatosensory neural responses. We found that certain trait values (especially depression and anxiety) play a major role in predicting how effective MS will be on an individual. We also showed that experience in meditation techniques can act as a buffer against the threat of mortality.

In addition, we provided a detailed analysis on both behavioural and neural data. We implemented a novel statistical method in analysing neural data and identifying IOIs and AOIs. In doing so, we created a foundation for future studies implementing mixed-effects models to identify significant effects in brain activity. Our results aligned with prior research on personality traits (Dobson, 1985; Mikulincer & Florian, 2000; Taubman-Ben-Ari et al., 2002; Menzies et al., 2021); however we failed to find the buffering effects of self-esteem. In the light of the current replication crisis, our results could explain the sporadic success in replication of the original TMT findings and further question some of its core tenants.

Overall, our findings showcased the importance of the inclusion of personality traits in TMT research and the effects of experience in meditation techniques in buffering death anxiety.

8 References

Abdoli, N., Farnia, V., Salemi, S., Davarinejad, O., Ahmadi Jouybari, T., Khanegi, M., Alikhani, M., & Behrouz, B. (2020). Reliability and Validity of Persian Version of State-Trait Anxiety Inventory Among High School Students. *East Asian Archives of Psychiatry : Official Journal of the Hong Kong College of Psychiatrists = Dong Ya Jing Shen Ke Xue Zhi : Xianggang Jing Shen Ke Yi Xue Yuan Qi Kan*, *30*(2), 44–47. https://doi.org/10.12809/eaap1870

Ackerman, R. A., Witt, E. A., Donnellan, M. B., Trzesniewski, K. H., Robins, R. W., & Kashy, D. A. (2011). What does the Narcissistic personality inventory really measure? *Assessment*, *18*(1), 67–87. https://doi.org/10.1177/1073191110382845

Adams, F. M., & Osgood, C. E. (1973). A Cross-Cultural Study of the Affective Meanings of Color. *Journal of Cross-Cultural Psychology*, *4*(2), 135–156. https://doi.org/10.1177/002202217300400201

Alfonsson, S., Maathz, P., & Hursti, T. (2014). Interformat reliability of digital psychiatric self-report questionnaires: a systematic review. *Journal of Medical Internet Research*, *16*(12), e268. https://doi.org/10.2196/jmir.3395

Arndt, J., Greenberg, J., Pyszczynski, T., & Solomon, S. (1997). Subliminal Exposure to Death-Related Stimuli Increases Defense of the Cultural Worldview. *Psychological Science*, *8*(5), 379–385. https://doi.org/10.1111/j.1467-9280.1997.tb00429.x

Arndt, J., Greenberg, J., Simon, L., Pyszczynski, T., & Solomon, S. (1998). Terror Management and Self-Awareness: Evidence that Mortality Salience Provokes

Avoidance of the Self-Focused State. *Personality and Social Psychology Bulletin*, *24*(11), 1216–1227. https://doi.org/10.1177/01461672982411008

Asmundson, J. G., & Katz, J. (2009). Understanding the co-occurrence of anxiety disorders and chronic pain: state-of-the-art. *Depression and Anxiety*, *26*(10), 888–901. https://doi.org/10.1002/da.20600

Atlas, L. Y., & Wager, T. D. (2012). How expectations shape pain. *Neuroscience Letters*, *520*(2), 140–148. https://doi.org/10.1016/j.neulet.2012.03.039

Austin, P. C. (2017). A Tutorial on Multilevel Survival Analysis: Methods, Models and Applications. *International Statistical Review = Revue Internationale de Statistique*, *85*(2), 185–203. https://doi.org/10.1111/insr.12214

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical Psychology: Science and Practice*, *10*(2), 125–143. https://doi.org/10.1093/clipsy/bpg015

Balsamo, M., Cataldi, F., Carlucci, L., & Fairfield, B. (2018). Assessment of anxiety in older adults: a review of self-report measures. *Clinical Interventions in Aging*, *13*, 573–593. https://doi.org/10.2147/CIA.S114100

Barkan, T., Hoerger, M., Gallegos, A. M., Turiano, N. A., Duberstein, P. R., & Moynihan, J. A. (2016). Personality Predicts Utilization of Mindfulness-Based Stress Reduction During and Post-Intervention in a Community Sample of Older Adults. *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, *22*(5), 390–395. https://doi.org/10.1089/acm.2015.0177

Barrera, A. Z., Moh, Y. S., Nichols, A., & Le, H.-N. (2021). The Factor Reliability and Convergent Validity of the Patient Health Questionnaire-4 Among an International Sample of Pregnant Women. *Journal of Women's Health (2002)*, *30*(4), 525–532. https://doi.org/10.1089/jwh.2020.8320

Basso, J. C., McHale, A., Ende, V., Oberlin, D. J., & Suzuki, W. A. (2019). Brief, daily meditation enhances attention, memory, mood, and emotional regulation in non-experienced meditators. *Behavioural Brain Research, 356,* 208–220. https://doi.org/10.1016/j.bbr.2018.08.023

Bauman, Z. (1992). *Mortality, Immortality and Other Life Strategies*. Stanford University Press. https://books.google.co.uk/books?id=JYNW-3fjGIoC

Baumeister, R. F., Smart, L., & Boden, J. M. (1996). Relation of Threatened Egotism to Violence and Aggression: The Dark Side of High Self-Esteem. *Psychological Review, 103*(1), 5–33. https://doi.org/10.1037/0033-295X.103.1.5

Beck, A. T. (1976). Cognitive therapy and the emotional disorders. In *Cognitive therapy and the emotional disorders.* International Universities Press.

Becker, E. (1973). *Denial of death*. Simon & Schuster.

Beedie, C. J., Foad, A. J., & Coleman, D. A. (2008). Identification of placebo responsive participants in 40km laboratory cycling performance. *Journal of Sports Science & Medicine, 7*(1), 166–175.

Berger, H. (1929). Über das elektroenkephalogramm des menschen. *Archiv Für Psychiatrie Und Nervenkrankheiten*, *87*(1), 527–570.

Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2012). Mindfulness-induced changes in gamma band activity – Implications for the default mode network, self-reference and attention. *Clinical Neurophysiology*, *123*(4), 700–710. https://doi.org/https://doi.org/10.1016/j.clinph.2011.07.048

Beyrak-Lev, J., Gerber, Z., Ein-Dor, T., & Hirschberger, G. (2018). Mortality salience reduces tactile attention among people with low body esteem. *Death Studies*, *42*(7), 426–431. https://doi.org/10.1080/07481187.2017.1363321

Bitner, R., Hillman, L., Victor, B., & Walsh, R. (2003). Subjective effects of antidepressants: a pilot study of the varieties of antidepressant-induced experiences in meditators. *The Journal of Nervous and Mental Disease*, *191*(10), 660–667. https://doi.org/10.1097/01.nmd.0000092175.15118.67

Bowlby, J. (1988). Attachment, Communication, and the Therapeutic Process. In *In A Secure Base: Parent-Child Attachment and Healthy Human Development* (pp. 137–157). Taylor & Francis Group.

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(27), 11483–11488. https://doi.org/10.1073/pnas.0606552104

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: emerging methods and principles. *Trends in Cognitive Sciences*, *14*(6), 277–290. https://doi.org/10.1016/j.tics.2010.04.004

Bruce Schaalje, G. (2008). Linear mixed models, a practical guide using statistical software.

Brady T. West, Kathleen B. Welch, Andrzej T. Galecki, Chapman & Hall/CRC, Boca Raton, FL, 2007. No. of pages: xix +353. Price: $71.96. ISBN: 1-58488-480-0. *Statistics in Medicine*, *27*(15), 2979–2980. https://doi.org/https://doi.org/10.1002/sim.3167

Buckholtz, J. W., & Marois, R. (2012). The roots of modern justice: cognitive and neural foundations of social norms and their enforcement. *Nature Neuroscience*, *15*(5), 655–661. https://doi.org/10.1038/nn.3087

Burish, T., & Kent Houston, B. (2006). Causal projection, similarity projection, and coping with threat to self-esteem. *Journal of Personality*, *47*, 57–70.

Burke, B. L., Martens, A., & Faucher, E. H. (2010). Two decades of terror management theory: a meta-analysis of mortality salience research. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *14*(2), 155–195. https://doi.org/10.1177/1088868309352321

Bushnell, M. C., Ceko, M., & Low, L. A. (2013). Cognitive and emotional control of pain and its disruption in chronic pain. *Nature Reviews. Neuroscience*, *14*(7), 502–511. https://doi.org/10.1038/nrn3516

Buzsáki, G. (2011). *Rhythms of the brain*. Oxford University Press Inc.

Buzsáki, G., Kaila, K., & Raichle, M. (2007). Inhibition and brain work. *Neuron*, *56*(5), 771–783. https://doi.org/10.1016/j.neuron.2007.11.008

Buzsáki, G., & Wang, X.-J. (2012). Mechanisms of Gamma Oscillations. *Annual Review of Neuroscience*, *35*(1), 203–225. https://doi.org/10.1146/annurev-neuro-062111-150444

Cahn, B. R., & Polich, J. (2006). Meditation states and traits: EEG, ERP, and neuroimaging studies. *Psychological Bulletin*, *132*(2), 180–211. https://doi.org/10.1037/0033-2909.132.2.180

Carleton, R. N. (2016a). Fear of the unknown: One fear to rule them all? *Journal of Anxiety Disorders*, *41*, 5–21. https://doi.org/https://doi.org/10.1016/j.janxdis.2016.03.011

Carleton, R. N. (2016b). Into the unknown: A review and synthesis of contemporary models involving uncertainty. *Journal of Anxiety Disorders*, *39*, 30–43. https://doi.org/10.1016/j.janxdis.2016.02.007

Caspi-Berkowitz, N., Mikulincer, M., Hirschberger, G., Ein-Dor, T., & Shaver, P. R. (2019). To die for a cause but not for a companion: Attachment-related variations in the terror management function of self-sacrifice. *Journal of Personality and Social Psychology*, *117*(6), 1105–1126. https://doi.org/10.1037/pspi0000172

Castano, E., Yzerbyt, V., Paladino, M. P., & Sacchi, S. (2002). I belong, therefore, I exist: Ingroup identification, ingroup entitativity, and ingroup bias. *Personality and Social Psychology Bulletin*, *28*(2), 135–143. https://doi.org/10.1177/0146167202282001

Chambers, R., Gullone, E., & Allen, N. B. (2009). Mindful emotion regulation: An integrative review. *Clinical Psychology Review*, *29*(6), 560–572. https://doi.org/https://doi.org/10.1016/j.cpr.2009.06.005

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior and Organization*, *81*(1), 1–8. https://doi.org/10.1016/j.jebo.2011.08.009

Chatard, A., Hirschberger, G., & Pyszczynski, T. (2020). *A Word of Caution about Many*

Labs 4: If You Fail to Follow Your Preregistered Plan, You May Fail to Find a Real Effect. *February*. https://doi.org/10.31234/osf.io/ejubn

Chen, Y., Shen, Y., Shi, Z., Zhang, X., Li, H., Xu, X., Guan, L., Han, S., & Yang, J. (2020). Mortality salience impairs self-referential processing: Neurophysiological and behavioral evidence. *Current Psychology*, *39*(3), 782–792. https://doi.org/10.1007/s12144-019-00193-1

Clark, C. R., Galletly, C. A., Ash, D. J., Moores, K. A., Penrose, R. A., & McFarlane, A. C. (2009). Evidence-based medicine evaluation of electrophysiological studies of the anxiety disorders. *Clinical EEG and Neuroscience*, *40*(2), 84–112. https://doi.org/10.1177/155005940904000208

Clauwaert, A., Torta, D. M., Forster, B., Danneels, L., & Van Damme, S. (2020). Somatosensory attentional modulations during pain-related movement execution. *Experimental Brain Research*, *238*(5), 1169–1176. https://doi.org/10.1007/s00221-020-05790-2

Cohen, M. X. (2014). A neural microcircuit for cognitive conflict detection and signaling. *Trends in Neurosciences*, *37*(9), 480–490. https://doi.org/https://doi.org/10.1016/j.tins.2014.06.004

Cohen, M. X. (2017). Where Does EEG Come From and What Does It Mean? *Trends in Neurosciences*, *40*(4), 208–218. https://doi.org/10.1016/j.tins.2017.02.004

Cohen, M. X., & Donner, T. H. (2013). Midfrontal conflict-related theta-band power reflects neural oscillations that predict behavior. *Journal of Neurophysiology*, *110*(12), 2752–2763. https://doi.org/10.1152/jn.00479.2013

Cohen, M. X., & Gulbinaite, R. (2013). Five methodological challenges in cognitive electrophysiology. *NeuroImage*, *85*, 702–710. https://doi.org/10.1016/j.neuroimage.2013.08.010

Colgin, L. L. (2013). Mechanisms and functions of theta rhythms. *Annual Review of Neuroscience*, *36*, 295–312. https://doi.org/10.1146/annurev-neuro-062012-170330

Collett, L.-J., & Lester, D. (1969). The Fear of Death and the Fear of Dying. *The Journal of Psychology*, *72*(2), 179–181. https://doi.org/10.1080/00223980.1969.10543496

Collins, G., Lundine, J. P., & Kaizar, E. (2021). Bayesian Generalized Linear Mixed-Model Analysis of Language Samples: Detecting Patterns in Expository and Narrative Discourse of Adolescents With Traumatic Brain Injury. *Journal of Speech, Language, and Hearing Research : JSLHR*, *64*(4), 1256–1270. https://doi.org/10.1044/2020_JSLHR-20-00471

Collins, N. L., Ford, M. B., Guichard, A. C., & Allard, L. M. (2006). Working models of attachment and attribution processes in intimate relationships. *Personality & Social Psychology Bulletin*, *32*(2), 201–219. https://doi.org/10.1177/0146167205280907

Collins, N. L., & Read, S. J. (1990). Adult attachment, working models, and relationship quality in dating couples. *Journal of Personality and Social Psychology*, *58*(4), 644–663. https://doi.org/10.1037/0022-3514.58.4.644

Comets, E., & Mentré, F. (2021). Developing Tools to Evaluate Non-linear Mixed Effect Models: 20 Years on the npde Adventure. *The AAPS Journal*, *23*(4), 75. https://doi.org/10.1208/s12248-021-00597-7

Corradi-Dell'Acqua, C., Tusche, A., Vuilleumier, P., & Singer, T. (2016). Cross-modal representations of first-hand and vicarious pain, disgust and fairness in insular and cingulate cortex. *Nature Communications*, *7*, 10904. https://doi.org/10.1038/ncomms10904

Cox, C. R., & Arndt, J. (2012). How sweet it is to be loved by you: the role of perceived regard in the terror management of close relationships. *Journal of Personality and Social Psychology*, *102*(3), 616–632. https://doi.org/10.1037/a0025947

Crawford, J. R., & Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, *43*(3), 245–265. https://doi.org/10.1348/0144665031752934

Crocq, M.-A. (2015). A history of anxiety: from Hippocrates to DSM. *Dialogues in Clinical Neuroscience*, *17*(3), 319–325. https://doi.org/10.31887/DCNS.2015.17.3/macrocq

Davidson, D. J. (2009). Functional mixed-effect models for electrophysiological responses. *Neurophysiology*, *41*(1), 71–79. https://doi.org/10.1007/s11062-009-9079-y

Davidson, R. J., Kabat-Zinn, J., Schumacher, J., Rosenkranz, M., Muller, D., Santorelli, S. F., Urbanowski, F., Harrington, A., Bonus, K., & Sheridan, J. F. (2003). Alterations in brain and immune function produced by mindfulness meditation. *Psychosomatic Medicine*, *65*(4), 564–570. https://doi.org/10.1097/01.psy.0000077505.67574.e3

Davis, M., Walker, D. L., Miles, L., & Grillon, C. (2010). Phasic vs sustained fear in rats and humans: role of the extended amygdala in fear vs anxiety. *Neuropsychopharmacology : Official Publication of the American College of Neuropsychopharmacology*, *35*(1), 105–

135. https://doi.org/10.1038/npp.2009.109

de Zwart, P. L., Jeronimus, B. F., & de Jonge, P. (2019). Empirical evidence for definitions of episode, remission, recovery, relapse and recurrence in depression: a systematic review. *Epidemiology and Psychiatric Sciences*, *28*(5), 544–562. https://doi.org/10.1017/S2045796018000227

Dobson, K. S. (1985). The relationship between anxiety and depression. *Clinical Psychology Review*, *5*(4), 307–324. https://doi.org/https://doi.org/10.1016/0272-7358(85)90010-8

Dor-Ziderman, Y, Lutz, A., & Goldstein, A. (2019). Prediction-based neural mechanisms for shielding the self from existential threat. *NeuroImage*, *202*, 116080. https://doi.org/https://doi.org/10.1016/j.neuroimage.2019.116080

Dor-Ziderman, Yair, Berkovich-Ohana, A., Glicksohn, J., & Goldstein, A. (2013). Mindfulness-induced selflessness: a MEG neurophenomenological study . In *Frontiers in Human Neuroscience* (Vol. 7, p. 582). https://www.frontiersin.org/article/10.3389/fnhum.2013.00582

Eimer, M., & Forster, B. (2003). Modulations of early somatosensory ERP components by transient and sustained spatial attention. *Experimental Brain Research*, *151*(1), 24–31. https://doi.org/10.1007/s00221-003-1437-1

Elben, S., Trenado, C., Vesper, J., Schnitzler, A., & Wojtecki, L. (2018). Human subthalamic oscillatory dynamics following somatosensory stimulation. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, *129*(1), 79–88. https://doi.org/10.1016/j.clinph.2017.10.015

Fabiani, M., Gratton, G., & Federmeier, K. D. (2007). Event-Related Brain Potentials: Methods, Theory, and Applications. In J. T. Cacioppo, L. G. Tassinary, & G. Berntson (Eds.), *Handbook of Psychophysiology* (3rd ed., pp. 85–119). Cambridge University Press.

Fan, X., & Han, S. (2018). Neural responses to one's own name under mortality threat. *Neuropsychologia*, *108*, 32–41. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2017.11.026

Farb, N. A. S., Segal, Z. V, & Anderson, A. K. (2013). Mindfulness meditation training alters cortical representations of interoceptive attention. *Social Cognitive and Affective Neuroscience*, *8*(1), 15–26. https://doi.org/10.1093/scan/nss066

Feng, C., Azarian, B., Ma, Y., Feng, X., Wang, L., Luo, Y.-J., & Krueger, F. (2017). Mortality salience reduces the discrimination between in-group and out-group interactions: A functional MRI investigation using multi-voxel pattern analysis. *Human Brain Mapping*, *38*(3), 1281–1298. https://doi.org/10.1002/hbm.23454

Finch, E. C., Iverach, L., Menzies, R. G., & Jones, M. (2016). Terror mismanagement: evidence that mortality salience exacerbates attentional bias in social anxiety. *Cognition & Emotion*, *30*(7), 1370–1379. https://doi.org/10.1080/02699931.2015.1065794

Fiorio, M., Recchia, S., Corrà, F., Simonetto, S., Garcia-Larrea, L., & Tinazzi, M. (2012). Enhancing non-noxious perception: behavioural and neurophysiological correlates of a placebo-like manipulation. *Neuroscience*, *217*, 96–104. https://doi.org/10.1016/j.neuroscience.2012.04.066

Fisher, R. A. (1919). XV.—The Correlation between Relatives on the Supposition of

Mendelian Inheritance. *Transactions of the Royal Society of Edinburgh*, *52*(2), 399–433. https://doi.org/10.1017/S0080456800012163

Florian, V., Mikulincer, M., & Hirschberger, G. (2002). The anxiety-buffering function of close relationships: Evidence that relationship commitment acts as a terror management mechanism. *Journal of Personality and Social Psychology*, *82*(4), 527–542. https://doi.org/10.1037//0022-3514.82.4.527

Forster, B., & Gillmeister, H. (2011). ERP investigation of transient attentional selection of single and multiple locations within touch. *Psychophysiology*, *48*(6), 788–796. https://doi.org/10.1111/j.1469-8986.2010.01147.x

Gao, T., Zhou, Y., Li, W., Pfabigan, D. M., & Han, S. (2020). Neural mechanisms of reinforcement learning under mortality threat. *Social Neuroscience*, *15*(2), 170–185. https://doi.org/10.1080/17470919.2019.1668846

Giraud, A.-L., & Poeppel, D. (2012). Cortical oscillations and speech processing: emerging computational principles and operations. *Nature Neuroscience*, *15*(4), 511–517. https://doi.org/10.1038/nn.3063

Goldenberg, J., & Arndt, J. (2008). The Implications of Death for Health: A Terror Management Health Model for Behavioral Health Promotion. *Psychological Review*, *115*, 1032–1053.

Goldenberg, J. L., Hart, J., Pyszczynski, T., Warnica, G. M., Landau, M., & Thomas, L. (2006). Ambivalence toward the body: death, neuroticism, and the flight from physical sensation. *Personality & Social Psychology Bulletin*, *32*(9), 1264–1277. https://doi.org/10.1177/0146167206289505

Goldin, P. R., & Gross, J. J. (2010). Effects of mindfulness-based stress reduction (MBSR) on emotion regulation in social anxiety disorder. *Emotion*, *10*(1), 83–91. https://doi.org/10.1037/a0018441

Gonzalez, A., Zvolensky, M. J., Hogan, J., McLeish, A. C., & Weibust, K. S. (2011). Anxiety sensitivity and pain-related anxiety in the prediction of fear responding to bodily sensations: A laboratory test. *Journal of Psychosomatic Research*, *70*(3), 258–266. https://doi.org/10.1016/j.jpsychores.2010.07.011

Goyal, M., Singh, S., Sibinga, E. M. S., Gould, N. F., Rowland-Seymour, A., Sharma, R., Berger, Z., Sleicher, D., Maron, D. D., Shihab, H. M., Ranasinghe, P. D., Linn, S., Saha, S., Bass, E. B., & Haythornthwaite, J. A. (2014). Meditation programs for psychological stress and well-being: a systematic review and meta-analysis. *JAMA Internal Medicine*, *174*(3), 357–368. https://doi.org/10.1001/jamainternmed.2013.13018

Greenberg, J., S., S., Veeder, M., Lyon, D., Pyszczynski, T., Rosenblatt, A., & Kirkland, S. (1990). Evidence for Terror Managenet Theory 2: The Effects of Mortlaity Salience on Reactions to Those Who Threaten or Bolster the Cultural Worldview. *Journal of Personality and Social Psychology*, *58*, 308–318.

Greenberg, J, Pyszczynski, T., Solomon, S., Simon, L., & Breus, M. (1994). Role of consciousness and accessibility of death-related thoughts in mortality salience effects. *Journal of Personality and Social Psychology*, *67*(4), 627–637.

Greenberg, Jeff, Arndt, J., Simon, L., Pyszczynski, T., & Solomon, S. (2000). Proximal and Distal Defenses in Response to Reminders of One's Mortality: Evidence of a Temporal Sequence. *Personality and Social Psychology Bulletin*, *26*(1), 91–99.

https://doi.org/10.1177/0146167200261009

Greenberg, Jeff, Kosloff, S., Solomon, S., Cohen, F., & Landau, M. (2010). Toward Understanding the Fame Game: The Effect of Mortality Salience on the Appeal of Fame. *Self and Identity - SELF IDENTITY*, *9*, 1–18.

Greenberg, Jeff, Martens, A., Jonas, E., Eisenstadt, D., Pyszczynski, T., & Solomon, S. (2003). Psychological Defense in Anticipation of Anxiety: Eliminating the Potential for Anxiety Eliminates the Effect of Mortality Salience on Worldview Defense. *Psychological Science*, *14*(5), 516–519. https://doi.org/10.1111/1467-9280.03454

Greenberg, Jeff, Pyszczynski, T., & Solomon, S. (1986). The Causes and Consequences of a Need for Self-Esteem: A Terror Management Theory. In R. F. Baumeister (Ed.), *Public Self and Private Self* (pp. 189–212). Springer New York. https://doi.org/10.1007/978-1-4613-9564-5_10

Greenberg, Jeff, Pyszczynski, T., Solomon, S., Pinel, E., Simon, L., & Jordan, K. (1993). Effects of Self-Esteem on Vulnerability-Denying Defensive Distortions: Further Evidence of an Anxiety-Buffering Function of Self-Esteem. *Journal of Experimental Social Psychology*, *29*(3), 229–251. https://doi.org/10.1006/jesp.1993.1010

Greenberg, Jeff, Solomon, S., & Arndt, J. (2008). A uniquely human motivation: Terror management. In *J. Shah & W. Gardner (Eds.), Handbook of motivation science* (pp. 113–134). Guilford Press.

Greenberg, Jeff, Solomon, S., Pyszczynski, T., Rosenblatt, A., Burling, J., Lyon, D., Simon, L., & Pinel, E. (1992). Why do people need self-esteem? Converging evidence that self-esteem serves an anxiety-buffering function. *Journal of Personality and Social*

Psychology, *63*(6), 913–922. https://doi.org/10.1037/0022-3514.63.6.913

Greenwald, A. G., & Farnham, S. D. (2000). Using the implicit association test to measure self-esteem and self-concept. *Journal of Personality and Social Psychology*, *79*(6), 1022–1038. https://doi.org/10.1037//0022-3514.79.6.1022

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: the implicit association test. *Journal of Personality and Social Psychology*, *74*(6), 1464–1480. https://doi.org/10.1037//0022-3514.74.6.1464

Gugino, V., & Chabot, R. J. (1990). Somatosensory evoked potentials. *International Anesthesiology Clinics*, *28*(3), 154–164. https://doi.org/10.1097/00004311-199002830-00005

Guillén-Riquelme, A., & Buela-Casal, G. (2014). [Meta-analysis of group comparison and meta-analysis of reliability generalization of the State-Trait Anxiety Inventory Questionnaire (STAI)]. *Revista espanola de salud publica*, *88*(1), 101–112. https://doi.org/10.4321/S1135-57272014000100007

H. Merskey, & Bogduk, N. (Eds.). (1994). *Part III: Pain Terms, A Current List with Definitions and Notes on Usage* (Second edi). IASP Press.

Han, S., Qin, J., & Ma, Y. (2010). Neurocognitive processes of linguistic cues related to death. *Neuropsychologia*, *48*(12), 3436–3442.

Han, Y., Fan, J., Wang, X., Xia, J., Liu, X., Zhou, H., Zhang, Y., & Zhu, X. (2020). Factor Structure and Gender Invariance of Chinese Version State-Trait Anxiety Inventory (Form Y) in University Students. *Frontiers in Psychology*, *11*, 2228.

https://doi.org/10.3389/fpsyg.2020.02228

Hanslmayr, S., Gross, J., Klimesch, W., & Shapiro, K. L. (2011). The role of α oscillations in temporal attention. *Brain Research Reviews*, *67*(1–2), 331–343. https://doi.org/10.1016/j.brainresrev.2011.04.002

Harlé, K. M., Chang, L. J., van ’t Wout, M., & Sanfey, A. G. (2012). The neural mechanisms of affect infusion in social economic decision-making: a mediating role of the anterior insula. *NeuroImage*, *61*(1), 32–40. https://doi.org/10.1016/j.neuroimage.2012.02.027

Harmon-Jones, E., Simon, L., Greenberg, J., Pyszczynski, T., Solomon, S., & McGregor, H. (1997). Terror management theory and self-esteem: evidence that increased self-esteem reduces mortality salience effects. *Journal of Personality and Social Psychology*, *72*(1), 24–36.

Harmony, T. (2013). The functional significance of delta oscillations in cognitive processing. *Frontiers in Integrative Neuroscience*, *7*, 83. https://doi.org/10.3389/fnint.2013.00083

Hashemi, A., Pino, L. J., Moffat, G., Mathewson, K. J., Aimone, C., Bennett, P. J., Schmidt, L. A., & Sekuler, A. B. (2016). Characterizing Population EEG Dynamics throughout Adulthood. *ENeuro*, *3*(6). https://doi.org/10.1523/ENEURO.0275-16.2016

Hauswald, A., Übelacker, T., Leske, S., & Weisz, N. (2015). What it means to be Zen: marked modulations of local and interareal synchronization during open monitoring meditation. *NeuroImage*, *108*, 265–273. https://doi.org/10.1016/j.neuroimage.2014.12.065

Hayes, J., Schimel, J., Arndt, J., & Faucher, E. H. (2010). A theoretical and empirical review of the death-thought accessibility concept in terror management research. *Psychological Bulletin*, *136*(5), 699–739. https://doi.org/10.1037/a0020524

Hayes, J., Schimel, J., Faucher, E., & J. Williams, T. (2008). Evidence for the DTA hypothesis II: Threatening self-esteem increases death-thought accessibility. *Journal of Experimental Social Psychology*, *44*, 600–613.

Heidegger, M. (1962). *Being and Time*. Blackwell.

Heine, S. J., Proulx, T., & Vohs, K. D. (2006). The meaning maintenance model: on the coherence of social motivations. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *10*(2), 88–110. https://doi.org/10.1207/s15327957pspr1002_1

Henry, E. A., Bartholow, B. D., & Arndt, J. (2010). Death on the brain: effects of mortality salience on the neural correlates of ingroup and outgroup categorization. In *Social Cognitive and Affective Neuroscience* (Vol. 5, Issue 1, pp. 77–87). https://doi.org/10.1093/scan/nsp041

Herrmann, C. S., Strüber, D., Helfrich, R. F., & Engel, A. K. (2016). EEG oscillations: From correlation to causality. *International Journal of Psychophysiology*, *103*, 12–21. https://doi.org/10.1016/j.ijpsycho.2015.02.003

Higo, M. (2012). Surviving Death-Anxieties in Liquid Modern Times: Examining Zygmunt Bauman'S Cultural Theory of Death and Dying. *OMEGA - Journal of Death and Dying*, *65*(3), 221–238. https://doi.org/10.2190/OM.65.3.e

Hillyard, S. A., Vogel, E. K., & Luck, S. J. (1998). Sensory gain control (amplification) as a mechanism of selective attention: Electrophysiological and neuroimaging evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *353*(1373), 1257–1270. https://doi.org/10.1098/rstb.1998.0281

Hoffman, D. D., & Richards, W. A. (1984). Parts of recognition. *Cognition*, *18*(1–3), 65–96. https://doi.org/10.1016/0010-0277(84)90022-2

Hollins, M., Harper, D., & Maixner, W. (2011). Changes in pain from a repetitive thermal stimulus: The roles of adaptation and sensitization. *PAIN*, *152*(7). https://journals.lww.com/pain/Fulltext/2011/07000/Changes_in_pain_from_a_repetitive_thermal.23.aspx

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How Does Mindfulness Meditation Work? Proposing Mechanisms of Action From a Conceptual and Neural Perspective. *Perspectives on Psychological Science, 6*(6), 537–559. https://doi.org/10.1177/1745691611419671

Hu, J., He, W., & Zhou, K. (2020). The mind, the heart, and the leader in times of crisis: How and when COVID-19-triggered mortality salience relates to state anxiety, job engagement, and prosocial behavior. *Journal of Applied Psychology*, *105*(11), 1218–1233. https://doi.org/10.1037/apl0000620

Hu, L., Peng, W., Valentini, E., Zhang, Z., & Hu, Y. (2013). Functional features of nociceptive-induced suppression of alpha band electroencephalographic oscillations. *Journal of Pain*, *14*(1), 89–99. https://doi.org/10.1016/j.jpain.2012.10.008

Hu, L., Zhao, C., Li, H., & Valentini, E. (2013). Mismatch responses evoked by nociceptive stimuli. *Psychophysiology*, *50*(2), 158–173. https://doi.org/10.1111/psyp.12000

Huang, S., Du, H., & Qu, C. (2021). Emotional responses to mortality salience: Behavioral and ERPs evidence. *PloS One*, *16*(3), e0248699. https://doi.org/10.1371/journal.pone.0248699

Huang, Y., Erdogmus, D., Pavel, M., & Mathan, S. (2008). Mixed effects models for eeg evoked response detection. *Proceedings of the 2008 IEEE Workshop on Machine Learning for Signal Processing, MLSP 2008*, *June 2014*, 91–96. https://doi.org/10.1109/MLSP.2008.4685461

Imperatori, C., Farina, B., Adenzato, M., Valenti, E. M., Murgia, C., Marca, G. Della, Brunetti, R., Fontana, E., & Ardito, R. B. (2019). Default mode network alterations in individuals with high-trait-anxiety: An EEG functional connectivity study. *Journal of Affective Disorders*, *246*, 611–618. https://doi.org/10.1016/j.jad.2018.12.071

Iverach, L., Menzies, R. G., & Menzies, R. E. (2014). Death anxiety and its role in psychopathology: Reviewing the status of a transdiagnostic construct. *Clinical Psychology Review*, *34*(7), 580–593. https://doi.org/10.1016/j.cpr.2014.09.002

Jackson, A. F., & Bolger, D. J. (2014). The neurophysiological bases of EEG and EEG measurement: A review for the rest of us. *Psychophysiology*, *51*(11), 1061–1071. https://doi.org/10.1111/psyp.12283

JASP Team. (2020). *JASP* (Version 0.14.1). https://jasp-stats.org/

Jessop, D. C., Albery, I. P., Rutter, J., & Garrod, H. (2008). Understanding the Impact of Mortality-Related Health-Risk Information: A Terror Management Theory Perspective. *Personality and Social Psychology Bulletin*, *34*(7), 951–964. https://doi.org/10.1177/0146167208316790

Jha, A. P., Krompinger, J., & Baime, M. J. (2007). Mindfulness training modifies subsystems of attention. *Cognitive, Affective & Behavioral Neuroscience*, *7*(2), 109–119. https://doi.org/10.3758/cabn.7.2.109

Jonas, E., McGregor, I., Klackl, J., Agroskin, D., Fritsche, I., Holbrook, C., Nash, K., Proulx, T., & Quirin, M. (2014). Threat and defense: From anxiety to approach. *Advances in Experimental Social Psychology2*, *49*, 219–286.

Jones, M. W., & Wilson, M. A. (2005). Theta Rhythms Coordinate Hippocampal–Prefrontal Interactions in a Spatial Memory Task. *PLOS Biology*, *3*(12), null. https://doi.org/10.1371/journal.pbio.0030402

Kabat-Zinn, J. (2003). Mindfulness-Based Interventions in Context: Past, Present, and Future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kahana, M J, Sekuler, R., Caplan, J. B., Kirschen, M., & Madsen, J. R. (1999). Human theta oscillations exhibit task dependence during virtual maze navigation. *Nature*, *399*(6738), 781–784. https://doi.org/10.1038/21645

Kahana, Michael J. (2006). The cognitive correlates of human brain oscillations. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *26*(6), 1669–1672. https://doi.org/10.1523/JNEUROSCI.3737-05c.2006

Kang, Y., & Demiris, G. (2018). Self-report pain assessment tools for cognitively intact older adults: Integrative review. *International Journal of Older People Nursing*, *13*(2), e12170. https://doi.org/10.1111/opn.12170

Kelley, J. M., Lembo, A. J., Ablon, J. S., Villanueva, J. J., Conboy, L. A., Levy, R., Marci, C. D., Kerr, C. E., Kirsch, I., Jacobson, E. E., Riess, H., & Kaptchuk, T. J. (2009). Patient and Practitioner Influences on the Placebo Effect in Irritable Bowel Syndrome. *Psychosomatic Medicine*, *71*(7), 789–797. https://doi.org/10.1097/PSY.0b013e3181acee12

Kida, T., Wasaka, T., Nakata, H., Akatsuka, K., & Kakigi, R. (2006). Active attention modulates passive attention-related neural responses to sudden somatosensory input against a silent background. *Experimental Brain Research*, *175*(4), 609–617. https://doi.org/10.1007/s00221-006-0578-4

Kielkiewicz, K., Mathúna, C. Ó., & McLaughlin, C. (2020). Construct Validity and Dimensionality of the Rosenberg Self-Esteem Scale and Its Association with Spiritual Values Within Irish Population. *Journal of Religion and Health*, *59*(1), 381–398. https://doi.org/10.1007/s10943-019-00821-x

Kilavik, B. E., Zaepffel, M., Brovelli, A., MacKay, W. A., & Riehle, A. (2013). The ups and downs of β oscillations in sensorimotor cortex. *Experimental Neurology*, *245*, 15–26. https://doi.org/10.1016/j.expneurol.2012.09.014

Kingston, J., Chadwick, P., Meron, D., & Skinner, T. C. (2007). A pilot randomized control trial investigating the effect of mindfulness practice on pain tolerance, psychological well-being, and physiological activity. *Journal of Psychosomatic Research*, *62*(3), 297–300. https://doi.org/10.1016/j.jpsychores.2006.10.007

Klackl, J., & Jonas, E. (2019). Effects of Mortality Salience on Physiological Arousal. *Frontiers in Psychology*, *10*, 1893. https://doi.org/10.3389/fpsyg.2019.01893

Klackl, J., Jonas, E., & Kronbichler, M. (2013). Existential neuroscience: neurophysiological correlates of proximal defenses against death-related thoughts. In *Social Cognitive and Affective Neuroscience* (Vol. 8, Issue 3, pp. 333–340). https://doi.org/10.1093/scan/nss003

Klein, R. A., Cook, C. L., Ebersole, C. R., Vitiello, C., Nosek, B. A., Ahn, P., Brady, A. J., Chartier, C. R., Christopherson, C. D., Clay, S., Collisson, B., Crawford, J., Cromar, R., Vidamuerte, D., Gardiner, G., Gosnell, C., Grahe, J., Hall, C., Howard, I., … Ratliff, K. (2019). *Many Labs 4: Replicating Mortality Salience with and without Original Author Involvement*. https://osf.io/8ccnw/

Klimesch, W. (1997). EEG-alpha rhythms and memory processes. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *26*(1–3), 319–340. https://doi.org/10.1016/s0167-8760(97)00773-3

Klimesch, W, Schimke, H., & Schwaiger, J. (1994). Episodic and semantic memory: an analysis in the EEG theta and alpha band. *Electroencephalography and Clinical Neurophysiology*, *91*(6), 428–441. https://doi.org/10.1016/0013-4694(94)90164-3

Klimesch, Wolfgang. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Research. Brain Research Reviews*, *29*(2–3), 169–195. https://doi.org/10.1016/s0165-0173(98)00056-3

Klimesch, Wolfgang. (2012). Alpha-band oscillations, attention, and controlled access to stored information. *Trends in Cognitive Sciences*, *16*(12), 606–617. https://doi.org/10.1016/j.tics.2012.10.007

Klimesch, Wolfgang. (2018). The frequency architecture of brain and brain body oscillations:

an analysis. *The European Journal of Neuroscience*, *48*(7), 2431–2453. https://doi.org/10.1111/ejn.14192

Knyazev, G. G. (2012). EEG delta oscillations as a correlate of basic homeostatic and motivational processes. *Neuroscience and Biobehavioral Reviews*, *36*(1), 677–695. https://doi.org/10.1016/j.neubiorev.2011.10.002

Kokonyei, G., Galambos, A., Edes, A. E., Kocsel, N., Szabo, E., Pap, D., Kozak, L. R., Bagdy, G., & Juhasz, G. (2019). Anticipation and violated expectation of pain are influenced by trait rumination: An fMRI study. *Cognitive, Affective and Behavioral Neuroscience*, *19*(1), 56–72. https://doi.org/10.3758/s13415-018-0644-y

Kosloff, S., Greenberg, J., Sullivan, D., & Weise, D. (2010). Of Trophies and Pillars: Exploring the Terror Management Functions of Short-Term and Long-Term Relationship Partners. *Personality & Social Psychology Bulletin*, *36*, 1037–1051.

Kourakou, A., Tigani, X., Bacopoulou, F., Vlachakis, D., Papakonstantinou, E., Simidala, S., Ktena, E., Katsaouni, S., Chrousos, G., & Darviri, C. (2021). The Rosenberg Self-Esteem Scale: Translation and Validation in the Greek Language in Adolescents. *Advances in Experimental Medicine and Biology*, *1339*, 97–103. https://doi.org/10.1007/978-3-030-78787-5_13

Kral, T. R. A., Schuyler, B. S., Mumford, J. A., Rosenkranz, M. A., Lutz, A., & Davidson, R. J. (2018). Impact of short- and long-term mindfulness meditation training on amygdala reactivity to emotional stimuli. *NeuroImage*, *181*, 301–313. https://doi.org/10.1016/j.neuroimage.2018.07.013

Kroenke, K., Spitzer, R. L., Williams, J. B. W., & Lowe, B. (2009). An Ultra-Brief Screening

Scale for Anxiety and Depression: The PHQ-4. *Psychosomatics*, *50*(6), 613–621. https://doi.org/10.1176/appi.psy.50.6.613

Krueger, C., & Tian, L. (2004). A comparison of the general linear mixed model and repeated measures ANOVA using a dataset with multiple missing data points. *Biological Research for Nursing*, *6*(2), 151–157. https://doi.org/10.1177/1099800404267682

Krueger, F., & Hoffman, M. (2016). The Emerging Neuroscience of Third-Party Punishment. *Trends in Neurosciences*, *39*(8), 499–501. https://doi.org/10.1016/j.tins.2016.06.004

Lagos, J. P. (2015). *Time-frequency analysis for responses evoked by nociceptive and non-nociceptive stimuli based on EEG signals Faculty of Engineer LTH Department of Biomedical Engineering*.

Lambert, A. J., Eadeh, F. R., Peak, S. A., Scherer, L. D., Schott, J. P., & Slochower, J. M. (2014). Toward a greater understanding of the emotional dynamics of the mortality salience manipulation: Revisiting the “affect-free” claim of terror management research. *Journal of Personality and Social Psychology*, *106*(5), 655–678. https://doi.org/10.1037/a0036353

Landau, M. J., Solomon, S., Pyszczynski, T., & Greenberg, J. (2007). On the Compatibility of Terror Management Theory and Perspectives on Human Evolution. *Evolutionary Psychology*, *5*(3), 147470490700500. https://doi.org/10.1177/147470490700500303

Legrain, V., Bruyer, R., Guérit, J.-M., & Plaghki, L. (2003). Nociceptive processing in the human brain of infrequent task-relevant and task-irrelevant noxious stimuli. A study with event-related potentials evoked by CO2 laser radiant heat stimuli. *Pain*, *103*(3), 237–248. https://doi.org/10.1016/s0304-3959(02)00451-7

Legrain, V., Perchet, C., & García-Larrea, L. (2009). Involuntary orienting of attention to nociceptive events: neural and behavioral signatures. *Journal of Neurophysiology*, *102*(4), 2423–2434. https://doi.org/10.1152/jn.00372.2009

Lester, D. (2004). The factorial structure of the Revised Collett-Lester Fear of Death Scale. *Death Studies*, *28*(8), 795–798. https://doi.org/10.1080/07481180490483472

Lester, D., & Abdel-Khalek, A. (2003). Erratum: The Collett-Lester Fear of Death Scale: A correction (Death Studies). *Death Studies*, *27*(1), 81–85. https://doi.org/10.1080/07481180302873

Lewine, J. D., & Orrison, W. W. (1995). *CHAPTER 8 - Clinical Electroencephalography and Event-Related Potentials* (W. W. Orrison, J. D. Lewine, J. A. Sanders, & M. F. B. T.-F. B. I. Hartshorne (Eds.); pp. 327–368). Mosby. https://doi.org/https://doi.org/10.1016/B978-0-8151-6509-5.50012-6

Li, X., Liu, Y., Luo, S., Wu, B., Wu, X., & Han, S. (2015). Mortality salience enhances racial in-group bias in empathic neural responses to others' suffering. *NeuroImage*, *118*, 376–385. https://doi.org/10.1016/j.neuroimage.2015.06.023

Lim, M., O'Grady, C., Cane, D., Goyal, A., Lynch, M., Beyea, S., & Hashmi, J. A. (2020). Threat Prediction from Schemas as a Source of Bias in Pain Perception. *The Journal of Neuroscience*, *40*(7), 1538 LP – 1548. https://doi.org/10.1523/JNEUROSCI.2104-19.2019

Liu, C.-H., Ma, X., Song, L.-P., Tang, L.-R., Jing, B., Zhang, Y., Li, F., Zhou, Z., Fan, J., & Wang, C.-Y. (2015). Alteration of spontaneous neuronal activity within the salience network in partially remitted depression. *Brain Research*, *1599*, 93–102.

https://doi.org/10.1016/j.brainres.2014.12.040

Loeser, J. D., & Melzack, R. (1999). Pain: An overview. *Lancet*, *353*(9164), 1607–1609. https://doi.org/10.1016/S0140-6736(99)01311-2

Lutz, A., Brefczynski-Lewis, J., Johnstone, T., & Davidson, R. J. (2008). Regulation of the neural circuitry of emotion by compassion meditation: effects of meditative expertise. *PloS One*, *3*(3), e1897–e1897. https://doi.org/10.1371/journal.pone.0001897

Lutz, J., Herwig, U., Opialla, S., Hittmeyer, A., Jäncke, L., Rufer, M., Grosse Holtforth, M., & Brühl, A. (2013). Mindfulness and Emotion Regulation - an fMRI Study. *Social Cognitive and Affective Neuroscience*, *9*. https://doi.org/10.1093/scan/nst043

Malinowski, P. (2013). Neural mechanisms of attentional control in mindfulness meditation . In *Frontiers in Neuroscience* (Vol. 7, p. 8). https://www.frontiersin.org/article/10.3389/fnins.2013.00008

Materu, J., Kuringe, E., Nyato, D., Galishi, A., Mwanamsangu, A., Katebalila, M., Shao, A., Changalucha, J., Nnko, S., & Wambura, M. (2020). The psychometric properties of PHQ-4 anxiety and depression screening scale among out of school adolescent girls and young women in Tanzania: a cross-sectional study. *BMC Psychiatry*, *20*(1), 321. https://doi.org/10.1186/s12888-020-02735-5

Mattos, T. B., Avila Matos, L., & Lachos, V. H. (2021). A semiparametric mixed-effects model for censored longitudinal data. *Statistical Methods in Medical Research*, *30*(12), 2582–2603. https://doi.org/10.1177/09622802211046387

Maxfield, M., Greenberg, J., Pyszczynski, T., Weise, D. R., Kosloff, S., Soenke, M., Abeyta,

A. A., & Blatter, J. (2014). Increases in generative concern among older adults following reminders of mortality. *International Journal of Aging & Human Development*, *79*(1), 1–21.

McCabe, S., & Daly, M. (2018). Work, love, and death-thought accessibility: A terror management investigation. *British Journal of Social Psychology*, *57*(4), 754–772. https://doi.org/10.1111/bjso.12258

McFarland, C., & Ross, M. (1982). Impact of causal attribution on affective reactions to success and failure. *Journal of Personality and Social Psychology*, *43*, 937–946.

Mcgregor, I., Nash, K., Mann, N., & Phills, C. E. (2010). *Anxious Uncertainty and Reactive Approach Motivation (RAM)*. *99*(1), 133–147. https://doi.org/10.1037/a0019701

McGregor, I, Zanna, M. P., Holmes, J. G., & Spencer, S. J. (2001). Compensatory conviction in the face of personal uncertainty: going to extremes and being oneself. *Journal of Personality and Social Psychology*, *80*(3), 472–488. https://doi.org/10.1037/0022-3514.80.3.472

McGregor, Ian, Gailliot, M. T., Vasquez, N. A., & Nash, K. A. (2007). Ideological and personal zeal reactions to threat among people with high self-esteem: Motivated promotion focus. *Personality and Social Psychology Bulletin*, *33*(11), 1587–1599. https://doi.org/10.1177/0146167207306280

McGregor, Ian, Zanna, M. P., Holmes, J. G., & Spencer, S. J. (2001). Compensatory conviction in the face of personal uncertainty: Going to extremes and being oneself. *Journal of Personality and Social Psychology*, *80*(3), 472–488. https://doi.org/10.1037/0022-3514.80.3.472

McLean, R. A., Sanders, W. L., & Stroup, W. W. (1991). A Unified Approach to Mixed Linear Models. *The American Statistician*, *45*(1), 54. https://doi.org/10.2307/2685241

Melnik, A., Legkov, P., Izdebski, K., Kärcher, S. M., Hairston, W. D., Ferris, D. P., & König, P. (2017). Systems, Subjects, Sessions: To What Extent Do These Factors Influence EEG Data? *Frontiers in Human Neuroscience*, *11*. https://doi.org/10.3389/fnhum.2017.00150

Menzies, R. E., Sharpe, L., & Dar-Nimrod, I. (2021). The effect of mortality salience on bodily scanning behaviors in anxiety-related disorders. *Journal of Abnormal Psychology*, *130*(2), 141–151. https://doi.org/10.1037/abn0000577

Michie, P. T. (1984). Selective attention effects on somatosensory event-related potentials. *Annals of the New York Academy of Sciences*, *425*, 250–255. https://doi.org/10.1111/j.1749-6632.1984.tb23542.x

Mikulincer, M, & Florian, V. (2000). Exploring individual differences in reactions to mortality salience: does attachment style regulate terror management mechanisms? *Journal of Personality and Social Psychology*, *79*(2), 260–273.

Mikulincer, Mario, Florian, V., & Hirschberger, G. (2003). The existential function of close relationships: introducing death into the science of love. *Personality and Social Psychology Review : An Official Journal of the Society for Personality and Social Psychology, Inc*, *7*(1), 20–40. https://doi.org/10.1207/S15327957PSPR0701_2

Miller, G., & Taubman-Ben-Ari, O. (2004). Scuba Diving Risk Taking—A Terror Management Theory Perspective. *Journal of Sport & Exercise Psychology*, *26*, 269–282. https://doi.org/10.1123/jsep.26.2.269

Mischkowski, D., Stavish, C. M., Palacios-Barrios, E. E., Banker, L. A., Dildine, T. C., & Atlas, L. Y. (2021). Dispositional Mindfulness and Acute Heat Pain: Comparing Stimulus-Evoked Pain With Summary Pain Assessment. *Psychosomatic Medicine*, *83*(6), 539–548. https://doi.org/10.1097/PSY.0000000000000911

Mitchell, D. J., McNaughton, N., Flanagan, D., & Kirk, I. J. (2008). Frontal-midline theta from the perspective of hippocampal "theta". *Progress in Neurobiology*, *86*(3), 156–185. https://doi.org/10.1016/j.pneurobio.2008.09.005

Morrison, A. B., & Jha, A. P. (2015). Mindfulness, Attention, and Working Memory. In *Handbook of Mindfulness and Self-Regulation* (pp. 33–45). Springer New York. https://doi.org/10.1007/978-1-4939-2263-5_4

Mouraux, A., Guérit, J. M., & Plaghki, L. (2003). Non-phase locked electroencephalogram (EEG) responses to CO2 laser skin stimulations may reflect central interactions between A partial partial differential- and C-fibre afferent volleys. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, *114*(4), 710–722. https://doi.org/10.1016/s1388-2457(03)00027-0

Nathan, P. E., Kappenman, E. S., & Luck, S. J. (Eds.). (2012). *Oxford Handbook of Event-Related Potential Components*. Oxford University Press. http://choicereviews.org/review/10.5860/CHOICE.50-5912

Nelli, S., Itthipuripat, S., Srinivasan, R., & Serences, J. T. (2017). Fluctuations in instantaneous frequency predict alpha amplitude during visual perception. *Nature Communications*, *8*(1), 2071. https://doi.org/10.1038/s41467-017-02176-x

Neuper, C., & Pfurtscheller, G. (2001). Event-related dynamics of cortical rhythms:

frequency-specific features and functional correlates. *International Journal of Psychophysiology*, *43*(1), 41–58. https://doi.org/10.1016/S0167-8760(01)00178-7

Niemiec, C. P., Brown, K. W., Kashdan, T. B., Cozzolino, P. J., Breen, W. E., Levesque-Bristol, C., & Ryan, R. M. (2010). Being present in the face of existential threat: The role of trait mindfulness in reducing defensive responses to mortality salience. *Journal of Personality and Social Psychology*, *99*(2), 344–365. https://doi.org/10.1037/a0019388

Northrup, D. A. (1997). *The Problem of the Self-report in Survey Research: Working Paper*. Institute for Social Research, York University. https://books.google.co.uk/books?id=ViYmYAAACAAJ

Ogihara, Y., & Kusumi, T. (2020). The Developmental Trajectory of Self-Esteem Across the Life Span in Japan: Age Differences in Scores on the Rosenberg Self-Esteem Scale From Adolescence to Old Age. *Frontiers in Public Health*, *8*, 132. https://doi.org/10.3389/fpubh.2020.00132

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716–aac4716. https://doi.org/10.1126/science.aac4716

Orth, U., & Robins, R. W. (2014). The Development of Self-Esteem. *Current Directions in Psychological Science*, *23*(5), 381–387. https://doi.org/10.1177/0963721414547414

Ospina, M. B., Bond, K., Karkhaneh, M., Tjosvold, L., Vandermeer, B., Liang, Y., Bialy, L., Hooton, N., Buscemi, N., Dryden, D. M., & Klassen, T. P. (2007). Meditation practices for health: state of the research. *Evidence Report/Technology Assessment*, *155*, 1–263.

Pagnoni, G., & Cekic, M. (2007). Age effects on gray matter volume and attentional performance in Zen meditation. *Neurobiology of Aging*, *28*(10), 1623–1627. https://doi.org/10.1016/j.neurobiolaging.2007.06.008

Park, Y. C., & Pyszczynski, T. (2019). Reducing defensive responses to thoughts of death: Meditation, mindfulness, and Buddhism. *Journal of Personality and Social Psychology*, *116*(1), 101–118. https://doi.org/10.1037/pspp0000163

Peciña, M., Azhar, H., Love, T. M., Lu, T., Fredrickson, B. L., Stohler, C. S., & Zubieta, J.-K. (2013). Personality trait predictors of placebo analgesia and neurobiological correlates. *Neuropsychopharmacology : Official Publication of the American College of Neuropsychopharmacology*, *38*(4), 639–646. https://doi.org/10.1038/npp.2012.227

Peng, W., Babiloni, C., Mao, Y., & Hu, Y. (2015). Subjective pain perception mediated by alpha rhythms. *Biological Psychology*, *109*, 141–150. https://doi.org/10.1016/j.biopsycho.2015.05.004

Pereira, S., Reay, K., Bottell, J., Walker, L., & Dzikiti, C. (2019). University Student Mental Health Survey 2018. *The Insight Network, Dig-In*, *March*, 35. https://uploads-ssl.webflow.com/561110743bc7e45e78292140/5c7d4b5d314d163fecdc3706_Mental Health Report 2018.pdf

Pérez-de la Cruz, S. (2021). Attitudes of health science students towards death in Spain. *International Journal of Palliative Nursing*, *27*(8), 402–409. https://doi.org/10.12968/ijpn.2021.27.8.402

Pérez-Fuentes, M. D. C., Molero Jurado, M. D. M., Gázquez Linares, J. J., Oropesa Ruiz, N. F., Simón Márquez, M. D. M., & Saracostti, M. (2019). Self-Expressive Creativity in the Adolescent Digital Domain: Personality, Self-Esteem, and Emotions. *International*

Journal of Environmental Research and Public Health, *16*(22). https://doi.org/10.3390/ijerph16224527

Pertermann, M., Mückschel, M., Adelhöfer, N., Ziemssen, T., & Beste, C. (2019). On the interrelation of 1/f neural noise and norepinephrine system activity during motor response inhibition. *Journal of Neurophysiology*, *121*(5), 1633–1643. https://doi.org/10.1152/jn.00701.2018

Pfurtscheller, G., Scherer, R., Müller-Putz, G., & da Silva, F. (2008). Short-lived brain state after cued motor imagery in naive subjects. *The European Journal of Neuroscience*, *28*, 1419–1426. https://doi.org/10.1111/j.1460-9568.2008.06441.x

Ploner, M., Sorg, C., & Gross, J. (2017). Brain Rhythms of Pain. *Trends in Cognitive Sciences*, *21*(2), 100–110. https://doi.org/10.1016/j.tics.2016.12.001

Porreca, F., & Navratilova, E. (2017). Reward, motivation, and emotion of pain and its relief. *Pain*, *158 Suppl*(Suppl 1), S43–S49. https://doi.org/10.1097/j.pain.0000000000000798

Porro, C. A. (2003). Functional imaging and pain: behavior, perception, and modulation. *The Neuroscientist : A Review Journal Bringing Neurobiology, Neurology and Psychiatry*, *9*(5), 354–369. https://doi.org/10.1177/1073858403253660

Porro, C. A., Baraldi, P., Pagnoni, G., Serafini, M., Facchin, P., Maieron, M., & Nichelli, P. (2002). Does anticipation of pain affect cortical nociceptive systems? *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *22*(8), 3206–3214. https://doi.org/10.1523/JNEUROSCI.22-08-03206.2002

Požgain, I., Požgain, Z., & Degmečić, D. (2014). Placebo and nocebo effect: a mini-review.

Psychiatria Danubina, *26*(2), 100–107.

Pyszczynski, T, Greenberg, J., & Solomon, S. (1999). A dual-process model of defense against conscious and unconscious death-related thoughts: an extension of terror management theory. *Psychological Review*, *106*(4), 835–845.

Pyszczynski, Tom. (2004). What Are We So Afraid Of? A Terror Management Theory Perspective on the Politics of Fear. *Social Research*, *71*(4), 827–848. http://www.jstor.org/stable/40971981

Pyszczynski, Tom, Greenberg, J., Solomon, S., Arndt, J., & Schimel, J. (2004). Why do people need self-esteem? A theoretical and empirical review. *Psychological Bulletin*, *130*(3), 435–468. https://doi.org/10.1037/0033-2909.130.3.435

Pyszczynski, Tom, Greenberg, J., Solomon, S., & Maxfield, M. (2006). On the Unique Psychological Import of the Human Awareness of Mortality: Theme and Variations. *Psychological Inquiry*, *17*(4), 328–356. https://doi.org/10.1080/10478400701369542

Pyszczynski, Tom, Solomon, S., & Greenberg, J. (2015). Thirty Years of Terror Management Theory: From Genesis to Revelation. *Advances in Experimental Social Psychology*, *52*(January), 1–70. https://doi.org/10.1016/bs.aesp.2015.03.001

Quirin, M., Loktyushin, A., Arndt, J., Kustermann, E., Lo, Y.-Y., Kuhl, J., & Eggert, L. (2012). Existential neuroscience: a functional magnetic resonance imaging investigation of neural responses to reminders of one’s mortality. *Social Cognitive and Affective Neuroscience*, *7*(2), 193–198. https://doi.org/10.1093/scan/nsq106

Ricci, S., Tatti, E., Mehraram, R., Panday, P., & Ghilardi, M. F. (2019). Beta band frequency differences between motor and frontal cortices in reaching movements. *IEEE ... International Conference on Rehabilitation Robotics : [Proceedings]*, *2019*, 1254–1259. https://doi.org/10.1109/ICORR.2019.8779373

Riha, C., Güntensperger, D., Kleinjung, T., & Meyer, M. (2020). Accounting for Heterogeneity: Mixed-Effects Models in Resting-State EEG Data in a Sample of Tinnitus Sufferers. *Brain Topography*, *33*(4), 413–424. https://doi.org/10.1007/s10548-020-00772-7

Rinpoche, K. (2003). *This Precious Life: Tibetan Buddhist Teachings on the Path to Enlightenment*. Shambhala Publications.

Robinson, G. K. (1991). That BLUP is a Good Thing: The Estimation of Random Effects. *Statistical Science*, *6*(1). https://doi.org/10.1214/ss/1177011926

Rodríguez-Ferreiro, J., Barberia, I., González-Guerra, J., & Vadillo, M. A. (2019). Are we truly special and unique? A replication of Goldenberg et al. (2001). *Royal Society Open Science*, *6*(11), 191114. https://doi.org/10.1098/rsos.191114

Rodríguez-Muñoz, M. de la F., Ruiz-Segovia, N., Soto-Balbuena, C., Le, H.-N., Olivares-Crespo, M. E., & Izquierdo-Méndez, N. (2020). The Psychometric Properties of the Patient Health Questionnaire-4 for Pregnant Women. *International Journal of Environmental Research and Public Health*, *17*(20). https://doi.org/10.3390/ijerph17207583

Rominger, C., Papousek, I., Perchtold, C. M., Weber, B., Weiss, E. M., & Fink, A. (2018). The creative brain in the figural domain: Distinct patterns of EEG alpha power during idea generation and idea elaboration. *Neuropsychologia*, *118*(Pt A), 13–19.

https://doi.org/10.1016/j.neuropsychologia.2018.02.013

Ronga, I., Valentini, E., Mouraux, A., & Iannetti, G. D. (2013). Novelty is not enough: laser-evoked potentials are determined by stimulus saliency, not absolute novelty. *Journal of Neurophysiology*, *109*(3), 692–701. https://doi.org/10.1152/jn.00464.2012

Rose, A. V, & Rimes, K. A. (2018). Self-criticism self-report measures: Systematic review. *Psychology and Psychotherapy*, *91*(4), 450–489. https://doi.org/10.1111/papt.12171

Rosenberg, M., Kozlovsky, A., Gelernter, I., Cherniak, O., Gabbay, J., Baht, R., & Eli, I. (1995). Self-estimation of oral malodor. *Journal of Dental Research*, *74*(9), 1577–1582. https://doi.org/10.1177/00220345950740091201

Rosenblatt, A., Greenberg, J., Solomon, S., Pyszczynski, T., & Lyon, D. (1989). Evidence for terror management theory: I. The effects of mortality salience on reactions to those who violate or uphold cultural values. *Journal of Personality and Social Psychology*, *57*(4), 681–690.

Routledge, C., Arndt, J., & Goldenberg, J. L. (2004). A time to tan: Proximal and distal effects of mortality salience on sun exposure intentions. *Personality and Social Psychology Bulletin*, *30*(10), 1347–1358. https://doi.org/10.1177/0146167204264056

Routledge, C., Ostafin, B., Juhl, J., Sedikides, C., Cathey, C., & Liao, J. (2010). Adjusting to Death: The Effects of Mortality Salience and Self-Esteem on Psychological Well-Being, Growth Motivation, and Maladaptive Behavior. *Journal of Personality and Social Psychology*, *99*(6), 897–916. https://doi.org/10.1037/a0021431

Šagát, P., Bartik, P., Lazić, A., Tohănean, D. I., Koronas, V., Turcu, I., Knjaz, D., Alexe, C.

I., & Curițianu, I. M. (2021). Self-Esteem, Individual versus Team Sports. *International Journal of Environmental Research and Public Health*, *18*(24). https://doi.org/10.3390/ijerph182412915

Sampaio, C. V. S., Lima, M. G., & Ladeia, A. M. (2017). Meditation, Health and Scientific Investigations: Review of the Literature. *Journal of Religion and Health*, *56*(2), 411–427. https://doi.org/10.1007/s10943-016-0211-1

Sarı, S. A., Bilek, G., & Çelik, E. (2018). Test anxiety and self-esteem in senior high school students: a cross-sectional study. *Nordic Journal of Psychiatry*, *72*(2), 84–88. https://doi.org/10.1080/08039488.2017.1389986

Sassenhagen, J., & Draschkow, D. (2019). Cluster-based permutation tests of MEG/EEG data do not establish significance of effect latency or location. *Psychophysiology*, *56*(6), e13335. https://doi.org/https://doi.org/10.1111/psyp.13335

Schimel, J., Simon, L., Greenberg, J., Pyszczynski, T., Solomon, S., Waxmonsky, J., & Arndt, J. (1999). Stereotypes and terror management: evidence that mortality salience enhances stereotypic thinking and preferences. *Journal of Personality and Social Psychology*, *77*(5), 905–926.

Schindler, S., & Reinhard, M.-A. (2015). Increasing skepticism toward potential liars: effects of existential threat on veracity judgments and the moderating role of honesty norm activation. *Frontiers in Psychology*, *6*, 1312. https://doi.org/10.3389/fpsyg.2015.01312

Schmeichel, B. J., & Vohs, K. (2009). Self-affirmation and self-control: affirming core values counteracts ego depletion. *Journal of Personality and Social Psychology*, *96*(4), 770–782. https://doi.org/10.1037/a0014635

Schrooten, M. G. S., Van Damme, S., Crombez, G., Peters, M. L., Vogt, J., & Vlaeyen, J. W. S. (2012). Nonpain goal pursuit inhibits attentional bias to pain. *PAIN*, *153*(6), 1180–1186. https://doi.org/10.1016/j.pain.2012.01.025

Schultz, D. M., & Arnau, R. C. (2017). Effects of a Brief Mindfulness Induction on Death-Related Anxiety. *OMEGA - Journal of Death and Dying*, 003022281772111. https://doi.org/10.1177/0030222817721115

Schürmann, M., & Başar, E. (2001). Functional aspects of alpha oscillations in the EEG. *International Journal of Psychophysiology : Official Journal of the International Organization of Psychophysiology*, *39*(2–3), 151–158. https://doi.org/10.1016/s0167-8760(00)00138-0

Sedikides, C. (1993). Assessment, enhancement, and verification determinants of the self-evaluation process. In *Journal of Personality and Social Psychology* (Vol. 65, Issue 2, pp. 317–338). American Psychological Association. https://doi.org/10.1037/0022-3514.65.2.317

Shadli, S. M., Ando, L. C., McIntosh, J., Lodhia, V., Russell, B. R., Kirk, I. J., Glue, P., & McNaughton, N. (2021). Right frontal anxiolytic-sensitive EEG "theta" rhythm in the stop-signal task is a theory-based anxiety disorder biomarker. *Scientific Reports*, *11*(1), 19746. https://doi.org/10.1038/s41598-021-99374-x

Shah, N. N., Schwandt, M. L., Hobden, B., Baldwin, D. S., Sinclair, J., Agabio, R., & Leggio, L. (2021). The validity of the state-trait anxiety inventory and the brief scale for anxiety in an inpatient sample with alcohol use disorder. *Addiction (Abingdon, England)*, *116*(11), 3055–3068. https://doi.org/10.1111/add.15516

Shapiro, S. L., Schwartz, G. E., & Bonner, G. (1998). Effects of Mindfulness-Based Stress Reduction on Medical and Premedical Students. *Journal of Behavioral Medicine*, *21*(6), 581–599. https://doi.org/10.1023/A:1018700829825

Siciliano, M., Trojano, L., Trojsi, F., Monsurrò, M. R., Tedeschi, G., & Santangelo, G. (2019). Assessing anxiety and its correlates in amyotrophic lateral sclerosis: The state-trait anxiety inventory. *Muscle & Nerve*, *60*(1), 47–55. https://doi.org/10.1002/mus.26475

Singh, K. D. (2012). Which "neural activity" do you mean? fMRI, MEG, oscillations and neurotransmitters. *NeuroImage*, *62*(2), 1121–1130. https://doi.org/https://doi.org/10.1016/j.neuroimage.2012.01.028

Sliter, M. T., Sinclair, R. R., Yuan, Z., & Mohr, C. D. (2014). Don't fear the reaper: trait death anxiety, mortality salience, and occupational health. *The Journal of Applied Psychology*, *99*(4), 759–769. https://doi.org/10.1037/a0035729

Solomon, S., & Greenberg, J. (2000). Pride and prejudice: Fear of death and social behavior. *Current Directions in Psychological Science*, *9*(6), 200–204. https://doi.org/10.1111/1467-8721.00094

Solomon, S., Greenberg, J., & Pyszczynski, T. (1991). Advances in Experimental Social Psychology Volume 24. *Advances in Experimental Social Psychology*, *24*, 93–159. https://doi.org/10.1016/S0065-2601(08)60328-7

Speyer, R., Kim, J.-H., Doma, K., Chen, Y.-W., Denman, D., Phyland, D., Parsons, L., & Cordier, R. (2019). Measurement properties of self-report questionnaires on health-related quality of life and functional health status in dysphonia: a systematic review using the COSMIN taxonomy. *Quality of Life Research : An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*, *28*(2), 283–296. https://doi.org/10.1007/s11136-018-2001-6

Spielberger, C D, Gorsuch, R. L., Lushene, P. R., Vagg, P. R., & Jacobs, A. G. (1983). Manual for the State-Trait Anxiety Inventory (Form Y). In *Manual for the statetrait anxiety inventory STAI*.

Spielberger, Charles D. (1987). State-Trait Anxiety Inventory. In *Anxiety* (Vol. 19, p. 2009). https://doi.org/10.1037/t06496-000

Stanhope, J. (2016). Patient Health Questionnaire-4. *Occupational Medicine (Oxford, England)*, *66*(9), 760–761. https://doi.org/10.1093/occmed/kqw165

Staudigl, T., Hartl, E., Noachtar, S., Doeller, C. F., & Jensen, O. (2017). Saccades are phase-locked to alpha oscillations in the occipital and medial temporal lobe during successful memory encoding. *PLoS Biology*, *15*(12), e2003404–e2003404. https://doi.org/10.1371/journal.pbio.2003404

Strachan, E., Schimel, J., Arndt, J., Williams, T., Solomon, S., Pyszczynski, T., & Greenberg, J. (2007). Terror mismanagement: evidence that mortality salience exacerbates phobic and compulsive behaviors. *Personality & Social Psychology Bulletin*, *33*(8), 1137–1151. https://doi.org/10.1177/0146167207303018

Streltsova, A., Berchio, C., Gallese, V., & Umilta’, M. A. (2010). Time course and specificity of sensory-motor alpha modulation during the observation of hand motor acts and gestures: a high density EEG study. *Experimental Brain Research*, *205*(3), 363–373. https://doi.org/10.1007/s00221-010-2371-7

Syropoulou, A., Vernadakis, N., Papastergiou, M., & Kourtessis, T. (2021). Psychometric evaluation of the Rosenberg Self-Esteem Scale in primary school students with mild intellectual disability: First evidence. *Research in Developmental Disabilities*, *114*, 103964. https://doi.org/10.1016/j.ridd.2021.103964

Tang, Y.-Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews. Neuroscience*, *16*(4), 213–225. https://doi.org/10.1038/nrn3916

Tang, Y.-Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(43), 17152–17156. https://doi.org/10.1073/pnas.0707678104

Taubman-Ben-Ari, O., Findler, L., & Mikulincer, M. (2002). The effects of mortality salience on relationship strivings and beliefs: the moderating role of attachment style. *The British Journal of Social Psychology*, *41*(Pt 3), 419–441.

Taubman-Ben-Ari, O., Florian, V., & Mikulincer, M. (1999). The impact of mortality salience on reckless driving: A test of terror management mechanisms. In *Journal of Personality and Social Psychology* (Vol. 76, Issue 1, pp. 35–45). American Psychological Association. https://doi.org/10.1037/0022-3514.76.1.35

Taylor, J. (1651). *Holy Dying*.

The Book of Miscellany. (n.d.). In *Book 1, Hadith 579*.

Thompson, B. L., & Waltz, J. (2007). Everyday mindfulness and mindfulness meditation:

Overlapping constructs or not? *Personality and Individual Differences*, *43*(7), 1875–1885. https://doi.org/10.1016/j.paid.2007.06.017

Tomás-Sábado, J., Limonero, J. T., & Abdel-Khalek, A. M. (2007). Spanish adaptation of the Collett-Lester Fear of Death Scale. *Death Studies*, *31*(3), 249–260. https://doi.org/10.1080/07481180601152625

Tomé, D., Barbosa, F., Nowak, K., & Marques-Teixeira, J. (2015). The development of the N1 and N2 components in auditory oddball paradigms: a systematic review with narrative analysis and suggested normative values. *Journal of Neural Transmission (Vienna, Austria : 1996)*, *122*(3), 375–391. https://doi.org/10.1007/s00702-014-1258-3

Torta, D. M., Legrain, V., Mouraux, A., & Valentini, E. (2017). Attention to pain! A neurocognitive perspective on attentional modulation of pain in neuroimaging studies. *Cortex*, *89*, 120–134. https://doi.org/10.1016/j.cortex.2017.01.010

Tracey, I. (2010). Getting the pain you expect: mechanisms of placebo, nocebo and reappraisal effects in humans. *Nature Medicine*, *16*(11), 1277–1283. https://doi.org/10.1038/nm.2229

Tritt, S. M., Inzlicht, M., & Harmon-Jones, E. (2012). Toward a Biological Understanding of Mortality Salience (And Other Threat Compensation Processes). *Social Cognition*, *30*(6), 715–733. https://doi.org/10.1521/soco.2012.30.6.715

Tsunetomo, Y., & Scott, W. (translate). (2002). *Hagakure: The Book of the Samurai*. Stackpole Books.

Valentini, E., & Gyimes, I. L. (2018). Visual cues of threat elicit greater steady-state electroencephalographic responses than visual reminders of death. *Biological Psychology*, *139*, 73–86. https://doi.org/10.1016/j.biopsycho.2018.10.004

Valentini, E., Koch, K., & Aglioti, S. M. (2014). Thoughts of death modulate psychophysical and cortical responses to threatening stimuli. *PLoS ONE*, *9*(11). https://doi.org/10.1371/journal.pone.0112324

Valentini, E., Koch, K., Nicolardi, V., & Aglioti, S. M. (2015). Mortality salience modulates cortical responses to painful somatosensory stimulation: Evidence from slow wave and delta band activity. *NeuroImage*, *120*, 12–24. https://doi.org/10.1016/j.neuroimage.2015.07.025

Valentini, E., Nicolardi, V., & Aglioti, S. M. (2017). Visual reminders of death enhance nociceptive-related cortical responses and event-related alpha desynchronisation. *Biological Psychology*, *129*(August), 121–130. https://doi.org/10.1016/j.biopsycho.2017.08.055

Van Damme, S., Crombez, G., Eccleston, C., & Goubert, L. (2004). Impaired disengagement from threatening cues of impending pain in a crossmodal cueing paradigm. *European Journal of Pain*, *8*(3), 227–236. https://doi.org/https://doi.org/10.1016/j.ejpain.2003.08.005

van Wijk, A. J., & Hoogstraten, J. (2009). Anxiety and pain during dental injections. *Journal of Dentistry*, *37*(9), 700–704. https://doi.org/10.1016/j.jdent.2009.05.023

Voytek, B., Kramer, M. A., Case, J., Lepage, K. Q., Tempesta, Z. R., Knight, R. T., & Gazzaley, A. (2015). Age-Related Changes in 1/f Neural Electrophysiological Noise. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *35*(38), 13257—13265. https://doi.org/10.1523/jneurosci.2332-14.2015

Wager, T. D., Rilling, J. K., Smith, E. E., Sokolik, A., Casey, K. L., Davidson, R. J., Kosslyn, S. M., Rose, R. M., & Cohen, J. D. (2004). Placebo-induced changes in FMRI in the anticipation and experience of pain. *Science (New York, N.Y.)*, *303*(5661), 1162–1167. https://doi.org/10.1126/science.1093065

Wang, C., & Tian, J. (2018). Reminders of mortality alter pain-evoked potentials in a Chinese sample. *Frontiers in Psychology*, *9*(SEP), 1–10. https://doi.org/10.3389/fpsyg.2018.01667

Wegner, D. M. (1994). Ironic processes of mental control. In *Psychological Review* (Vol. 101, Issue 1, pp. 34–52). American Psychological Association. https://doi.org/10.1037/0033-295X.101.1.34

Wiech, K., Lin, C. S., Brodersen, K. H., Bingel, U., Ploner, M., & Tracey, I. (2010). Anterior insula integrates information about salience into perceptual decisions about pain. *J Neurosci*, *30*(48), 16324–16331. https://doi.org/10.1523/jneurosci.2087-10.2010

Wiercioch-Kuzianik, K., & Bąbel, P. (2019). Color Hurts. The Effect of Color on Pain Perception. *Pain Medicine (Malden, Mass.)*, *20*(10), 1955–1962. https://doi.org/10.1093/pm/pny285

Wieser, M. J., Gerdes, A. B. M., Reicherts, P., & Pauli, P. (2014). Mutual influences of pain and emotional face processing. *Frontiers in Psychology*, *5*(October), 1–6. https://doi.org/10.3389/fpsyg.2014.01160

Wisman, A., Heflick, N., & Goldenberg, J. L. (2015). The great escape: The role of self-esteem and self-related cognition in terror management. *Journal of Experimental Social Psychology*, *60*, 121–132. https://doi.org/https://doi.org/10.1016/j.jesp.2015.05.006

Wolff, N., Zink, N., Stock, A.-K., & Beste, C. (2017). On the relevance of the alpha frequency oscillation's small-world network architecture for cognitive flexibility. *Scientific Reports*, *7*(1), 13910. https://doi.org/10.1038/s41598-017-14490-x

Woodgate, R. L., West, C. H., & Tailor, K. (2014). Existential anxiety and growth: An exploration of computerized drawings and perspectives of children and Adolescents with Cancer. *Cancer Nursing*, *37*(2), 146–159. https://doi.org/10.1097/NCC.0b013e31829ded29

Wu, J., Mai, X., Yu, Z., Qin, S., & Luo, Y.-J. (2010). Effects of discrepancy between imagined and perceived sounds on the N2 component of the event-related potential. *Psychophysiology*, *47*(2), 289–298. https://doi.org/10.1111/j.1469-8986.2009.00936.x

Yaakobi, E. (2015). Desire to Work as a Death Anxiety Buffer Mechanism. *Experimental Psychology*, *62*(2), 110–122. https://doi.org/10.1027/1618-3169/a000278

Yalom, I. D. (1989). *Love's Executioner & Other Tales of Psychotherapy*.

Yanagisawa, K., Abe, N., Kashima, E. S., & Nomura, M. (2016). Self-esteem modulates amygdala-ventrolateral prefrontal cortex connectivity in response to mortality threats. *Journal of Experimental Psychology. General*, *145*(3), 273–283. https://doi.org/10.1037/xge0000121

Yanagisawa, K., Kashima, E. S., Moriya, H., Masui, K., Furutani, K., Nomura, M., Yoshida, H., & Ura, M. (2013). Non-conscious neural regulation against mortality concerns.

Neuroscience Letters, *552*, 35–39. https://doi.org/10.1016/j.neulet.2013.07.027

Yordanova, J., Banaschewski, T., Kolev, V., Woerner, W., & Rothenberger, A. (2001). Abnormal early stages of task stimulus processing in children with attention-deficit hyperactivity disorder--evidence from event-related gamma oscillations. *Clinical Neurophysiology : Official Journal of the International Federation of Clinical Neurophysiology*, *112*(6), 1096–1108. https://doi.org/10.1016/s1388-2457(01)00524-7

Zeidan, F., Emerson, N. M., Farris, S. R., Ray, J. N., Jung, Y., McHaffie, J. G., & Coghill, R. C. (2015). Mindfulness Meditation-Based Pain Relief Employs Different Neural Mechanisms Than Placebo and Sham Mindfulness Meditation-Induced Analgesia. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *35*(46), 15307–15325. https://doi.org/10.1523/JNEUROSCI.2542-15.2015

Zhang, W.-R., Wang, K., Yin, L., Zhao, W.-F., Xue, Q., Peng, M., Min, B.-Q., Tian, Q., Leng, H.-X., Du, J.-L., Chang, H., Yang, Y., Li, W., Shangguan, F.-F., Yan, T.-Y., Dong, H.-Q., Han, Y., Wang, Y.-P., Cosci, F., & Wang, H.-X. (2020). Mental Health and Psychosocial Problems of Medical Health Workers during the COVID-19 Epidemic in China. *Psychotherapy and Psychosomatics*, *89*(4), 242–250. https://doi.org/10.1159/000507639

Zielinski, M. C., Shin, J. D., & Jadhav, S. P. (2019). Coherent Coding of Spatial Position Mediated by Theta Oscillations in the Hippocampus and Prefrontal Cortex. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *39*(23), 4550–4565. https://doi.org/10.1523/JNEUROSCI.0106-19.2019

Zorn, J., Abdoun, O., Bouet, R., & Lutz, A. (2020). Mindfulness meditation is related to sensory-affective uncoupling of pain in trained novice and expert practitioners. *European Journal of Pain (London, England), 24*(7), 1301–1313. https://doi.org/10.1002/ejp.1576

9 Appendix for Study 1

9.1 Experiment 1

9.1.1 STAI and PANAS results

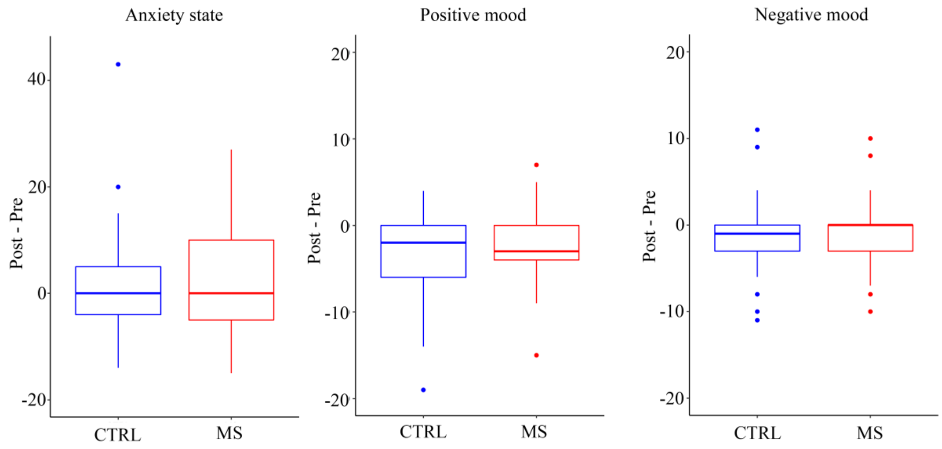

Figure 9-1 Differences between pre- and post-MM anxiety state, positive and negative mood. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue – CTRL, red – MS. Note the similar central tendency before and after MM and across the two mind-sets.

9.1.1.1 Anxiety state

	Sum of Squares	df	Mean Square	F	p	ω²
Mind-set	100.000	1	100.000	2.673	0.115	0.014
Residuals	898.000	24	37.417	-	-	-
Time	139.240	1	139.240	1.425	0.244	0.007
Residuals	2344.760	24	97.698	-	-	-
Mind-set x Time	0.160	1	0.160	0.007	0.935	0.000
Residuals	571.840	24	23.827	-	-	-

Table 9-1 Results of the repeated measure ANOVA on the anxiety state scores. No significant main effect or interaction has been found.

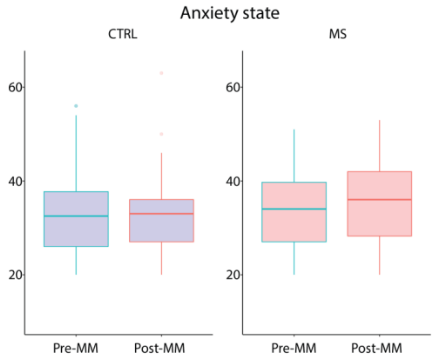

Figure 9-2. Difference between pre- and post-MM anxiety state scores in both Mind-set conditions. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue fill– CTRL, red fill – MS, green contour – pre-MM, orange contour – post-MM.

9.1.1.2 Negative mood

	Sum of Squares	df	Mean Square	F	p	ω²
Mind-set	2.250	1	2.250	0.295	0.592	0.000
Residuals	183.000	24	7.625	-	-	-
Time	30.250	1	30.250	1.801	0.192	0.012
Residuals	403.000	24	16.792	-	-	-
Mind-set x Time	1.690	1	1.690	0.424	0.521	0.000
Residuals	95.560	24	3.982	-	-	-

Table 9-2. Results of the repeated measure ANOVA on the negative mood scores. No significant main effect or interaction has been found.

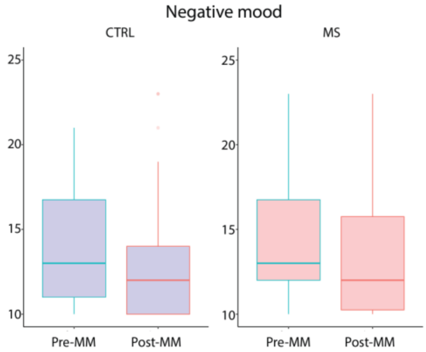

Figure 9-3. Difference between pre- and post-MM negative mood scores in both Mind-set conditions. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue fill– CTRL, red fill – MS, green contour – pre-MM, orange contour – post-MM.

9.1.2 Pain ratings

9.1.2.1 Assessment of the effect of Threat (Model 1)

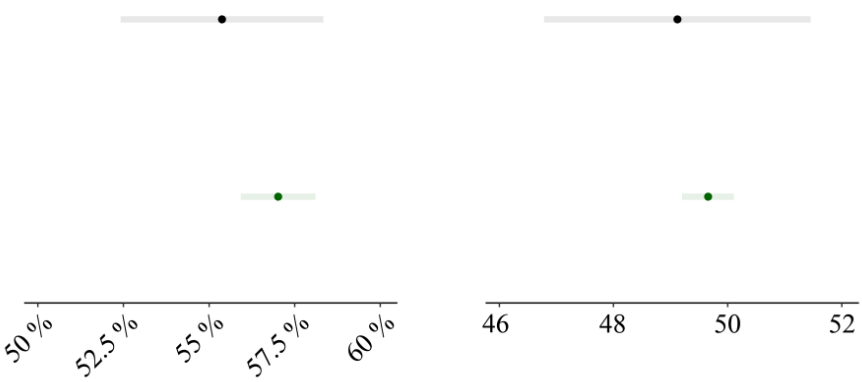

Figure 9-4. Main effect of Threat on normalised (left) and non-normalised (right) visual analogue scale (VAS) ratings. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, green – Threat effect.

9.1.2.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			58.091	1.568	37.059	55.019; 61.163	< 0.001	-	-
	Non-threatening	MS	-3.393	0.938	-3.616	-5.232; -1.554	< 0.001	50.216(4)	< 0.001
		CTRL	-4.974	0.938	-5.301	-6.813; -3.135	< 0.001		
	Threatening	MS	-3.493	0.938	-3.722	-5.332; -1.654	< 0.001		
		CTRL	-3.109	0.938	-3.314	-4.948; -1.270	0.001		
Fear of Death	**Non-threatening**	MS	5.699	1.092	5.221	3.560; 7.839	< 0.001	84.500(4)	< 0.001
		CTRL	5.536	1.076	5.144	3.426; 7.645	< 0.001		
	Threatening	MS	6.239	1.092	5.715	4.099; 8.378	< 0.001		
		CTRL	5.640	1.076	5.241	3.531; 7.749	< 0.001		
Anxiety	**Non-threatening**	MS	6.423	1.711	3.754	3.070; 9.776	< 0.001	24.193(4)	< 0.001
		CTRL	-1.789	1.687	-1.061	-5.095; 1.516	0.289		
	Threatening	MS	6.551	1.711	3.830	3.198; 9.904	< 0.001		
		CTRL	-2.407	1.687	-1.427	-5.712; 0.899	0.154		
Depression	**Non-threatening**	MS	-5.994	1.545	-3.878	-9.022; -2.965	< 0.001	38.128(4)	< 0.001
		CTRL	-1.358	1.524	-0.891	-4.344; 1.628	0.373		
	Threatening	MS	-8.389	1.545	-5.429	-11.418; -5.361	< 0.001		
		CTRL	-3.070	1.524	-2.015	-6.056; -0.084	0.044		
Self-esteem	**Non-threatening**	MS	5.250	1.295	4.053	2.711; 7.788	< 0.001	37.056(4)	< 0.001
		CTRL	3.958	1.277	3.099	1.455; 6.460	0.002		
	Threatening	MS	5.053	1.295	3.901	2.514; 7.592	< 0.001		
		CTRL	3.648	1.277	2.857	1.145; 6.150	0.004		
AAS Anxious	**Non-threatening**	MS	2.566	1.301	1.973	0.017; 5.116	0.049	39.343(4)	< 0.001
		CTRL	3.542	1.282	2.762	1.029; 6.056	0.006		
	Threatening	MS	5.371	1.301	4.129	2.821; 7.920	< 0.001		
		CTRL	5.752	1.282	4.485	3.239; 8.266	< 0.001		
AAS Close	**Non-threatening**	MS	4.465	1.178	3.791	2.157; 6.773	< 0.001	19.198(4)	0.001
		CTRL	-1.326	1.161	-1.142	-3.601; 0.950	0.253		
	Threatening	MS	1.200	1.178	1.019	-1.108; 3.508	0.308		
		CTRL	-2.396	1.161	-2.064	-4.672; -0.121	0.039		
AAS Dependent	**Non-threatening**	MS	1.145	1.248	0.917	-1.301; 3.591	0.359	2.752(4)	0.600
		CTRL	1.226	1.230	0.997	-1.185; 3.638	0.319		
	Threatening	MS	1.363	1.248	1.092	-1.083; 3.809	0.275		
		CTRL	0.927	1.230	0.753	-1.484; 3.338	0.451		

Table 9-3. Changes in pain ratings associated with Mind-set, personality traits and level of Threat. 95% CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.3 Somatosensory-evoked potentials

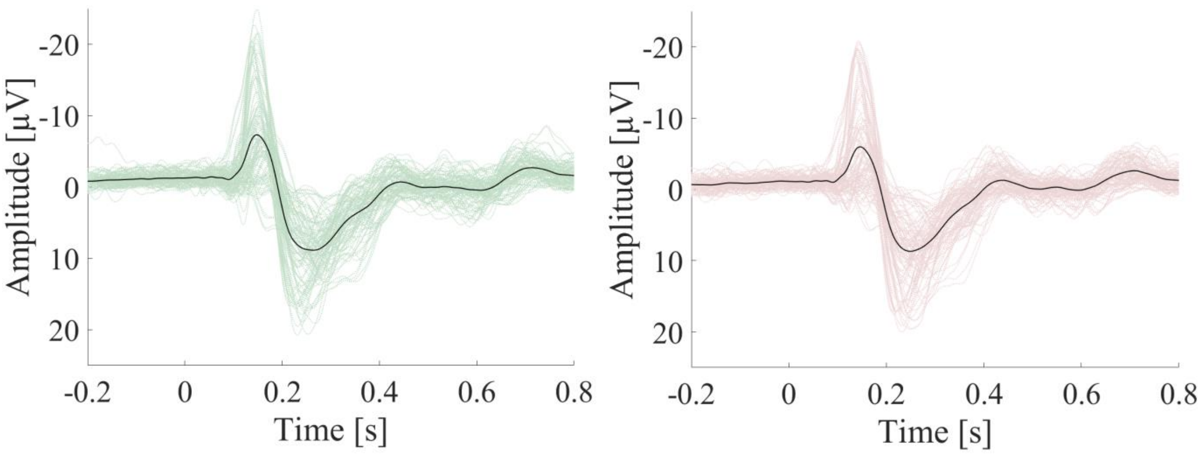

Figure 9-5. Pre- (left) and post-MM (right) SEPs. Coloured dotted lines show the single subject SEPs and the solid black line represents the average SEP for both Time conditions.

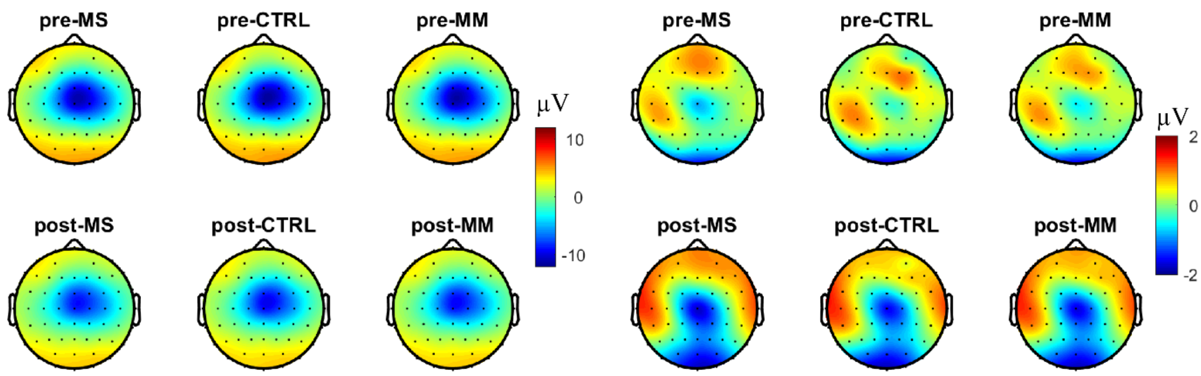

Figure 9-6. Topographies of the N2 component (left) and the P2 component (right) identified by the linear mixed-effects models.

9.1.3.1 The modulatory role of Personality on Mind-set (Model 2)

9.1.3.1.1 N2

		β	SE	t	95% CI	p	χ^2(npar)	χ^2 p
Intercept		-6.809	1.325	-5.138	-9.406; -4.211	< 0.001	-	-
MS		1.437	0.180	8.001	1.085; 1.789	< 0.001	100.790(2)	< 0.001
CTRL		1.149	0.180	6.397	0.797; 1.501	< 0.001		
Fear of Death	MS	-0.840	0.209	-4.025	-1.249; -0.431	< 0.001	16.206(2)	< 0.001
	CTRL	-0.065	0.209	-0.313	-0.475; 0.344	0.754		
Anxiety	MS	0.933	0.327	2.851	0.291; 1.574	0.004	9.124(2)	0.010
	CTRL	0.357	0.328	1.088	-0.286; 0.999	0.277		
Depression	MS	0.231	0.296	0.781	-0.348; 0.810	0.435	1.015(2)	0.602
	CTRL	0.198	0.296	0.670	-0.382; 0.779	0.503		
Self-esteem	MS	-0.387	0.248	-1.561	-0.872; 0.099	0.119	2.883(2)	0.237
	CTRL	0.151	0.248	0.610	-0.335; 0.638	0.542		
AAS Anxious	MS	-1.275	0.249	-5.127	-1.763; -0.788	< 0.001	28.898(2)	< 0.001
	CTRL	0.365	0.249	1.464	-0.124; 0.853	0.143		
AAS Close	MS	-0.011	0.225	-0.048	-0.452; 0.431	0.962	0.146(2)	0.930
	CTRL	-0.088	0.226	-0.390	-0.530; 0.354	0.697		
AAS Dependent	MS	0.385	0.239	1.612	-0.083; 0.852	0.107	11.597(2)	0.003
	CTRL	0.731	0.239	3.056	0.262; 1.199	0.002		

Table 9-4. Changes in N2 component amplitude associated with Mind-set and personality traits. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.3.1.2 P2

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		0.803	0.422	1.902	-0.025; 1.630	0.069	-	-
MS		-0.953	0.151	-6.309	-1.249; -0.657	< 0.001	96.584(2)	< 0.001
CTRL		-1.193	0.151	-7.903	-1.489; -0.897	< 0.001		
Fear of Death	MS	0.295	0.175	1.686	-0.048; 0.638	0.092	4.939(2)	0.085
	CTRL	0.266	0.175	1.522	-0.077; 0.609	0.128		
Anxiety	MS	0.165	0.274	0.603	-0.372; 0.703	0.546	0.524(2)	0.770
	CTRL	0.121	0.274	0.441	-0.417; 0.659	0.659		
Depression	MS	-0.220	0.248	-0.887	-0.705; 0.266	0.375	3.811(2)	0.149
	CTRL	-0.44	0.248	-1.774	-0.925; 0.046	0.076		
Self-esteem	MS	0.122	0.208	0.585	-0.285; 0.528	0.558	0.941(2)	0.625
	CTRL	-0.153	0.208	-0.739	-0.560; 0.254	0.460		
AAS Anxious	MS	0.030	0.208	0.144	-0.379; 0.439	0.886	0.448(2)	0.799
	CTRL	-0.135	0.209	-0.645	-0.543; 0.274	0.519		
AAS Close	MS	0.132	0.189	0.701	-0.238; 0.502	0.483	0.963(2)	0.618
	CTRL	0.138	0.189	0.732	-0.232; 0.508	0.465		
AAS Dependent	MS	0.486	0.200	2.428	0.094; 0.877	0.015	9.402(2)	0.009
	CTRL	-0.353	0.200	-1.764	-0.745; 0.039	0.078		

Table 9-5. Changes in late P2 amplitude associated with Mind-set and personality traits. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.3.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

9.1.3.2.1 N2

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			-6.809	1.325	-5.138	-9.406; -4.211	< 0.001	-	-
	Non-threatening	MS	1.712	0.221	7.732	1.278; 2.146	< 0.001	106.046(4)	< 0.001
		CTRL	1.249	0.221	5.642	0.815; 1.683	< 0.001		
	Threatening	MS	1.163	0.221	5.252	0.729; 1.597	< 0.001		
		CTRL	1.049	0.221	4.739	0.615; 1.483	< 0.001		
Fear of Death	**Non-threatening**	MS	-0.796	0.257	-3.091	-1.300; -0.291	0.002	16.424(4)	0.002
		CTRL	-0.020	0.258	-0.076	-0.525; 0.485	0.939		
	Threatening	MS	-0.885	0.257	-3.437	-1.389; -0.380	0.001		
		CTRL	-0.111	0.258	-0.432	-0.616; 0.394	0.666		
Anxiety	**Non-threatening**	MS	1.052	0.403	2.607	0.261; 1.842	0.009	11.281(4)	0.024
		CTRL	0.680	0.404	1.683	-0.112; 1.471	0.092		
	Threatening	MS	0.814	0.403	2.017	0.023; 1.604	0.044		
		CTRL	0.033	0.404	0.083	-0.758; 0.825	0.934		
Depression	**Non-threatening**	MS	-0.026	0.364	-0.071	-0.740; 0.688	0.943	2.574(4)	0.631
		CTRL	0.132	0.365	0.361	-0.583; 0.847	0.718		
	Threatening	MS	0.488	0.364	1.338	-0.227; 1.202	0.181		
		CTRL	0.265	0.365	0.727	-0.450; 0.980	0.467		
Self-esteem	**Non-threatening**	MS	-0.359	0.305	-1.177	-0.958; 0.239	0.239	4.222(4)	0.377
		CTRL	0.355	0.306	1.162	-0.244; 0.954	0.245		
	Threatening	MS	-0.414	0.305	-1.355	-1.012; 0.185	0.176		
		CTRL	-0.053	0.306	-0.172	-0.652; 0.547	0.863		
AAS Anxious	**Non-threatening**	MS	-1.206	0.307	-3.931	-1.807; -0.604	< 0.001	29.158(4)	< 0.001
		CTRL	0.404	0.307	1.315	-0.198; 1.006	0.188		
	Threatening	MS	-1.345	0.307	-4.384	-1.946; -0.744	< 0.001		
		CTRL	0.326	0.307	1.061	-0.276; 0.928	0.289		
AAS Close	**Non-threatening**	MS	0.123	0.278	0.444	-0.421; 0.668	0.657	1.374(4)	0.849
		CTRL	-0.207	0.278	-0.745	-0.752; 0.338	0.456		
	Threatening	MS	-0.145	0.278	-0.522	-0.689; 0.399	0.602		
		CTRL	0.031	0.278	0.113	-0.514; 0.576	0.910		
AAS Dependent	**Non-threatening**	MS	0.245	0.294	0.832	-0.332; 0.822	0.405	14.013(4)	0.007
		CTRL	0.956	0.295	3.246	0.379; 1.534	0.001		
	Threatening	MS	0.525	0.294	1.783	-0.052; 1.101	0.075		
		CTRL	0.505	0.295	1.713	-0.073; 1.082	0.087		

Table 9-6. Changes in N2 component amplitude associated with Mind-set, Threat and personality traits. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.3.2.2 P2

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			0.803	0.422	1.902	-0.024; 1.630	0.069	-	-
Non-threatening		MS	-0.888	0.187	-4.759	-1.254; -0.522	< 0.001	99.386(4)	< 0.001
		CTRL	-1.029	0.187	-5.516	-1.395; -0.664	< 0.001		
Threatening		MS	-1.017	0.187	-5.452	-1.383; -0.652	< 0.001		
		CTRL	-1.357	0.187	-7.274	-1.723; -0.992	< 0.001		
Fear of Death	Non-threatening	MS	0.264	0.217	1.217	-0.161; 0.688	0.224	5.072(4)	0.280
		CTRL	0.298	0.217	1.374	-0.127; 0.722	0.169		
	Threatening	MS	0.326	0.217	1.506	-0.098; 0.751	0.132		
		CTRL	0.235	0.217	1.085	-0.189; 0.660	0.278		
Anxiety	Non-threatening	MS	0.256	0.339	0.755	-0.409; 0.921	0.450	1.562(4)	0.816
		CTRL	0.303	0.339	0.891	-0.363; 0.968	0.373		
	Threatening	MS	0.075	0.339	0.220	-0.591; 0.740	0.826		
		CTRL	-0.061	0.339	-0.178	-0.726; 0.605	0.858		
Depression	Non-threatening	MS	-0.211	0.307	-0.690	-0.812; 0.389	0.490	5.675(4)	0.225
		CTRL	-0.685	0.307	-2.234	-1.286; -0.084	0.026		
	Threatening	MS	-0.228	0.307	-0.743	-0.829; 0.373	0.458		
		CTRL	-0.194	0.307	-0.634	-0.795; 0.407	0.526		
Self-esteem	Non-threatening	MS	0.263	0.257	1.026	-0.240; 0.767	0.305	2.675(4)	0.619
		CTRL	-0.290	0.257	-1.129	-0.794; 0.214	0.259		
	Threatening	MS	-0.020	0.257	-0.080	-0.524; 0.483	0.937		
		CTRL	-0.017	0.257	-0.065	-0.520; 0.487	0.948		
AAS Anxious	Non-threatening	MS	0.066	0.258	0.256	-0.440; 0.572	0.798	0.763(4)	0.943
		CTRL	-0.212	0.258	-0.820	-0.717; 0.294	0.413		
	Threatening	MS	-0.006	0.258	-0.024	-0.512; 0.499	0.981		
		CTRL	-0.057	0.258	-0.223	-0.563; 0.448	0.824		
AAS Close	Non-threatening	MS	0.374	0.234	1.600	-0.084; 0.832	0.110	6.802(4)	0.147
		CTRL	-0.089	0.234	-0.382	-0.547; 0.369	0.702		
	Threatening	MS	-0.109	0.234	-0.467	-0.567; 0.349	0.640		
		CTRL	0.366	0.234	1.564	-0.092; 0.824	0.118		
AAS Dependent	Non-threatening	MS	0.350	0.248	1.414	-0.135; 0.835	0.158	11.845(4)	0.019
		CTRL	-0.172	0.248	-0.693	-0.657; 0.314	0.488		
	Threatening	MS	0.621	0.248	2.509	0.136; 1.106	0.012		
		CTRL	-0.534	0.248	-2.157	-1.020; -0.049	0.031		

Table 9-7. Changes in late P2 amplitude associated with Mind-set, Threat and personality traits. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4 Time-frequency analysis

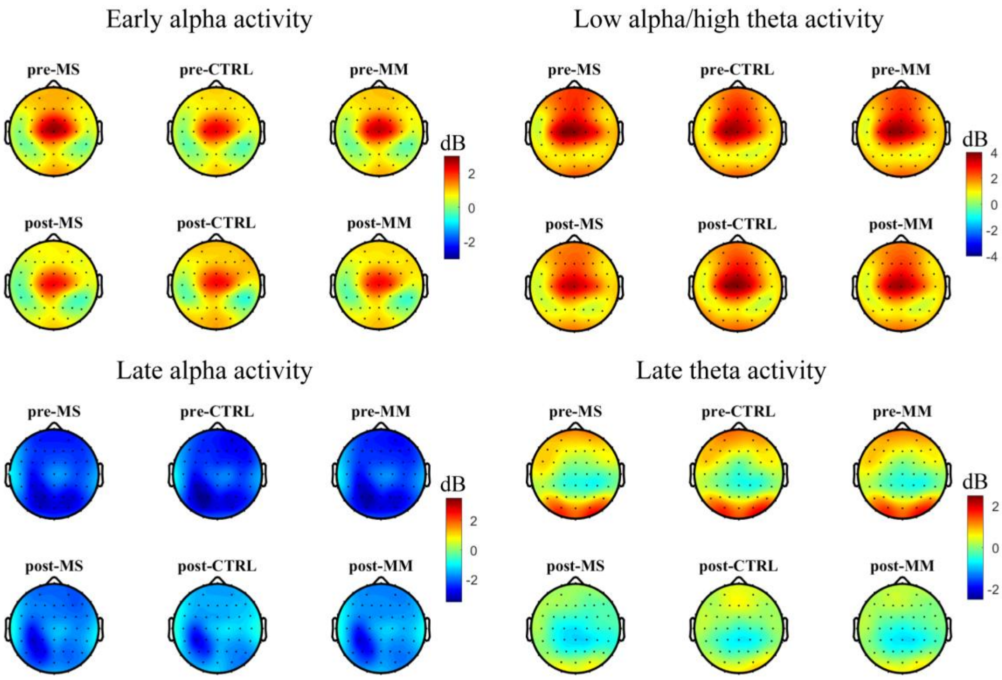

Figure 9-7. Topographies of the early alpha AOI (top left), the low alpha/high theta AOI (top right), the late alpha AOI (bottom left) and the late theta AOI (bottom right). The changes in power from pre- to post-MM were affected by anxiety, depression and fear of death scores.

9.1.4.1 The modulatory role of Personality on Mind-set (Model 2)

9.1.4.1.1 Early alpha activity

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		0.687	0.419	1.640	-0.134; 1.508	0.114	-	-
MS		-0.433	0.082	-5.300	-0.594; -0.273	0.000	59.628 (2)	< 0.001
CTRL		-0.443	0.082	-5.411	-0.603; -0.282	0.000		
Fear of Death	MS	-0.082	0.095	-0.860	-0.268; 0.105	0.390	32.153 (2)	<0.001
	CTRL	-0.536	0.095	-5.638	-0.722; -0.349	0.000		
Anxiety	MS	-0.799	0.149	-5.358	-1.091; -0.507	0.000	42.506 (2)	<0.001
	CTRL	0.537	0.149	3.611	0.246; 0.829	0.000		
Depression	MS	-0.014	0.135	-0.105	-0.278; 0.250	0.916	1.496 (2)	0.473
	CTRL	-0.164	0.134	-1.218	-0.427; 0.100	0.223		
Self-esteem	MS	-0.336	0.113	-2.975	-0.557; -0.115	0.003	9.521 (2)	0.009
	CTRL	0.084	0.113	0.744	-0.137; 0.305	0.457		
AAS Anxious	MS	0.211	0.113	1.860	-0.011; 0.433	0.063	3.908 (2)	0.142
	CTRL	-0.072	0.113	-0.632	-0.293; 0.150	0.527		
AAS Close	MS	-0.017	0.103	-0.161	-0.218; 0.185	0.872	3.304 (2)	0.192
	CTRL	0.185	0.102	1.810	-0.015; 0.386	0.070		
AAS Depend	MS	0.043	0.109	0.399	-0.170; 0.257	0.690	3.003 (2)	0.223
	CTRL	0.184	0.109	1.692	-0.029; 0.397	0.091		

Table 9-8. Changes in early alpha activity associated with Mind-set and personality traits. 95 % CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.1.2 Late alpha activity

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		-3.396	0.315	-10.780	-4.014; -2.779	< 0.001	-	-
MS		0.122	0.091	1.344	-0.056; 0.300	0.179	85.579 (2)	< 0.001
CTRL		0.301	0.091	3.309	0.123; 0.479	0.001		
Fear of Death	MS	0.101	0.106	0.954	-0.106; 0.308	0.340	2.399 (2)	0.301
	CTRL	-0.121	0.104	-1.160	-0.326; 0.084	0.246		
Anxiety	MS	-1.304	0.166	-7.863	-1.629; -0.979	< 0.001	61.802 (2)	< 0.001
	CTRL	-0.195	0.164	-1.192	-0.516; 0.126	0.233		
Depression	MS	0.976	0.150	6.511	0.682; 1.269	< 0.001	44.897 (2)	< 0.001
	CTRL	-0.180	0.148	-1.220	-0.470; 0.109	0.223		
Self-esteem	MS	-0.148	0.126	-1.175	-0.394; 0.099	0.240	4.846 (2)	0.089
	CTRL	-0.238	0.124	-1.923	-0.481; 0.005	0.055		
AAS Anxious	MS	0.243	0.126	1.929	-0.004; 0.491	0.054	3.999 (2)	0.135
	CTRL	0.078	0.124	0.630	-0.166; 0.322	0.529		
AAS Close	MS	-0.147	0.114	-1.286	-0.371; 0.077	0.199	4.111 (2)	0.128
	CTRL	0.167	0.113	1.484	-0.054; 0.388	0.138		
AAS Depend	MS	0.322	0.121	2.661	0.085; 0.559	0.008	13.454 (2)	0.001
	CTRL	0.320	0.119	2.681	0.086; 0.554	0.007		

Table 9-9. Changes in late alpha activity associated with Mind-set and personality traits. 95 % CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.1.3 Late theta activity

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		-1.414	0.221	-6.404	-1.847; -0.981	< 0.001	-	-
MS		-0.501	0.109	-4.599	-0.714; -0.287	< 0.001	23.982 (2)	< 0.001
CTRL		-0.339	0.109	-3.115	-0.552; -0.126	0.002		
Fear of Death	MS	0.602	0.125	4.814	0.357; 0.847	< 0.001	12.76 3(2)	< 0.001
	CTRL	0.008	0.125	0.061	-0.237; 0.253	0.951		
Anxiety	MS	-0.626	0.196	-3.194	-1.009; -0.242	0.001	8.02 7(2)	< 0.001
	CTRL	0.253	0.196	1.290	-0.131; 0.636	0.197		
Depression	MS	0.076	0.177	0.428	-0.271; 0.423	0.668	0.570 (2)	0.566
	CTRL	-0.140	0.177	-0.793	-0.487; 0.206	0.428		
Self-esteem	MS	-0.307	0.148	-2.073	-0.598; -0.017	0.038	4.769 (2)	0.009
	CTRL	0.225	0.148	1.520	-0.065; 0.516	0.128		
AAS Anxious	MS	-0.257	0.149	-1.728	-0.549; 0.035	0.084	3.184 (2)	0.041
	CTRL	0.179	0.149	1.201	-0.113; 0.471	0.230		
AAS Close	MS	-0.210	0.135	-1.559	-0.474; 0.054	0.119	2.444 (2)	0.087
	CTRL	0.135	0.135	0.998	-0.130; 0.399	0.318		
AAS Depend	MS	-0.402	0.143	-2.811	-0.682; -0.122	0.005	4.23 7(2)	0.015
	CTRL	-0.229	0.143	-1.604	-0.509; 0.051	0.109		

Table 9-10. Changes in late theta activity associated with Mind-set and personality traits. 95 % CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

9.1.4.2.1 Early alpha activity

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
	Intercept		0.687	0.419	1.640	-0.134; 1.508	0.114	-	-
	Non-threatening	MS	-0.430	0.100	-4.297	-0.627; -0.234	<0.001	126.938(4)	<0.001
		CTRL	-0.541	0.100	-5.399	-0.737; -0.344	<0.001		
	Threatening	MS	-0.437	0.100	-4.360	-0.633; -0.240	<0.001		
		CTRL	-0.344	0.100	-3.440	-0.541; -0.148	0.001		
Fear of Death	**Non-threatening**	MS	0.025	0.117	0.216	-0.203; 0.254	0.829	38.095 (4)	<0.001
		CTRL	-0.654	0.116	-5.623	-0.882; -0.426	<0.001		
	Threatening	MS	-0.189	0.117	-1.619	-0.417; 0.040	0.106		
		CTRL	-0.417	0.116	-3.584	-0.645; -0.189	<0.001		
Anxiety	**Non-threatening**	MS	-0.747	0.183	-4.094	-1.105; -0.390	<0.001	43.345(4)	<0.001
		CTRL	0.575	0.182	3.151	0.217; 0.932	0.002		
	Threatening	MS	-0.850	0.183	-4.657	-1.208; -0.493	<0.001		
		CTRL	0.500	0.182	2.742	0.143; 0.857	0.006		
Depression	**Non-threatening**	MS	-0.380	0.165	-2.301	-0.703; -0.056	0.021	22.960(4)	<0.001
		CTRL	-0.416	0.165	-2.527	-0.739; -0.093	0.012		
	Threatening	MS	0.351	0.165	2.126	0.027; 0.674	0.034		
		CTRL	0.089	0.165	0.542	-0.234; 0.412	0.588		
Self-esteem	**Non-threatening**	MS	-0.367	0.138	-2.652	-0.638; -0.096	0.008	10.039(4)	0.040
		CTRL	0.125	0.138	0.902	-0.146; 0.395	0.367		
	Threatening	MS	-0.305	0.138	-2.208	-0.576; -0.034	0.027		
		CTRL	0.043	0.138	0.312	-0.228; 0.314	0.755		
AAS Anxious	**Non-threatening**	MS	0.432	0.139	3.110	0.160; 0.704	0.002	13.269(4)	0.010
		CTRL	0.037	0.139	0.269	-0.234; 0.309	0.788		
	Threatening	MS	-0.010	0.139	-0.071	-0.282; 0.262	0.944		
		CTRL	-0.180	0.139	-1.302	-0.452; 0.091	0.193		
AAS Close	**Non-threatening**	MS	-0.173	0.126	-1.377	-0.419; 0.073	0.169	19.868(4)	0.001
		CTRL	-0.067	0.126	-0.533	-0.313; 0.179	0.594		
	Threatening	MS	0.140	0.126	1.111	-0.107; 0.386	0.266		
		CTRL	0.438	0.126	3.489	0.192; 0.684	<0.001		
AAS Depend	**Non-threatening**	MS	-0.054	0.133	-0.407	-0.315; 0.207	0.684	4.652(4)	0.325
		CTRL	0.172	0.133	1.292	-0.089; 0.433	0.197		
	Threatening	MS	0.141	0.133	1.058	-0.120; 0.402	0.290		
		CTRL	0.196	0.133	1.471	-0.065; 0.456	0.141		

Table 9-11. Changes in early alpha activity associated with Mind-set, personality traits and level of Threat. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.2.2 Low alpha/high theta activity

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			2.014	0.537	3.749	0.961; 3.066	0.001	-	-
	Non-threatening	MS	-0.429	0.119	-3.623	-0.662; -0.197	<0.001	129.16(4)	<0.001
		CTRL	-0.277	0.119	-2.341	-0.510; -0.045	0.019		
	Threatening	MS	-0.675	0.119	-5.694	-0.907; -0.442	<0.001		
		CTRL	-0.325	0.119	-2.741	-0.557; -0.093	0.006		
Fear of Death	**Non-threatening**	MS	0.113	0.137	0.826	-0.156; 0.382	0.409	16.454(4)	0.002
		CTRL	-0.461	0.138	-3.341	-0.731; -0.190	0.001		
	Threatening	MS	0.095	0.137	0.696	-0.174; 0.364	0.487		
		CTRL	-0.419	0.138	-3.037	-0.689; -0.149	0.002		
Anxiety	**Non-threatening**	MS	-0.668	0.215	-3.105	-1.089; -0.246	0.002	33.104(4)	0.004
		CTRL	-0.164	0.216	-0.760	-0.588; 0.259	0.448		
	Threatening	MS	-1.188	0.215	-5.525	-1.610; -0.767	<0.001		
		CTRL	-0.059	0.216	-0.272	-0.482; 0.365	0.786		
Depression	**Non-threatening**	MS	-0.194	0.194	-0.996	-0.574; 0.187	0.319	47.316(4)	<0.001
		CTRL	-0.344	0.195	-1.763	-0.727; 0.038	0.078		
	Threatening	MS	1.136	0.194	5.849	0.756; 1.517	<0.001		
		CTRL	-0.271	0.195	-1.390	-0.654; 0.111	0.165		
Self-esteem	**Non-threatening**	MS	-0.266	0.163	-1.634	-0.585; 0.053	0.102	4.709(4)	0.218
		CTRL	-0.119	0.164	-0.726	-0.439; 0.202	0.468		
	Threatening	MS	-0.203	0.163	-1.248	-0.522; 0.116	0.212		
		CTRL	0.109	0.164	0.665	-0.212; 0.430	0.506		
AAS Anxious	**Non-threatening**	MS	-0.066	0.164	-0.402	-0.386; 0.255	0.687	17.285(4)	0.002
		CTRL	0.514	0.164	3.126	0.192; 0.836	0.002		
	Threatening	MS	-0.312	0.164	-1.908	-0.633; 0.008	0.056		
		CTRL	0.444	0.164	2.699	0.122; 0.766	0.007		
AAS Close	**Non-threatening**	MS	-0.122	0.148	-0.826	-0.413; 0.168	0.409	4.988(4)	0.289
		CTRL	0.054	0.149	0.363	-0.238; 0.346	0.717		
	Threatening	MS	0.219	0.148	1.482	-0.071; 0.510	0.138		
		CTRL	0.148	0.149	0.996	-0.143; 0.440	0.319		
AAS Dependent	**Non-threatening**	MS	-0.463	0.157	-2.951	-0.771; -0.156	0.003	10.656(4)	0.031
		CTRL	-0.112	0.158	-0.713	-0.421; 0.197	0.476		
	Threatening	MS	-0.299	0.157	-1.906	-0.607; 0.008	0.057		
		CTRL	0.054	0.158	0.342	-0.255; 0.363	0.733		

Table 9-12. Changes in low alpha/high theta activity associated with Mind-set, personality traits and level of Threat. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.2.3 Late alpha activity

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			-3.396	0.315	-10.780	-4.014; -2.779	< 0.001	-	-
Non-threatening		MS	0.178	0.112	1.586	-0.042; 0.397	0.113	126.611(4)	< 0.001
		CTRL	0.503	0.112	4.485	0.283; 0.722	< 0.001		
Threatening		MS	0.067	0.112	0.596	-0.153; 0.286	0.551		
		CTRL	0.099	0.112	0.884	-0.121; 0.319	0.377		
Fear of Death	**Non-threatening**	MS	0.240	0.130	1.838	-0.016; 0.495	0.066	6.199(4)	0.185
		CTRL	-0.175	0.129	-1.351	-0.428; 0.079	0.177		
	Threatening	MS	-0.038	0.130	-0.292	-0.294; 0.218	0.770		
		CTRL	-0.067	0.129	-0.518	-0.320; 0.186	0.604		
Anxiety	**Non-threatening**	MS	-1.481	0.204	-7.248	-1.882; -1.081	< 0.001	65.545(4)	<0.001
		CTRL	-0.321	0.203	-1.582	-0.718; 0.077	0.114		
	Threatening	MS	-1.127	0.204	-5.511	-1.527; -0.726	< 0.001		
		CTRL	-0.070	0.203	-0.348	-0.468; 0.327	0.728		
Depression	**Non-threatening**	MS	0.842	0.185	4.558	0.480; 1.203	< 0.001	55.255(4)	<0.001
		CTRL	0.136	0.183	0.741	-0.223; 0.494	0.459		
	Threatening	MS	1.110	0.185	6.011	0.748; 1.472	< 0.001		
		CTRL	-0.497	0.183	-2.712	-0.855; -0.138	0.007		
Self-esteem	**Non-threatening**	MS	-0.193	0.155	-1.247	-0.496; 0.110	0.212	10.798(4)	0.0.29
		CTRL	-0.023	0.153	-0.147	-0.323; 0.278	0.883		
	Threatening	MS	-0.102	0.155	-0.657	-0.405; 0.202	0.511		
		CTRL	-0.454	0.153	-2.961	-0.755; -0.154	0.003		
AAS Anxious	**Non-threatening**	MS	0.474	0.155	3.048	0.169; 0.778	0.002	12.406(4)	0.015
		CTRL	0.207	0.154	1.343	-0.095; 0.509	0.179		
	Threatening	MS	0.013	0.155	0.084	-0.292; 0.318	0.933		
		CTRL	-0.050	0.154	-0.324	-0.352; 0.252	0.746		
AAS Close	**Non-threatening**	MS	-0.278	0.141	-1.974	-0.554; -0.002	0.048	7.888(4)	0.096
		CTRL	0.075	0.140	0.541	-0.198; 0.349	0.588		
	Threatening	MS	-0.016	0.141	-0.111	-0.291; 0.260	0.912		
		CTRL	0.259	0.140	1.853	-0.015; 0.532	0.064		
AAS Depend	**Non-threatening**	MS	0.504	0.149	3.378	0.211; 0.796	0.001	19.015(4)	< 0.001
		CTRL	0.228	0.148	1.542	-0.062; 0.518	0.123		
	Threatening	MS	0.140	0.149	0.938	-0.152; 0.432	0.348		
		CTRL	0.413	0.148	2.794	0.123; 0.703	0.005		

Table 9-13. Changes in late alpha activity associated with Mind-set, personality traits and level of Threat. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.1.4.2.4 Late theta activity

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			-1.414	0.221	-6.404	-1.847; -0.981	<0.001	-	-
Non-threatening		MS	-0.540	0.140	-3.849	-0.815; -0.265	0.000	26.244 (4)	<0.001
		CTRL	-0.216	0.140	-1.543	-0.491; 0.058	0.123		
Threatening		MS	-0.461	0.140	-3.290	-0.736; -0.186	0.001		
		CTRL	-0.462	0.140	-3.292	-0.737; -0.187	0.001		
Fear of Death	**Non-threatening**	MS	0.483	0.162	2.980	0.165; 0.800	0.003	8.328(4)	<0.001
		CTRL	0.268	0.162	1.655	-0.049; 0.585	0.098		
	Threatening	MS	0.721	0.162	4.452	0.403; 1.038	0.000		
		CTRL	-0.253	0.162	-1.559	-0.570; 0.065	0.119		
Anxiety	**Non-threatening**	MS	-0.839	0.254	-3.306	-1.336; -0.342	0.001	4.740(4)	0.001
		CTRL	0.082	0.254	0.324	-0.415; 0.580	0.746		
	Threatening	MS	-0.412	0.254	-1.625	-0.910; 0.085	0.104		
		CTRL	0.423	0.254	1.666	-0.075; 0.920	0.096		
Depression	**Non-threatening**	MS	0.029	0.229	0.126	-0.420; 0.478	0.900	0.768(4)	0.546
		CTRL	-0.338	0.229	-1.473	-0.787; 0.112	0.141		
	Threatening	MS	0.123	0.229	0.536	-0.326; 0.572	0.592		
		CTRL	0.057	0.229	0.250	-0.392; 0.507	0.803		
Self-esteem	**Non-threatening**	MS	-0.269	0.192	-1.401	-0.646; 0.107	0.161	2.552(4)	0.037
		CTRL	0.136	0.192	0.706	-0.241; 0.512	0.480		
	Threatening	MS	-0.345	0.192	-1.796	-0.722; 0.031	0.073		
		CTRL	0.316	0.192	1.643	-0.061; 0.692	0.101		
AAS Anxious	**Non-threatening**	MS	-0.151	0.193	-0.781	-0.529; 0.228	0.435	2.803(4)	0.024
		CTRL	0.427	0.193	2.214	0.049; 0.805	0.027		
	Threatening	MS	-0.364	0.193	-1.886	-0.742; 0.014	0.059		
		CTRL	-0.069	0.193	-0.359	-0.447; 0.309	0.720		
AAS Close	**Non-threatening**	MS	-0.519	0.175	-2.970	-0.861; -0.176	0.003	5.389(4)	0.046
		CTRL	-0.199	0.175	-1.140	-0.542; 0.143	0.254		
	Threatening	MS	0.098	0.175	0.563	-0.244; 0.441	0.573		
		CTRL	0.468	0.175	2.680	0.126; 0.810	0.007		
AAS Depend	**Non-threatening**	MS	-0.348	0.185	-1.880	-0.711; 0.015	0.060	2.423(4)	0.046
		CTRL	-0.112	0.185	-0.606	-0.475; 0.251	0.545		
	Threatening	MS	-0.455	0.185	-2.458	-0.818; -0.092	0.014		
		CTRL	-0.346	0.185	-1.870	-0.709; 0.017	0.062		

Table 9-14. Changes in late theta activity associated with Mind-set, personality traits and level of Threat. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2 Experiment 2

9.2.1 STAI and PANAS results

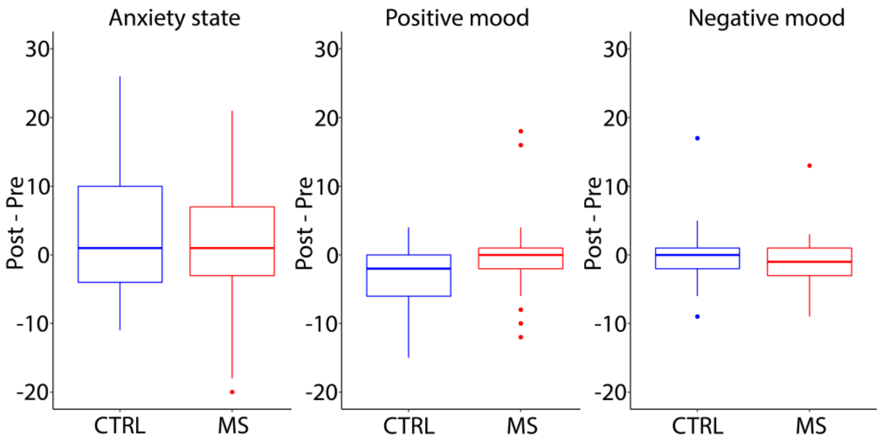

Figure 9-8. Differences between pre- and post-MM anxiety state, positive and negative mood in Experiment 2. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue – CTRL, red – MS. Note the similar central tendency before and after MM and across the two mind-sets.

9.2.1.1 Anxiety state

	Sum of Squares	df	Mean Square	F	p	ω^2
Mind-set	0.310	1	0.310	0.006	0.941	0.000
Residuals	1557.315	24	55.618	-	-	-
Time	1.940	1	1.940	0.053	0.820	0.000
Residuals	1027.435	24	36.694	-	-	-
Mind-set x Time	18.241	1	18.241	1.399	0.247	< 0.001
Residuals	365.134	24	13.040	-	-	-

Table 9-15. Results of the repeated measure ANOVA on the anxiety state scores in Experiment 2. No significant main effect or interaction has been found.

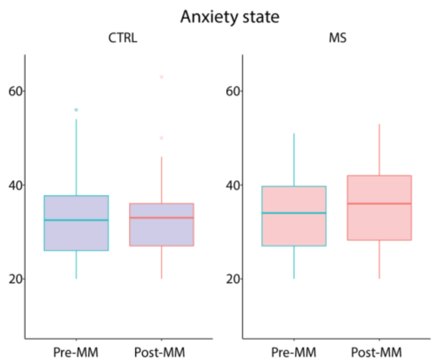

Figure 9-9. Difference between pre- and post-MM anxiety state scores in both Mind-set conditions in Experiment 2. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue fill– CTRL, red fill – MS, green contour – pre-MM, orange contour – post-MM.

9.2.1.2 Negative mood

	Sum of Squares	df	Mean Square	F	p	ω²
Mind-set	1.140	1	1.140	0.054	0.818	0.000
Residuals	590.422	28	21.087	-	-	-
Time	2.347	1	2.347	0.356	0.556	0.000
Residuals	184.716	28	6.597	-	-	-
Mind-set x Time	2.640	1	2.640	0.585	0.451	0.000
Residuals	126.422	28	4.515	-	-	-

Table 9-16. Results of the repeated measure ANOVA on the negative mood scores in Experiment 2. No significant main effect or interaction has been found.

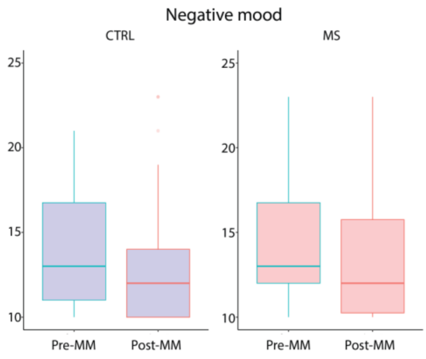

Figure 9-10. Difference between pre- and post-MM negative mood scores in both Mind-set conditions in Experiment 2. The boxes represent the interquartile range, the line within each box represents the median and the dots represent outliers. Blue fill– CTRL, red fill – MS, green contour – pre-MM, orange contour – post-MM.

9.2.2 Pain ratings

9.2.2.1 Assessment of the effect of Threat (Model 1)

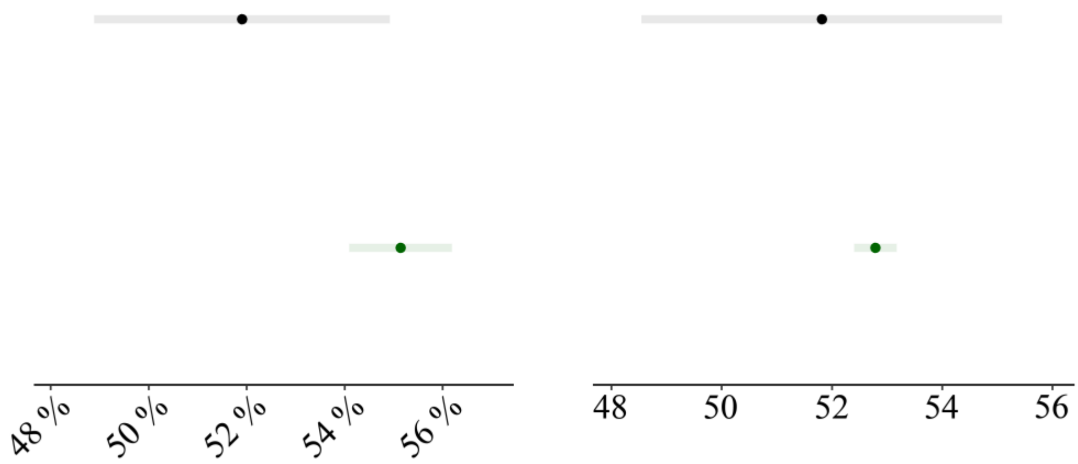

Figure 9-11. Main effect of Threat on normalised (left) and non-normalised (right) visual analogue scale (VAS) ratings in Experiment 2. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, green – Threat effect

9.2.2.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

			β	SE	t	95% CI	*p*	χ2(npar)	χ2 p
Intercept			53.091	1.530	34.704	50.093; 56.089	*< 0.001*	-	-
Non-threatening	MS		3.560	0.908	3.921	1.781; 5.340	< 0.001	85.807(4)	< 0.001
	CTRL		-4.872	0.908	-5.366	-6.651; -3.092	< 0.001		
Threatening	MS		6.584	0.908	7.251	4.804; 8.363	< 0.001		
	CTRL		-2.503	0.908	-2.757	-4.283; -0.724	0.006		
Fear of other's Death	Non-threatening	MS	0.379	1.441	0.263	-2.446; 3.204	0.793	5.058(4)	0.080
		CTRL	-3.240	1.442	-2.247	-6.065; -0.414	0.025		
	Threatening	MS	0.744	1.441	0.516	-2.081; 3.569	0.606		
		CTRL	-1.914	1.442	-1.327	-4.739; 0.912	0.184		
Anxiety	Non-threatening	MS	3.004	2.064	1.455	-1.042; 7.050	0.146	50.932(4)	< 0.001
		CTRL	11.707	2.065	5.669	7.659; 15.754	< 0.001		
	Threatening	MS	4.534	2.064	2.196	0.488; 8.580	0.028		
		CTRL	11.095	2.065	5.372	7.047; 15.142	< 0.001		
Depression	Non-threatening	MS	-8.385	1.488	-5.634	-11.302; -5.468	< 0.001	61.150(4)	< 0.001
		CTRL	-3.556	1.489	-2.389	-6.474; -0.638	0.017		
	Threatening	MS	-9.602	1.488	-6.451	-12.519; -6.685	< 0.001		
		CTRL	-2.425	1.489	-1.629	-5.343; 0.493	0.103		
Self-esteem	Non-threatening	MS	0.020	1.321	0.015	-2.568; 2.609	0.988	12.786(4)	0.002
		CTRL	4.505	1.321	3.410	1.916; 7.094	0.001		
	Threatening	MS	0.151	1.321	0.115	-2.437; 2.740	0.909		
		CTRL	3.178	1.321	2.405	0.588; 5.767	0.016		
AAS Anxious	Non-threatening	MS	2.559	1.918	1.334	-1.201; 6.319	0.182	5.196(4)	0.074
		CTRL	1.965	1.919	1.024	-1.797; 5.726	0.306		
	Threatening	MS	3.467	1.918	1.807	-0.293; 7.227	0.071		
		CTRL	1.817	1.919	0.947	-1.945; 5.578	0.344		
AAS Close	Non-threatening	MS	3.139	1.445	2.172	0.307; 5.970	0.030	17.601(4)	< 0.001
		CTRL	3.977	1.445	2.752	1.144; 6.809	0.006		
	Threatening	MS	2.876	1.445	1.991	0.045; 5.708	0.047		
		CTRL	3.889	1.445	2.691	1.057; 6.722	0.007		
AAS Dependent	Non-threatening	MS	-0.672	1.666	-0.403	-3.937; 2.594	0.687	1.911(4)	0.385
		CTRL	-3.635	1.667	-2.181	-6.902; -0.369	0.029		
	Threatening	MS	1.571	1.666	0.943	-1.695; 4.836	0.346		
		CTRL	-0.010	1.667	-0.006	-3.277; 3.257	0.995		

Table 9-17. Changes in pain ratings associated with Mind-set, personality traits and level of Threat in Experiment 2. 95% CIs were calculated by Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3 Somatosensory-evoked potentials

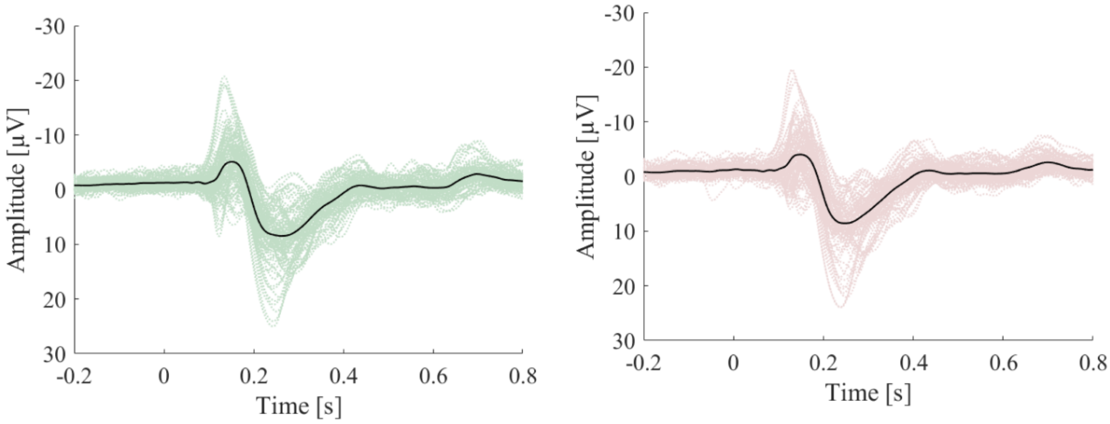

Figure 9-12. Pre- (left) and post-MM (right) SEPs in Experiment 2. Coloured dotted lines show the single subject SEPs and the solid black line represents the average SEP for both Time conditions.

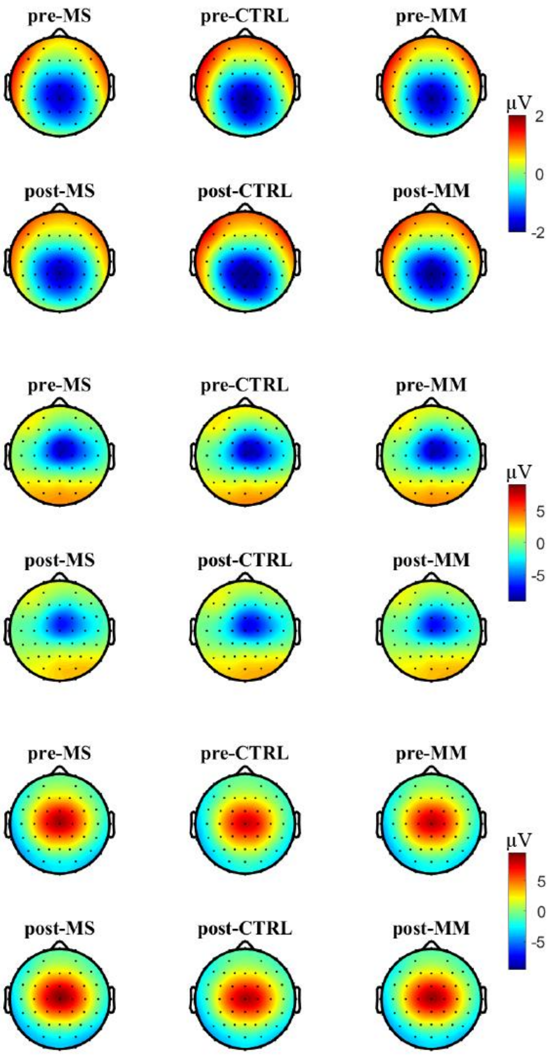

Figure 9-13. Topographies of the N1 component (top), the N2 component (middle) and the P2 component (bottom) identified by the linear mixed-effects models in Experiment 2.

9.2.3.1 The modulatory role of Personality on Mind-set (Model 2)

9.2.3.1.1 N1

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		-0.608	0.082	-7.379	-0.770; -0.447	< 0.001	-	-
MS		0.011	0.109	0.100	-0.203; 0.225	0.920	0.450(2)	0.799
CTRL		-0.064	0.109	-0.591	-0.278; 0.149	0.554		
Fear of other's Death	MS	-0.010	0.156	-0.066	-0.316; 0.296	0.947	0.108(2)	0.947
	CTRL	0.042	0.156	0.270	-0.264; 0.348	0.787		
Anxiety	MS	-0.564	0.224	-2.522	-1.003; -0.126	0.012	12.331(2)	0.002
	CTRL	0.441	0.224	1.970	0.002; 0.879	0.049		
Depression	MS	0.079	0.161	0.492	-0.237; 0.395	0.623	1.016(2)	0.602
	CTRL	-0.128	0.161	-0.793	-0.444; 0.188	0.428		
Self-esteem	MS	0.028	0.143	0.198	-0.252; 0.309	0.843	2.539(2)	0.281
	CTRL	0.226	0.143	1.579	-0.054; 0.507	0.115		
AAS Anxious	MS	0.390	0.208	1.874	-0.018; 0.797	0.061	3.476(2)	0.176
	CTRL	-0.020	0.208	-0.095	-0.427; 0.388	0.924		
AAS Close	MS	-0.477	0.157	-3.049	-0.784; -0.171	0.002	11.706(2)	0.003
	CTRL	0.151	0.157	0.964	-0.156; 0.458	0.335		
AAS Dependent	MS	0.145	0.181	0.801	-0.209; 0.499	0.423	1.712(2)	0.425
	CTRL	-0.159	0.181	-0.881	-0.513; 0.195	0.379		

Table 9-18. Changes in N1 amplitude associated with Mind-set and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3.1.2 N2

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		-4.639	0.862	-5.383	-6.328; -2.950	< 0.001	-	-
MS		1.249	0.161	7.751	0.933; 1.564	< 0.001	91.814(2)	< 0.001
CTRL		0.948	0.161	5.884	0.632; 1.263	< 0.001		
Fear of other's Death	MS	-0.060	0.257	-0.232	-0.562; 0.443	0.816	0.139(2)	0.933
	CTRL	-0.078	0.257	-0.303	-0.581; 0.426	0.762		
Anxiety	MS	-0.471	0.368	-1.281	-1.191; 0.249	0.200	1.836(2)	0.399
	CTRL	0.161	0.368	0.438	-0.560; 0.882	0.661		
Depression	MS	-0.229	0.265	-0.863	-0.748; 0.291	0.388	2.011(2)	0.366
	CTRL	-0.305	0.265	-1.150	-0.825; 0.215	0.250		
Self-esteem	MS	-0.359	0.235	-1.525	-0.819; 0.102	0.127	9.112(2)	0.011
	CTRL	-0.621	0.235	-2.639	-1.083; -0.160	0.008		
AAS Anxious	MS	0.509	0.342	1.490	-0.160; 1.178	0.136	2.190(2)	0.335
	CTRL	0.018	0.342	0.053	-0.652; 0.688	0.958		
AAS Close	MS	-0.035	0.257	-0.136	-0.539; 0.469	0.892	11.459(2)	0.003
	CTRL	0.870	0.257	3.377	0.365; 1.374	0.001		
AAS Dependent	MS	-0.191	0.297	-0.644	-0.772; 0.390	0.519	1.126(2)	0.569
	CTRL	-0.257	0.297	-0.866	-0.839; 0.325	0.387		

Table 9-19. Changes in N2 component amplitude associated with Mind-set and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3.1.3 P2

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		6.560	0.782	8.392	5.028; 8.092	< 0.001	-	-
MS		0.445	0.164	2.703	0.122; 0.767	0.007	12.756(2)	0.002
CTRL		0.395	0.164	2.403	0.073; 0.718	0.016		
Fear of other's Death	MS	0.052	0.262	0.197	-0.463; 0.566	0.844	0.501(2)	0.779
	CTRL	-0.176	0.261	-0.674	-0.688; 0.336	0.501		
Anxiety	MS	-0.489	0.376	-1.302	-1.226; 0.247	0.193	8.646(2)	0.013
	CTRL	-1.002	0.374	-2.678	-1.735; -0.269	0.007		
Depression	MS	-0.290	0.271	-1.070	-0.821; 0.241	0.285	6.103(2)	0.047
	CTRL	-0.607	0.270	-2.249	-1.136; -0.078	0.025		
Self-esteem	MS	0.237	0.240	0.987	-0.234; 0.709	0.324	2.093(2)	0.351
	CTRL	0.260	0.239	1.085	-0.209; 0.729	0.278		
AAS Anxious	MS	0.732	0.349	2.096	0.048; 1.417	0.036	13.743(2)	0.001
	CTRL	1.082	0.348	3.111	0.400; 1.763	0.002		
AAS Close	MS	0.273	0.263	1.036	-0.243; 0.788	0.300	9.538(2)	0.009
	CTRL	-0.761	0.262	-2.907	-1.275; -0.248	0.004		
AAS Dependent	MS	-0.192	0.303	-0.633	-0.787; 0.403	0.527	0.471(2)	0.790
	CTRL	-0.085	0.302	-0.280	-0.676; 0.507	0.780		

Table 9-20. Changes in P2 amplitude associated with Mind-set and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

9.2.3.2.1 N1

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			-0.608	0.082	-7.379	-0.770; -0.447	< 0.001	-	-
Non-threatening	MS		0.024	0.141	0.171	-0.252; 0.300	0.864	0.774(4)	0.942
	CTRL		-0.113	0.141	-0.804	-0.389; 0.163	0.421		
Threatening	MS		-0.002	0.141	-0.015	-0.278; 0.274	0.988		
	CTRL		-0.016	0.141	-0.112	-0.292; 0.260	0.911		
Fear of other's Death	**Non-threatening**	MS	0.217	0.211	1.030	-0.196; 0.631	0.303	3.390(4)	0.495
		CTRL	-0.076	0.211	-0.362	-0.490; 0.337	0.717		
	Threatening	MS	-0.238	0.211	-1.128	-0.652; 0.176	0.259		
		CTRL	0.161	0.211	0.762	-0.253; 0.575	0.446		
Anxiety	**Non-threatening**	MS	-1.058	0.302	-3.499	-1.651; -0.466	0.000	18.857(4)	0.001
		CTRL	0.597	0.302	1.973	0.004; 1.189	0.049		
	Threatening	MS	-0.070	0.302	-0.232	-0.663; 0.523	0.817		
		CTRL	0.285	0.302	0.942	-0.308; 0.878	0.346		
Depression	**Non-threatening**	MS	0.142	0.218	0.650	-0.286; 0.569	0.516	1.576(4)	0.813
		CTRL	-0.038	0.218	-0.176	-0.466; 0.389	0.861		
	Threatening	MS	0.017	0.218	0.077	-0.411; 0.444	0.939		
		CTRL	-0.217	0.218	-0.998	-0.645; 0.210	0.319		
Self-esteem	**Non-threatening**	MS	-0.156	0.193	-0.805	-0.535; 0.223	0.421	6.581(4)	0.160
		CTRL	0.041	0.193	0.211	-0.338; 0.420	0.833		
	Threatening	MS	0.212	0.193	1.098	-0.167; 0.592	0.272		
		CTRL	0.411	0.193	2.125	0.032; 0.790	0.034		
AAS Anxious	**Non-threatening**	MS	0.487	0.281	1.735	-0.063; 1.038	0.083	3.803(4)	0.443
		CTRL	-0.060	0.281	-0.213	-0.611; 0.491	0.831		
	Threatening	MS	0.292	0.281	1.038	-0.259; 0.843	0.299		
		CTRL	0.020	0.281	0.073	-0.530; 0.571	0.942		
AAS Close	**Non-threatening**	MS	-0.829	0.212	-3.916	-1.244; -0.414	0.000	18.705(4)	0.001
		CTRL	0.284	0.212	1.340	-0.131; 0.698	0.180		
	Threatening	MS	-0.126	0.212	-0.595	-0.541; 0.289	0.552		
		CTRL	0.018	0.212	0.086	-0.397; 0.433	0.931		
AAS Dependent	**Non-threatening**	MS	0.434	0.244	1.779	-0.044; 0.913	0.075	4.908(4)	0.297
		CTRL	-0.203	0.244	-0.832	-0.681; 0.275	0.406		
	Threatening	MS	-0.145	0.244	-0.594	-0.623; 0.334	0.553		
		CTRL	-0.115	0.244	-0.472	-0.594; 0.363	0.637		

Table 9-21. Changes in N1 amplitude associated with Mind-set, Threat and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3.2.2 N2

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			-4.639	0.862	-5.383	-6.328; -2.950	< 0.001	-	-
Non-threatening		MS	1.266	0.198	6.392	0.877; 1.654	< 0.001	94.441(4)	< 0.001
		CTRL	0.776	0.198	3.920	0.388; 1.164	< 0.001		
Threatening		MS	1.232	0.198	6.220	0.843; 1.620	< 0.001		
		CTRL	1.119	0.198	5.654	0.731; 1.507	< 0.001		
Fear of other's Death	**Non-threatening**	MS	-0.063	0.316	-0.199	-0.681; 0.556	0.842	0.365(4)	0.985
		CTRL	0.009	0.316	0.028	-0.610; 0.628	0.977		
	Threatening	MS	-0.056	0.316	-0.178	-0.675; 0.562	0.859		
		CTRL	-0.165	0.316	-0.523	-0.784; 0.454	0.601		
Anxiety	**Non-threatening**	MS	-0.454	0.452	-1.004	-1.340; 0.432	0.316	3.135(4)	0.536
		CTRL	-0.136	0.452	-0.302	-1.023; 0.750	0.763		
	Threatening	MS	-0.488	0.452	-1.081	-1.374; 0.397	0.280		
		CTRL	0.459	0.452	1.015	-0.427; 1.346	0.310		
Depression	**Non-threatening**	MS	-0.334	0.326	-1.024	-0.972; 0.305	0.306	2.406(4)	0.662
		CTRL	-0.358	0.326	-1.098	-0.997; 0.281	0.272		
	Threatening	MS	-0.124	0.326	-0.379	-0.762; 0.515	0.704		
		CTRL	-0.252	0.326	-0.772	-0.891; 0.387	0.440		
Self-esteem	**Non-threatening**	MS	-0.431	0.289	-1.489	-0.997; 0.136	0.137	17.935(4)	0.001
		CTRL	-0.127	0.289	-0.439	-0.694; 0.440	0.660		
	Threatening	MS	-0.286	0.289	-0.990	-0.853; 0.280	0.322		
		CTRL	-1.115	0.289	-3.854	-1.682; -0.548	< 0.001		
AAS Anxious	**Non-threatening**	MS	0.641	0.420	1.526	-0.182; 1.464	0.127	3.275(4)	0.513
		CTRL	0.234	0.420	0.557	-0.590; 1.058	0.578		
	Threatening	MS	0.377	0.420	0.897	-0.446; 1.200	0.370		
		CTRL	-0.198	0.420	-0.471	-1.022; 0.626	0.638		
AAS Close	**Non-threatening**	MS	0.286	0.316	0.903	-0.334; 0.906	0.367	21.608(4)	< 0.001
		CTRL	0.379	0.317	1.199	-0.241; 1.000	0.231		
	Threatening	MS	-0.355	0.316	-1.124	-0.975; 0.264	0.261		
		CTRL	1.360	0.317	4.296	0.739; 1.980	< 0.001		
AAS Dependent	**Non-threatening**	MS	-0.341	0.365	-0.935	-1.056; 0.374	0.350	1.937(4)	0.747
		CTRL	-0.140	0.365	-0.383	-0.855; 0.576	0.702		
	Threatening	MS	-0.041	0.365	-0.113	-0.756; 0.674	0.910		
		CTRL	-0.374	0.365	-1.026	-1.090; 0.341	0.305		

Table 9-22. Changes in N2 amplitude associated with Mind-set, Threat and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.3.2.3 P2

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			6.560	0.782	8.392	5.028; 8.092	< 0.001	-	-
Non-threatening		MS	0.443	0.202	2.189	0.046; 0.840	0.029	12.834(4)	0.012
		CTRL	0.446	0.202	2.205	0.050; 0.843	0.027		
Threatening		MS	0.369	0.202	1.822	-0.028; 0.765	0.068		
		CTRL	0.422	0.202	2.084	0.025; 0.818	0.037		
Fear of other's Death	Non-threatening	MS	0.260	0.323	0.805	-0.373; 0.893	0.421	1.744(4)	0.783
		CTRL	-0.155	0.322	-0.483	-0.786; 0.476	0.629		
	Threatening	MS	-0.156	0.323	-0.485	-0.789; 0.476	0.628		
		CTRL	-0.197	0.322	-0.611	-0.827; 0.434	0.541		
Anxiety	Non-threatening	MS	-0.427	0.462	-0.922	-1.333; 0.480	0.356	8.886(4)	0.064
		CTRL	-0.893	0.461	-1.937	-1.797; 0.011	0.053		
	Threatening	MS	-0.552	0.462	-1.193	-1.458; 0.355	0.233		
		CTRL	-1.111	0.461	-2.409	-2.015; -0.207	0.016		
Depression	Non-threatening	MS	-0.407	0.333	-1.220	-1.060; 0.247	0.223	7.947(4)	0.094
		CTRL	-0.372	0.332	-1.119	-1.023; 0.280	0.263		
	Threatening	MS	-0.173	0.333	-0.519	-0.826; 0.480	0.604		
		CTRL	-0.842	0.332	-2.532	-1.493; -0.190	0.011		
Self-esteem	Non-threatening	MS	0.057	0.296	0.191	-0.523; 0.636	0.848	3.486(4)	0.480
		CTRL	0.352	0.295	1.192	-0.227; 0.930	0.233		
	Threatening	MS	0.418	0.296	1.412	-0.162; 0.998	0.158		
		CTRL	0.168	0.295	0.569	-0.410; 0.746	0.569		
AAS Anxious	Non-threatening	MS	0.704	0.43	1.638	-0.138; 1.546	0.101	14.692(4)	0.005
		CTRL	0.844	0.428	1.970	0.004; 1.684	0.049		
	Threatening	MS	0.760	0.430	1.769	-0.082; 1.603	0.077		
		CTRL	1.320	0.428	3.080	0.480; 2.160	0.002		
AAS Close	Non-threatening	MS	0.521	0.324	1.611	-0.113; 1.156	0.107	11.924(4)	0.018
		CTRL	-0.909	0.323	-2.817	-1.542; -0.277	0.005		
	Threatening	MS	0.024	0.324	0.074	-0.610; 0.658	0.941		
		CTRL	-0.614	0.323	-1.901	-1.246; 0.019	0.057		
AAS Dependent	Non-threatening	MS	-0.263	0.373	-0.705	-0.995; 0.468	0.481	1.230(4)	0.873
		CTRL	0.090	0.372	0.243	-0.639; 0.820	0.808		
	Threatening	MS	-0.121	0.373	-0.324	-0.852; 0.611	0.746		
		CTRL	-0.259	0.372	-0.697	-0.989; 0.470	0.486		

Table 9-23. Changes in P2 amplitude associated with Mind-set, Threat and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.4 Time-frequency analysis

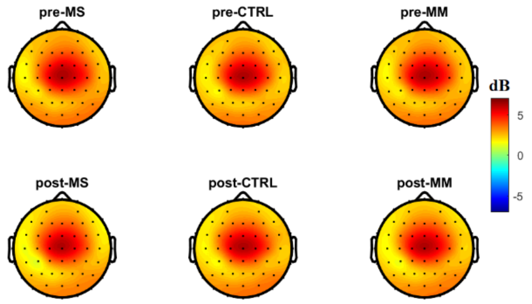

Figure 9-14. Topography of theta AOI in Experiment 2. The change in power from pre- to post-MM was influenced by close attachment type scores.

9.2.4.1 The modulatory role of Personality on Mind-set (Model 2)

		β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept		0.424	0.311	1.365	-0.185; 1.033	0.183	-	-
MS		-0.282	0.093	-3.044	-0.464; -0.100	0.002	61.341(2)	< 0.001
CTRL		-0.022	0.093	-0.241	-0.204; 0.159	0.810		
Fear of Death	MS	0.302	0.148	2.049	0.013; 0.592	0.041	4.224(2)	0.121
	CTRL	0.041	0.147	0.279	-0.247; 0.329	0.781		
Anxiety	MS	-0.584	0.211	-2.761	-0.998; -0.169	0.006	8.614(2)	0.013
	CTRL	0.183	0.211	0.867	-0.230; 0.596	0.386		
Depression	MS	-0.337	0.152	-2.210	-0.636; -0.038	0.027	12.412(2)	0.002
	CTRL	-0.432	0.152	-2.841	-0.729; -0.134	0.005		
Self-esteem	MS	-0.048	0.135	-0.353	-0.313; 0.217	0.724	1.975(2)	0.372
	CTRL	0.180	0.135	1.339	-0.084; 0.445	0.181		
AAS Anxious	MS	0.582	0.196	2.960	0.197; 0.967	0.003	11.661(2)	0.003
	CTRL	0.360	0.196	1.839	-0.024; 0.744	0.066		
AAS Close	MS	-0.377	0.148	-2.551	-0.667; -0.087	0.011	10.873(2)	0.004
	CTRL	0.291	0.147	1.973	0.002; 0.580	0.049		
AAS Depend	MS	0.397	0.171	2.329	0.063; 0.732	0.020	6.098(2)	0.047
	CTRL	0.167	0.170	0.981	-0.166; 0.500	0.326		

Table 9-24. Changes in theta activity associated with Mind-set and personality traits in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

9.2.4.2 The modulatory role of Personality on the interaction between Mind-set and Threat (Model 3)

			β	SE	t	95% CI	*p*	χ^2(npar)	χ^2 *p*
Intercept			0.424	0.311	1.365	-0.185; 1.033	0.183	-	-
Non-threatening		MS	-0.380	0.114	-3.320	-0.604; -0.155	0.001	95.433(4)	< 0.001
		CTRL	-0.043	0.114	-0.375	-0.267; 0.181	0.708		
Threatening		MS	-0.185	0.114	-1.615	-0.409; 0.039	0.106		
		CTRL	-0.002	0.114	-0.014	-0.226; 0.222	0.989		
Fear of Death	**Non-threatening**	MS	0.571	0.182	3.134	0.214; 0.928	0.002	11.528(4)	0.021
		CTRL	-0.065	0.182	-0.355	-0.421; 0.292	0.723		
	Threatening	MS	0.034	0.182	0.185	-0.324; 0.391	0.854		
		CTRL	0.147	0.182	0.808	-0.210; 0.503	0.419		
Anxiety	**Non-threatening**	MS	-0.974	0.261	-3.730	-1.485; -0.462	0.000	15.246(4)	0.004
		CTRL	0.236	0.260	0.906	-0.275; 0.746	0.365		
	Threatening	MS	-0.194	0.261	-0.743	-0.706; 0.318	0.458		
		CTRL	0.130	0.260	0.497	-0.381; 0.640	0.619		
Depression	**Non-threatening**	MS	-0.266	0.188	-1.415	-0.635; 0.103	0.157	12.881(4)	0.012
		CTRL	-0.433	0.188	-2.307	-0.801; -0.065	0.021		
	Threatening	MS	-0.408	0.188	-2.166	-0.776; -0.039	0.030		
		CTRL	-0.430	0.188	-2.289	-0.798; -0.062	0.022		
Self-esteem	**Non-threatening**	MS	-0.268	0.167	-1.607	-0.596; 0.059	0.108	7.599(4)	0.107
		CTRL	0.107	0.167	0.645	-0.219; 0.434	0.519		
	Threatening	MS	0.173	0.167	1.035	-0.155; 0.500	0.301		
		CTRL	0.253	0.167	1.520	-0.073; 0.580	0.129		
AAS Anxious	**Non-threatening**	MS	0.509	0.243	2.098	0.033; 0.984	0.036	12.083(4)	0.017
		CTRL	0.405	0.242	1.675	-0.069; 0.880	0.094		
	Threatening	MS	0.654	0.243	2.698	0.179; 1.130	0.007		
		CTRL	0.314	0.242	1.299	-0.160; 0.789	0.194		
AAS Close	**Non-threatening**	MS	-0.793	0.183	-4.343	-1.151; -0.435	0.000	33.591(4)	< 0.001
		CTRL	0.588	0.182	3.226	0.231; 0.945	0.001		
	Threatening	MS	0.038	0.183	0.209	-0.320; 0.396	0.834		
		CTRL	-0.006	0.182	-0.033	-0.363; 0.351	0.974		
AAS Depend	**Non-threatening**	MS	0.618	0.211	2.933	0.205; 1.031	0.003	12.504(4)	0.014
		CTRL	-0.054	0.210	-0.258	-0.466; 0.358	0.796		
	Threatening	MS	0.177	0.211	0.841	-0.236; 0.590	0.400		
		CTRL	0.388	0.210	1.846	-0.024; 0.800	0.065		

Table 9-25. Changes in theta activity associated with Mind-set, personality traits and level of Threat in Experiment 2. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations. All scores were centred as z-scores for the analysis.

10 Appendix for Study 2

10.1 Anxiety and mood

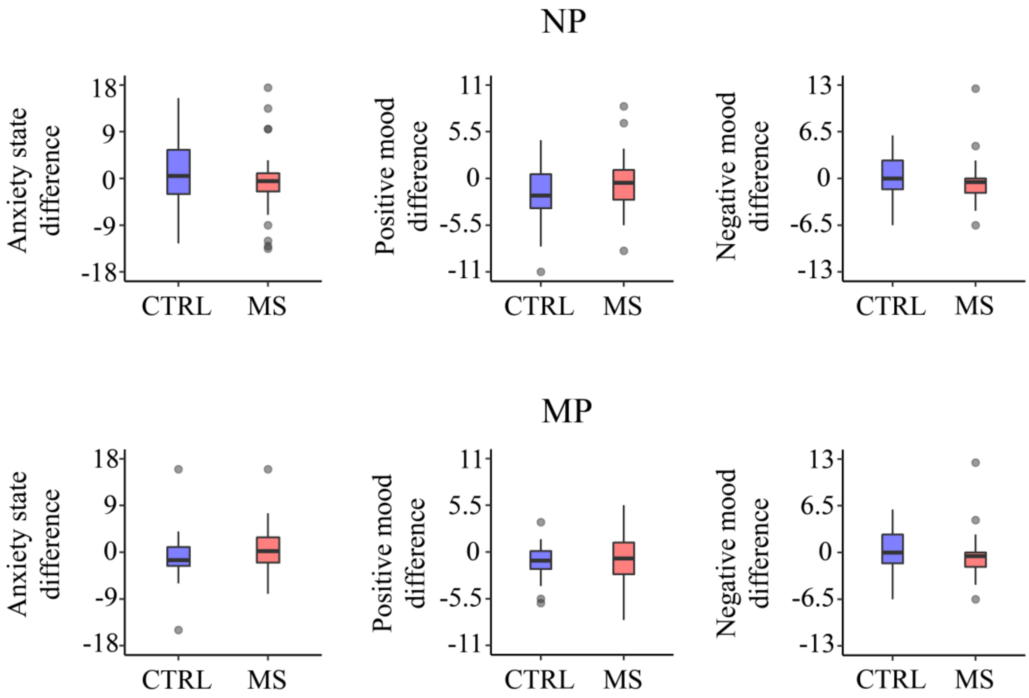

Figure 10-1. Differences of anxiety state (left), positive mood (middle) and negative mood (right) between pre- and post-MM for NP (top) and MP (bottom). The boxes represent the interquartile range, the line within the each box represents the median and the dots represent outliers. Blue – CTRL, red – MS. Note the similar central tendency before and after MM and across the two mind-sets.

10.1.1 Anxiety state

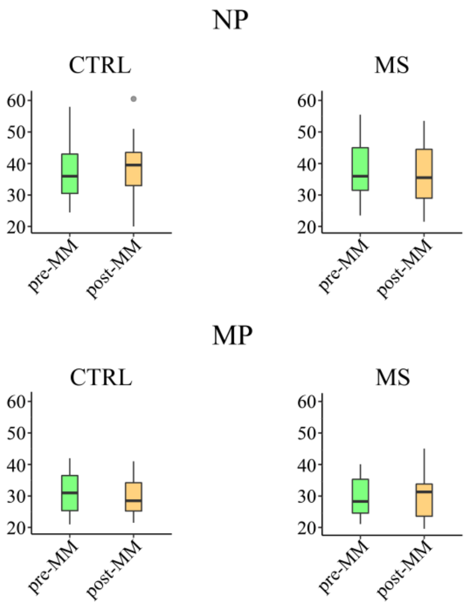

Figure 10-2. Difference between pre- (green) and post-MM (orange) anxiety state scores in both Mind-set conditions for NP (top) and MP (bottom). The boxes represent the interquartile range, the line within the each box represents the median and the dots represent outliers.

Cases	Sum of Squares	df	Mean Square	F	p	ω^2
Time	0.313	1	0.313	0.013	0.910	0.000
Time x ME	1.728	1	1.728	0.071	0.791	0.000
Residuals	1246.050	51	24.432	-	-	-
Mind-set	0.139	1	0.139	0.009	0.924	0.000
Mind-set x ME	37.459	1	37.459	2.503	0.120	0.002
Residuals	763.248	51	14.966	-	-	-
Time x Mind-set	0.958	1	0.958	0.027	0.871	0.000
Time x Mind-set x ME	0.052	1	0.052	0.001	0.970	0.000
Residuals	1830.023	51	35.883	-	-	-

Table 10-1. Within-subject results of the 2 x 2 x 2 repeated measure ANOVA on the anxiety state scores. We investigated how state anxiety scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels. Note the absence of main effect or interaction.

Cases	Sum of Squares	df	Mean Square	F	p	ω^2
ME	2654.815	1	2654.815	14.993	<0.001	0.119
Residuals	9030.756	51	177.074	-	-	-

Table 10-2. Between-subject results of the 2 x 2 x 2 repeated measure ANOVA on the anxiety state scores. We investigated how state anxiety scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels.

10.1.2 Positive mood

Cases	Sum of Squares	df	Mean Square	F	p	ω^2
ME	2289.279	1	2289.279	11.118	0.002	0.089
Residuals	10501.158	51	205.905	-	-	-

Table 10-3. Between-subject results of the 2 x 2 x 2 repeated measure ANOVA on the positive mood scores. We investigated how positive mood scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels.

10.1.3 Negative mood

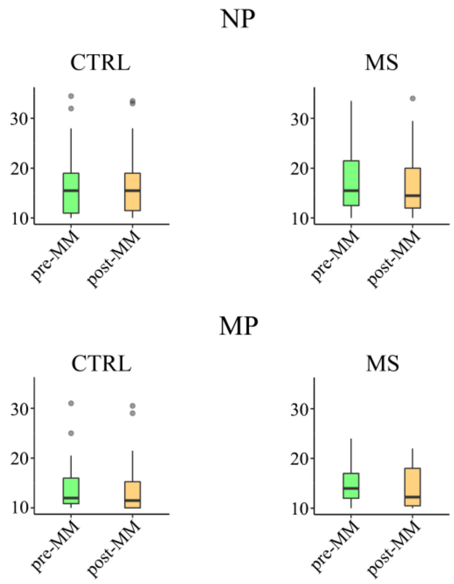

Figure 10-3. Difference between pre- (green) and post-MM (orange) negative mood scores in both Mind-set conditions for NP (top) and MP (bottom). The boxes represent the interquartile range, the line within the each box represents the median and the dots represent outliers.

Cases	Sum of Squares	df	Mean Square	F	p	ω^2
Time	11.366	1	11.366	2.472	0.122	0.001
Time x ME	1.715	1	1.715	0.373	0.544	0.000
Residuals	234.455	51	4.597	-	-	-
Mind-set	3.711	1	3.711	0.159	0.692	0.000
Mind-set x ME	0.240	1	0.240	0.010	0.920	0.000
Residuals	1189.756	51	23.329	-	-	-
Time x Mind-set	7.176	1	7.176	1.969	0.167	< 0.001
Time x Mind-set x ME	0.242	1	0.242	0.066	0.798	0.000
Residuals	185.829	51	3.644	-	-	-

Table 10-4. Within-subject results of the 2 x 2 x 2 repeated measure ANOVA on the negative mood scores. We investigated how negative mood scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels. Note the absence of main effect or interaction.

Cases	Sum of Squares	df	Mean Square	F	p	ω²
ME	399.532	1	399.532	3.981	0.051	0.028
Residuals	5118.751	51	100.368	-	-	-

Table 10-5. Between-subject results of the 2 x 2 x 2 repeated measure ANOVA on the negative mood scores. We investigated how negative mood scores are different between Time (pre/post), Mind-set (CTRL/MS) and Meditation experience (ME, NP/MP) levels. Note the absence of main effect or interaction.

10.2 Pain ratings

10.2.1 Assessment of the effect of Threat (Model 1)

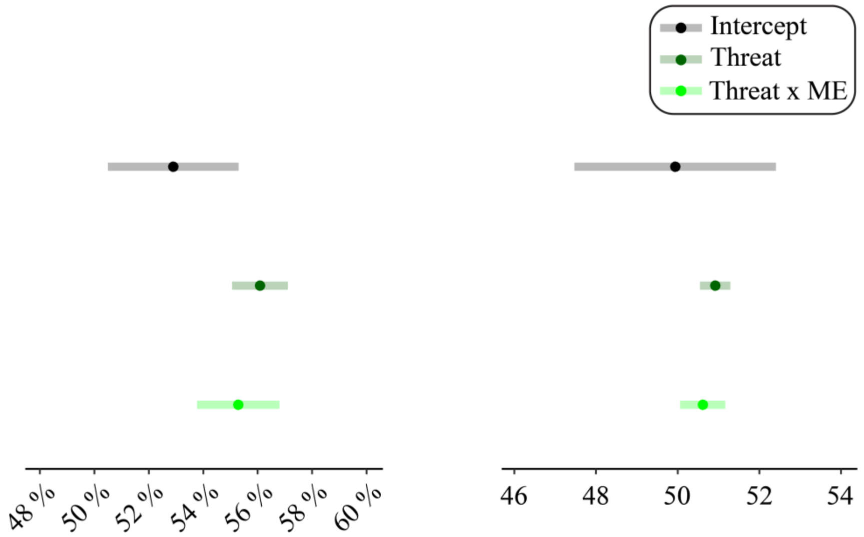

Figure 10-4. Main effect of Threat and interaction between Threat and Meditation experience (ME) on normalised (left) and non-normalised (right) visual analogue scale (VAS) ratings. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, dark green – Threat effect, light green – Threat x ME interaction

10.2.2 Assessment of the effect of Mind-set on Time (Model 2)

	β	SE	t-value	95% CIs	*p-value*
Intercept	54.531	1.227	44.446	52.126; 56.935	< 0.001
Time	-3.683	0.735	-5.014	-5.122; -2.243	< 0.001
Time x Mind-set	8.639	1.031	8.378	6.618; 10.660	< 0.001
Time x ME	1.658	1.087	1.525	-0.472; 3.788	< 0.127
Time x Mind-set x ME	-6.623	1.532	-4.323	-9.626; -3.620	< 0.001

Table 10-6. Summary of Model 2 partitioning the effects of Time, Mind-set and Meditation experience (ME) on the normalised visual analogue scale (VAS) ratings. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

10.2.3 Assessing effect of Threat on the interaction between Mind-set and Time (Model 3)

	β	SE	t-value	95% CIs	*p-value*
Intercept	54.530	1.227	44.446	52.126; 56.935	< 0.001
Time	-3.683	0.734	-5.016	-5.122; -2.244	< 0.001
Time x Mind-set	7.127	1.158	6.158	4.859; 9.396	< 0.001
Time x Mind-set x Threat	3.024	1.053	2.871	0.960; 5.088	0.004
Time x ME	1.658	1.087	1.526	-0.472; 3.788	0.127
Time x Mind-set x ME	-5.861	1.720	-3.408	-9.233; -2.490	0.001
Time x Mind-set x Threat x ME	-1.524	1.565	-0.974	-4.591; 1.544	0.330

Table 10-7. Summary of Model 3 partitioning the effects of Time, Mind-set, Threat and Meditation experience (ME) on the normalised visual analogue scale (VAS) ratings. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

10.3Brain oscillations

<u>10.3.1.1 Assessing the effects of Mind-set on Time (Model 2)</u>

10.3.1.1.1 Theta

	β	SE	t-value	95% CIs	*p-value*
Intercept	-0.221	0.230	-0.960	-0.673; 0.230	0.342
Time	-0.155	0.104	-1.480	-0.359; 0.050	0.139
Time x Mind-set	0.101	0.142	0.713	-0.177; 0.379	0.476
Time x ME	-0.146	0.155	-0.942	-0.449; 0.157	0.346
Time x Mind-set x ME	0.189	0.211	0.896	-0.224; 0.601	0.370

Table 10-8. Summary of Model 2 partitioning the effects of Time, Mind-set and Meditation experience (ME) on the theta activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

10.3.1.1.2 Late low alpha

	β	SE	t-value	95% CIs	*p-value*
Intercept	-2.988	0.211	-14.194	-3.401; -2.576	< 0.001
Time	0.000	0.085	0.001	-0.167; 0.168	0.999
Time x Mind-set	-0.196	0.113	-1.726	-0.418; 0.027	0.085
Time x ME	-0.032	0.127	-0.252	-0.281; 0.217	0.801
Time x Mind-set x ME	0.507	0.169	3.010	0.177; 0.838	0.003

Table 10-9. Summary of Model 2 partitioning the effects of Time, Mind-set and Meditation experience (ME) on the late low alpha activity. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

10.4 Somatosensory-evoked potentials

We did not include our SEP findings into our submitted paper (Gyimes & Valentini, 2021b) as we focused on the time-frequency domain. I provide further reasoning for this decision in Section 7. The SEP results are detailed below to balance the narrative of the thesis. However, it is important to stress that the event-induced oscillatory activity of the brain holds more information about neural processes compared to SEPs (Buzsáki, 2011).

By applying our models, we identified 2 IOIs corresponding to two ascending parts of the P2 component: P218 (180 – 256ms) IOI was identified by the consecutive significant interaction between Time x Meditation experience (Appendix Figure 10-7, purple); P245 (230 – 260ms) IOI was identified by the consecutive significant interaction between Time x Mind-set (Appendix Figure 10-7, pink). We applied Model 1, 2 and 3 on the average values within these IOIs to report our findings. Single-subject SEPs showcasing the variability of the data is represented in the Appendix Figure 10-5 with the corresponding topographies in the Appendix Figure 10-6.

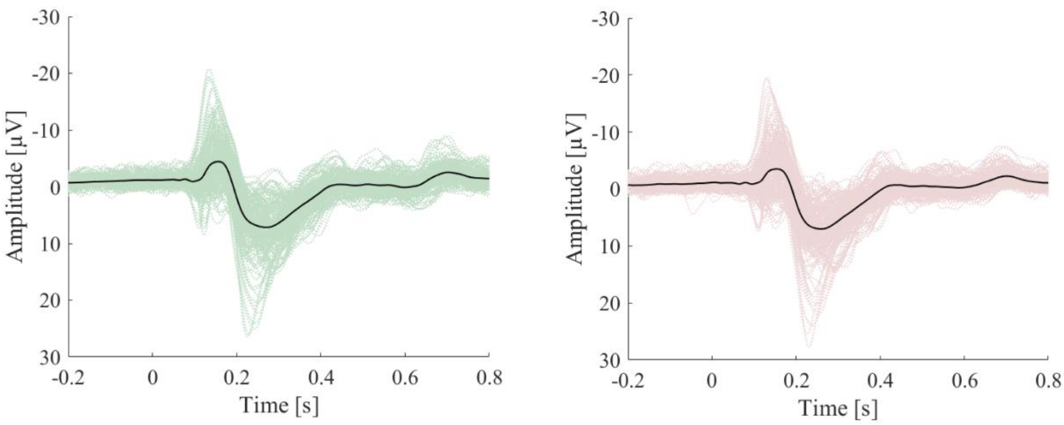

Figure 10-5. Pre- (left) and post-MM (right) SEPs. Coloured dotted lines show the single subject SEPs and the solid black line represents the average SEP for both Time conditions.

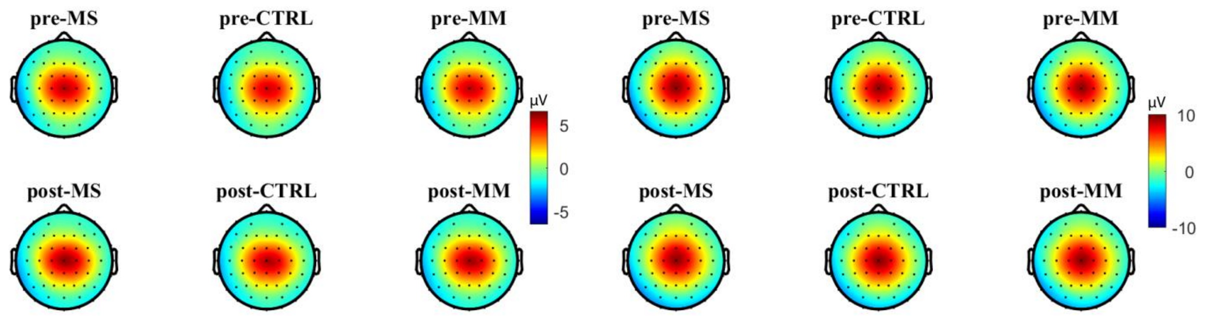

Figure 10-6. Topographies of the P518 wave (left) and the P245 wave (right) identified by the linear mixed-effects models.

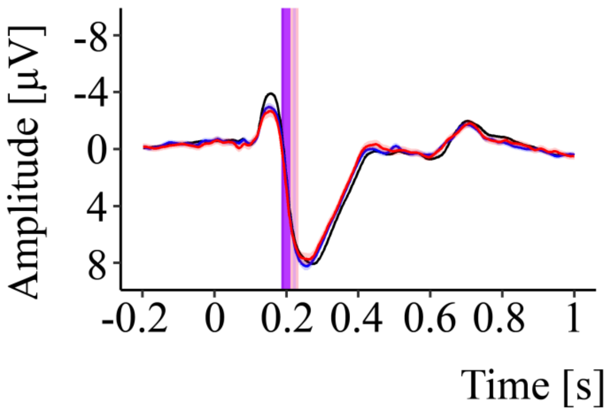

Figure 10-7. The IOIs identified by the LMM method. The lines represent the pre-MM (β_0, intercept, black), post-MS (β_{MS}, red) and post-CTRL (β_{CTRL}, blue) SEPs. The P218 wave (180 – 256ms, purple) was identified by the significant interaction between Time x Mind-set. The P245 wave (230 – 260ms, pink) emerged the interaction between Time x Meditation experience.

There was no main effect of Threat on the identified SEP components. While the P218 wave showed a significant increase post-CTRL for the non-meditation practitioners, meditation practitioners showed no change in Time (Appendix Table 10-10). P245 amplitude decreased significantly post-MS compared to post-CTRL. Similarly, meditation practitioners showed a significant decrease in P245 amplitude in CTRL condition compared to non-practitioners (Appendix Table 10-11). We did not find any significant interaction involving Threat (Appendix Table 10-12 &Table 10-13).

10.4.1.1.1 Assessment of the effect of Threat (Model 1)

10.4.1.1.1.1 P218

The random slope improved the model's fit ($\chi^2(2) = 1076.339$, $p < 0.001$). We found no significant effect of Threat on the P218 amplitude ($\chi^2(1) = 0.758$, $p = 0.384$) or interaction between Threat and Meditation experience ($\chi^2(1) = 0.011$, $p = 0.918$). The model estimated the intercept at 4.569 ± 0.483 µV (t = 9.452, 95% CI: [3.622; 5.517], $p < 0.001$, $R^2_{marginal} < 0.001$, $R^2_{conditional} = 0.539$). The amplitudes following Threatening stimuli were non-significantly higher ($\beta_1 = 0.071 \pm 0.082$ µV, t = 0.869, 95% CIs: [-0.089; 0.231], $p = 0.385$). Meditation experience predicted a non-significantly higher difference ($\beta_1 = 0.013 \pm 0.121$ µV, t = 0.916, 95% CIs: [-0.225; 0.250], $p = 0.916$).

10.4.1.1.1.2 P245

The random slope improved the model's fit ($\chi^2(2) = 1111.192$, $p < 0.001$). We found no significant effect of Threat on the P218 amplitude ($\chi^2(1) = 0.156$, $p = 0.693$) or interaction between Threat and Meditation experience ($\chi^2(1) = 0.027$, $p = 0.869$). The model estimated the intercept at 7.523 ± 0.628 µV (t = 11.984, 95% CI: [6.293; 8.753], $p < 0.001$, $R^2_{marginal} < 0.001$, $R^2_{conditional} = 0.554$). The amplitudes following Threatening stimuli were non-significantly higher ($\beta_1 = 0.040 \pm 0.103$ µV, t = 0.393, 95% CIs: [-0.161; 0.242], $p = 0.695$). Meditation experience predicted a non-significantly higher difference ($\beta_1 = 0.026 \pm 0.152$ µV, t = 0.167, 95% CIs: [-0.273; 0.324], $p = 0.867$).

10.4.1.1.2 Assessing the effects of Mind-set on Time (Model 2)

<u>10.4.1.1.2.1 P218</u>

The random slope improved the model's fit ($\chi^2(2) = 1066.947$, $p < 0.001$). We found a significant effect of Time on the P218 amplitude ($\chi^2(1) = 14.626$, $p < 0.001$) and interaction between Time and Meditation experience ($\chi^2(1) = 4.439$, $p = 0.035$). We did not find significant interaction between Time and Mind-set ($\chi^2(1) = 0.001$, $p = 0.970$) or Time, Mind-set and Meditation experience ($\chi^2(1) = 0.241$, $p = 0.623$). The model estimated the intercept at 4.460 ± 0.480 µV (t = 9.301, 95% CI: [3.520; 5.400], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.536$). The amplitude significantly increased from pre- to post-CTRL, however, this increase was not present, or was counteracted for meditators (Appendix Table 10-10 & Figure 10-8, left).

	β	SE	t-value	95% CIs	*p-value*
Intercept	4.460	0.480	9.301	3.520; 5.400	<0.001
Time	0.437	0.114	3.826	0.213; 0.661	<0.001
Time x Mind-set	-0.006	0.160	-0.037	-0.320; 0.308	0.970
Time x Meditation experience	-0.357	0.170	-2.107	-0.690; -0.025	0.035
Time x Mind-set x Meditation experience	0.117	0.238	0.492	-0.349; 0.583	0.623

Table 10-10. Summary of Model 2 modelling the effects of Time, Mind-set and Meditation experience on the P218 wave. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

<u>10.4.1.1.2.2 P245</u>

The random slope improved the model's fit ($\chi^2(2) = 1110.298$, $p < 0.001$). We found a significant effect of Time on the P218 amplitude ($\chi^2(1) = 10.623$, $p = 0.001$), an interaction between Time and Meditation experience ($\chi^2(1) = 9.327$, $p = 0.002$) and an interaction between Time and Mind-set ($\chi^2(1) = 4.212$, $p = 0.040$). There was no significant interaction between Time, Mind-set and Meditation experience ($\chi^2(1) = 2.420$, $p = 0.120$). The model estimated the intercept at 7.525 ± 0.623 µV (t = 12.073, 95% CI: [6.304; 8.747], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.551$). The amplitude significantly increased from pre- to post-CTRL, however, this increase was not present, or was counteracted for meditators (Appendix Table 10-11). Furthermore, the post-MS amplitude was significantly lower compared to post-CTRL (Appendix Table 10-11 & Figure 10-8, right).

	β	SE	t-value	95% CIs	*p-value*
Intercept	7.525	0.623	12.073	6.304; 8.747	< 0.001
Time	0.469	0.144	3.260	0.187; 0.752	0.001
Time x Mind-set	-0.654	0.214	-3.056	-1.073; -0.234	0.002
Time x Meditation experience	-0.415	0.202	-2.054	-0.810; -0.019	0.040
Time x Mind-set x Meditation experience	0.467	0.300	1.559	-0.120; 1.055	0.119

Table 10-11. Summary of Model 2 modelling the effects of Time, Mind-set and Meditation experience on the P245 wave. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

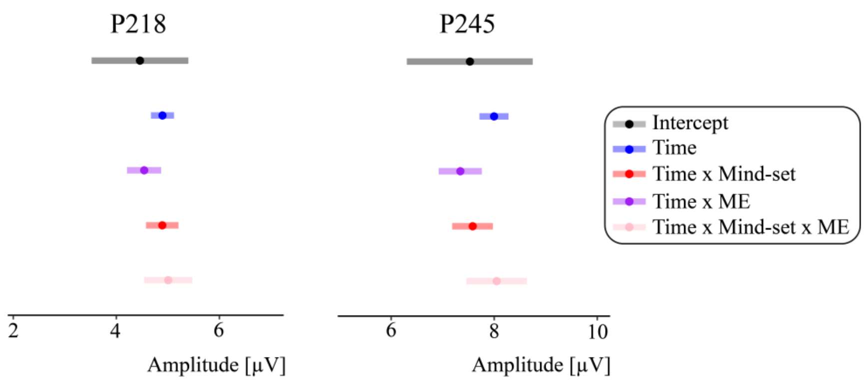

Figure 10-8. Results of Model 2 on the P218 (left) and the P245 (right) waves. Dots represent the βs and the matted lines represent the 95% confidence intervals calculated by Wald method. Black – intercept, blue – Time effect, red – Time x Mind-set interaction, purple – Time x Meditation experience (ME) interaction, salmon – Time x Mind-set x ME interaction.

10.4.1.1.3 Assessing effect of Threat on the interaction between Mind-set and Time (Model 3)

10.4.1.1.3.1 P218

The random slope improved the model's fit ($\chi^2(2) = 1066.950$, $p < 0.001$). Similarly to Model 2, there were a significant effect of Time on the P218 amplitude ($\chi^2(1) = 14.626$, $p < 0.001$) and interaction between Time and Meditation experience ($\chi^2(1) = 4.439$, $p = 0.035$). There was no significant interaction between Time and Mind-set ($\chi^2(1) < 0.001$, $p = 0.989$), Time, Mind-set and Meditation experience ($\chi^2(1) = 0.138$, $p = 0.710$, Time, Mind-set and Threat

($\chi^2(1) = 0.002$, $p = 0.966$), or Time, Mind-set, Threat and Meditation experience ($\chi^2(1) = 0.022$, $p = 0.883$). The model estimated the intercept at 4.460 ± 0.480 µV (t = 9.301, 95% CI: [3.520; 5.400], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.536$). We found no effect of Threat on any interactions (Appendix Table 10-12).

<u>10.4.1.1.3.2 P245</u>

The random slope improved the model's fit ($\chi^2(2) = 1110.310$, $p < 0.001$). Similarly to Model 2, a significant effect of Time on the P218 amplitude ($\chi^2(1) = 10.623$, $p < 0.001$), an interaction between Time and Meditation experience ($\chi^2(1) = 9.327$, $p = 0.002$) and between Time and Mind-set ($\chi^2(1) = 3.911$, $p = 0.048$) came up. There was no significant interaction between Time, Mind-set and Meditation experience ($\chi^2(1) = 2.073$, $p = 0.150$), Time, Mind-set and Threat ($\chi^2(1) = 0.107$, $p = 0.743$), or Time, Mind-set, Threat and Meditation experience ($\chi^2(1) = 0.014$, $p = 0.907$). The model estimated the intercept at 7.525 ± 0.623 µV (t = 12.073, 95% CI: [6.304; 8.747], $p < 0.001$, $R^2_{marginal} = 0.001$, $R^2_{conditional} = 0.551$). We found no effect of Threat on any interactions (Appendix Table 10-13).

10.4.2 Assessing effect of Threat on the interaction between Mind-set and Time (Model 3)

10.4.2.1 P218

	β	SE	t-value	95% CIs	*p-value*
Intercept	4.460	0.480	-9301	3.520; 5.400	< 0.001
Time	0.437	0.114	3.826	0.213; 0.661	< 0.001
Time x Mind-set	-0.003	0.180	-0.014	-0.355; 0.350	0.989
Time x Mind-set x Threat	-0.007	0.163	-0.042	-0.327; 0.313	0.966
Time x Meditation experience	-0.357	0.170	-2.107	-0.690; -0.025	0.035
Time x Mind-set x ME	0.099	0.242	0.147	-0.440; 0.511	0.883
Time x Mind-set x Threat x ME	0.036	0.267	0.372	-0.424; 0.623	0.710

Table 10-12. Summary of Model 3 modelling the effects of Time, Mind-set and Meditation experience on the P218 wave. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.

10.4.2.2 P245

	β	SE	t-value	95% CIs	*p-value*
Intercept	7.525	0.623	12.073	6.304; 8.747	0
Time	0.469	0.144	3.26	0.187; 0.752	0.001
Time x Mind-set	-0.448	0.226	-1.979	-0.892; -0.004	0.048
Time x Mind-set x Threat	0.067	0.206	0.327	-0.336; 0.470	0.743
Time x ME	-0.654	0.214	-3.056	-1.073; -0.234	0.002
Time x Mind-set x ME	0.485	0.336	1.442	-0.174; 1.145	0.149
Time x Mind-set x Threat x ME	-0.036	0.305	-0.117	-0.634; 0.563	0.907

Table 10-13. Summary of Model 3 modelling the effects of Time, Mind-set and Meditation experience on the P245 wave. 95 % CIs were calculated using the Wald method and p-values for the fixed effects were calculated using Satterthwaites approximations.