Through a Mirror Darkly: Shedding Light on Individual Differences in the Neural Correlates of Empathy

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“Through our eyes, the universe is perceiving itself. Through our ears, the universe is listening to its harmonies. We are the witnesses through which the universe becomes conscious of its glory, of its magnificence.” – Alan Watts

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"We all change, when you think about it. We're all different people all through our lives. And that's OK, that's good, you gotta keep moving, so long as you remember all the people that you used to be." – The 11th Doctor (Matt Smith)

I feel that these past seven years have seen a drastic change in who I am. I have been many people, done many things, learned many lessons, and left many things behind. Whilst it is of course normal to experience much over so many years, there is much scope for many positive and negative experiences. This is a celebration of these past seven years (positive and negative) and of the people who have made a positive impact of my life. There have been a great many people who have helped to shape me and make me the person who I am today, I cannot include you all, but you know who you are. Below are some of the most amazing people I have ever met.

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"*Everything ends and it's always sad, but everything begins again, too. And that's always happy.*" – The 12th Doctor (Peter Capaldi)

General Abstract

The aim of this thesis was to explore individual differences in the neural correlates of empathy. This was achieved over the course of three experimental studies to gain a better understanding of mirror neuron activity as a putative index of empathy and its relationship with self-report measures of empathy. In the first study we built upon the existing literature by exposing participants to two EEG protocols. Findings demonstrated a more reactive mirror neuron system in response to crying relative to laughing sounds and to painful relative to non-painful imagery. We also found inverse relationships with empathy that could be related to expertise. In our second study we examined the long-term effect of loving-kindness meditation (compared to controls) on empathy by comparing the mirror neuron activity from three EEG protocols. It is argued that we found meaningful differences in mirror neuron activity (for each protocol) that might again be explained by an expertise effect. The final study investigated the potential effect of power-posing on empathy as measured by both EEG and behavioural tasks. Findings demonstrated that those in an open pose (counter to predictions) actually performed better on an empathic accuracy task than those in a closed or control posture. In terms of mirror neuron activity, we find no conclusive evidence to suggest that open posing has a negative effect on empathy, however again we see evidence to suggest that expertise might be driving our data.

Overview of Chapters

Chapter 1

The first chapter of this thesis provides an introduction to empathy and is intended as a primer. We discuss both historical and contemporary definitions of empathy before moving on to eight psychological states of empathy as defined by Decety and Ickes (2009). We then go on to discuss two main methods of assessing empathy: the empathy quotient (Baron-Cohen & Wheelwright, 2004) and the interpersonal reactivity index (Davis 1980). We end by introducing two techniques that have been said to alter trait and state empathy: loving-kindness meditation and power-posing.

Chapter 2

We begin the second chapter by discussing the discovery of mirror neurons in primates. We then move on to provide evidence of an analogous system in the human brain by examining evidence from functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation (TMS) and electroencephalogram (EEG) studies. We end by discussing the relationship between mirror neuron activity and empathy.

Chapter 3

In our first experimental chapter we begin by reporting a pilot study in which we search for the most affective emotional sound (laughing and crying) to be used in the following study.

We also report the first main study of the thesis in which we examine mirror neuron activity (as measured by the mu rhythm) in response to two EEG protocols: an emotional sound protocol and a pain protocol which consisted of images of various body parts either being pricked by a needle or stimulated by a Q-tip. The aim was to build upon previous mu/empathy research.

Chapter 4

In our fourth chapter we begin by providing an explanation of loving-kindness meditation - the focus of this chapter. In doing do so we discuss the reported positive benefits of practicing this meditation and link it to empathy. We then report the second study of the thesis investigating differences in empathy between a group of meditators who practice loving-kindness meditation and a control group. In order to do this we expose them to three EEG protocols: a pain protocol, a simple mirror neuron activation protocol and an international affective picture system (IAPS) protocol. We look for meaningful differences in both the mu rhythm and in the EQ and IRI.

Chapter 5

In our fifth chapter we introduce the topic of power-posing and describe the literature suggesting that adopting a powerful, open posture can increase feelings of power at both a behavioral and neuroendocrine level. We then go on to report the final study of the thesis investigating both the potential behavioral and EEG based changes that might come from power-posing. We use three protocols, the reading the mind in the voice, the Reading the Mind in the Eyes (RMITE) and finally the pain protocol used in both studies one and two.

Chapter 6

In our final chapter we focus on summarizing the findings of the three studies and discuss limitations of this thesis and look at possible future directions.

Contents

Chapter 1: Empathy: Perspectives and Measurement

"Human progress isn't measured by industry. It's measured by the value you place on a life"
– The 12th Doctor (Peter Capaldi)

1.1 Chapter Introduction

Empathy can be thought of as a prosocial behaviour which allows us to understand not just how other humans feel in terms of their experienced emotions such as happiness and pain, but also their intentions and how they may react in a given situation. The importance of empathy should not be understated, as the ability to 'share someone's emotion' or to 'feel with another' could potentially lead to active helping behaviour (compassion, which will be explored in chapter 4). Also, empathy is not purely a behaviour that we feel solely for our own species, as it has been shown that empathy also has heterospecific qualities. For instance, Taylor and Signal (2005) found significant correlations between scores on the Empathic Concern dimension of the Interpersonal Reactivity Index (IRI; Davis, 1980) and scores on the Animal Attitude Scale (AAS; Herzog, Betchart & Pittman, 1991). The conclusion was that those who scored higher on empathic concern believed more in animal welfare.

Empathy has been studied for hundreds of years and has received intellectual contributions from many fields including philosophy, neuroscience and ethology. Social psychologists have been interested in empathy for many years due to its perceived interpersonal benefits, and much time has been spent researching the topic in order to unravel understanding on different levels and to understand how and why empathy occurs. Singer and Lamm (2009), for example, comment that researchers have been interested in the mechanisms that allow us to see something from the perspective of another person. These mechanisms being perceptual, affective and cognitive in nature. Singer and Lamm go on to explain that neuroscience has been fairly slow in providing possible answers to the different questions that surround empathy and its mechanisms and this might be due to the difficulty in establishing a clear definition as to what empathy is. This has changed over the past few years as a clearer understanding of what empathy is and how it can be measured has emerged. Now many researchers have created effective paradigms, which can be used alongside neuroscience techniques such as electroencephalography (EEG), transcranial magnetic stimulation (TMS), positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). These techniques will be examined in more detail in chapter 2. The aim of this chapter is not to identify a unifying theory of empathy, but to a) provide historical and contemporary definitions of empathy b) describe a potentially unifying model of empathy c) discuss modern methods of assessing empathy in participants and d) briefly touch upon thesis relevant techniques which may impact upon empathy. We will now examine historical perspectives of empathy.

1.2 Historical Perspectives of Empathy

The word empathy derived from the term sympathy (Davis, 1996). One of the first explanations of sympathy came from Smith (1759). Smith believed that we possess an evolved ability with which we are able to share another's strong emotion, a type of "fellow-feeling" as he describes it. Smith stated that we are able to match this emotion in ourselves in an almost precise manner as the observed person experiences it. Smith argues that we achieve this state of emotional sharing via imagination, that we are unable to use our senses alone to access someone else's emotions and physical state. The following quote by Smith sums up his explanation of empathy succinctly, "(we) place ourselves in his situation...enter as it were into his body, and become in some measure the same person with him" (Smith, 1759 p. 60), a description which encompasses some aspects of what occurs when we experience an empathic reaction and a good starting point in the investigation of empathy. Another historical explanation of sympathy comes from Spencer (1855). Spencer thought of sympathy as an underlying sociality that was present in humans and other species. Spencer argues that sympathy is an adaptive function that is particularly useful when it comes to self-defence. Sympathy for others encourages the idea of safety in numbers. This will in time lead to positive feelings of pleasure and affiliation. Spencer appears to view sympathy as primarily a means of communication. For example, suppose one person experiences fear at the sight of a predator, another person who does not observe the predator would pick up on the emotions of the person and through time learn what fear like reactions look like and mean (e.g. that a predator approaches). In a similar vein, McDougall (1908, 1928) discussed sympathy as a pseudo-instinct along with suggestion and imitation. McDougall states that in order for these three pseudo-instincts to manifest themselves there needs to be between two or more people, one, the agent and one other who to some degree takes on the mental state of the agent. These 'mental interactions' are thought by McDougall to be of great fundamental importance to the social life of both humans and non-human animals. McDougall goes on to state that these three pseudo-instincts rely on three processes, primarily a cognitive mental process but also on an affective and cognitive aspect. Suggestion, McDougall states, occurs when an agent expresses ideas or beliefs that then induces similar process in the observer(s). Sympathy relies on effective/emotional induction caused by the agent. Finally imitation relies on a person taking on the bodily movements of the agent (McDougall, 1908, 1928).

Around the late nineteenth and early twentieth century we see the term ‘einfuhlung’ being used; a German word that is translated as ‘empathy’. The word empathy itself came into being in English in 1909 and was coined by Titchener (1909). The opinion of Titchener and Lipps was that empathy is a mechanism by which an inner imitation occurs in an observer; here can be seen the introduction of the idea of motor mimicry (Titchener, 1909; Lipps, 1903). Historical views treated sympathy as more of a passive experience, later we see a shift in this belief to a more active process. A debate then began over the source of empathy and whether it was a cognitive or affective construct, or both. Kohler (1929) held a cognitive view of empathy and believed that empathy was more the understanding of what the person was experiencing rather than any real feeling sharing: we pick up the cues of another’s motor actions and other physical cues. As the 20th century progressed, a shift towards viewing empathy as more reflecting affective mechanisms took hold. In the next paragraph we shall examine this shift, and the more contemporary views of empathy.

1.3 Contemporary Views of Empathy

Early contemporary views of empathy pointed towards a solely affective dimension of empathy, although later a multidimensional approach would be taken (e.g. Davis, 1980). Stotland (1969) described empathy as an emotional reaction, which occurs when we observe another person or people who are experiencing an emotion. He refers to people “sharing” the emotions of others and brings up the idea of people becoming “emotionally aroused” by watching a play or reading a novel: a concept on which the fantasy dimension of the Interpersonal Reactivity Index (Davis 1980) is based upon (which we will come to later in this chapter). Stotland also states that sharing the feelings of another person does not necessarily directly lead to us acting in a supportive or sympathetic manner, that instead we might not engage with the person (or novel/play/etc.) due to negative emotions that we feel from sharing these feelings. Wispe (1986) tried to clarify what sympathy and empathy were and drew a distinction between the two. Sympathy she said was being aware of the suffering of another person with the goal of wanting to alleviate it. In terms of empathy, Wispe saw it as an active process by which one can understand the positive and negative experiences of another. This appears to be much more cognitive in nature than other contemporary views of her time.

1.3.1 The Eight Psychological States of Empathy According to Decety and Ickes

Now we will move on to what could be considered to be a more comprehensive definition of empathy from Decety and Ickes (2009). Decety and Ickes define eight concepts that underlie what may be understood as empathy.

- The first concept is the knowledge of another person's internal state. This involves picking up on cues from another based on the way they act and the things that they say. This experience has been referred to in different ways. Preston and de Waal (2002) and Wispe (1986), describe this simply using the term 'empathy'. Eslinger (1998) and Zahn-Waxler, Robinson and Emde (1992) call it 'cognitive empathy'. Finally, Ickes (1993) refers to it as 'empathic accuracy'.

- The second concept relates to a person feeling as another person feels; not necessarily experiencing precisely the same emotion but a similar one (Hoffman, 2000). A key aspect here is the notion of 'emotion catching' or perhaps the more widely term 'emotional contagion' (Hatfield, Cacioppo & Rapson, 1994). Evidence for this idea comes from Hoffman (1976). In this study infants who were at most two days old were exposed to tape recordings of either another infant crying, a synthetic non-human cry or no recording. It was found that infants cried significantly more times to the audio recording of an infant crying than to the other conditions. It is thought that this finding may be evidence of a type of mechanism present at birth that allows the matching of another's emotional state.

- The third concept involves the projection of oneself into a situation that another is experiencing. This concept comes from the German 'einfuhlung' coined by Lipps (1903) and later translated into empathy by Titchener (1909). This may be considerd a rather dated definition of empathy however, one which appears to have little depth and relates primarily to the ability to imagine.

- Following on from this rather closely is the fourth concept, which appears to rely on imagination. A person might imagine how a friend is feeling by taking in to consideration their knowledge about her, for example her character (Dececy & Ickes, 2009). Aside from this mechanism being named 'empathy' by Ruby and Decety

(2004), it has had other names such as ‘imagine other’ (Batson, 1991), ‘psychological empathy’ (Wispe, 1968).

- The fifth concept again relates to imagination and how a person themselves would feel in a particular situation, rather than trying to imagine how another would feel in that situation. This imagine-self perspective was proposed by Stotland (1969). There seems to be empirical evidence in support of the idea that imagining how another person feels is different from imagining how the self would feel. Batson, Early and Salvarani (1997) asked three groups of participants to listen to a mock radio interview of a woman in distress. When listening, the first group was asked to remain objective, the second to imagine how the woman felt and the last group to imagine how they would feel if they were in her situation. Results suggested different motivational consequences in the two groups that were asked to imagine. The group that imagined how the woman felt produced empathy, however the group who imagined how they would feel in the woman’s situation produced both empathy and personal distress.

- The sixth concept concerns distress. This relates to the feeling of distress that one experiences due to the state of distress of another person. Like other definitions of empathy, this too has been given various names: Krebs (1975) simply names it ‘empathy’, Hoffman (1981) ‘empathic distress’ and Batson (1991) ‘personal distress’.

- The penultimate concept (a more contemporary one) sees empathy as an appropriate experience that is elected by observing another who is suffering. The experience elicited by the other person is said to be congruent with the state of the other person (Decety & Ickes, 2009). For example, if a person is experiencing pain then the observer might experience sorrow for that person.

- The final concept relates to empathy as defined as the adopting or 'mimicking' the posture or facial features of another person. Again, there have been different names given to this type of empathy. Gordon (1995) describes this as 'facial empathy'. To others it is motor mimicry (Hoffman, 2000) and as described under historical views, as imitation (lipps, 1903; Titchener, 1909). A relevant model of empathy by Preston and de Waal (2002) was introduced which focuses not on motor mimicry, but rather on the mimicking of neural representations. The next section will delve deeper into this model.

1.5 Methods of assessing empathy

In the literature there are two main methods for assessing empathy in humans, the Interpersonal Reactivity Index (IRI; Davis 1980) and the Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004) . Each will be discussed in turn here.

1.5.1 The Interpersonal Reactivity Index

The IRI (Davis, 1980) treats empathy as a multidimensional construct instead of just two dimensions that consists of cognitive and emotional aspects. Davis' idea was that even though empathy relates to the concern towards others, there are other dimensions that relate to separate but related constructs. Thus, the IRI consists of four subscales, Perspective-taking, Fantasy, Empathic Concern and Personal Distress. The Perspective-taking dimension examines how likely a person is to take on another person's psychological point of view. The Fantasy dimension is used to measure how likely a person is to become absorbed by the feelings and actions of a fictitious character, (i.e. within a book or film). The Empathic Concern dimension looks at a person's ability to feel sympathy and concern for another person who is experiencing an unfortunate situation. Finally the Personal Distress dimension assesses a person's potential to feel anxious and uneasy in response to others' distress. In order to investigate the reliability of the four scales, 109 participants completed the IRI on two separate occasions between 60 and 75 days apart. The correlation coefficient for the Fantasy scale was .79 (females .81), Perspective Taking .61 (females .62), Empathic Concern .72 (females .70) and Personal Distress .68 (females .76). All of which show good test-retest reliability. Sex differences were found by running a 4X2 ANOVA (IRI scales by sex); all ANOVAs were significant at the .001 level showing that the scores of females were higher than males for each subscale. This is typical of the literature, as sex differences have often been found in empathy research. For instance, Hoffman (1977) found that females exhibit higher empathy then males; this, they argue may be a prosocial mechanism in which females experience more guilt over harming others and are able to put themselves in another's place. Additional studies by Dymond (1950) and Mehrabian and Epstein (1972) also lend evidence to sex differences in empathy. The evidence presented in Davis’ 1983 paper suggests that empathy can be separated in to four separately meaningful but still related dimensions. In light of this, the IRI will be utilised in this thesis.

1.5.2 The Empathy Quotient

The EQ is a 60-item scale with each question including four possible responses which range from strongly agree to strongly disagree. The EQ was developed to assess clinical samples that may possess an absence or deficit of empathy. The original scale consists of 40 questions which assess a person’s empathy however 20 questions were added which act as fillers. The EQ has been found not just to be useful in examining empathy in normal samples but also in individuals with autism spectrum disorder and people with psychopathy (Blair, 1995) and people suffering from depersonalisation (Baker et al. 2003). Lawrence, Shaw, Baker, Baron-Cohen and David (2004) investigated the reliability and validity of the EQ over a period of four experiments. In the first study, participants (50% taken from a clinical population) were given four questionnaires: the EQ; the Social Desirability Scale (SDS; Crowne & Marlowe, 1960), which assesses peoples predisposition to respond in a way which shows them in a good light; the Reading the Mind in the Eyes (RMITE) test (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) in which people are asked to infer the mental state of a person from a picture which only shows their eyes (a task that will be introduced in chapter four of this thesis); and the National Adults Reading Test (NART; Nelson, 1983) in which participants have to pronounce 50 irregular sounding words. Results from this first study demonstrated: a higher EQ score for females, a general positive correlation with the total of the SDS, a positive correlation between the total EQ score and the RMITE and a non-significant correlation between the EQ total and the NART. Within the second study, two groups of participants were acquired, a control group, which contained psychologically healthy people and a group with depersonalization disorder (DPD), in order to examine between group differences in empathy between the clinical and healthy group. Factor loadings and correlations were examined within this study, which revealed three factors which the authors named 'cognitive empathy', 'emotional empathy' and 'social skills' (three possible dimensions even though the EQ is generally looked at as one score, and will be for the duration of this thesis.). A third study was initiated in order to investigate test-retest reliability of the EQ, with the additional introduction of the IRI in order to examine correlations between the EQ and the IRI. The test-retest correlation between the scores of the EQ at time one and time 2 were significant and found to be .84, which indicated that the scale was reliable. Scores from the IRI were correlated with EQ (collected at time two), it was found that moderate correlations existed between EQ and empathic concern (r = .42, p= .025) and perspective taking (r = .49, p =.009). As study 4 focussed on the DPD sample, and DPD is not directly relevant to this thesis, it will not be discussed. These series of studies demonstrate that the EQ is a well-tested, valid and reliable measure of empathy. Along with the IRI, the EQ will be used to assess empathy in this thesis.

1.6 Future Investigations

Later in the thesis we will look in more detail at two distinct techniques that could have an impact upon a person's level of empathy: meditation (chapter 4) and posture (chapter 5). The following two sections will give a brief introduction to these two topics and how they might relate to empathy.

1.6.1 Meditation

Over the past few decades, meditation has become a major topic of interest. Whilst there are different types of meditative techniques originating from various religions/spiritual belief systems, it is arguable that one of the most popular is a Buddhist technique known as mindfulness (Fredrickson, Cohn, Coffey, Pek & Finkel, 2008). Searching for 'mindfulness meditation' on google will result in 75,800,000 results being brought back compared to 'zen meditation' which results in 22,700,000 hits. This interest is also present in the scientific community with google scholar bringing back 99,900 results for the search term 'mindfulness meditation'. Whilst there has been a focus on mindfulness within psychology (Fredrickson, et al. 2008), another related meditation technique has gained interest, that of loving-kindness meditation (LKM; also known as metta bhavana or metta meditation). Loving-kindness meditation, like mindfulness meditation originates from a Buddhist philosophy. In a similar vain to mindfulness, LKM involves the practitioner to partake in a contemplative, comfortable posture whilst spending their time focussing on various steps. Rather than the focus being on the subjects' non-judgemental present experiences as they meditate (such as breathing and thoughts), the focus is instead on generating feelings of unconditional love and affection towards oneself and others. LKM has received interest over the past decade or so as a technique that has been found to have a positive effect on various aspects of a persons' life. These include: chronic back pain (Carson, et al. 2005); increasing daily experiences of positive emotions (Fredrickson, Cohn, Coffey, Pek & Finkel, 2008); feelings of social connectedness (Hutcherson, Seppala & Gross, 2008); increased positive emotions and decreased negative symptoms associated with schizophrenia (Johnson, et al. 2011); a variety of psychopathologies (Shonin, Van Gordon, Compare, Zangeneh & Griffiths, 2015); and affective learning and cognitive control (Hunsinger, Livingston & Isbell, 2013). It has also been reported that practicing LKM can lead to increased grey matter in the right angular and posterior parahippocampal gyri (Leung, et al. 2013). Despite the empirical findings mentioned above, there is limited evidence supporting the idea that LKM can directly improve one's level of empathy. A comparative technique called compassion meditation, however has been shown to improve ones empathic accuracy (Mascaro, Rilling, Negi & Raison, 2012). For a more detailed examination of LKM, its research and its possible relation to empathy please see Chapter 4.

1.6.2 Posture

In 2010, Carney, Cuddy and Yap released an interesting paper apparently demonstrating that open posing can elicit both neuroendocrine and behavioural alterations in humans. Power posing involves the adopting of a specific posture that expresses power and dominance (Ranehill, et al. 2015). These open poses typically involve a person expanding their body in order to become larger. In contrast, a closed pose involves a person reducing the space that they occupy, making themselves smaller (Carney, et al, 2010). In the Carney paper, evidence was reported that adopting an open pose in comparison to a closed pose increased levels of the hormone testosterone, a hormone related to dominant behaviours. The researchers also found that adopting an open pose decreases levels of the stress hormone cortisol. Another interesting finding was that open posers reported feeling more powerful and were more likely to take risks. These findings however came under some doubt as other researchers found a lack of evidence to support the idea that open poses can affect testosterone, cortisol and risk taking (Ranehill, et al. 2015). The authors did however find that those in the open pose reported increased feelings of power.

The idea that increased levels of testosterone could be generated via adopting a open pose could prove to be an interesting and easily accessible manner in which to investigate the effect of testosterone on empathy albeit in an indirect manner. Increased levels of testosterone have been found to have a detrimental impact upon empathy with Hermans, Putman and van Honk, (2006) finding that the administering of testosterone reduces facial mimicry (the spontaneous matching of an emotional expression). Zilioli, Ponzi, Henry & Maestripieri (2015) found that a higher testosterone level was associated with lower empathy scores on the IRI. Bos, et al. (2016) provided fMRI evidence that administration of testosterone affected connectivity of areas involved in empathy (the left inferior frontal gyrus with the anterior cingulate cortex and the supplementary motor area) during completion of the Reading the Mind in the Eyes (RMITE) task. The RMITE being (as referred to above) a task which requires the identification of an emotion from a picture of a face, which shows only the eye region. More important to this thesis is the idea that adopting an open pose can have a detrimental impact upon empathy. This rather simple manipulation is well suited to being tested in a laboratory setting, and possible effects on empathy can be assessed with simple questionnaires, behavioural and EEG tasks. A more detailed literature review on relationship between power posing and feelings of power (and to a lesser degree testosterone) on empathy can be found in Chapter 5 which will include the final study in this thesis.

1.7 Ending comments

This chapter has introduced the topic of empathy. Initially we have looked at both early and more contemporary interpretations of empathy, followed this by looking at two well documented tests that are commonly used in empathy research: the EQ and the IRI, and closed on briefly looking at two techniques that have been found to have an impact upon empathy (meditation and posture). Empathy is the core subject of this thesis, along with the use of neuroscience as a methodological tool. This makes understanding the neural underpinnings of empathy important and of great relevance for this thesis. Therefore, the following chapter will focus on the neuroscientific approach to studying empathy and introduce the concept of mirror neurons, which have been argued to be a core mechanism involved in the feelings of empathy.

Chapter 2: Investigating Empathy through the Human Mirror Neuron System

"Pain is a gift. without the capacity for pain, we can't feel the hurt we inflict" – The 12th Doctor (Peter Capaldi)

2.1 Chapter Introduction

In the previous chapter, we examined empathy as a topic and discussed both historic and contemporary views. We also examined self-report methods of examining empathy and ended by briefly discussing two techniques that the literature states can affect empathy. The aim of this chapter is to provide the reader with an introduction to the concept of mirror neurons. We will firstly give a background to the literature by discussing the discovery of mirror neurons in primates and then discuss the evidence for an analogous system in humans and a possible relationship between this type of cortical activity and empathy.

2.2 The Discovery of Mirror Neurons in Primates

The term 'Mirror Neuron' (MN) was coined due to the apparent ability of a certain class of neuron to 'mirror' the actions of another. We start our examination of these cells in 1988 with the discovery of neurons that were responsible for goal-directed actions in the ventral premotor cortex (inferior area 6) of the macaque monkey (Macaca nemestrina; Rizzolatti, et al. 1988). Rizzolatti inferred that there were multiple classes of neurons in this area: grasping with the hand and the mouth neurons; grasping with the hand neurons; holding neurons; tearing neurons; reaching neurons and bringing to the mouth neurons. These classes were then condensed into three higher-order groups: 1) precision grip neurons; 2) finger prehension neurons; 3) whole hand neurons. This study therefore indicates the idea of different classes of neurons in this motor domain. Further research by Rizzolatti and colleagues (Rizzolatti et al., 1990) investigated single neuron recordings of the agranular frontal cortex (the more rostral area of Broca’s area 6) again in the macaque monkey. Here it was found that neurons in this area are responsible for control of arm movement, not just for the movement itself, but there was also evidence that the area is involved in the preparation of a motor task. A neuronal discharge was recorded upon stimulus presentation and continued until the end of the arm movement. Stimulus distance was relevant to the activation pattern, with half of the neurons activating when the stimulus was close and the other half when it was out of reach. This study provides an interesting context for the idea of neurons being active not just during a movement itself but also being active prior to the action, implying an internalised representation of the action itself.

In 1996, we see an early mirror neuron study in which Rizzolatti, Fadiga, Gallese and Fogassi (1996) investigating the idea that area F5 in the macaque has the ability to represent both observations and actions (that not only is that area active during action but also during observation of meaningful hand movements). Single neuron recordings were taken at area F5. In order to test the mirror properties of these neurons, experimenters performed motor actions in front of the monkeys. Actions included food grasping, manipulation of food and other objects and intransitive gestures. The authors examined neuronal discharge to the above categories of stimuli. They found that when objects were merely handled by the experimenter then there was no discharge from the F5 region of the monkey. They found however that there was neuronal discharge when the experimenter grasped the food object, and then discharges again when the monkey grasps the food themselves. This demonstrates that neurons in the F5 region of monkeys are active both during meaningful action observation and meaningful action execution. However when the experimenter manipulated the food item with a tool and gave it to the monkey there was no discharge until the monkey grasps the food item. When hand movements were not paired with the food object (therefore taking away the meaning of the action) the neurons did not activate. In a similar manner when the manipulation of the food object was hidden the neurons did not activate either. This demonstrated that activation of these mirror neurons is not down to purely motor actions but there seems to be additional intentional processing that is paired with this. This shows that a complex neuron type exists in area F5 of primates that not only activates when a monkey manipulates a food item, but also when the monkey observes the same food item being manipulated by another person. Rizzolatti et al. (1996) also suggest that these mirror neurons may not just be localized the F5 area but may also exist in more frontal and parietal regions, due to idea that these may be responsible for the organization of goal-directed movements. It is clear that the function of these neurons is not just related to motor preparation as there is no immediate motor action that follows the experimenter manipulating the food. Also, the neurons stop being active after the manipulation from the experimenter.

A review of the purpose of mirror neurons was undertaken by Jeannerod (1994) in which the author suggests that mirror neurons represent actions internally. Rizzolatti et al, (1996) however suggest that in addition to this, these neurons are also responsible for the understanding of motor events. By this, the authors refer to “the capacity of an individual to recognize the presence of another individual performing an action, to differentiate the observed action from other actions, and to use this information in order to act appropriately” (Rizzolatti et al., 1996, p. 137). Based on their findings, the authors proposed that a similar mechanism is likely to exist within humans. Further findings discovered that these neurons located in the ventral premotor cortex of monkeys not only activated when performing an action and observing the same action, but also when hearing sounds that were associated with that action such as peanut breaking (Kohler, Keysers, Umilta, Nanetti, Fogassi & Gallese, 2002). The visual and motor qualities of 497 neurons were examined in three macaque monkeys. When looking at the audio properties of 211 neurons, it was found that 13% of them activated in response both to a hand ripping paper and hearing paper being ripped made by another (even when the action was made out of sight). When non-action-related sounds were played there was no excitatory response.

Thus, there appears to be evidence of the multimodal aspects of this mirror system in primates where a collection of neurons respond to both action, observing the action and hearing the action. We now move on to the examination of the literature providing evidence of an analogous system in humans.

2.3 The Human Mirror Neuron System

A core assumption of this thesis is the existence of the hMNS. In order to provide support for this tenet, the remainder of this chapter will a) investigate the evidence for the existence of a hMNS by examining various neuroimaging techniques and, b) look at the relationship between the hMNS and empathy with a focus on EEG measures. We will start this process by first examining fMRI & PET studies, move on to TMS studies and then conclude with EEG, the technique of choice for this thesis.

2.3.1 Direct Evidence with fMRI and PET

Functional Magnetic Resonance Imaging (fMRI), along with positron emission tomography (PET) are types of functional neuroimaging in which the dynamics of brain activation such as changes in blood oxygenation (fMRI) and glucose uptake (PET) are measured and related to a psychological task (Andrewes, 2004). In 1996, Rizzolatti and colleagues ran a PET study in which human participants were exposed to three conditions: object observation (inspecting objects being held by the experimenter), grasping observation (observing objects being grasped by the experimenter) and object prehension (participants reached for and grasped the objects). Results demonstrated that in the object prehension condition there was significant activation located in the posterior part of the left inferior frontal gyrus which corresponds with the rostral part of Broca’s area. Rizzolatti et al, (1996). This is homologous with area F5 in the monkey. This research has lead to a surge of research over the subsequent years and sparked interest in the idea of a neural system in humans that is analogous to the mirror system of monkeys. Subsequently, the human mirror neuron system has been found to be extended beyond this one original area. Occipital, temporal, parietal visual areas and motor regions have been implicated as locations that are active upon both action observation and action.

In 1998 Gallese and Goldman provided an opinion piece discussing the (at the time) new class of neuron. As part of the article the authors discuss the possible functions of the mirror system. They suggest that one possible function is that of imitation. They go on to posit that when we are learning a new skill that relies on our motor system we spend time practicing the skill by imitating another and that the hMNS might facilitate this process. Iacoboni et al. (1999) investigated the cortical mechanisms of human imitation using fMRI. They tested the direct matching hypothesis, which states that we understand the actions of others because observing them resonates with our own motor system. They showed participants finger movements and asked them to imitate these movements in a separate condition. Results demonstrated that there were two areas that were active during these conditions, the inferior frontal cortex and the rostral-most region of the right superior parietal lobule. Buccino et al, (2001) investigated potential areas that were active during both action and observation. They found that during the observation of object-related actions and non-object-related actions, the premotor cortex was activated. Additionally, it was found that the posterior parietal lobe was also active during object related actions. This implies various neural areas that are involved within the mirror system. Decety, Chaminade, Grezes and Meltzoff (2002) utilized PET in order to investigate reciprocal imitation. They found increases in hemodynamic changes in the left superior temporal sulcus and in the inferior parietal cortex in general imitation conditions. In regards to producing imitation, it was found that the left inferior parietal region appeared to be responsible. The authors concluded that the left superior temporal sulcus and inferior parietal cortex seem to be able to distinguish other/self actions. Koski, Iacoboni, Dubeau, Woods and Mazziotta, (2003) also investigated the modulation of cortical activity during various types of imitative behavior.

They asked participants to imitate both left and right hand movements with their right hand. The authors examined neural changes as a result of the participants being required to respond in a specular manner (i.e. imitation as if looking in a mirror) or in a anatomical fashion (i.e. imitation by responding by moving the identical hand as the actor). Results found that during specular imitation, the bilateral inferior frontal and the right posterior parietal cortex were more active than with anatomical imitation. The researchers state that they believe that their data provides evidence for the mirror system being a basic mechanism for simple imitation. The authors also posit that the system may develop from a simple to a more complex system once systems responsible for visuospatial transformation have matured.

In 2003 Gallese proposed the shared manifold hypothesis (Gallese, 2003). This hypothesis is a conceptual tool, which can be applied to many different levels of interpersonal experience with others and allows us to understand how another feels. Such experiences with others can involve sharing emotions, body schema and many other experiences (Gallese, 2003). It is Gallese's opinion that due to the process of the shared manifold hypothesis that we are able to understand that others are similar to us. There are three levels to this hypothesis: the phenomenological level, the functional level and the sub-personal level. The phenomenological related to the notion that while we are individuals, we are aware that we are part of a social structure with other similar individuals and that others' emotions are important because we too experience similar feelings. The functional level allows for self-other models to be created. The sub-personal level involves an expressive and receptive circuitry.

This provides additional evidence of an analogous mirror system in humans. In the next section we shall examine indirect evidence of this system via the use of transcranial magnetic stimulation (TMS).

2.3.2 Indirect Evidence with TMS Studies

Merton and Morton (1980) were the first researchers to demonstrate that it is possible to stimulate the cortex of an intact human scalp. This stimulation was effective at activating the motor cortex of the subject, causing a muscular twitch that could be measured by observing the motor-evoked potential (MEP). Using TMS, researchers can also both inhibit and excite brain areas, which allows them to functionally map cortical regions with a high temporal resolution – down to a millisecond scale. In addition there is an added advantage of being able to penetrate tissues more effectively than electrical stimulation due to the lack of an issue with electrical resistance (Chawla, 2016). TMS works by a high-current pulse being generated within a magnetic coil. This coil is then placed above the scalp and an electromagnetic field is generated which is strong enough to artificially cause action potentials within a person's underlying neurons. An MEP is the result of magnetic (or electric) stimulation to the motor cortex, which stimulates a cluster of neurons into firing action potentials, the end result being movement of specific regions of the body and an observable MEP.

MEPs have been used in investigations into the role of mirror neurons in action observation and imitation. Fadiga, Fogassi, Pavesi & Rizzolatti (1995) conducted a study examining the excitability of the motor cortex (due to changes in cortical excitability being related to hMNS activation). Participants were stimulated during four conditions: in the first, participants observed the experimenter grasping objects; in the second, participants observed the same objects; in the third, participants observed the experimenter tracing geometric shapes in the air; in the final condition, participants had to state when a light had been dimmed. The authors found that there was a significant increase in motor evoked potentials when participants observed actions that the experimenter made. Interestingly this increase in MEP only occurred in the muscles that were previously used to execute those very actions; thus presumably, the same brain area was involved in both instances. This provides TMS evidence that humans may have an area of the brain that is analogous to the primate mirror system.

Avenanti, Bueti, Galati and Aglioti (2005) investigated motor responses utilising TMS when participants observed a needle penetrating hands, feet and a non-corporeal object. TMS was used to measure corticospinal motor representations of the first dorsal interosseus (FDI) while participants observed a needle penetrating that region. The abductor digiti minimi (ADM) muscle was also stimulated as a control. MEPs were recorded via an electrode placed on that muscle. Their first study focused on three conditions: a) observation of a needle penetrating the FDI; b) a Qtip stimulating the same area and c) a needle penetrating a tomato. Results demonstrated a modulation in MEPs recorded in the FDI muscle. The MEP amplitude was lower in the needle in FDI condition compared with the other two conditions. This study demonstrated that the mere observation of another person in pain is enough to produce a reduction in the excitability of hand muscles at the same region as was receiving the painful stimulation.

Fecteau, Pascual-Leone and Theoret (2007) went on to investigate this phenomenon further by examining the relationship between psychopathic personality traits and the mirror neuron system in a non-psychiatric sample during pain observation. While using TMS to induce motor evoked potentials (MEP) participants watched video clips of a needle penetrating a hand. Psychopathy was measured using the Psychopathic Personality Inventory (PPI). As before, there was a reduction in the size of the MEP as a result of observing the painful video clips. Upon correlating PPI with MEPs it was found that participants who were high on the cold-heartedness scale of the PPI had the greatest MEP reduction. The authors suggest that there is a link between motor empathy and psychopathy. Motor empathy is thought to be an automatic process controlled by the superior temporal, inferior parietal and inferior frontal cortex regions (De Waal, 2012). This process is said to be automatic (Blair, 2005) and thought to synchronise the physical attributes of emotion such as facial expression, vocalization, posture and movement between the target and the observer (Khvatskaya & Lenzenweger, 2016).

2.3.3 Indirect Evidence with EEG Studies

Within this section we shall examine indirect evidence for the existence of a hMNS by looking at EEG research. Firstly we will look at a method of examining the putative mirror neuron system using EEG, by looking at the mu rhythm. We will then look at how the mu rhythm is related to empathy.

2.3.3.1 Mu-suppression and Event-Related Desynchronisation

One indirect way of examining MN activity is to examine an EEG rhythm known as the mu rhythm (8-13 Hz). This oscillation, which is of particular relevance to this thesis, is recorded from the scalp over sensorimotor areas during rest (Pineda, 2005) and has dominant frequencies in the 8-13 Hz and 15-25 Hz bands (Pineda, 2005; Hari & Salmelin 1997). Suppression of the mu rhythm is therefore seen as an indicator of sensorimotor activation as this oscillation exists in the absence of movement and the processing of sensory information. The typical duration of this rhythm is thought to be limited to 0.5 to 2 seconds (Niedermeyer, Goldszmidt & Ryan, 2004). Mu rhythms are similar to alpha rhythms in that alpha and mu share a similar frequency (alpha - 8-12 Hz; mu 8-13 Hz) however whereas the mu rhythm is associated with the sensorimotor cortex, alpha is generated around parieto-occipital areas, predominantly the calcarine sulcus (Hari, Salmelin, Makela, Salenius & Helle, 1997). Thus, mu rhythms show an anterior focus whereas alpha rhythms are located in a more posterior region (Goldman, Stern, Engel & Cohen, 2012). As the mu rhythm falls between high alpha and low beta bandwidths, research investigating the mirror neuron system (and indeed this thesis) typically focuses on suppression of both low and high alpha and low beta (i.e. decreases in amplitude at these frequencies).

Even before the discovery of mirror neurons in primates, research had been carried out by Gastaut and Bert (1954) in which a central derived rhythm had been found to desynchronise not only when a participant made a movement but also when they observed a movement, a result that was also found by Cohen-Seat, Gastaut, Faure and Heuyer (1954). This has been fairly well established by other EEG studies such as Cochin, Barthelemy, Lejeune, Roux and Martineau (1998) who showed participants video footage of still and moving shots involving humans or objects. They found that human movement footage modified EEG in high alpha, high beta and low beta bandwidths over the motor cortex. Similarly, Cochin, Barthelemy, Roux and Martineau (1999) examined various EEG frequencies while participants took part in three conditions. In the first condition participants were asked to execute finger movements, in the second to watch finger movements and in a third to just rest. A significant decrease in power was observed in the high alpha frequency (7.5-10.5 Hz) in both the observation and execution condition compared to the resting condition. This effect was observed over frontal (F7, F8), temporal (T5, T6), central (C3, C4) and parietal (P3, P4) electrode sites. These findings indicated that both the frontal and the motor cortex in particular are activated during both observation and execution of identical actions. Such mu-blocking (or mu suppression) was found by Altshuler et al. (1997) over the central sulcus during the observation of a person moving. This was followed by a later investigation (Altschuler, 2000) by the main author, discovering that whilst mu blocking was found to observation of movement, and to a lesser degree to the imagination of a movement, it was not found during the observation of an equivalent movement of an inanimate object, in this case that of a ping-pong ball moving up and down. This provided evidence that our motor system resonates only when observing actions that are closely related to our own. Other research that implicates changes in both alpha and beta oscillations as an index of human mirror neuron system activation comes from Babiloni, et al. (2002). In their study, both event-related desynchronisation and synchronisation occurred at central regions in both alpha and beta rhythms in response to the observation of a finger movement and to the execution of the same movement. There has been a wealth of research over the years promoting the idea of mu suppression being a reliable index of mirror neuron activity (for example, Muthukumaraswamy & Johnson, 2004; Pineda, 2005; Oberman, McCleery, Ramachandran & Pineda, 2007).

To strengthen this argument, researchers have combined both fMRI and EEG in order to gain a more detailed understanding of the human mirror system. Arnstein, Cui, Keysers, Maurits and Gazzola (2011) investigated whether regions assumed to be part of the mirror neuron system are the source of the mu rhythm by combining EEG with fMRI. The results of an action-observation paradigm demonstrated that suppression of the mu rhythm co-varied with blood oxygen level dependent (BOLD) in areas associated with the mirror neuron system (inferior parietal lobe, dorsal premotor region and the primary somatosensory cortex). Braadbart, Wiliams and Waiter (2013) also utilised both EEG and fMRI in order to investigate correlations between the mu rhythm and BOLD during an imitation/observation task. As part of the task, participants were required to either observe a handle moving by itself with a yellow circle representing the only possible manipulator, observe a hand manipulating the handle and mimicking the same action themselves or finally simply observing the hand manipulating the handle. Again, it was found that mu power modulation correlated with BOLD response in areas associated with putative mirror neuron areas such as inferior parietal lobe, premotor cortex and inferior frontal gyrus. Additional clusters were also identified. The authors therefore suggest that a range of structures are implicated in modulating motor preparation, some of which are analogous to the human mirror neuron system. Both of the above pieces of research suggesting that mu suppression appears to be related to BOLD changes in the brain that are thought to be associated with the hMNS

2.4 The Human Mirror Neuron System and Empathy

The evidence for an analogous mirror neuron system in humans is strong and has been shown directly in fMRI (such as Iacoboni et al. 1999) and PET (such as Decety, et al. 2001), and indirectly with TMS (such as Fadiga et al. 1995) and EEG (such as Altschuler, 2000). We shall now provide some brief background for the connection between the hMNS and empathy. The majority of (relevant) literature on empathy surrounds empathy to pain which will be covered in the next chapter. Simulation theory is a name given to our ability to both understand and empathise with the thoughts and feelings of others (Hobson & Bishop, 2017). Preson and de Waal (2002) defined a model of empathy which posits that empathy is based on the neural stimulation that results from observing others expressing emotions. When we observe others (observable) mental states our own neural networks activate in a similar manner to that of the observed person. That, the authors argue, then lead to other associated responses such as autonomic and somatic - and this leads us to feel what the other person feels. Hobson and Bishop state that the hMNS could be the link between perception and action and if the hMNS is involved in empathic processes then we should observe changes in mu suppression in response to experimental tasks that rely on empathy. Moore, Gorodnitsky and Pineda (2012) conducted a study examining mu suppression to the observation of emotional faces. In their experiment participants were ask to: observe and rate the attractiveness of a face, observe and empathise with the face or observe a building and rate how much they liked it. Whilst there was no difference in mu ERD between the empathising and rating for attractiveness conditions, there was a difference in mu ERD between the faces and the building conditions with greater suppression and therefore mirror neuron activity to the faces. Whilst it is argued that these findings could imply an automatic mirror response to faces (relative to non-human images) it is also proposed by the authors that the finding (at the motor cortex) could be explained by facial movement rather than an automatic empathic process. In another mu suppression study Gutsell and Inzlicht (2010) examined differences in the mu rhythm in response to: performing an action, observing an in-group member (same ethnicity) performing the same action and observing an out-group (different ethnicity) member performing the same action. Results demonstrated significant levels of mu ERD were present upon performing an action and when observing an in-group member performing the same action (although self and other differed significantly from each other) and critically they found no significant levels of mu suppression to observing out-group members performing actions. Additional evidence from self-report measures of prejudice indicated that those with higher levels of prejudice experienced less mu suppression. The authors state that this finding fits with the idea that we less vicarious actions along with associated somatic and autonomic states when observing out-group compared with in-group members. Whilst the authors make no clear link between these findings and empathy per se, they discuss the importance of empathy as part of this perception-action process.

2.5 Ending Comments

The aim of this chapter was to provide evidence of a hMNS. We began by looking at the discovery of mirror neurons in primates and moved on to discuss direct and indirect evidence pointing to an analogous system in humans. We also discussed the mu rhythm as a putative measure of the hMNS and ended by briefly talking about a link between the hMNS and empathy. This theme will continue in the next chapter where we will discuss empathy for pain in our introduction for study 1.

Chapter 3: Neural Correlates of Empathy

"There's something that doesn't make sense. Let's go and poke it with a stick" - The 11th Doctor (Matt Smith)

3.1 Introduction – Piot Study

In the previous two chapters we have discussed two main topics: empathy, and neuroscience tools and techniques for empirically studying empathy and the human mirror neuron system. In order to investigate neural correlates of empathy and techniques that can have an impact upon a person's ability to empathise with others (see chapters 4 and 5) we firstly need a reliable technique that is able to elicit mirror neuron activity and that correlates with self-report measures of empathy (the EQ and the IRI). Later in this chapter we will examine the literature on empathy to pain which indicates that protocols featuring images of body parts being pricked by a needle versus having a Qtip pressing against the skin are effective at eliciting mirror neuron activity . However relying solely on this type of protocol for the duration of this thesis is perhaps not logical. Due to this, and the apparent multimodal nature of the mirror neuron system, it was decided to develop an emotional sounds protocol that features both crying and laughing sounds along with a control sound and use this in addition to a pain protocol.

In order to develop an emotional sound protocol multiple audio clips were taken from various sources and participants were asked to assess each sound by using the Self Assessment Manikin (SAM; Bradley & Lang, 1994). The SAM is a pictorial scale, which can be used to tap into three dimensions of emotion, namely pleasure, arousal and dominance. The SAM is based on the Semantic Differential Scale (Mehrabian & Russel, 1974) that consists of 18 bipolar pairs of questions, rated on a 9-point scale. According to Bradley and Lang, this scale is informative but contains some slight issues, namely that it is a awkward scale due to its size, requires more time than is necessary and also statistical expertise such as factor analysis is needed in order to come to any resolution. Another problem is that due to the use of a verbal rating system it can potentially be an issue when using the scale on persons for whom English is not their first language, or for people who have difficulty with language in general such as the young or aphasics. Due to these concerns Lang (1980; Hodes, Cook & Lang, 1985) constructed an alternative method of tapping in to these three factors of pleasure, arousal and dominance. Starting off as a computer-based questionnaire it soon developed into a pen and paper version that could be used in group settings. The SAM has been effectively used on differing populations of people such as children (Greenbaum, Turner, Cook & Melamed, 1990), patients who suffer from anxiety (Cook, Melamed, Cuthbert, McNeil & Lang, 1988) and many other clinical populations. The SAM can be of use when rating different types of information such as pictures (Greenwald, Cook & Lang, 1989), sounds (Bradley, 1994), advertisements (Morris, Bradley, Waine & Lang, 1992).

In the present study, the SAM was used in order to rate 80 sounds in order to find the most affective five for each category of stimulus, male laughing, male crying, female laughing and female crying. The most affective sounds will then be used in further studies in order to facilitate investigation into neural correlates of empathy.

3.2 Method

3.2.1 Participants

Thirty-seven participants (29 female) were acquired from the University of Essex student population. Participants participated on a voluntary basis for course credits. The mean sample age was 22.32 years (SD was 4.71).

3.2.2 Apparatus

Presentation of stimuli was on an Apple iMac computer. Sound volume was kept constant through testing. Sounds were presented through headphones.

3.2.3 Materials

Eighty emotional sound clips were obtained from audiomicro.com, sound-effect.com and soundsnap.com. These consisted of 20 males laughing, 20 males crying, 20 females laughing and 20 females crying. All clips were edited so that their total duration was three seconds. Participants were required to rate these sounds by both filling in the SAM and by answering three other questions assessing the authenticity of the sound, assessing the category of sound (fear, anger, sadness, joy, surprise, disgust and contempt) and finally by rating how effectively they believed the sound represented the emotion that they chose. The SAM (see figure 1 below) consists of 3 nine-point scales; each point on the scale is represented both by a picture and a square on which the participant is required to place an “x” to indicate their choice in relation to the stimuli. The three scales measure valence, arousal and dominance.

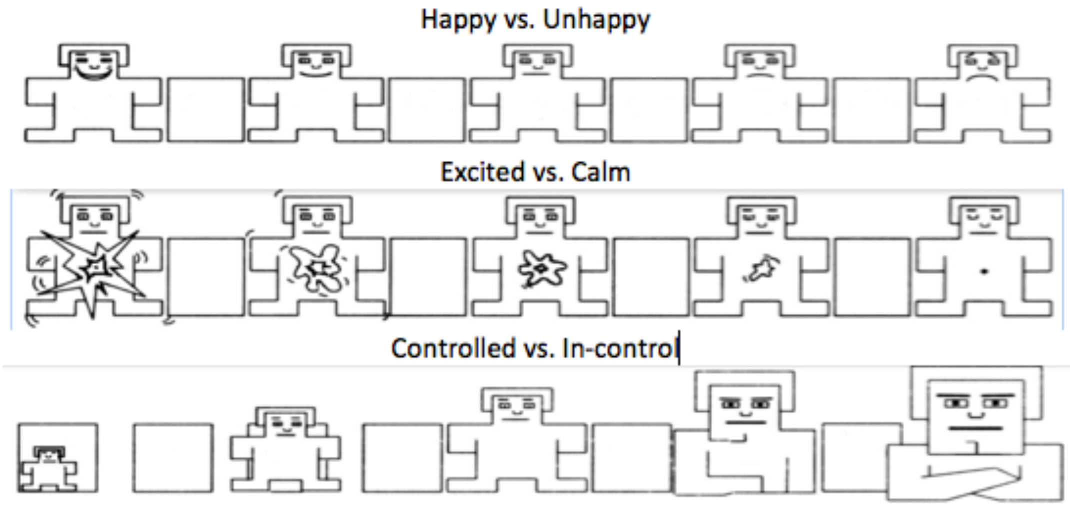

Figure 1: The three scales of the SAM: Valence, Arousal and Dominance

3.2.4 Design

Within this non-manipulation study, the dependent variables were the answers to the questions. Each participant gave seven responses to each of the 80 sounds. The participant selected each sound until all 80 were played and rated.

3.2.5 Procedure

Data was initially collected via pen and paper; however the study was later computerised using SuperCard (Solutions Etcetera). The layout for both pen and paper and computerised versions was kept similar to aid reliability. Participants were required to listen to a sound and then rate each sound using the questions that were on the screen/paper. Participants completed the study in their own time.

3.3 Results

Excel pivot tables were used to extract the most meaningful and relevant information for each sound category, male cry, male laugh, female cry and female laugh. For each category, valence rating, sound authenticity, sound sex (which gender the participant believed the source of the sound was), sound sex correct (whether the participant correctly identified the gender of the sound) and correct emotion was used in order to ascertain the most effective sounds in each category. Once these categories were selected, the means of interest were displayed in the Excel pivot table. The means for the top five sounds for each category of sound are reported in table 1.

Table 1: Top five mean ratings for the valence dimension on the Self Assessment. Please note that low values denote a more positive valence score and higher values a more negative score.

Order	Male Laugh	Male Cry	Female Laugh	Female Cry
1	2.58	7.00	2.56	7.38
2	2.60	6.93	2.83	6.77
3	2.65	6.92	2.91	6.64
4	2.69	6.88	2.96	6.56
5	2.81	6.80	3.04	6.52

3.4 Discussion

The purpose of this pilot study was to rate sounds of males and females laughing and crying, with the intention of finding the five most affective sounds that could be used in study one in investigating the neural correlates of empathy. These sounds were found using Excel pivot tables examining the mean scores of the valence dimension on the SAM controlling for perceived sound authenticity and correct gender identity of the clip.

3.5 Introduction – Study 1

The aim of the study 1 is to establish an EEG protocol that is effective at both eliciting mirror neuron activity, and is sensitive to individual differences in empathy. To this end, two protocols will be run, each examining event-related desynchronisation (ERD) at three groups of locations over sensorimotor areas, designated fronto-central (FC), central (C) and centro-parietal (CP). Each of these areas are made up of 'strips' of seven electrodes which cover both hemispheres and the midline (e.g. FC5, FC3, FC1, FCz, FC2, FC4, FC6). The rationale for these regions to be examined are due to the sensorimotor cortex being identified as a source of the mu rhythm (Hari, Salmelin, Makela, Salenius & Helle, 1997; Pineda, 2005; Cheng et al. 2008; Yang, Decety, Lee, Chen & Chery, 2009) Two protocols were chosen for inclusion to gain a better understanding into the relationship between empathy and mirror neuron activity across both auditory and visual stimuli. The two protocols were made up firstly from an emotional sound protocol which consisted of the stimuli reported in the pilot study (laughing and cring sounds). And secondly, a pain protocol, consisting of images of hands, feet and mouths either being pricked with a needle or having a Qtip resting against the skin (similar to Avenanti, Bueti, Galati & Aglioti, 2005; Bufalari, Aprile, Avenanti, Di Russo & Agliori, 2007; Perry, Bentin, Bartal, Lamm & Decety, 2010).

The rationale for the inclusion of an emotional sounds protocol is initially based on the discovery of auditory mirror neurons in monkeys (Kohler et al. 2002; Keysers et al, 2003), and then later found in humans (Fadiga, Craighero, Buccino & Rizzolatti, 2002; Aziz-Zadeh, Iacoboni, Zaidel, Wilson & Mazziotta, 2004; Pizzamiglio et al., 2005; Bangert et al., 2006;

Gazzola, Aziz-Zadeh & Keysers, 2006). These papers discuss the finding that the MNS resonates not only to observed actions but also to the sound of object-related actions such as the cracking of a peanut (when observed by a monkey), when pianists listen to monophonic piano sequences, and when humans listen to action related sounds. It has been hypothesised that the mirror neuron system might have helped facilitate the emergence of language in humans (Rizzolatti & Arbib, 1998) due to the original discovery of multimodal mirror neurons in the F5 area of the monkey brain which is similar in position and structure to Brodmann area 44 in the human brain which is thought to be important in language. Language being written, read but also more importantly for this argument – spoken (Iacoboni, 2008). If this hypothesis is correct, and the hMNS has played a part in the emergence of language and indeed continues to play a part, then one might suppose that hearing sounds such as laughing and crying might elicit activation of mirror neurons. Despite the research suggesting that the hMNS resonates to action-oriented sounds, there seems to be a lack of research in this area utilising EEG and the examination of mu as an index of the hMNS. Also to this authors knowledge there has been no hMNS studies examining emotional sounds. Laughing and crying are both sounds that are associated with distinct facial features, and as such have associated motor mapping, and are sounds which communicate potentially important social information. It is also suggested by Preston and de Waal (2017) that emotional expressions are supported by the mirror system. Thus, the participants in this study will be exposed to sounds of adults laughing and crying. A control sound of pink noise was chosen in addition to the emotional sounds due to evidence from the literature that demonstrated that non-action related sounds such as white noise did not elicit mu desynchronisation (Kohler, et al. 2002; Crawcour, Bowers, Harkrider &

Saltuklaroglu, 2009). Whilst the use of any sound that has a motor representation could theoretically be utilised to investigate hMNS activation, the inclusion and examination of sounds which vary in terms of valence (laughing and crying) could be an interesting addition to the literature.

One key method of studying empathy is through examining the effects of the observation of pain in others. We shall now examine the literature related to empathy to pain. Aside from the different imaging tools that can be used to investigate empathy, there are also various different types of stimuli used within the literature, which include: facial expressions of pain (Botvinick et al., 2005); mechanical, thermal and pressure pain to feet and hands (Cheng, et al. 2008) and images of body parts being pricked with a needle (Cheng, et al. 2007). In Botvinick's (2005) study, participants were exposed both to video clips of participants displaying painful expressions and in alternating conditions were exposed to thermal pain themselves. Analysis of fMRI data revealed that both observation of others in pain and the experience of thermal pain engaged both the anterior cingulate cortex (ACC) and insula, areas involved in empathy. Cheng et al. (2008) used MEG in order to investigate sensorimotor suppression whilst participants observed others in pain and whilst experiencing pain themselves via the stimulation of the left median nerve on participants wrists. Data revealed significantly more EEG sensorimotor suppression to both of the images (painful and non-painful) compared to a baseline condition (fixation cross). Between the painful and non-painful conditions there was significantly more suppression to the observation of the painful images. Finally, Cheng et al. (2007) examined neurohemodynamic response to the observation of body regions (hand, foot and mouth) being pricked with a needle or touched by a Q-tip in two groups of participant - physicians with expertise of acupuncture and a novice group with no experience. As it is important for physicians to become detached in their daily work, the authors expected a between group difference in neurohemodynamic activation in both the ACC and the anterior insula, areas involved in the pain matrix. Significant activation in these regions was found in the control group (who had no such professional detachment), but not in the physician group. Interestingly, it was shown that there was significant activation in regions associated with emotional regulation and cognitive control in the physician group which was argued perhaps related to their ability to detach themselves from the experience.

Further evidence discussing the relationship between pain, mu and empathy comes from Yang, Decety, Lee, Chen and Chery (2009), who used EEG techniques to look at gender differences in mu rhythm for empathy to pain of others. They exposed participants to pictures of feet and hands in painful and non-painful situations along with a neutral picture for each situation. Painful pictures induced sensorimotor activation in both genders, however, suppression was strongest in females. In terms of self-reported empathy, correlations were found to be similar to the results of previous research, with mu suppression positively correlated with scores on the personal distress scale of the IRI (r = .68, p = .004). This result implies that there is an association between observing people who are portrayed as experiencing pain and the observer experiencing an empathic reaction to that pain exemplified by sensorimotor suppression. Perry, Bentin, Bartal, Lamm and Decety (2010) also investigated a similar process by showing participants images of hands being pricked by a needle or a Qtip touching the skin. The authors were interested in whether EEG suppression could be found by assigning some of their sample to a condition in which they were told that the people in the images suffered from a neurological disease by which they felt pain when being touched with a Q-tip and no pain when a needle pricked them, this was classified as a dissimilar-other group. There was also a similar-other condition (a reverse of the above condition) in which the people felt the expected amount of pain (when they saw a hand being pricked by a needle) or no pain (when they saw a hand being touched with a Q-tip. Twenty-eight participants were shown pictures of hands being pricked with a needle or being touched with a Q-tip. The participants were shown a picture of a person for whom the hands belonged and were told what group they belonged to (dissimilar-other or similar-other). The authors examined activity in the 8-12 Hz (mu) frequency bandwidth from sites located in left and right central, parietal and occipital locations. It was found that suppression was greater for pain conditions all over the scalp, however this effect was significantly greater at frontal and central locations than at others. Interestingly in the dissimilar-other condition there was no difference between the pain and no-pain condition, however the suppression values were as large as they were for the pain conditions in the similar-other condition. The authors state that they captured two empathic components which were 1) automatic reactions – participants know that a needle prick caused some level of pain or discomfort and 2) a controlled reaction, which they describe as mediated by cognitive mechanisms based on participants trying to understand how the dissimilar-other group feel. Their results show that participants were able to infer the targets affective state as they felt the relevant amount of empathic concern and personal distress for the painful picture rather than the non-painful one. However, interestingly when observing non-painful needle pricks (i.e. in the condition where the needle prick is said to result in no pain), it was found that scores on empathic concern and personal distress were higher than they were for the non-painful Q-tip condition. The authors suggest that this may be due to participants not being able to differentiate how the needle would make them feel rather than it not causing the person any pain, or that it was a general reaction to the neurological patients' condition. They suggest that whilst participants could imagine the pain that the neurological patients felt, they could not suppress their own feeling to the needle prick (i.e. in some form they felt the pain themselves).

Hypotheses for the sound protocol were partly exploratory in nature due to the lack of literature in this area, however were also based firstly on evidence suggesting auditory properties of the hMNS (Fadiga, Craighero, Buccino & Rizzolatti, 2002; Aziz-Zadeh, Iacoboni, Zaidel, Wilson & Mazziotta, 2004; Pizzamiglio et al., 2005; Bangert et al., 2006; Gazzola, Aziz-Zadeh & Keysers, 2006), on evidence suggesting that emotional expressions are supported by the mirror system Preston and de Waal (2017) and finally based on the suggestion that mirror neurons have been implicated in the emergence of language in humans (Rizzolatti & Arbib, 1998). It is hypothesised that if one's MNS were to resonate with listening to another crying and laughing then we would observe mu desynchronisation (8-12 Hz) to both of the emotional sounds and that if we were to empathise more with another who is crying then we should observe increased mu desynchronization to the crying sounds relative to the laughing sounds or the pink noise. It is also hypothesised that this mu desynchronisation is also likely to correlate with measures of empathy (the EQ and the IRI), in that increased mu desynchronisation will be associated with higher empathy scores. Finally, mu desynchronisation will be increased for both laughing and crying relative to the pink noise sound which is acting as a control and theoretically should not elicit mu desynchronisation. In relation to the pain protocol, it is expected that painful images will elicit increased EEG desynchronisation in the mu band than non-painful images at all above sites (as Perry, Bentin, Bartal, Lamm & Decety 2010). This increased desynchronisation is expected to correlate with measures of empathy in such a way that increased mu desynchronisation will correspond with a higher empathy score. It is expected that all results will be found within the 8 – 13 Hz band (this band incorporates high alpha, low alpha and low beta) as this is theorised to indicate mirror neuron activity over the sensorimotor cortex.

3.6 Method

3.6.1 Participants

This study consisted of 20 participants (17 female). Convenience sampling was used alongside recruiting via the psychology department's volunteer email database. The mean age was 26 (SD = 8.15).

3.6.2 Stimuli

Self-report Scales

Both the EQ (Baron-Cohen & Wheelwright, 2004) and the IRI (Davis, 1980) were adopted as self-report measures of empathy for this study. Details for both scales can be found on page 23-26. The shortened version of the EQ was used which consisted of 40 questions (without the 20 filler questions). Participants had to rate a series of statement on a four-point scale (strongly agree, slightly agree, slightly disagree and strongly disagree). Examples of questions are "I can easily tell if someone else wants to enter a conversation" and "I find it hard to know what to do in a social situation". The IRI consists of 28 questions for which participants are required to rate a series of statements on a five-point scale which ranges from "does not describe me well" on one end of the pole to "describes me very well". The IRI consists of four subscales: Perspective Taking (e.g. "I sometimes find it difficult to see things from the "other guy's" point of view"), Personal Distress (e.g. "In emergency situations, I feel apprehensive and ill-at-ease"), Empathic Concern (e.g. "Sometimes I don't feel very sorry for other people when they are having problems") and, Fantasy (e.g. "I really get involved with the feelings of the characters in a novel").

Emotional Sounds Protocol

The emotional sound protocol consisted of twenty different emotional sounds (three seconds in duration) that were rated the highest in the previous pilot study. Of these 20 sounds, there were four categories: male laughing, male crying, female laughing and female crying (although no gender distinction was examined). A pink noise sound clip was also used as a control condition. Each sound was normalised so that each of the peak dB levels were matched.

Pain Protocol

The pain protocol was based on various studies investigating both empathy to pain and the role of the hMNS in empathy (Yang, et al., 2009; Decety et al., 2010; Perry, et al., 2010). Twelve types of picture were used, consisting of three body locations (foot, hand and mouth) either being pricked by a needle or touched with a Q-tip. Pictures were taken of both male and female models, examples of image types are shown in figure 3 below. All pictures were taken under similar lighting conditions, were on a black background and were taken from a third person point of view. The needle comprised of a syringe and a modified needle that was blunted with a file and attached which was made to give the impression of a sharp needle that could prick the skin.

Figure 2: The six categories of stimuli for the pain protocol

3.6.3 Procedure

Once participants were in the lab, they were given a detailed explanation of the process of the study followed by a consent form. As the EEG cap and facial electrodes were fitted and gelling all electrodes took place, participants were asked to complete the EQ and IRI. Once this stage had been completed participants moved on to the emotional sound and pain protocol which were presented in a counterbalanced order and were asked to sit as still as possible throughout the process. When presented with the sound protocol participants took part in 90 trials in total, made up of 30 pink noise, 30 laughing and 30 crying clips. Presentation of all stimuli was random. The protocol began with a key press. The flow of the protocol consisted of a 2500ms ISI, a 3000ms presentation of the audio clip and finally a 2000 ISI. When presented with the pain protocol participants took part in a total of 198 trials, which consisted of 180 painful and non-painful colour digital pictures. Five of each of the 12 type of picture were presented three times each (male and female hand, foot and mouth (needle and Qtip). The remaining 18 trials consisted of attentional checks that participants were told to watch out for and call out “cross” when they appeared. The aim of the attentional check was to make sure that the participant was engaged and observant. The study flow consisted of a 2000ms ISI followed by a randomly selected image being presented for a total of 3000ms.

3.7 EEG Data Acquisition

Stimuli were presented in Superlab version 4 on an iMac computer. A windows XP computer was used as an EEG control computer which ran SCAN 4.4. Data were acquired via an 64 electrode mounted cap arranged according to the extended 10-20 system (Jasper, 1958) and Synamps II amplifiers (Compumedics, Melbourne Australia). A reference electrode on the cap was used located midway between the Cz and CPz electrodes. The cap was grounded using an electrode midway between Fz and FPz. In order to account for horizontal and vertical eye movements, two electrodes were placed above and below the left eye and on the outer canthi of each eye. Impedances for each of the electrodes were lowered to

10kΩ. EEG data were sampled continuously 1000Hz with a band-pass filter of .05 - 200Hz and a 50Hz notch filter.

3.8 EEG Data Preparation

Once acquired, the continuous data files were visually inspected for noisy data blocks and bad electrodes. Noisy blocks were manually highlighted to be rejected from further analysis. Faulty electrodes were marked as 'bad' and therefore rejected from further analysis also. Eye-movement artefacts were then rejected according to methods described by Croft & Barry (2000). All data were re-referenced to a common average reference. Remaining artefacts exceeding ± 75 mV were automatically rejected in an automatic rejection sweep before event-related desynchronization / synchronization (ERD/S) was computed using event-related band-power transform in Neuroscan Edit 4.4 (Compumedics, Melbourne, Australia). EEG bandwidths of interest were prepared in alpha and low beta (13 – 20 Hz). Alpha was further split into two sub-bands: low (8 - 10 Hz) and high (10 - 12 Hz) because functions associated with each end of the alpha spectrum differ (Klimesch et al., 2007; Petsche, Kaplan, von Stein, & Filz, 1997; Aftanas & Golocheikine, 2001). Electrodes of interest included those overlying the premotor cortex and supplementary motor area (FC5, FC3, FC1, FCz, FC2, FC4, FC6), those overlying the motor cortex (C5, C3, C1, Cz, C2, C4, C4, C6) and finally those over the sensory area (CP5, CP3, CP1, CPz, CP2, CP4, CP4, CP6).

All data for the emotional sound protocol were epoched from -500 to 3250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 3000 ms) was calculated using the formula adapted from Pfurtscheller and colleagues (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999): ERD% = (R−A) / R × 100, where R = power in the reference interval and A = power in the active or task phase. Using this formula ERD is expressed as positive values and ERS as negative. All data for the pain protocol were epoched from -500 to 2250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 2000 ms) was calculated using the same formula as above.

3.9 Results

3.9.1 Experiment 1a - Emotional Sounds Protocol

The following results are of 3 x 7 repeated measures ANOVAs that were conducted to compare the main effect of type of auditory stimuli (laughing, crying and pink noise) x electrode (seven electrode strip). Analyses were performed on three different epochs: early (0-1000ms), middle (1000-2000ms) and late (2000-3000ms). For each section below, the focus will be on the main effect of stimuli type, pairwise comparisons upon the discovery of a significant main effect and correlational analysis. Correlations between ERD and self-report measures of empathy are only conducted when a significant difference is found between ERD elicited by stimuli type.

3.9.1.1 Fronto-central channels (FC-strip)

3.9.1.1.1 Early Epoch

Table 2: Mean and Standard Error for ERD elicited by each sound for the early epoch

	Laughing	Pink Noise	Crying
Low Alpha	10.47 (4.00)	15.54 (4.74)	9.57 (3.53)
High Alpha	11.65 (5.27)	5.79 (5.70)	6.80 (4.99)
Low Beta	-2.11 (5.12)	5.13 (3.09)	3.89 (3.02)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (ps > .281).

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (ps > .720).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (ps > .115).

3.9.1.1.2 Middle Epoch

Table 3: Mean and Standard Error for ERD elicited by each sound for the middle epoch

	Laughing	Pink Noise	Crying
Low Alpha	16.21 (6.39)	34.95 (4.71)	17.19 (6.62)
High Alpha	18.91 (6.74)	-.21 (10.65)	20.21 (5.87)
Low Beta	-2.85 (6.74)	17.15 (2.63)	11.69 (3.02)

Low Alpha (8-10 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 7.38$ $p = .002$). Pairwise comparisons revealed a significant difference in ERD between the pink noise and the laughing conditions (mean difference = -18.75, p=.007, CI(95%) -32.73 - -4.77) and pink noise and the crying conditions (mean difference = -17.77, p=.031, CI(95%) -41.10 - -1.42) conditions, with more ERD being elicited to the pink noise. There was no interaction between stimuli type and electrode (p = .560). No significant correlations were found between ERD and self-reported measures of empathy.

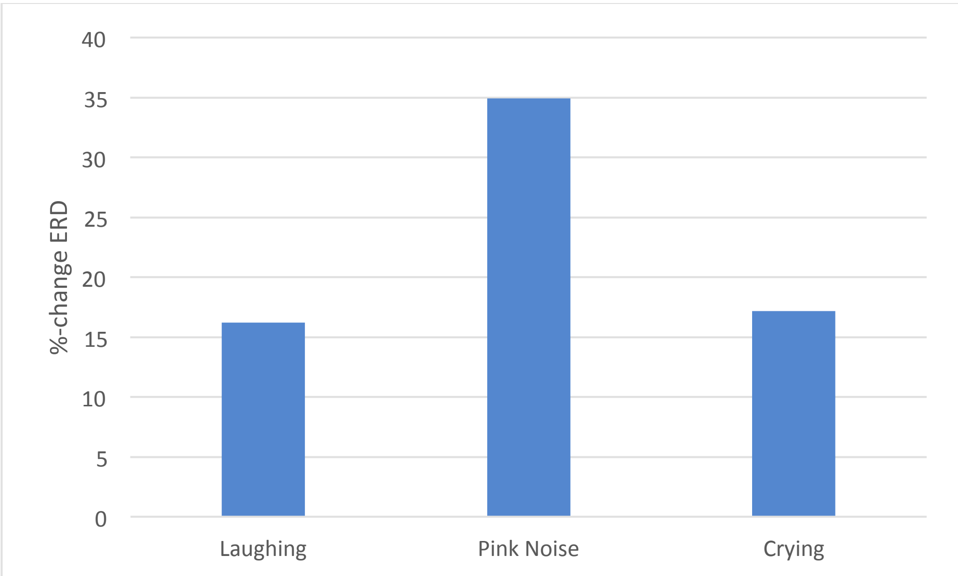

Figure 4: Chart showing %-change ERD for each stimuli type

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .090).

Low Beta (12.5-16 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 9.70$, $p < .001$). Pairwise comparisons found significant differences in ERD between both the pink noise and laughing conditions (mean difference = 20.00, p=.018, CI(95%) 3.00 - 36.99), the pink noise and crying conditions (mean difference = 5.47, p=.030, CI(95%) .46 - 10.48) and finally between the laughing and crying conditions (mean difference = -14.53, p=.016, CI(95%) -26.64 - -2.43). Highest ERD elicited was to the pink noise condition, the next highest ERD was elicited by the crying condition. There was no interaction between stimuli type and electrode (p = .155). A significant negative correlation was found between perspective taking and the crying condition (r = -.50, n = 19, p = .028), demonstrating that higher ERD was associated with lower scores on the perspective taking dimension.

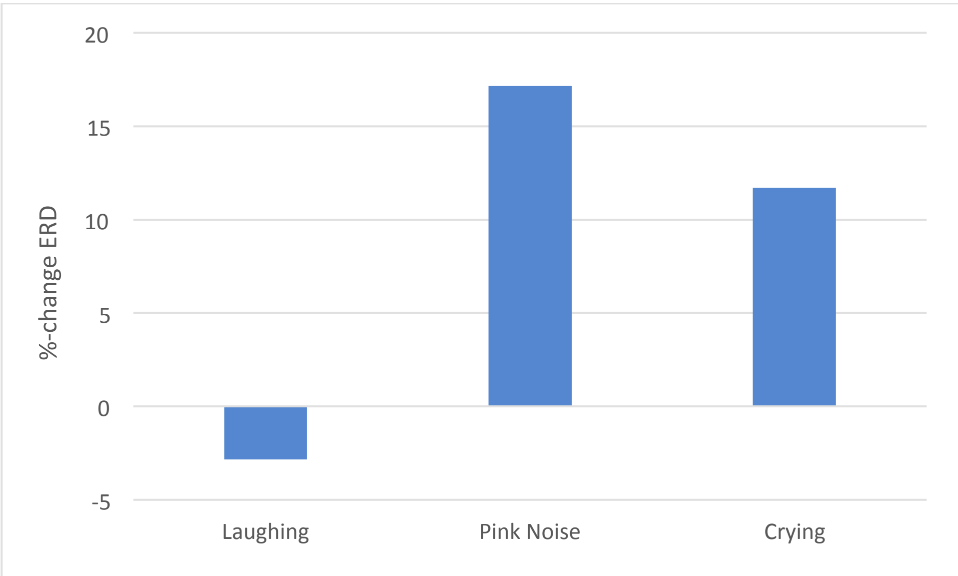

Figure 5: Chart showing %-change ERD for each stimuli type

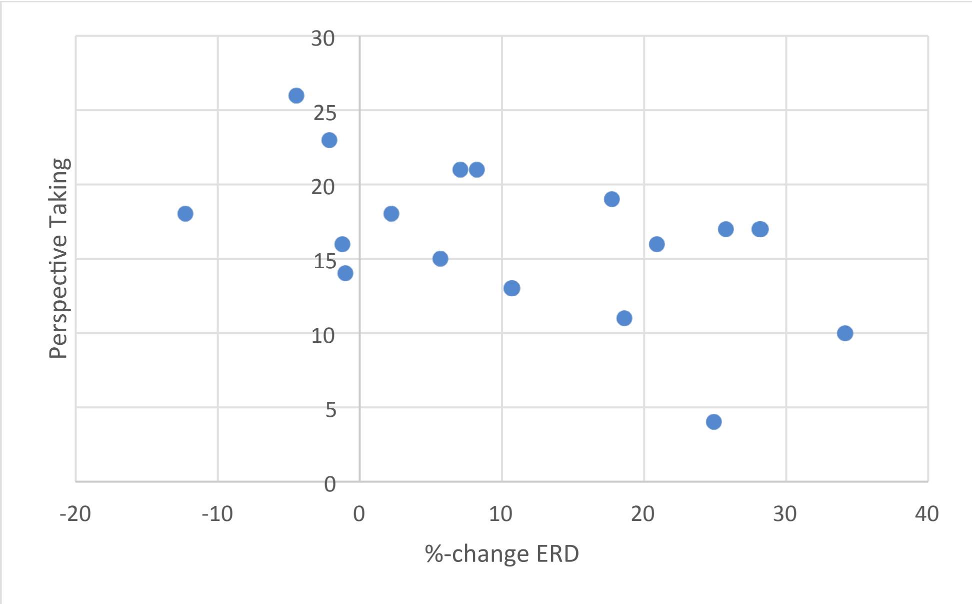

Figure 6: Scatter plot demonstrating negative association between ERD elicited by the crying condition and perspective taking scores.

3.9.1.1.3 Late Epoch

Table 4: Mean and Standard Error for ERD elicited by each sound for the late epoch

	Laughing	Pink Noise	Crying
Low Alpha	9.95 (8.49)	24.02 (4.20)	10.91 (9.18)
High Alpha	9.65 (8.48)	-11.08 (14.68)	10.56 (7.02)
Low Beta	-2.44 (4.76)	14.41 (2.92)	9.73 (2.53)

<u>Low Alpha (8-10 Hz)</u>

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .099).

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode ($ps > .162$).

Low Beta (12.5-16 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 11.28$, $p < .001$). Pairwise comparisons revealed significant differences between ERD for both the pink noise and laughing conditions (mean difference = -16.85, p=.012, CI(95%) -30.29 - -3.41) and the laughing and crying conditions (mean difference = -12.17, p=.005, CI(95%) -20.91 - -3.42). There was a borderline difference between the pink noise and crying conditions (mean difference = 4.68, p=.059, CI(95%) -.15 - 9.51). There was no interaction between stimuli type and electrode ($p = .976$). Significant negative correlations were found between perspective taking and the laughing condition ($r = -.47$, n = 19, $p = .043$), and perspective taking and the crying condition ($r = -.57$, n = 19, $p = .011$). Both correlations demonstrated that higher ERD was associated with lower scores on the perspective taking dimension.

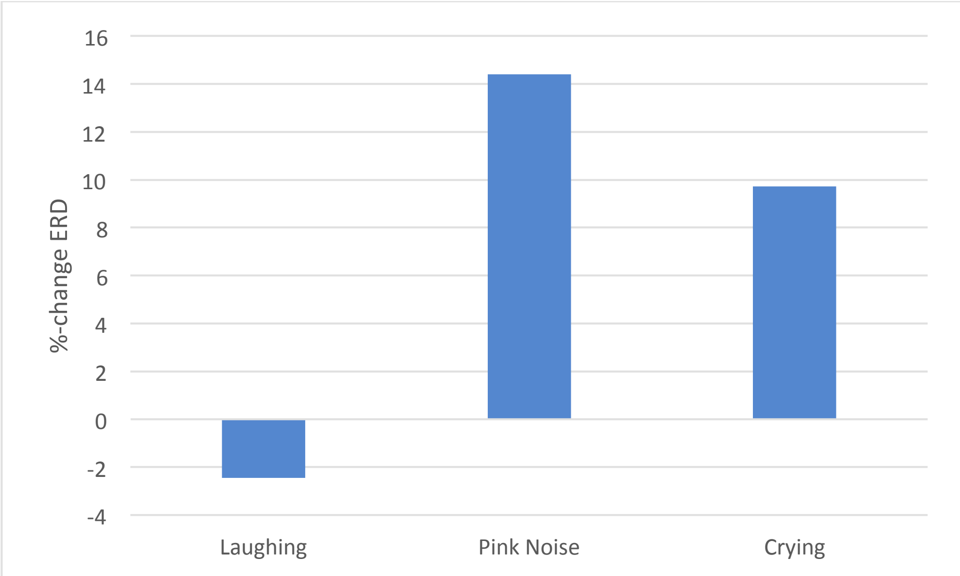

Figure 7: Chart showing %-change ERD for each stimuli type

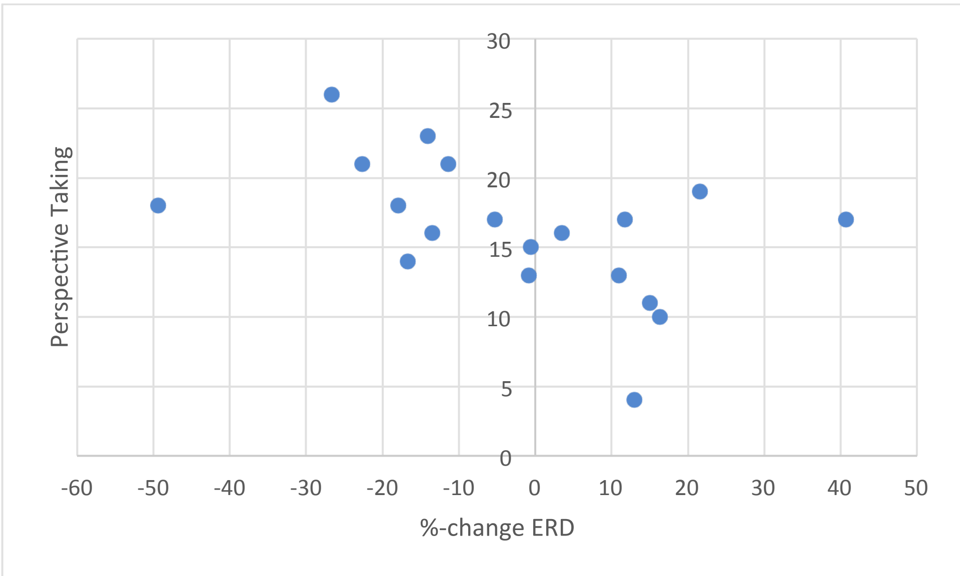

Figure 8: Scatter plot demonstrating negative association between ERD elicited by the laughing condition and perspective taking scores.

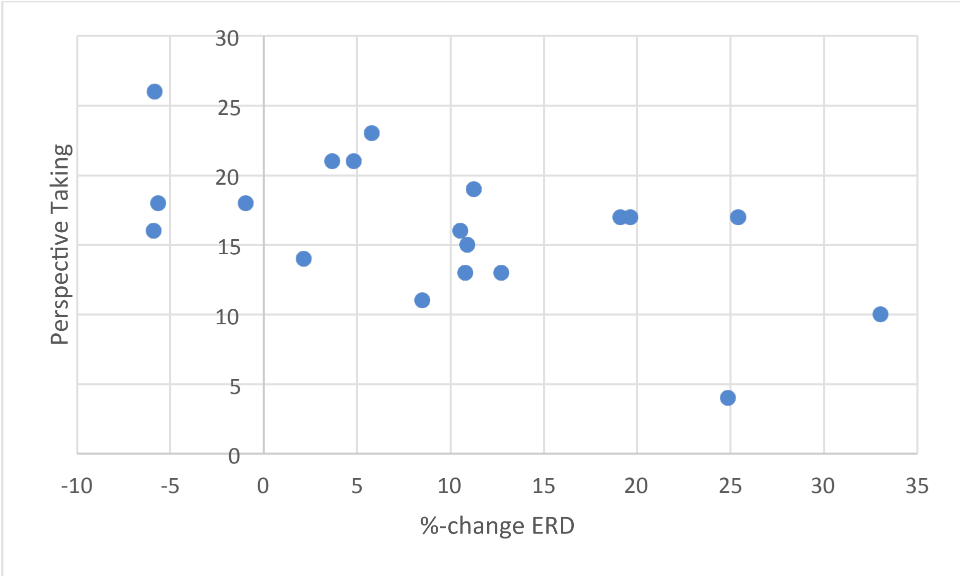

Figure 9: Scatter plot demonstrating negative association between ERD elicited by the crying condition and perspective taking scores.

3.9.1.2 Central channels (C-strip)

3.9.1.2.1 Early Epoch

Table 5: Mean and Standard Error for ERD elicited by each sound for the early epoch

	Laughing	Pink Noise	Crying
Low Alpha	2.37 (5.77)	13.71 (4.49)	3.05 (5.22)
High Alpha	6.75 (4.58)	-1.65 (7.82)	6.69 (3.94)
Low Beta	-.25 (4.10)	3.81 (2.66)	3.78 (2.43)

Low Alpha (8-10 Hz)

A borderline main effect of type of stimuli was found ($F(2,36) = 2.95$, $p = .065$), there was no interaction between stimuli type and electrode ($p = .549$). Pairwise comparisons revealed no significant difference between conditions (*ps* > .220). No significant correlations were found between ERD and self-reported measures of empathy.

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .492).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .301).

3.9.1.2.2 Middle Epoch

Table 6: Mean and Standard Error for ERD elicited by each sound for the middle epoch

	Laughing	Pink Noise	Crying
Low Alpha	12.08 (6.28)	32.63 (3.43)	10.51 (6.35)
High Alpha	10.20 (7.27)	-.89 (9.53)	15.57 (6.55)
Low Beta	-.85 (5.59)	12.70 (2.76)	9.46 (2.79)

Low Alpha (8-10 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 8.93$, $p = .001$) Pairwise comparisons revealed significant differences between ERD in both the pink noise and the laughing conditions (mean difference = 20.55, p=.012, CI(95%) 4.19 - 36.91) and the pink noise and crying conditions (mean difference = 22.11, p=.008, CI(95%) 5.38 - 38.84). More ERD was elicited by the pink noise condition. There was no interaction between stimuli type and electrode (p = .288). No significant correlations were found between ERD and self-reported measures of empathy.

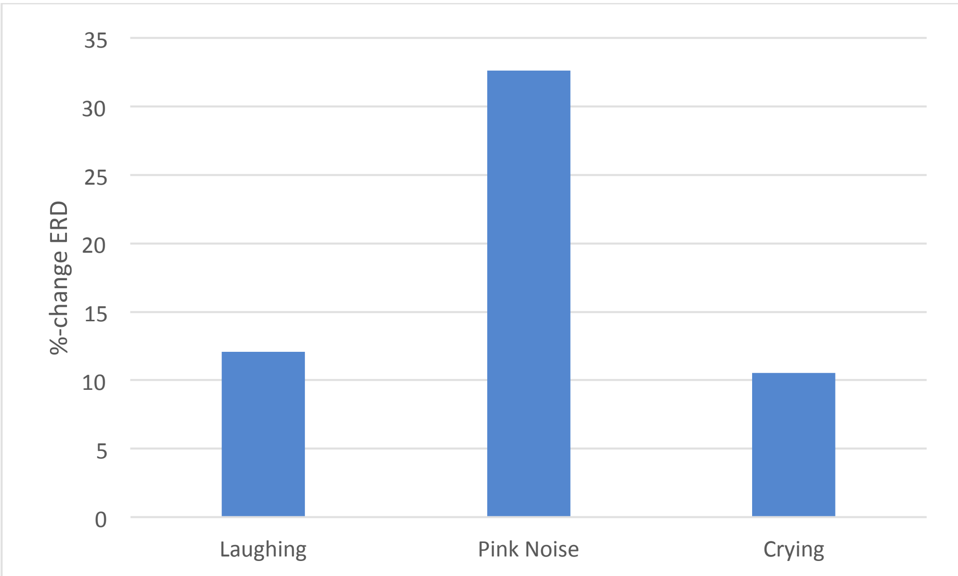

Figure 11: Chart showing %-change ERD for each stimuli type

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode ($ps > .273$).

Low Beta (12.5-16 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 6.27$, $p = .005$). Pairwise comparisons revealed a significant difference in ERD between both the laughing and crying conditions (mean difference = -10.30, p=.044, CI(95%) -20.39 - -.23), with higher ERD to the crying condition. There was no interaction between stimuli type and electrode ($p = .789$). No significant correlations were found between ERD and self-reported measures of empathy.

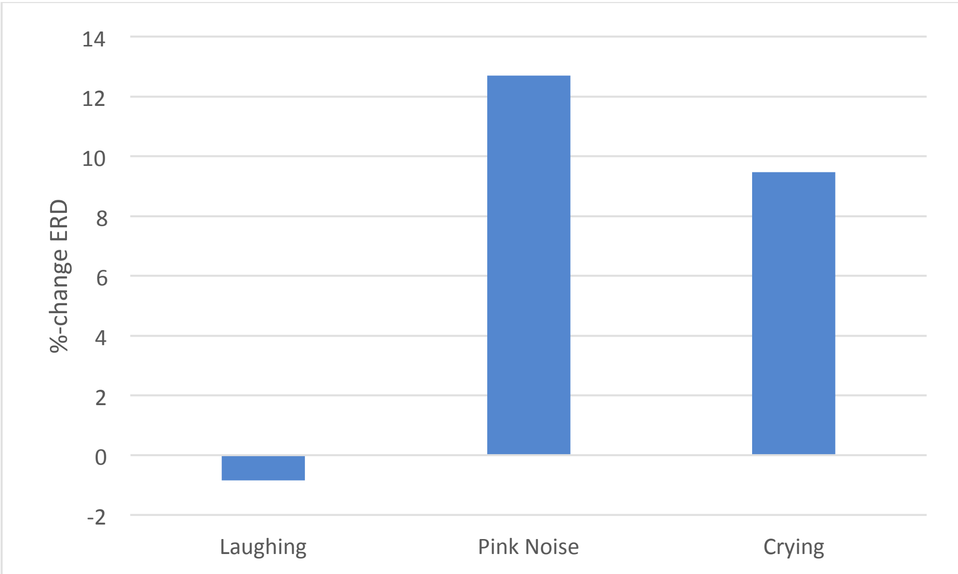

Figure 10: Chart showing %-change ERD for each stimuli type

3.9.1.2.3 Late Epoch

Table 7: Mean and Standard Error for ERD elicited by each sound for the late epoch

	Laughing	Pink Noise	Crying
Low Alpha	9.56 (7.57)	24.48 (3.81)	7.82 (6.79)
High Alpha	5.12 (8.13)	-12.64 (13.84)	8.31 (7.97)
Low Beta	-1.79 (5.27)	12.84 (2.48)	9.17 (2.39)

Low Alpha (8-10 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 4.43$, $p = .019$). Pairwise comparisons revealed a borderline significant difference between ERD for the pink noise and the crying conditions (mean difference = 16.66, p=.051, CI(95%) -.08 - 33.40). There was no interaction between stimuli type and electrode ($p = .878$). No significant correlations were found between ERD and self-reported measures of empathy.

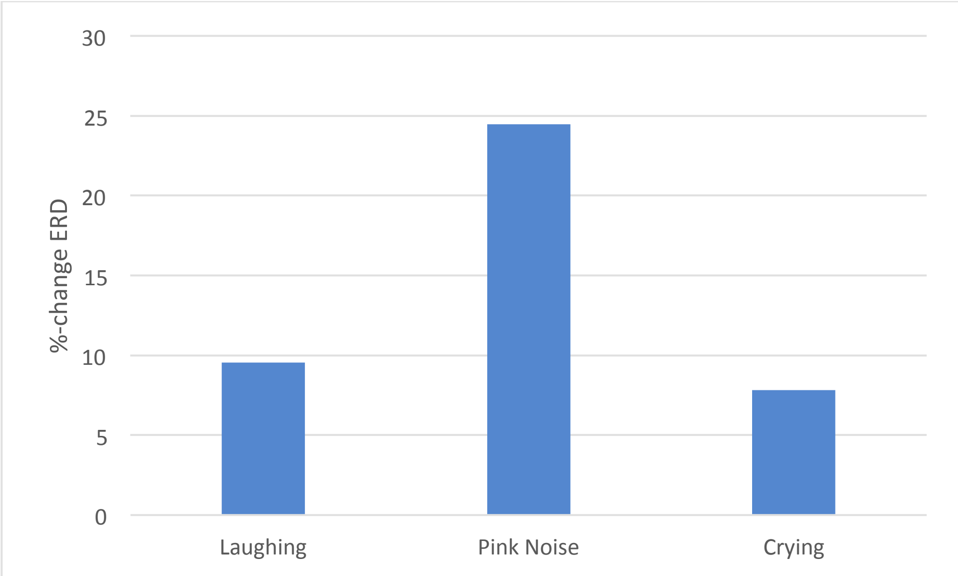

Figure 11: Chart showing %-change ERD for each stimuli type

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .214).

Low Beta (12.5-16 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 7.10$, $p = .003$). Pairwise comparisons revealed significant differences between ERD for both the laughing condition and the pink noise conditions (Borderline, mean difference = -14.63, p=.051, CI(95%) -29.29 - .04) and laughing and crying conditions (mean difference = -10.96, p=.033, CI(95%) -21.15 - -.77). There was no interaction between stimuli type and electrode ($p = .708$). A significant negative correlation was found between the crying condition and perspective taking (r = -

.46, n = 19, *p* = .049), showing that increased ERD was associated with lower perspective taking scores.

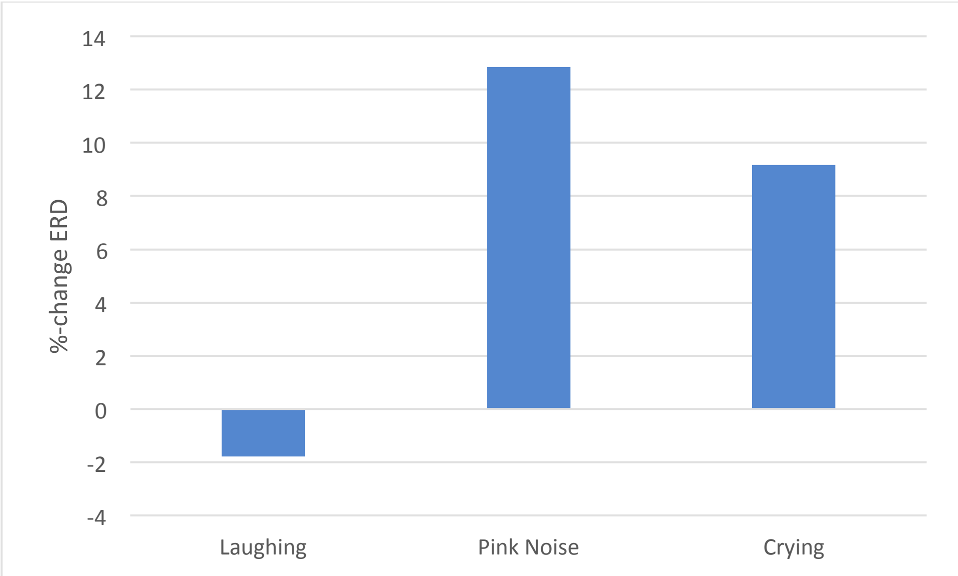

Figure 12: Chart showing %-change ERD for each stimuli type

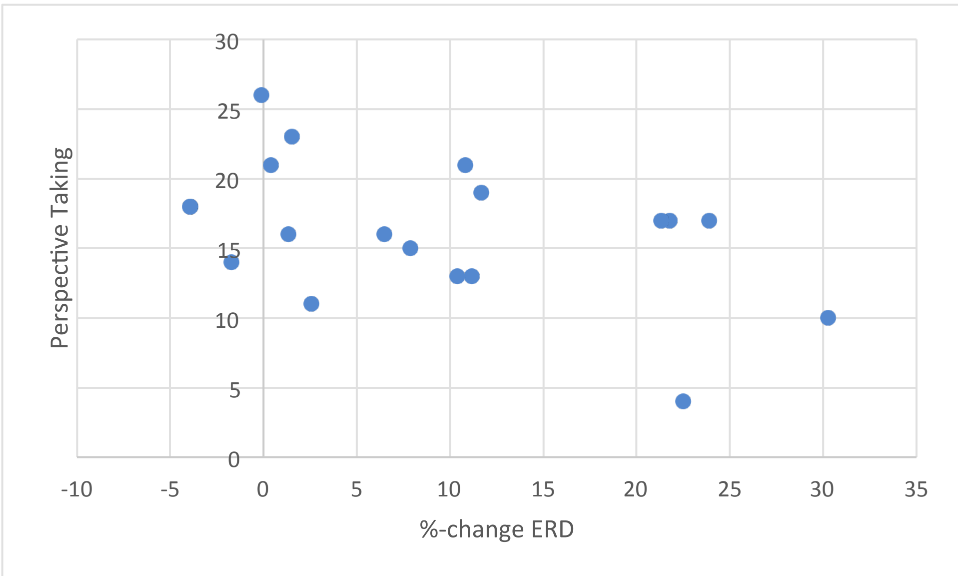

Figure 13: Scatter plot demonstrating negative association between ERD elicited by the crying condition and perspective taking scores

3.9.1.3 Centro-parietal channels (CP-strip)

3.9.1.3.1 Early Epoch

Table 8: Mean and Standard Error for ERD elicited by each sound for the early epoch

	Laughing	Pink Noise	Crying
Low Alpha	3.86 (6.00)	13.88 (4.76)	4.13 (6.95)
High Alpha	.67 (5.10)	-5.62 (7.27)	7.33 (3.72)
Low Beta	-.71 (4.09)	2.46 (2.45)	2.87 (1.97)

<u>Low Alpha (8-10 Hz)</u>

There was no main effect of stimuli type, or interaction between stimuli type and electrode ($ps > .221$).

<u>High Alpha (10-12 Hz)</u>

There was no main effect of stimuli type, or interaction between stimuli type and electrode ($ps > .282$).

<u>Low Beta (12.5-16 Hz)</u>

There was no main effect of stimuli type, or interaction between stimuli type and electrode ($ps > .543$).

3.9.1.3.2 Middle Epoch

Table 9: Mean and Standard Error for ERD elicited by each sound for the middle epoch

	Laughing	Pink Noise	Crying
Low Alpha	6.92 (7.58)	33.12 (3.87)	7.42 (9.11)
High Alpha	4.11 (6.99)	1.55 (6.48)	12.13 (6.03)
Low Beta	-3.05 (6.17)	11.58 (2.64)	8.14 (2.80)

<u>Low Alpha (8-10 Hz)</u>

A significant main effect of stimuli type was found ($F(2,36) = 6.94$, $p = .003$). Pairwise comparisons revealed significant differences between ERD for both the pink noise and the laughing conditions (mean difference = 26.20, p=.007, CI(95%) 6.60 - 45.81) and the pink noise and crying conditions (mean difference = 25.70, p=.048, CI(95%) .21 - 51.19) conditions. There was no interaction between stimuli type and electrode (p = .960). No significant correlations were found between ERD and self-reported measures of empathy.

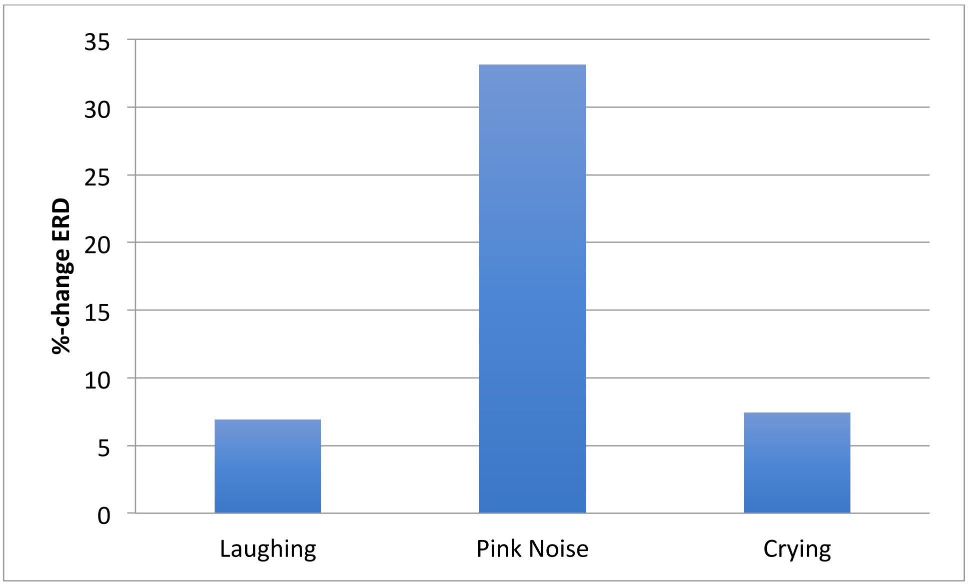

Figure 14: Chart showing %-change ERD for each stimuli type

High Alpha (10-12 Hz)

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .413).

Low Beta (12.5-16 Hz)

A significant main effect of stimuli type was found ($F(2,36) = 6.04$ $p = .005$). Pairwise comparisons revealed significant differences between ERD for the laughing and crying conditions (mean difference = -11.18, p=.048, CI(95%) -22.28 - -.08). There was no interaction between stimuli type and electrode ($p = .998$). No significant correlations were found between ERD and self-reported measures of empathy.

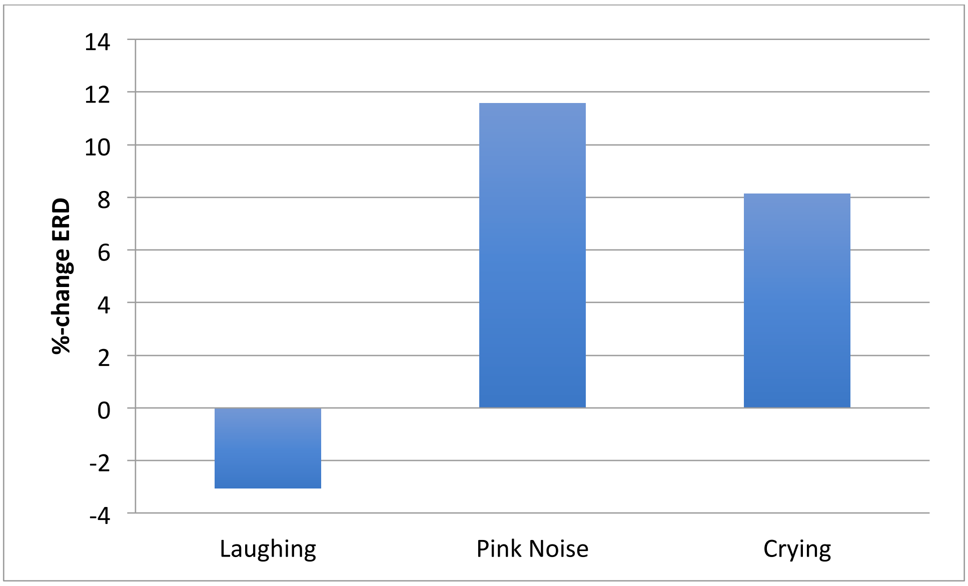

Figure 15: Chart showing %-change ERD for each stimuli type

3.9.1.3.3 Late Epoch

Table 10: Mean and Standard Error for ERD elicited by each sound for the late epoch

	Laughing	Pink Noise	Crying
Low Alpha	5.34 (8.95)	22.56 (4.59)	4.77 (7.48)
High Alpha	2.15 (8.02)	-12.21 (9.15)	8.18 (6.91)
Low Beta	-3.31 (6.12)	9.36 (2.12)	6.71 (2.40)

<u>Low Alpha (8-10 Hz)</u>

A significant main effect of stimuli type was found ($F(2,36) = 3.46$, $p = .042$). However, pairwise comparisons revealed no significant differences between ERD for conditions (*ps* >

.075). There was no interaction between stimuli type and electrode (*p* = .977). No significant correlations were found between ERD and self-reported measures of empathy.

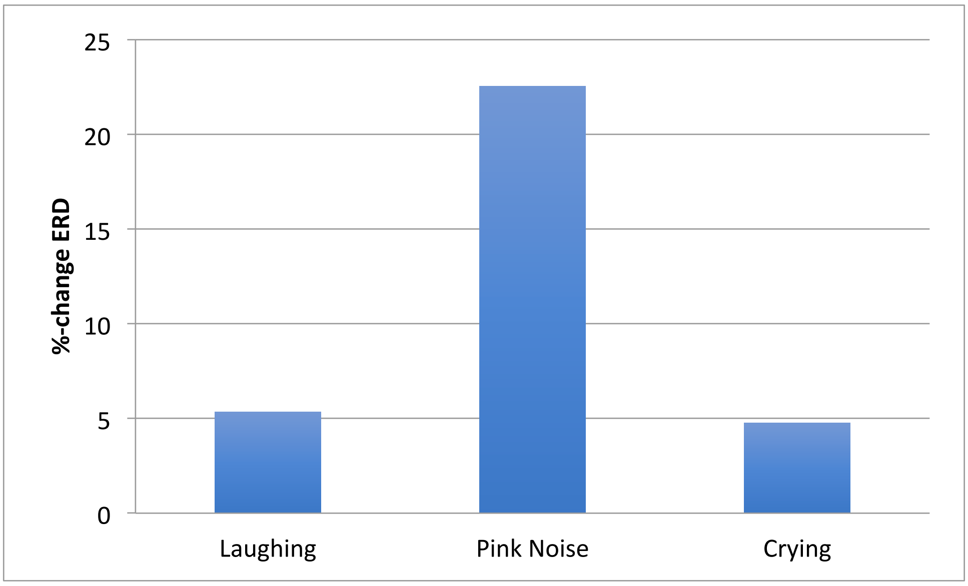

Figure 16: Chart showing %-change ERD for each stimuli type

<u>High Alpha (10-12 Hz)</u>

There was no main effect of stimuli type, or interaction between stimuli type and electrode (*ps* > .132).

<u>Low Beta (12.5-16 Hz)</u>

A significant main effect of stimuli type was found ($F(2,36) = 4.13$, $p = .024$). However, pairwise comparisons revealed no significant differences between ERD for conditions (*ps* > .106). There was no interaction between stimuli type and electrode (*p* = .970). No significant correlations were found between ERD and self-reported measures of empathy.

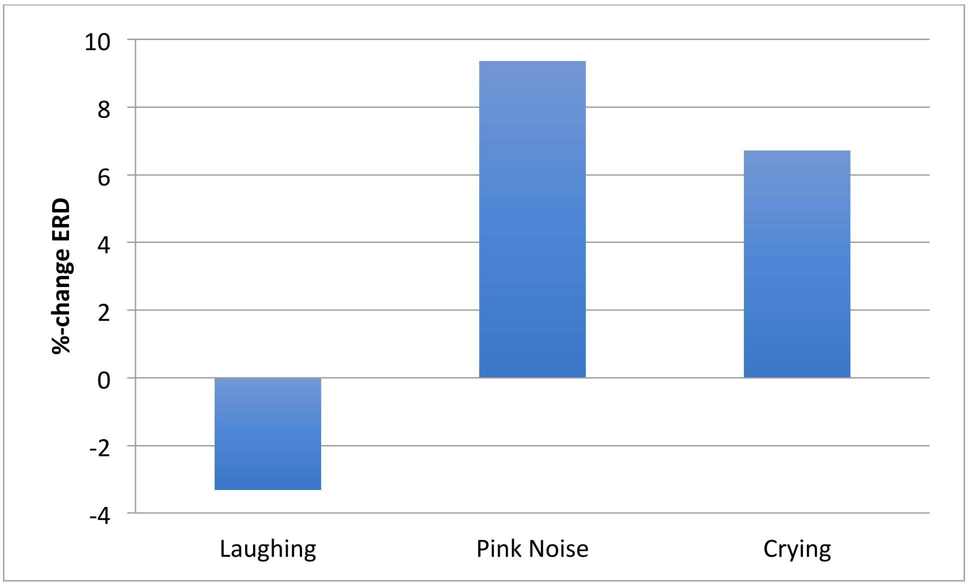

Figure 17: Chart showing %-change ERD for each stimuli type

3.9.2 Results summary and Interim Discussion – Emotional Sound Protocol

The emotional sounds protocol was developed due to a lack of previous research investigating mirror system reactivity to emotional sounds. The aim was to create and investigate a protocol which presented people with the most affective positive (laughing) and negative (crying) sounds. The former was achieved in the pilot study that precedes this study. Due to a lack of past research investigating this specific topic, expectations were partly exploratory, however did have some theoretical background. There was an assumption that there would be a significant difference in mu ERD elicited by the laughing and crying sounds and that if participants were to empathise more with the crying sounds then they should elicit a significantly higher ERD than the laughing sounds. In addition to this, if increased cortical excitability of the mirror system is involved in empathic processes then this increased activity should correlate with self-report measures of empathy. It was therefore expected that along with an increased ERD to the crying sounds, that increase would correlate positively with the EQ and the empathic concern dimension of the IRI. Due to the negative affective nature of the crying sounds. It was also possible that the crying sound could elicit negative feelings in the participants, which may result in an association with the personal distress dimension of the IRI. In the following paragraphs, we will focus on three main findings: a main effect of type of stimuli in the low beta bandwidth, a main effect of stimuli that was found in the low alpha bandwidth and lastly, the significant correlations.

The first pertinent point is that in the low beta band, a persistent significant difference between ERD elicited by the laughing and crying conditions occurs. This difference is found in each electrode strip (FC, C and CP) in the middle time epoch. This finding also occurs in the late time epoch at the FC and C-strip. In all of these instances (matching predictions) ERD is higher to the crying than to the laughing sound (which actually caused ERS). This finding provides evidence of increased mu activity and therefore arguably a more active mirror system in response to the negative emotional sound of crying, whilst also potentially demonstrating a non-reactive mirror system when hearing the positive emotional sound of laughing. In conjunction with this finding and providing additional evidence of a link between mu activation and empathy, we see a negative correlation between ERD to the crying sounds and perspective taking (both at frontocentral and central locations). We also observe another negative correlation between ERS to the laughing sounds and perspective taking in the late epoch at fronto-central locations. Gazzola, Aziz-Zadeh and Keysers (2006) report higher level of perspective taking scores was associated with higher activation of auditory mirror neurons, however this is a positive association rather an our negative one.

The stimuli between our study and there's however differs, with Gazzola et al. using action related sounds and the present study using emotional sounds of laughing and crying. As mentioned, we observed negative correlations in our study, which is perhaps not expected. One possible explanation (and indeed one that will feature throughout this thesis) relates to the neural efficiency hypothesis, which posits that when a person is more experienced at a task we see less neural activation than someone who is a novice of a task. Of lesser interest in this bandwidth, at the FC-strip in the middle epoch, we observe significant differences between the pink noise condition and both the laughing and crying difference, with higher ERD elicited by the pink noise. Lastly within the low beta band at both the FC and C-strip in the late epoch we find a significant difference between the pink noise and laughing conditions, with higher ERD again to the pink noise. No differences are found in the early time epoch suggesting that no differentiation of the stimuli relevant to the study is occurring there. It perhaps should be acknowledged that mu ERD elicited by the pink noise sound was higher than mu ERD elicited by the laughing or crying sounds. The reason for this is uncertain, however it could be that the sound was overly negative in some manner, perhaps aversive. As no subjective participant ratings were taken for this sound, this cannot be explored. A concern, of course is that it is the aversive nature of the crying sound that is causing this ERD and not distinct mirror neuron activity, however based on findings mentioned below, it is argued that this is not the case.

For the second pertinent point, we see that in the low alpha band, a persistent significant difference between both the pink noise and the laughing conditions and between the pink noise and crying conditions occurs. This difference occurs primarily in each electrode strip in the middle time epoch, and whilst is present at the early and late time epoch at central regions there are no significant differences in mu ERD at the early time epoch and only borderline differences in the late time epoch. Whilst predictions of a significant difference between the pink noise (the control sound) and the laughing and crying sounds were accurate, the prediction that mu ERD would be higher to the laughing and crying rather than the pink noise was not correct due to the observation that the pink noise condition elicited higher levels of mu ERD than to both of the other sounds. Again, similar to findings mentioned above, we see that the pink noise elicits more mu ERD than the other sounds, however in this instance we see no increased levels of mu ERD for the crying sound, providing evidence that it is not the potential aversive nature of the crying sounds which is driving the effect mentioned in the above paragraph. Still this level of mu ERD was not expected and goes against previous literature that has shown that white noise does not elicit an excitatory response (Kohler, et al. 2002; Crawcour, Bowers, Harkrider & Saltuklaroglu, 2009). Whilst the effect of the pink noise is interesting, it is however not pertinent to our hypotheses and assumed to be merely an effect of aversive neural reactivity.

In summary, it is argued that evidence has been found which supports the idea of hMNS engagement in relation to auditory stimuli. Data suggests that crying sounds activate mu activity when compared to laughing sounds which elicit mu ERS, which is potentially related to a non-engaged mirror system. Further evidence linking mu ERD to empathy is found with negative associations between perspective taken (a dimension of the IRI) and mu ERD elicited by the crying sounds. Mu ERD to the pink noise conditions was unexpected, however it is argued that this is not related to true mu activity and is perhaps more related to the stimuli being aversive in nature. Finally the negative correlations were also unexpected, however may be explained when taking the neural efficiency hypothesis in to consideration.

3.11.2 Experiment 1b - Pain Protocol

The following results are of 2 x 3 x 7 repeated measures ANOVAs that were conducted to compare the main effect of type of stimuli (needle and Qtip) x body location (hand, foot, mouth) x electrode (seven electrode strip). Analysis was performed on three different epochs: early (500-1000ms), middle (1000-1500ms) and late (1500-2000ms). For each section below, the focus will be on the main effect of stimuli type, interactions between stimuli type and body location and correlational analysis. Correlations between ERD and self-report measures of empathy are only conducted when a significant difference is found between ERD elicited by stimuli type.

3.11.2.1 Fronto-central channels (FC-strip)

3.11.2.1.1 Early Epoch

Table 11: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	44.35 (10.28)	50.64 (8.50)
High Alpha	51.57 (11.48)	53.75 (11.27)
Low Beta	30.33 (7.38)	31.56 (7.18)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .174).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .557).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .690).

3.11.2.1.2 Middle Epoch

Table 12: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	46.37 (9.09)	50.66 (7.94)
High Alpha	52.89 (9.29)	56.37 (8.91)
Low Beta	28.43 (6.79)	28.76 (6.70)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .204).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .511).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .146).

3.11.2.1.3 Late Epoch

Table 13: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	43.58 (8.96)	48.31 (7.74)
High Alpha	50.81 (9.23)	56.76 (8.11)
Low Beta	28.91 (6.64)	28.41 (6.84)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .262).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .272).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .609).

3.11.2.2 Central channels (C-strip)

3.11.2.2.1 Early Epoch

Table 14: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	45.70 (8.48)	46.41 (8.39)
High Alpha	47.26 (7.23)	45.90 (7.49)
Low Beta	29.56 (5.78)	27.42 (6.20)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .850).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .706).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .491).

3.11.2.2.2 Middle Epoch

Table 15: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	42.01 (9.88)	42.27 (9.14)
High Alpha	43.07 (7.88)	44.71 (8.62)
Low Beta	23.28 (5.41)	21.38 (5.61)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .491).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .696).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .483).

3.11.2.2.3 Late Epoch

Table 16: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	39.03 (9.14)	36.68 (10.20)
High Alpha	39.54 (8.34)	42.31 (10.26)
Low Beta	24.38 (4.84)	23.00 (5.05)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .123).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .360).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .561).

3.11.2.3 Centro-parietal channels (CP-strip)

3.11.2.3.1 Early Epoch

Table 17: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	45.18 (5.88)	43.94 (8.77)
High Alpha	50.08 (7.30)	38.28 (9.73)
Low Beta	29.01 (6.90)	26.69 (7.03)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .726).

High Alpha (10-12 Hz)

A main effect of stimuli type was found (F (1,10) = 10.53, p = .009). A significant negative correlation was found between ERD elicited by the Qtip condition and perspective taking (r = -.53, n = 19, p = .018).

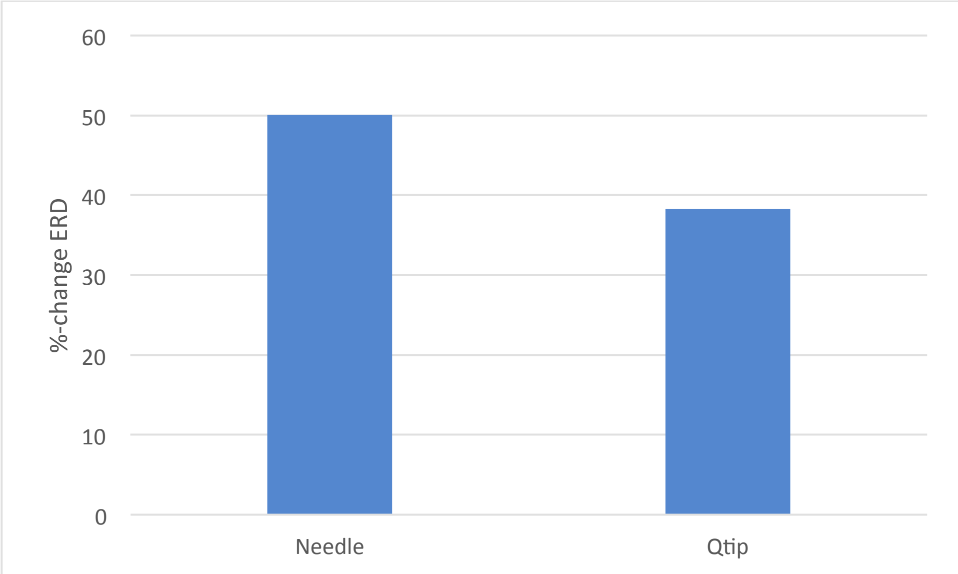

Figure 18: Table showing ERD for both needle and Qtip condition

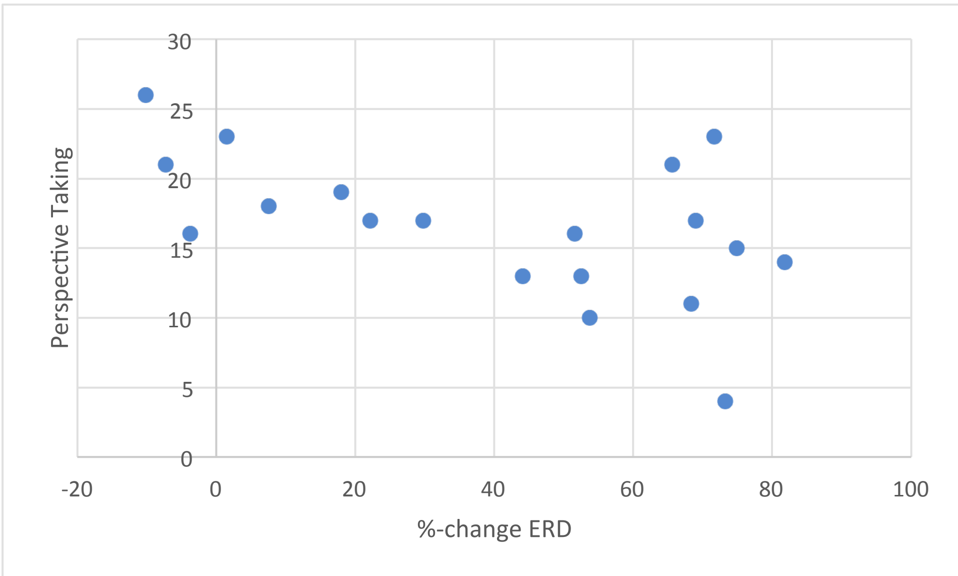

Figure 19: Scatter plot demonstrating negative association between ERD elicited by the Qtip (non-painful) condition and perspective taking scores

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .561).

3.11.2.3.2 Middle Epoch

Table 18: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	42.58 (5.50)	42.68 (6.63)
High Alpha	49.54 (5.85)	41.87 (7.45)
Low Beta	23.55 (6.12)	21.88 (6.51)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .414).

High Alpha (10-12 Hz)

A main effect of stimuli type was found (F (1,10) = 6.37, p = .030). A significant negative correlation was found between ERD elicited by the Qtip condition and perspective taking (r = -.49, n = 19, p = .034).

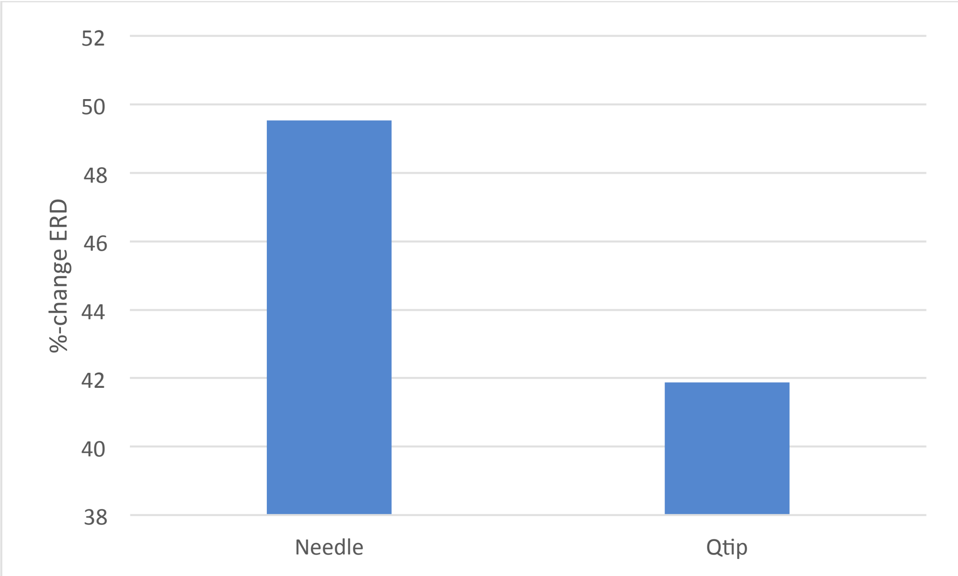

Figure 20: Table showing ERD for both needle and Qtip condition

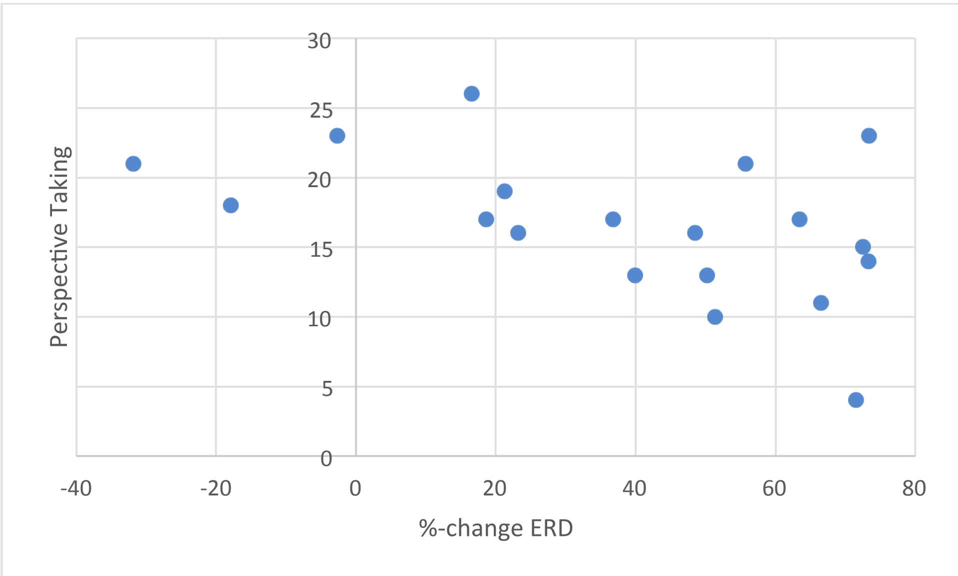

Figure 21: Scatter plot demonstrating negative association between ERD elicited by the Qtip (non-painful) condition and perspective taking scores

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .597).

3.11.2.3.3 Late Epoch

Table 19: Mean and Standard Error for ERD elicited by each image

	Needle	Qtip
Low Alpha	38.22 (4.98)	38.05 (7.16)
High Alpha	47.44 (6.07)	43.77 (6.61)
Low Beta	22.78 (5.48)	22.24 (5.94)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .121).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .308).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and body location (*ps* > .522).

3.11.2. Interim Discussion – Pain Protocol

The pain protocol was constructed to examine mirror neuron activation in relation to needle (painful) and Q-tip (non-painful) images. Whilst this protocol was purpose built for this study, it was based on previous research (such as Yang, et al., 2009; Decety et al., 2010; Perry, et al., 2010). Whilst there is literature supporting the involvement of the mirror neuron system in perception of pain, the vast majority of studies have focussed on either fMRI or ERP methodology. The aim of using a pain protocol in this study was to further investigate the involvement of the mirror neuron system in perception of pain by investigating the link between oscillatory activity (i.e. mu ERD) and self-report measures of empathy. There was an expectation of finding significant differences between stimulus evoked mu ERD at fronto-central, central and centro-parietal regions (regions which have been implicated as part of the mirror neuron system) with higher mu ERD to the needle images than to the Qtip images. In terms of these expectations, this protocol was partially successful. Within the fronto-central and central regions we find no differences in mu ERD between the needle and Qtip condition. However, significant differences in stimulus evoked mu ERD were found at centro-parietal regions within the high alpha bandwidth in both early and middle epochs. In both time periods, mu ERD was found to be higher for observing the needle rather than Qtip condition – matching predictions of increased mu ERD to painful images. This is interesting as these centro-parietal electrodes overlay somatosensory areas and may therefore be involved in some aspect of mirroring of the tactile experience. Why mu suppression was not found over fronto-central or central regions in the present study is not certain, however research examining mu suppression has not found strict localization for this activity. Perry et al. (2010) for example found mu suppression primarily over fronto-central regions, whilst Yang et al. (2009) found similar findings over central regions.

Alongside these findings, we see two negative associations (albeit at the same region spanning the early and middle time epoch of the stimuli) in the high alpha range. These correlations are found along with the differences in ERD elicited by the painful and non-painful images. Counter to expectations, we observe no correlations with the painful images, but instead between the Q-tip images and the perspective taking dimension of the IRI. These negative associations, similar to the findings for the emotional sound protocol, imply that the higher a person's perspective taking score, the less active the mirror neuron system and may again relate to the neural efficiency hypothesis. These findings do not support previous findings (such as Singer, et al., 2004; Lamm, Nusbaum, Meltzoff & Decety, 2007; Yang et al. 2009) who found positive correlations between mirror neuron activity and measures of empathy.

In summary, it should be noted that the data as they are do not provide strong evidence that mu ERD elicited by the stimuli in this pain protocol is related to mirror neuron system due to no association between the painful stimuli and measures of empathy. However, it is argued that the results found indicate that the hMNS responds to both painful and non-painful images, and perhaps more importantly with a difference in mu ERD between the two types of stimuli and higher mu ERD to the painful image. We also found a possible link between mu ERD and empathy in relation to these images, however only with the non-painful images. It is tentatively suggested that there is potential in this protocol based on the argument made above, and with the current state of the literature suggesting the usefulness of pain protocols in investigating both mirror neuron activity and in turn, empathy.

3.12 Chapter Discussion

The main objective of this study was to expand upon the mirror neuron literature. This was achieved by investigating cortical reactivity elicited by stimuli in two different protocols and investigating associations between this activity and self-report measures of empathy. The mu rhythm was examined in relation to low alpha (8 - 10 Hz), high alpha (10 - 12 Hz) and low beta (13 - 20 hz) that make up the mu rhythm. The self-report measures of empathy that were used were the EQ, and the IRI. The EQ was used as a global measure of empathy, and the IRI was examined in relation to its four dimensions, namely fantasy, empathic concern, perspective taking and personal distress, rather than one value. The first method of investigation involved the use of an emotional sounds protocol that comprised of sounds of males and females laughing and crying, with control sound of pink noise. The second method of investigation comprised of a pain protocol which consisted of images of hands, feet and mouths either being pricked by a needle (painful condition) or having a Q-tip pressing against them (non-painful condition). As the results of each protocol has been discussed in its relevant interim discussion, the aim of this section will be to summarise and bring together the findings from both protocols.

3.12.1 Emotional Sounds Protocol

The emotional sounds protocol was chosen due to the lack of research investigating the mirror neuron reactivity to emotional sounds and its potential relationship with empathy. The most pertinent finding for this protocol was that there was a difference in mu activation between the laughing and crying sounds with higher mu ERD elicited by the crying sounds.

Whilst this supported predictions of the possible involvement of the hMNS with this emotional sound, there was a lack of definitive evidence to support the idea that this increase in mu activity was associated with empathy as measured by the EQ and IRI, with only negative correlations between crying and perspective taking and laughing and perspective taking found. Whilst no correlations were found between the crying sounds and the EQ or the empathic concern dimension, the presence of a correlation with perspective taking implies a more subtle and counter intuitive relationship between mirror system involvement of our participants and empathy. Whilst it could perhaps be logical to expect that mirror neuron activation would correlate in a positive manner with empathy in that higher activation would be associated with a higher score on the measure of empathy, this negative correlation may provide some evidence in support of the idea that those who are more skilled at a task elicit less ERD than those who are not (neural efficiency hypothesis). Negative associations between mu ERD and empathy are also found in the second and third study of this thesis, perhaps demonstrating the need to take this in to consideration when planning further research. These correlations were only ever associated with cortical excitability in the low beta bandwidth. Three of these correlations were related to cortical excitability to the crying sounds, with only one with the laughing sound, perhaps implying a need to take the perspective of someone who is crying (and therefore sad) rather than someone who is laughing (and therefore happy). It should also be noted that inverse relationships between affective perspective taking and perception of others in pain have been found in samples exhibiting psychopathic traits (Decety, Chen, Harenski & Kiehl, 2013), however it is highly unlikely that our sample exhibited the same level of psychopathy as a clinical sample, but this should be considered in the future. Other evidence of a negative association between empathy (this time the empathy quotient) and mu suppression comes from Perry, Troje and Bentin (2010). The authors investigated mu suppression while participants were required to identify either the intention, emotion or gender of a series of dynamic stimuli. Results demonstrated a higher reduction in mu amplitude when judging the intention of the stimuli in relation to the other two conditions. This reduction in mu amplitude correlated negatively with the empathy quotient. It however should be stated that in the Perry, et al. study the suppression to the intention condition was stronger at occipital sites which may not reflect mirror neuron activation. Research by Woodruff, Martin and Bilyk (2011) investigating the relationship between mu and self-other discrimination found that higher perspective taking scores were related to a greater difference in mu suppression between the observation and execution conditions - thus a finding that is counter to ours, however they used a difference in mu power between conditions of interest, whilst we did not in our study. A final finding of lesser interest to our study was that of a high level of mu ERD to the control sound (pink noise). This might be considered to be an issue due to the fact of it being a control sound, however it is argued that it merely reflects the sound being overly aversive in nature. To summarise, we find a difference in cortical excitability between listening to sounds of people laughing and crying, with more mirror system involvement with the crying sounds. We also find an inverse relationship between this activity and the ability to take the perspective of others.

3.12.2 Pain Protocol

The pain protocol was included as similar tasks are traditionally used in the literature to investigate empathy to pain, and therefore this was thought to be a reliable measure. The aim was to further mu ERD pain literature, due to the vast majority being related to fMRI and ERP techniques. The most pertinent finding for this protocol was that there was a difference in mu activation relative to the needle and Q-tip images with the needle images eliciting higher levels of mirror activity than the Q-tip images. This supported predictions and previous research (Yang, et al. 2009; Perry, et al. 2010). In a similar vein to our findings for the emotional sounds protocol we find no clear conclusive evidence of an association between mirror system activation and empathy per se. What we do find however, drawing a similarity with the emotional sounds findings, is a negative correlation with perspective taking. This correlation between perspective taking and mirror activity relating to the observation of the Q-tip images was not expected and illustrates that a higher perspective taking score is associated with less mirror activity, perhaps again demonstrating that expertise at perspective taking is causing less mu ERD and indicting a more nuanced relationship between mu ERD and empathy (again evidence in support of the neural efficiency hypothesis). It is however uncertain as to why this relationship is only present with the Q-tip images. The reason for this could possibly be due to the non-painful conditions causing participants to consider more or differently how it would feel to have a Q-tip pressing against the skin. It could be argued that the vast majority of people know what it feels like to be pricked by a needle, however perhaps less so to have a Q-tip pressed against them. This of course, remains speculative and the effects of novelty and effort on

MN activation remains to be investigated further. This could perhaps be investigated by introducing a wider range of stimuli that has been pre-rated for novelty factor.

3.13 Concluding Comments

To summarise, we found higher mu ERD when observing painful images, however the only relationship we found to empathy was a negative one between the non-painful images and perspective taking demonstrating that less mirror activation was associated with a higher ability to take the perspectives of others. This chapter leaves us with some evidence to suggest the involvement of the hMNS in perception of both emotional sounds (laughing and crying) and a classic pain protocol (painful and non-painful images). We also found evidence to suggest a more nuanced relationship between mirror neuron activity and empathy where we are perhaps seeing an effect of expertise at play. Whilst the stimuli used in the emotional sounds protocol was piloted and rated prior to study 1, the image used for the pain protocol were not. It is unlikely that our images were not fit for purpose however as the images were based on examples from the literature which were successful in eliciting mirror neuron activity – however piloting and rating them would be useful. One of the main objectives of this first study was to identify a protocol which can be reliably used to measure changes in mirror neuron activity whilst also demonstrating a link between said activity and subjective empathic scores on the EQ and IRI. This protocol would then be used in study two in order to investigate the potential benefits of practicing loving-kindness meditation - a technique said to make one more empathic. Whilst it could be argued that a reliable protocol was not found, one of the above protocols must be chosen. The emotional sounds protocol was primarily experimental in nature and does not have a solid basis in the literature. There is also the potential issue with the high neural reactivity in response to the control sound. Due to these reasons and the fact that pain protocols are commonly used in empathy studies, the pain protocol will be used in study two. In the next Chapter, we examine whether long-term practice of loving-kindness meditation can have an effect on empathy.

Chapter 4: Neural Correlates of Loving-Kindness Meditation

"Resolve to be tender with the young, compassionate with the aged, sympathetic with the striving and tolerant with the weak and wrong. Sometime in your life, you will have been all of these." – Gautama Buddha

4.1 Introduction

At the end of Chapter 1, we briefly touched upon the topic of meditation, specifically loving-kindness mediation (LKM) and the potential positive improvements that this technique can elicit. The focus of this experimental chapter is on LKM where we will examine what LKM is and whether LKM as a technique can elicit meaningful alterations to both self-report measures of empathy (as measured by the empathy quotient and interpersonal reactivity index) and mirror neuron activity (as measured by ERD in low/high alpha and low beta) as a putative measure of empathy. We will firstly discuss LKM by examining it in a Buddhist framework, move on to what the technique itself involves, include some general research which highlights the effectiveness of LKM, research linking LKM to empathy and finally expectations for study two.

First of all, we will look at the background of LKM. Just as mindfulness meditation techniques cultivate awareness and acceptance of yourself and others, the practice of LKM helps to cultivate compassion, for oneself and others. Loving-Kindness Meditation and compassion are closely linked: to the Buddhist, true compassion involves the understanding that every other person wants to be happy and be free from suffering (just like ourselves). This is not the same kind of compassion that entails emotional attachment as you might have for a friend or a loved one, which according to the Dalai Lama can turn negative (Dalai Lama & Cutler, 1998). These authors explain that because we recognise that other people feel as we do, that they want to be happy and free from suffering, it becomes a universal truth and therefore we can still be compassionate even though we may not like a particular person. Hofmann, Grossman and Hinton (2011; pg.3) describe LKM as “a mental state of unselfish and unconditional kindness to all beings”. It is not just love or kindness, but kindness which has a focus of love and care. This appears to give the process a nurturing aspect. Loving-kindness is one of the four “sublime states” of Buddhism: loving-kindness, compassion, sympathetic joy and equanimity. They are seen as specific attitudes that can be cultivated. Training in these four characteristics allows us to gain insight into our minds and the world around us (Hofmann, Grossman & Hinton, 2011), and without them we would have difficulty, when presented with negative perceptions/emotions, to experience the sensation with mindful awareness.

Loving-Kindness Meditation is an integral part of Buddhist meditative practices and philosophy often being combined with mindfulness (Bodhi, 2005). Whilst the technique of LKM appears to vary slightly, the shared factors seem to focus on a series of aspiration-like statements during a multi-stage technique. These stages include: 1) focussing on oneself; 2) focusing on a close friend; 3) focussing on a neutral person; 4) focussing on a ‘difficult’ person (e.g. a person who you might have had a conflict with); 5) stretching out your focus to all beings (Hofmann, Grossman & Hinton, 2011). The aspirations that are repeated vary slightly, however generally they involve the wishing of wellness, happiness and the freedom from suffering. The goal is to attempt to generate these desires as you are repeating the aspirations rather than just repeat the words mechanically (Hofmann, Grossman & Hinton).

The Dalai Lama and Cutler (1998) state that by practicing LKM a person can broaden their attention, improve positive emotions, lessen negative emotional states and increase empathy and compassion. In a recent study, Cho, et al., (2018) interviewed experts in Buhddism in order to gain a broad definition of loving-kindness to develop a lovingkindness-compassion scale (LCS). Based on this interview multiple potential items for the scale were created and subsequently tested on 469 participants. Based on factor analysis, three factors were found: compassion, loving-kindness and self-centeredness. Further analysis found significant correlations between the LCS and: self-compassion, compassionate love, social connectedness, empathy and satisfaction with life.

We will now examine empirical findings relating to LKM starting with research by Hutcherson, Seppala and Gross (2008) who investigated LKM in relation to social connectedness. The authors investigated the question as to whether positive feelings and connection towards others could be generated by using LKM. The study involved two experimental groups. In the LKM group participants were first led through a guided meditation for seven minutes and then asked for four minutes to visualise two loved ones standing next to the participant sending loving feelings to the participant. After this, they were asked to open their eyes and send these feelings of love towards a picture of a stranger presented on a computer. In the visualisation group, participants were also exposed to the seven-minute guided mediation. This was followed by four minutes of visualising the features of two acquaintances standing next to the participant. The next stage for the visualisation group was to then attend to an image on the screen of a stranger and attempt to focus on the features of that person including what the person might be wearing. This was followed by an explicit and implicit task which required participants to rate how connected, similar and positive they felt to images of strangers (explicit) and an affective priming task (implicit), a measure of mood was also taken. It was found that LKM participants became more positive and less negative. Both groups became more positive towards the target after the seven-minute meditation with the LKM being more positive than the visualisation group. In relation to the implicit responses, it was also found that participants in the LKM group became more positive towards the target pictures. Thus this study demonstrates that short-term practice of LKM can lead to increased positive feelings towards others (specifically strangers).

Fredrickson, Cohn, Coffey, Pek and Finkel (2008) conducted a thorough longitudinal study investigating the impact of LKM on various personal resources including: 1) cognitive resources, 2) psychological resources, 3) social resources and 4) physical resources. Participants were either assigned to a LKM meditation group or a waitlist group (where they received the same treatment as the meditation group but after the conclusion of the study). During the LKM workshop, participants completed daily reports of emotions experienced and of their meditation practice. This continued until a week after the end of the LKM workshop. The authors hypothesised that over time, participants would experience an increase in positive emotions which would lead to an increase in positive personal resources. Results demonstrated that those in the LKM group experienced an increase in positive emotions (all positive emotions combined) over the course of the study. Generally, time spent in meditative activity predicted positive emotions. LKM did not have an effect on negative emotions experienced over the course of the study. There was some evidence to suggest that changes in positive emotion influenced changes in life satisfaction, however only to the extent that the extend that the emotions built personal resources. Overall the authors conclude that practice of LKM can increase experience of positive emotions which can lead to an increase in positive resources which can increase life satisfaction.

We see therefore that LKM involves the training of awareness of both one's own and others emotional states. Neurobiological research has implicated both the insula and the anterior cingulate cortex (areas also implicated in empathy) in perception of another's emotional state as well as the emotional state in oneself (Ruby & Decety, 2004; Singer, et al. 2004; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008; Lutz, Greischar, Perlman, & Davidson, 2009). Research has also found that activation of these areas is greater based on meditative expertise. A study by Lutz et al. (2008) saw experienced Tibetan monks and novice compassion based meditators undergoing fMRI whilst listening to audio clips of babies laughing, women in distress and neutral background noises. Insula activation was increased in experienced meditators during the sounds of women in distress in comparison to the baby laughing and the neutral sounds. The intensity of the increase depended on the level of expertise with meditation with the experts showing a more intense activation. This demonstrates evidence for compassion-based meditation techniques potentially building upon a person's ability to empathise. If this is the case then it could be hypothesised that empathy scores would be higher in long term practitioners of meditation than for novices or for non-meditators. In another brain imaging study researchers utilised a longitudinal design to examine empathic accuracy. Participants were assigned to two groups: the first who took part in a cognitive-based compassion training (CBCT) course and the second, a control group who were assigned to a health discussion group. Both groups received fMRI scans (both before and after the interventions) while completing the Reading the Mind in the Eyes (RMITE) task, a measure of empathic accuracy. It was found that those who were assigned to the CBCT intervention were more likely to have improved RMITE scores compared to the control group. In addition to this, the CBCT group also had increased neural activity in the inferior frontal gyrus. The studies above indicate that loving-kindness/compassion-based techniques have the ability to increase empathy and other measures closely related to empathy.

Accordingly, the following study was designed, which featured two groups of participants: long-term practitioners of LKM and a control group with no meditative experience. Each group completed the EQ and IRI and were exposed to three experimental protocols: a pain protocol, a simple hand movement protocol and an international affective image protocol (IAPS). The pain protocol was brought forward from the last chapter and involved images of a needle pricking body locations (painful condition) and Q-tip pressing against the same locations (non-painful condition. However, due to the inconclusive findings from this protocol two other protocols will be used in order to maximise potential findings. The moving hands protocol is a simple mirror neuron activation protocol. This protocol has been successful in the past at eliciting mu desynchronisation (see Oberman, Hubbard, McCleery, Altschuler, Ramachandran & Pineda, 2005) and as such will be used in study two in conjunction with the pain and IAPS protocol. The IAPS protocol consists of positive, negative and neutral images. This protocol will be used in order to examine neural reactivity in the mu bandwidth in response to these three categories of image valence. We looked to ascertain whether 1) long-term practice of LKM can increase levels of empathy as recorded by the EQ and the IRI; 2) whether long-term practice of LKM can modulate mirror neuron activity as measured by mu ERD (low-high alpha and low beta) upon the observation of the stimuli contained within three experimental protocols and 3) whether there is an association between the neural response to these protocols and self-reported measures of empathy. It was expected that the LKM group would show higher levels of empathy as shown by the EQ and the IRI compared to the control group. For each participant, EEG will be analysed in the alpha (low and high) and beta (low) frequency bands, as it has been found that mu frequency falls within these bands and as discussed in Chapter two, there is considerable evidence to support this rhythm being related to the human mirror system. Based on this, for the pain protocol, it is expected that there will be increased mu ERD to images of needles piercing skin (painful condition) compared to images of Q-tips pressing against the skin (as was found in study one). For the hand movement protocol, it is expected that practice of LKM will facilitate the mirror neuron system, and thus we will see increased mu ERD to the moving hand condition (beyond that of the non-meditators) rather than the still hand or the two moving balls. Finally, in the IAPS protocol, it is expected to see decreased mu ERD to negative images rather than positive and neutral images. The rationale for this is based on previous research involving EEG to IAPS stimuli that has found that meditators process emotional images differently and are less effected by negative valenced stimuli (Sobolewski, Holt, Kublik & Wrobel, 2011).

4.2 Method

4.2.1 Participants

This study consisted of 30 participants of whom 19 were female. Control participants were recruited via the psychology department's volunteer email database and using convenience sampling. Meditators (14) were recruited from the Colchester Buddhist Centre and from volunteers at the University of Essex who were long time practitioners of Metta Bhavana (LKM) meditation. The mean age of the sample was 23.24 (SD = 13.69). Participants were reimbursed financially in exchange for their participation or awarded experimental credits for their Research Methods module. All meditators had over a year of experience with LKM and practiced on a regular (weekly) basis.

4.2.2 Stimuli

Self-report Scales

Both the empathy quotient and the interpersonal reactivity index were used and are described in Chapter 1.

Moving Hands Protocol

The stimuli used for this protocol comprised of three clips (figure 22 below) which depicted a pair of balls bouncing, a static hand or a moving hand. The balls moved up and down at the same rate as the moving hand (1Hz). The static hand represented the moving hand in a static open position. The moving hand represented a right-hand opening and closing in a "quacking duck beak" manner. Each of the three stimuli were recorded against a black background. The balls were of a flesh colour in order to maintain as much similarity as possible to the other stimuli.

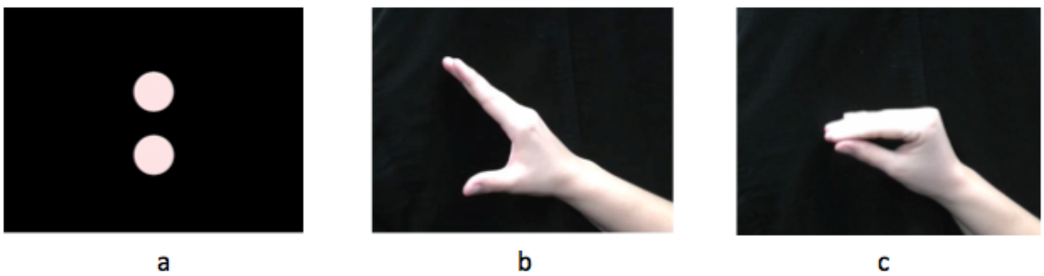

Figure 22: The three types of stimuli used in the moving hands protocol: a) moving balls, b) moving hand and c) still hand

International Affective Picture System (IAPS)

The IAPS (Lang, Bradley & Cuthbert, 2008) is a large image database that provides standardised emotional images that were obtained via an online application form from the University of Florida. Images from the IAPS are categorised as either positive (e.g. a rabbit), negative (e.g. a snake) or neutral (e.g. a clock) in valence. Images within each category can vary greatly in terms of semantic content however all images have been rated prior to distribution. Forty positive, negative and neutral images were used from the selection available. As images are not typically shown outside of a experimental setting, examples will not be included here.

Pain Protocol

As used in study 1 (see page 63 for details).

4.2.3 Procedure

After obtaining informed consent, participants were measured for and fitted with an appropriately sized EEG cap. Once the cap was fitted and the eyes electrodes were placed, participants were required to work through and complete all questionnaires while the experimenter lowered the EEG signal impedance using conductive gel. Once this had been completed, the impact of muscle movement was demonstrated to the participant in order for them to understand that they needed to remain as still as possible for the duration of the experiment. Two minutes of resting EEG was recorded before the study commenced. The order of the following tasks was counterbalanced. The moving hand protocol consisted of a total of 96 trials, broken down into 32 moving balls, 32 static hand and 32 moving hands. Each trial began with an ISI (1000ms) followed by the random presentation of a stimuli(3000ms) and ended with a blank screen (2000ms). The IAPS protocol began with an instruction screen instructing participants to remain as still as possible for the duration of the protocol. After a key press the study began with a fixation cross (1000ms), this was followed by the presentation of an image (5000ms) and concluded with a ISI (2000ms). Details for the pain protocol can be found on page 63.

4.3 EEG Data Acquisition

As page 65

4.4 EEG Data Preparation

Once acquired, the continuous data files were visually inspected for noisy data blocks and bad electrodes. Noisy blocks were manually highlighted to be rejected from further analysis. Faulty electrodes were marked as 'bad' and therefore rejected from further analysis also. Eye-movement artefacts were then rejected according to methods described by Croft & Barry (2000). All data were re-referenced to a common average reference. Remaining artefacts exceeding ± 75 mV were automatically rejected in an automatic rejection sweep before event-related desynchronization / synchronization (ERD/S) was computed using event-related band-power transform in Neuroscan Edit 4.4 (Compumedics, Melbourne, Australia). EEG bandwidths of interest were prepared in alpha and low beta (13 – 20 Hz). Alpha was further split into two sub-bands: low (8 - 10 Hz) and high (10 - 12 Hz) because functions associated with each end of the alpha spectrum differ (Klimesch et al., 2007; Petsche, Kaplan, von Stein, & Filz, 1997; Aftanas & Golocheikine, 2001). Electrodes of interest included those overlying the premotor cortex and supplementary motor area (FC5, FC3, FC1, FCz, FC2, FC4, FC6), those overlying the motor cortex (C5, C3, C1, Cz, C2, C4, C4, C6) and finally those over the sensory area (CP5, CP3, CP1, CPz, CP2, CP4, CP4, CP6).

All data for the moving hand protocol were epoched from -500 to 3250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 3000 ms) was calculated using the formula adapted from Pfurtscheller and colleagues (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999): $ERD\% = (R-A) / R \times 100$, where R = power in the reference interval and A = power in the active or task phase. Using this formula ERD is expressed as positive values and ERS as negative. All data for the pain protocol were epoched from -500 to 2250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 2000 ms) was calculated using the same formula as above. Finally, All data for the IAPS protocol were epoched from -500 to 5250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 5000 ms) was calculated using the same formula as above.

4.5 Results

4.5.1 Empathy Differences

To answer the initial question as to whether there were any group difference in empathy as measured by the EQ and IRI, interim descriptive statistics and independent t-tests were conducted.

Table 20: Group means and standard deviations for empathy scores for both the control and LKM group

Group	EQ	PT	FS	EC	PD
Control	51.88	20.13	18.63	20.25	10.13
	(13.86)	(5.15)	(4.82)	(4.44)	(4.83)
LKM	53.00	20.36	15.29	22.14	11.21
	(9.18)	(6.95)	(7.58)	(6.47)	(7.10)
Global		17.37	17.24	20.36	10.87
(Davis, 1980)		(4.79)	(5.39)	(4.02)	(4.78)

Global scores for each dimension of the IRI were taken from Davis (1980). As global scores were originally split into male and female (and this thesis is not examining gender differences) these scores were averaged into the scores seen in table 20. Independent samples t-tests were conducted in order to investigate potential differences between control, meditator and global empathy scores. Tests revealed no significant differences between control and meditator group (*ps* > .086). On a positive note, despite the lack of significant differences it is important to note that scores for EQ, EC and PD are higher in the LKM group. This could indicate the need for more statistical power in future studies.

4.5.2 Pain Protocol

The following presented results are of 2 x 2 x 3 x 7 mixed measures ANOVAs that were conducted to compare the main effects of the type of group (control and meditators) x stimuli (needle and Qtip) x body location (hand, foot and mouth) x electrode (seven electrode strip, e.g. C5, C3, C1, Cz, C2, C4, C6). Analysis was performed on three different epochs: early (500-1000ms after stimulus onset), middle (1000-1500ms) and late (1500-2000ms). Analysis will focus on, a) main effect of stimuli type (Qtip/needle), b) interaction between stimuli type and group (control/meditators), c) interaction between stimuli type and body location, d) group differences regardless of stimuli type and e) correlations (only when accompanied by a significant main effect/interaction) between stimulus evoked ERD and the EQ, IRI and the four dimensions of the IRI – Perspective Taking, Empathic Concern, Fantasy and Personal Distress.

4.5.2.1 Fronto-central channels (FC5, FC3, FC1, FCz, FC2, FC4, FC6)

4.5.2.1.1 Early Epoch

Table 21: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	58.30 (26.33)	39.64 (22.90)
	Needle	59.51 (23.63)	38.68 (31.03)
High Alpha	Qtip	40.41 (33.19)	34.06 (19.52)
	Needle	43.06 (30.59)	33.35 (20.68)
Low Beta	Qtip	23.48 (20.75)	17.31 (19.09)
	Needle	20.67 (23.71)	17.57 (21.07)

<u>Low Alpha (8-10 Hz)</u>

An interaction between stimuli type and body location was found ($F(2,44) = 3.48$, $p = .039$). No other significant main effects of interactions of interest were found (*ps* > .096). Follow-up tests were conducted to investigate the significant interaction. Paired t-tests comparing ERD elicited by hands versus foot and mouth versus foot (for both needle and Qtip conditions) found no significant differences (*ps* > .070). No significant correlations were found between ERD and self-report measures of empathy.

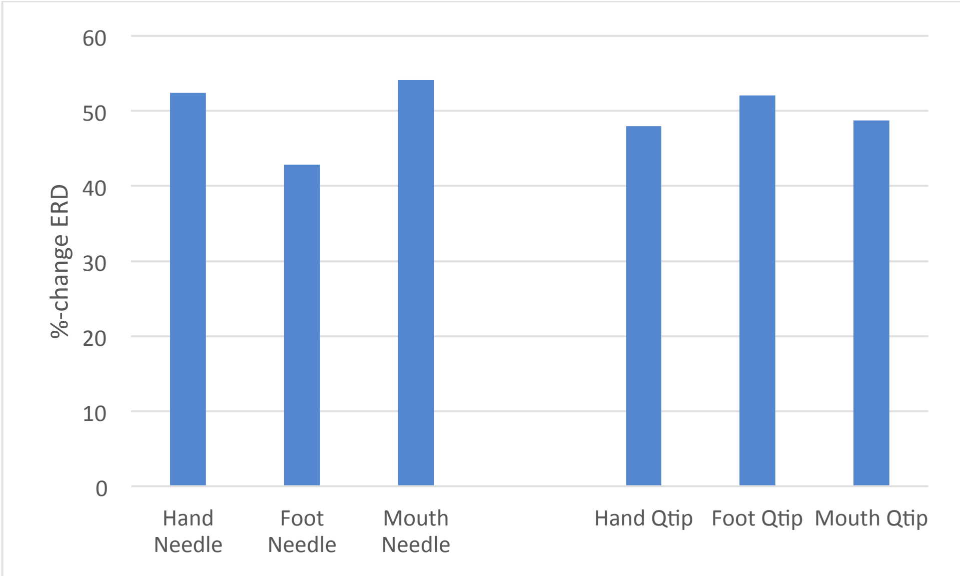

Figure 23: Chart showing low alpha ERD for each body location (left pain condition, right non-pain condition)

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .358) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No significant main effects or interactions of interest were found (*ps* > .359) and consequently, no correlations were tested.

4.5.2.1.2 Middle Epoch

Table 22: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	56.76 (23.16)	40.49 (19.68)
	Needle	59.26 (21.26)	41.82 (21.98)
High Alpha	Qtip	37.83 (32.48)	32.88 (23.66)
	Needle	41.61 (28.76)	36.34 (16.94)
Low Beta	Qtip	22.48 (19.55)	17.66 (14.14)
	Needle	19.66 (19.76)	20.12 (23.84)

Low Alpha (8-10 Hz)

No significant main effects or interactions of interest were found (*ps* > .074) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .125) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No significant main effects or interactions of interest were found (*ps* > .191) and consequently, no correlations were tested.

4.5.2.1.3 Late Epoch

Table 23: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	51.85 (25.65)	38.40 (19.87)
	Needle	55.92 (21.09)	41.12 (21.67)
High Alpha	Qtip	37.98 (30.64)	34.04 (17.76)
	Needle	39.72 (26.77)	36.01 (16.96)
Low Beta	Qtip	22.24 (16.81)	16.11 (14.84)
	Needle	17.74 (20.64)	17.91 (22.10)

Low Alpha (8-10 Hz)

No significant main effects or interactions of interest were found (*ps* > .099) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .347) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No significant main effects or interactions of interest were found (*ps* > .283) and consequently, no correlations were tested.

4.5.2.2 Central channels (C5, C3, C1, Cz, C2, C4, C6)

4.5.2.2.1 Early Epoch

Table 24: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	55.77 (28.92)	41.43 (21.95)
	Needle	59.44 (22.96)	37.16 (35.35)
High Alpha	Qtip	27.67 (40.72)	25.39 (23.74)
	Needle	32.68 (36.02)	26.37 (23.27)
Low Beta	Qtip	24.24 (22.27)	19.60 (17.31)
	Needle	23.27 (23.05)	21.58 (19.36)

Low Alpha (8-10 Hz)

As for fronto-central sites, an interaction between stimuli type and body location was found ($F(2,44) = 4.35$, $p = .018$) during the early epoch. Further investigation of this interaction revealed a significant difference between ERD elicited by the needle pricking mouth (M=55.13, SD=25.87) and needle pricking foot stimuli (M=39.94, SD=53.97), $t(29) = 2.05$, $p = .050$, with more ERD elicited to the mouth. A significant main effect of group was also observed ($F(1,25) = 5.16$, $p = .032$), illustrating that more ERD was elicited in the control group (M=62.01) than in the meditator group (M=39.30). No other significant main effects of interactions of interest were found (*ps* > .344). No significant correlations were found between ERD and self-report measures of empathy.

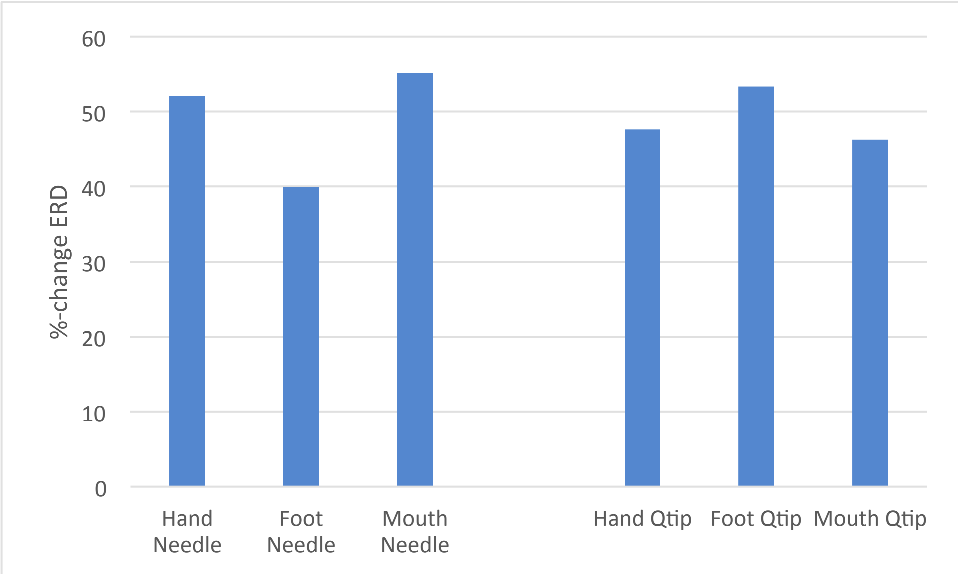

Figure 23: Chart showing low alpha? ERD for each body location (left pain condition, right non-pain condition)

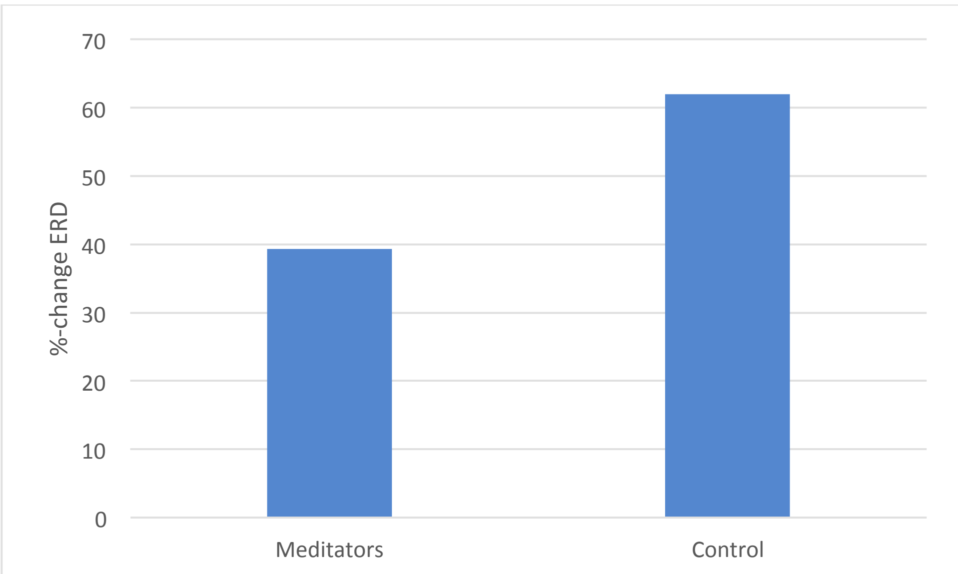

Figure 24: Chart showing group difference in ERD to pooled stimuli

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .430) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No significant main effects or interactions of interest were found (*ps* > .447) and consequently, no correlations were tested.

4.5.2.2.2 Middle Epoch

Table 25: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	50.62 (27.95)	43.25 (19.57)
	Needle	55.04 (24.36)	40.35 (24.96)
High Alpha	Qtip	29.89 (33.80)	26.01 (27.73)
	Needle	34.00 (32.31)	30.30 (23.42)
Low Beta	Qtip	23.15 (19.37)	20.57 (13.96)
	Needle	21.10 (21.76)	21.59 (26.98)

Low Alpha (8-10 Hz)

An interaction between stimuli type and body location was found ($F(2,50) = 3.84$, $p = .028$). Follow-up tests revealed significant differences between ERD elicited by mouth being pricked by a needle (M=52.53, SD=26.63) and foot being pricked (M=43.23, SD=32.50), t (29) = 2.13, p = .042. Also between hand being touch with a Qtip (M=44.58, SD=29.96) and foot being touched with a Qtip (M=51.14, SD=23.11), t (29) = -2.17, p = .038. No other significant main effects or interactions of interest were found (*ps* > .352). No significant correlations were found between ERD and self-report measures of empathy.

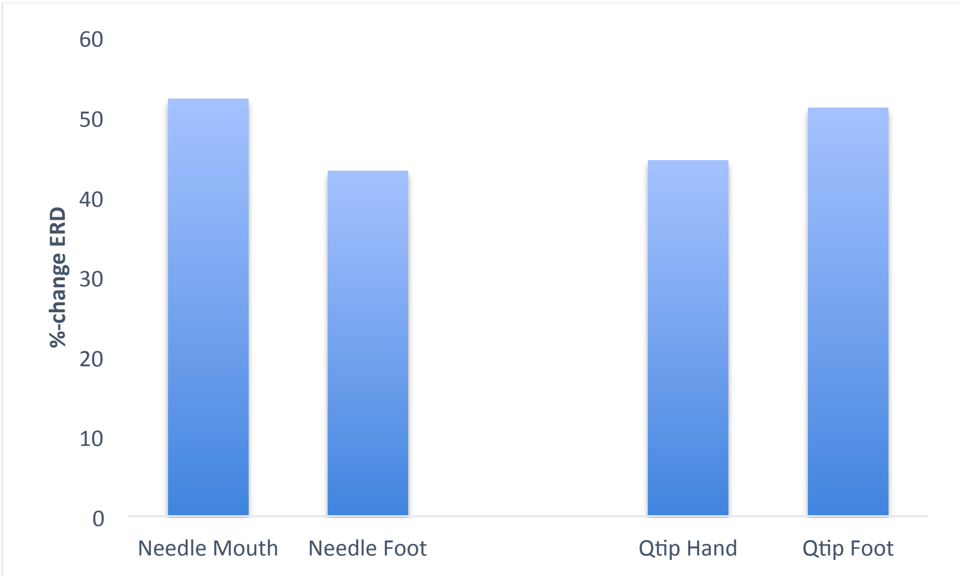

Figure 25: Chart showing ERD for mouth and foot being stimulated by a needle (left) and hand and foot being stimulated by a Qtip (right)

<u>High Alpha (10-12 Hz)</u>

No significant main effects or interactions of interest were found (*ps* > .236) and consequently, no correlations were tested.

<u>Low Beta (12.5-16 Hz)</u>

A main effect of body location was found (F(2,50) = 4.27, .019). Pairwise comparisons revealed significant differences between ERD elicited by the hand (M=18.75, SE=4.55) condition and the foot (M=25.78, SE=3.21) condition (mean difference = -7.04, *p*=.038, CI(95%) -13.64 - -.436), with higher ERD elicited to the foot image. Significant differences were also found between the hand (M=18.75, SE=4.55) condition and the mouth (M=24.63, SE=3.28) condition (mean difference = -5.88, *p*=.028, CI(95%) -11.08 - -.686), with higher ERD elicited by the mouth stimuli. No other significant main effects or interactions were found (*ps* > .151). No significant correlations were found between ERD and self-report measures of empathy.

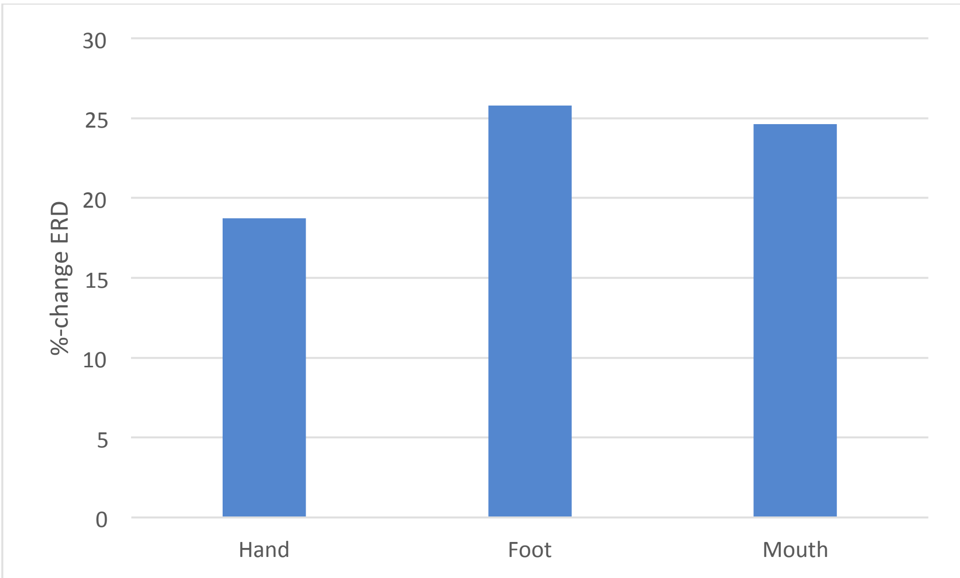

Figure 26: Chart showing ERD for hand, foot and mouth, regardless of condition

4.5.2.2.3 Late Epoch

Table 26: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	45.92 (28.62)	39.46 (20.18)
	Needle	50.44 (24.11)	41.67 (23.86)
High Alpha	Qtip	29.46 (29.21)	25.53 (23.30)
	Needle	32.44 (28.18)	30.31 (22.93)
Low Beta	Qtip	21.93 (15.22)	18.38 (15.13)
	Needle	19.50 (20.47)	20.55 (22.48)

Low Alpha (8-10 Hz)

No significant main effects or interactions of interest were found (*ps* > .171) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .211) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A main effect of body location was found ($F(2,50) = 3.58$, $p = .035$). Pairwise comparisons revealed a significant difference between ERD elicited by the hand stimuli (M=18.56) and foot stimuli only (M=24.50; mean difference = -5.92, *p*=.013, CI(95%) -10.50 - -1.34), with foot stimuli inducing greater ERD than hands. No other significant main effects or interactions of interest were found (*ps* > .530). No significant correlations were found between ERD and self-report measures of empathy.

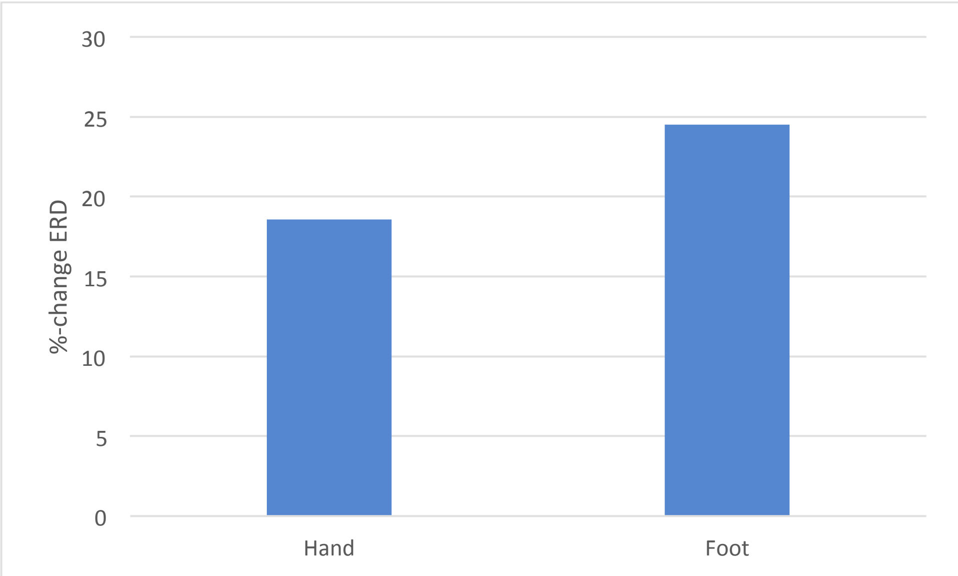

Figure 26: Chart showing ERD to hand and foot, regardless of condition

4.5.2.2 Centro-parietal channels (CP5, CP3, CP1, CPz, CP2, CP4, CP6)

4.5.2.2.1 Early Epoch

Table 27: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	61.61 (27.17)	47.99 (27.95)
	Needle	65.10 (20.07)	44.65 (32.37)
High Alpha	Qtip	28.59 (40.58)	30.47 (24.10)
	Needle	37.02 (33.33)	28.28 (29.63)
Low Beta	Qtip	31.78 (21.95)	23.03 (18.32)
	Needle	32.05 (22.03)	26.23 (18.68)

<u>Low Alpha (8-10 Hz)</u>

No main effects or interactions of interest were found (*ps* > .133) and consequently, no correlations were tested.

<u>High Alpha (10-12 Hz)</u>

No main effects or interactions of interest were found (*ps* > .084) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No main effects or interactions of interest were found (*ps* > .129) and consequently, no correlations were tested.

4.5.2.2.2 Middle Epoch

Table 28: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	52.73 (28.22)	48.77 (26.97)
	Needle	56.98 (24.04)	45.84 (27.77)
High Alpha	Qtip	28.68 (31.61)	31.12 (27.34)
	Needle	34.17 (28.93)	29.54 (31.79)
Low Beta	Qtip	28.40 (18.88)	24.19 (16.70)
	Needle	25.23 (19.62)	25.33 (25.58)

Low Alpha (8-10 Hz)

No main effects or interactions of interest were found (*ps* > .135) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

No main effects or interactions of interest were found (*ps* > .087) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A main effect of body location was found ($F(2,50) = 3.21$, $p = .049$), however pairwise comparisons revealed no significant differences between body location (*ps* > .052). No other main effects or interactions of interest were found (*ps* > .064). No significant correlations were found between ERD and self-report measures of empathy.

4.5.2.2.3 Late Epoch

Table 29: Means and standard deviations for ERD elicited by both Qtip and needle images

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Qtip	44.78 (33.46)	43.96 (26.81)
	Needle	51.20 (26.07)	46.20 (25.61)
High Alpha	Qtip	25.30 (26.81)	29.11 (24.21)
	Needle	30.04 (27.97)	28.59 (31.80)
Low Beta	Qtip	24.67 (16.45)	22.69 (17.45)
	Needle	23.40 (17.53)	24.12 (20.61)

Low Alpha (8-10 Hz)

No significant main effects or interactions of interest were found (*ps* > .064) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

No significant main effects or interactions of interest were found (*ps* > .216) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

No significant main effects or interactions of interest were found (*ps* > .392) and consequently, no correlations were tested.

4.5.2.3 Interim Discussion – Pain Protocol

We will firstly discuss the only group difference finding, that of a significant difference in cortical excitability of stimuli in general. Here in the central region, in the early time epoch, in the low alpha bandwidth, we see at a group difference in the mu ERD response elicited by the pooled stimuli (regardless of specific conditions). Here it was found that in general, mu ERD to stimuli was less in the LKM group than it was in the control group. It is tentatively suggested that this general group difference in cortical excitability in response to painful and non-painful images, could reflect differences in neural processing (in the mu bandwidth) resulting from the long-term practice of LKM. Research investigating differences in affective appraisal of pain, found that long-term mindfulness meditators rated inflicted painful feelings as less than those in a control group (Brown & Jones, 2010). Similar findings were reported by (Zeidan et al., 2011) who found that pain ratings from noxious pain stimulation were reduced after only four days of mindfulness meditation practice compared to controls.

Whist these studies provide evidence to suggest that both novice and experienced meditators are less reactive to physical pain, it could be inferred that meditation modifies the neural circuitry involved in pain perception – this could be what we are seeing in our data. The only issue with this argument however is that our group difference incorporates both painful and non-pain images. It would be useful in future to ask participants to rate the perceived pain of the people in the images in addition to recording EEG.

The main expectation of these data was that a between group difference in cortical excitability would be found in relation to the painful images, the direction which was uncertain. The two possible outcomes being a less reactive mirror neuron system, expressed as a lower relative ERD to painful images compared to the control group. The second possibility being a more reactive mirror system, expressed as a higher relative ERD to painful images compared to the control group. Within our data neither outcome was specifically observed. A possible reason as to why no between group differences in pain mu ERD were observed relative to controls could be due to the overall low cortical reactivity in the LKM group compared to the control group. Based on findings from study one it was also expected that we would find a difference in cortical excitability between painful and non-painful images at centro-parietal regions across both groups - this was not observed in the data. Consulting the means for painful and non-painful images (for both LKM and control groups) at centro-parietal regions it can be observed that the means for the control group match this pattern of increased mu ERD to painful images relative to non-painful images, however the reverse is true for the LKM group. It is possible that this is the reason for the lack of a statistical difference in mu ERD between the painful and non-painful stimuli in this study.

Perhaps the most prominent finding was that of an interaction between stimulus type (needle/Qtip) and body location (hand/foot/mouth) in the low alpha bandwidth. This is a finding that is more widespread in the early time epoch (being present in the fronto-central and central strip) that shifts entirely to central regions in the middle time epoch where the effect ends. Whilst this interaction is significant in the early epoch at the fronto-central strip, follow up tests found no significant differences between conditions. This effect is strongest at central regions due to the presence of 1) the same significant interaction and, 2) follow-up tests revealing significant differences in ERD elicited by different body locations. Considering point two, at the early time epoch we see higher low alpha ERD being elicited to the mouth being pricked than to the foot being pricked. At the middle time epoch, we see two significant differences: firstly, between the mouth and foot being pricked (higher ERD to the mouth), and secondly between the hand being touched with a Qtip and the foot being touched with a Qtip (higher ERD to the hand). Thus firstly (in terms of mu ERS as a putative index of mirror neuron activation) it would appear that our participants demonstrated increased mu activation to images of mouths being pricked by needles relative to feet being pricked by needles. Secondly, as we move on to the mid point of the stimuli processing, we see the addition of increased mu activation to images of feet being stimulated by Q-tips relative to hands being stimulated by Q-tips. Finding increased mu ERD to needles pricking mouths relative to feet might simply relate to a more accessible cortical representation of the mouth (see cortical homunculus, pg. 260). However it should be noted that we do not see this when looking at the Q-tip images, instead we see increased mu ERD to the foot rather than the hand (the hand having a higher cortical representation). These findings are less likely to relate simply to cortical representations and it is suggested more to the different processing of painful and non-painful images.

The second finding was a main effect of body type (hand/foot/mouth, regardless of stimulus type or group) in the low beta bandwidth. This effect is most prominent at the central region during the middle time epoch, where differences in mu ERD were observed between both the hand and foot condition and the hand and mouth conditions (with more low beta ERD elicited by the foot and mouth conditions respectively). In the late stage of processing we see only a difference in mu ERD between the hand and the foot images (still highest ERD to the feet). At the same time epoch, we see the same effect at the centro-parietal region, however no differences between the conditions were found in follow-up. In all instances mu ERD was higher for the foot stimuli, which while interesting is not directly relevant to this thesis.

To summarise, firstly in relation to between group findings (the main focus of the study) we found a centrally derived general stimuli difference in mirror neuron activation with increased excitation in the control group in comparison to the meditators, perhaps indicating a less reactive mirror system in those practicing LKM long-term. Secondly we observed increased mirror neuron activity when participants observed needles pricking mouths relative to needles pricking feet and higher mirror neuron activation to Q-tips stimulating feet relative to hands. Finally we found higher mirror neuron activity upon observing feet and mouths relative to hands (regardless of painful or non-painful image type).

4.5.3 Moving Hands Protocol

The following results are of 2 x 3 x 7 mixed measures ANOVAs that were conducted to compare the main effects of the type of group (control and meditators) x stimuli (balls moving, static hands and moving hands) x electrode (seven electrode strip). Analysis was performed on three different epochs: early (0-1000ms), middle (1000-2000ms) and late (2000-3000ms). Analysis will focus on a) main effect of stimuli type, b) interactions between stimuli type and group, c) between group differences, and d) correlations between stimulus evoked ERD and the EQ, IRI and the four dimensions of the IRI – Perspective Taking, Empathic Concern, Fantasy and Personal Distress. Correlations will only be conducted for significant EEG findings.

4.5.3.1 Fronto-central (FC5, FC3, FC1, FCz, FC2, FC4, FC6)

4.5.3.1.1 Early Epoch

Table 30: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	35.25 (21.81)	25.16 (24.97)
	Still Hand	34.95 (17.94)	25.81 (18.64)
	Moving Hand	31.51 (26.16)	23.82 (19.48)
High Alpha	**Moving Balls**	26.40 (24.72)	21.97 (20.62)
	Still Hand	24.31 (20.86)	22.00 (15.58)
	Moving Hand	26.46 (20.36)	15.16 (17.42)
Low Beta	**Moving Balls**	10.79 (12.87)	12.53 (12.89)
	Still Hand	10.45 (13.86)	6.99 (14.36)
	Moving Hand	13.48 (14.60)	-4.51 (32.26)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .277) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .408) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

There was no main effect of type of stimuli, *F* (2,48) = 1.58, *p* = 216. An interaction between stimuli and group was found, *F* (2,48) = 3.32, *p* = .044. Follow-up tests revealed a borderline significant group difference for the moving hands condition (*F*(1,28) = 4.05, *p* = .054) with higher ERD elicited by the control group (M=13.48, SE=3.65) than to the meditators (M=-4.51, SE=8.62) who actually exhibited event-related synchronisation (ERS). Other comparisons were not significant (*ps* > .508). No significant correlations of interest were found.

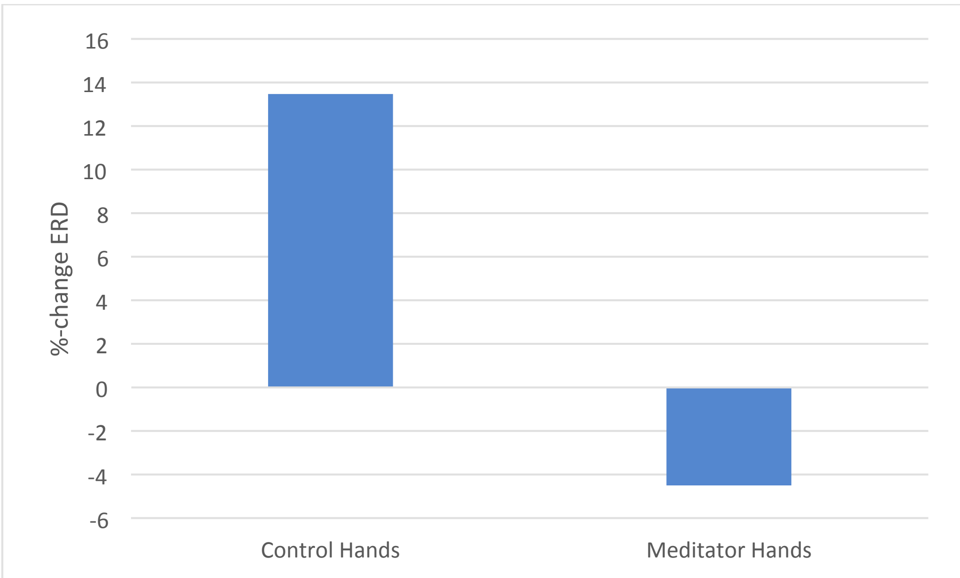

Figure 27: Chart showing group low beta ERD/S differences to the moving hands conditions

4.5.3.1.2 Middle Epoch

Table 31: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	38.96 (46.27)	38.57 (24.70)
	Still Hand	34.95 (17.93)	25.81 (18.64)
	Moving Hand	47.25 (29.14)	38.56 (21.92)
High Alpha	**Moving Balls**	25.49 (55.84)	32.19 (25.67)
	Still Hand	24.31 (20.86)	22.00 (15.58)
	Moving Hand	38.79 (31.76)	33.55 (22.14)
Low Beta	**Moving Balls**	15.30 (21.54)	20.01 (16.49)
	Still Hand	10.45 (13.86)	6.99 (14.36)
	Moving Hand	24.71 (18.84)	5.70 (42.77)

<u>Low Alpha (8-10 Hz)</u>

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .178) and consequently, no correlations were tested.

<u>High Alpha (10-12 Hz)</u>

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .147) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

We found a significant quadratic contrast for type of stimuli, $F(1,24) = 5.81$, $p = .024$. Indicating that the means of the balls moving (M=17.07, SE=3.98) and hand moving stimuli (M=14.09, SE=6.69) differ to that of the still hand stimuli (M=7.18, SE=2.70), with ERD being higher for the moving stimuli. This finding simply relates to differences in moving relative to still stimuli and is not relevant to our hypotheses. No significant correlations were found for either group.

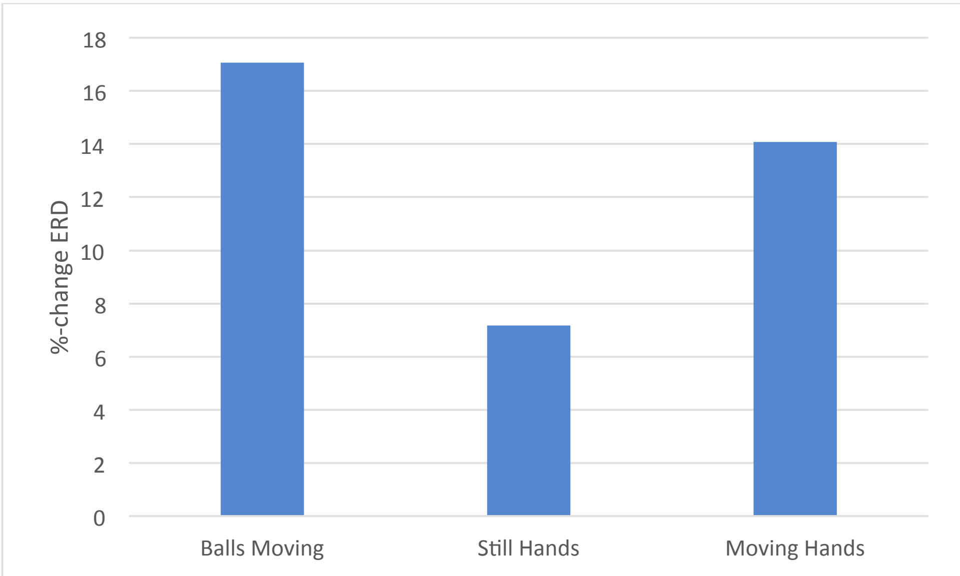

Figure 28: Chart showing ERD differences to each of the three conditions

4.5.3.1.3 Late Epoch

Table 32: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	24.50 (68.10)	41.70 (21.19)
	Still Hand	40.98 (28.43)	36.84 (28.98)
	Moving Hand	41.47 (42.90)	39.23 (22.91)
High Alpha	**Moving Balls**	20.24 (72.82)	33.32 (27.51)
	Still Hand	25.40 (47.48)	28.72 (23.33)
	Moving Hand	40.99 (30.22)	35.76 (19.72)
Low Beta	**Moving Balls**	9.88 (29.74)	20.10 (15.79)
	Still Hand	12.50 (16.21)	14.10 (14.80)
	Moving Hand	23.07 (19.40)	9.89 (29.96)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .243) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .139) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .112) and consequently, no correlations were tested.

4.5.3.2 Central Electrodes (C5, C3, C1, Cz, C2, C4, C6)

4.5.3.2.1 Early Epoch

Table 33: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	34.77 (19.63)	26.15 (24.37)
	Still Hand	36.11 (17.18)	24.13 (19.40)
	Moving Hand	31.40 (23.24)	22.00 (23.72)
High Alpha	**Moving Balls**	14.68 (25.16)	19.08 (20.85)
	Still Hand	15.71 (16.24)	20.23 (14.72)
	Moving Hand	19.90 (22.42)	16.84 (18.57)
Low Beta	**Moving Balls**	9.57 (17.73)	13.76 (12.78)
	Still Hand	13.34 (13.69)	4.57 (15.55)
	Moving Hand	14.81 (13.64)	-0.20 (33.51)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .326) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .269) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

There was no main effect of type of stimuli, F (2,50) = 0.69, p = .502. An interaction between type of stimuli and group was found: F (2,50) = 3.31, p = .045. Follow-up tests were run to investigate group differences based on this interaction, however no significant group differences for each of the conditions (*ps* > .111).

4.5.3.2.2 Middle Epoch

Table 34: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	44.04 (29.03)	40.93 (23.37)
	Still Hand	36.11 (17.18)	24.13 (19.40)
	Moving Hand	51.64 (25.35)	52.10 (21.86)
High Alpha	**Moving Balls**	17.23 (42.61)	28.24 (27.60)
	Still Hand	15.71 (16.24)	20.23 (14.72)
	Moving Hand	32.77 (27.85)	32.99 (22.85)
Low Beta	**Moving Balls**	15.35 (23.83)	21.90 (15.72)
	Still Hand	13.34 (13.69)	4.57 (15.55)
	Moving Hand	25.77 (17.15)	12.65 (44.42)

Low Alpha (8-10 Hz)

A significant main effect was found for type of stimuli, $F(2,50) = 6.65$, $p = .003$. Pairwise comparisons revealed that there was a significant difference between the hands moving (M=46.24, SE=4.78) and still hand (M=31.34, SE=3.32) conditions (mean difference = -14.90, p=.001, CI(95%) -23.77 - -6.03), with increased ERD elicited to the moving hand condition. No significant correlations were observed.

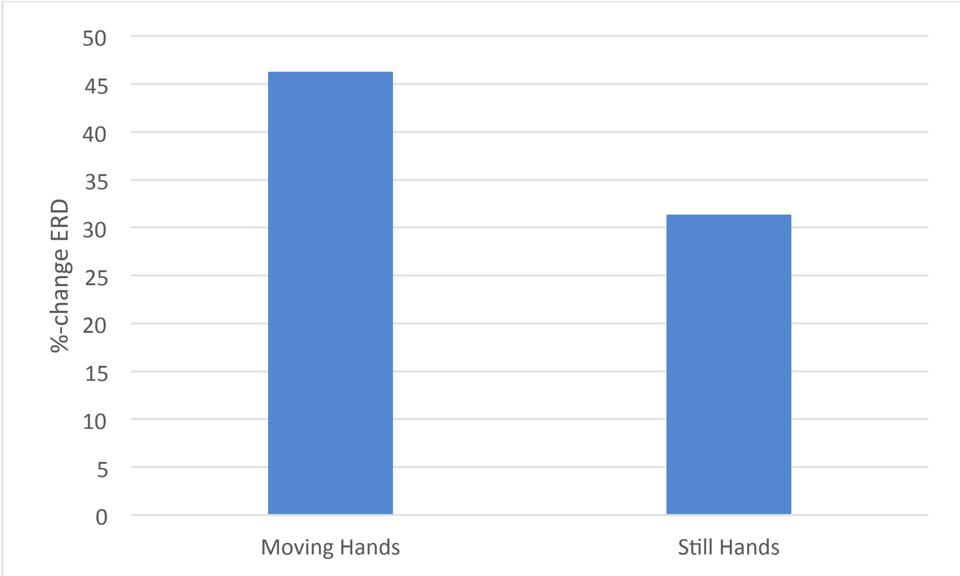

Figure 29: Chart showing ERD differences to the moving hands and still hands conditions

<u>High Alpha (10-12 Hz)</u>

A main effect of stimuli type was found, $F(2,50) = 5.96$, $p = .005$. Pairwise comparisons found a significant difference between the moving (M=34.84, SE=5.04) and the still hand (M=18.19, SE=3.14) conditions (mean difference = -16.67, p=.001, CI(95%) -26.96 - -6.36). No significant correlations were observed.

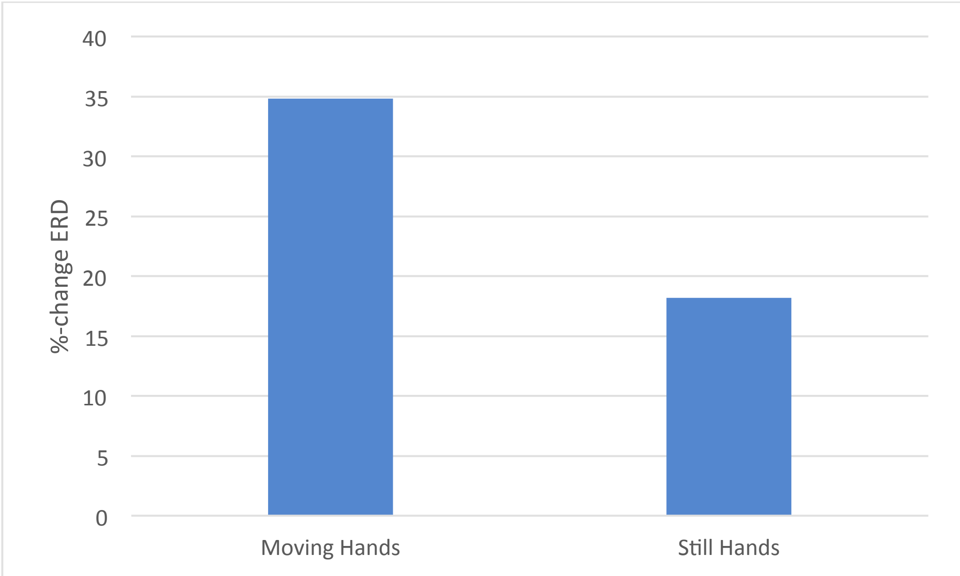

Figure 30: Figure showing ERD differences to the moving hands and still hands conditions

<u>Low Beta (12.5-16 Hz)</u>

Whilst no significant main effect of stimuli type or interaction between stimuli type and group was found (*ps* > .060), a significant quadratic trend was observed for type of stimuli, $F(1,25) = 12.32$, $p = .002$. ERD for both the moving balls (M=20.51, SE=3.27) and moving hand (M=20.07, SE=6.57) conditions were higher than that for the still hands (M=9.52, SE=2.81) condition. Again, as stated above, this finding does not relate to our hypotheses and will not be discussed. No significant correlations were observed.

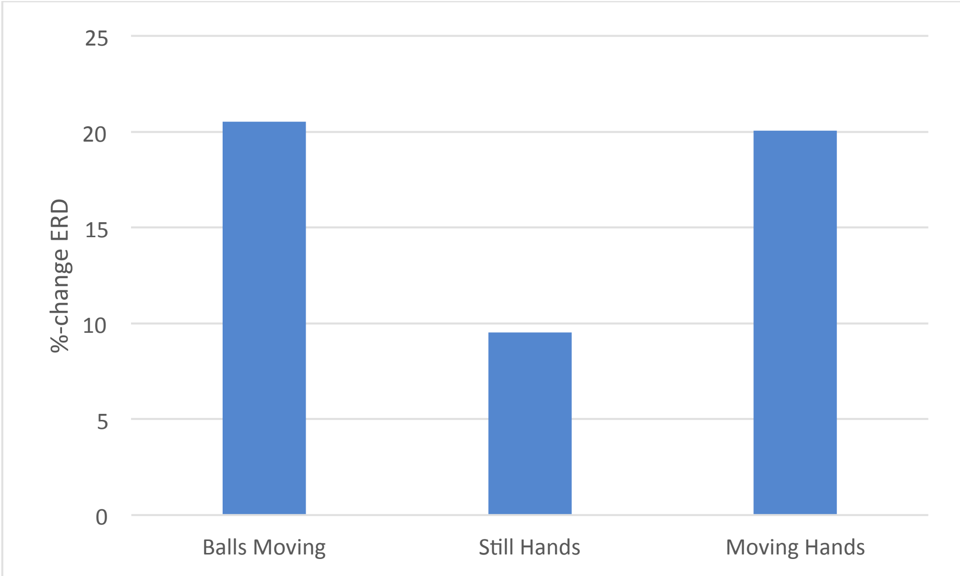

Figure 31: Chart showing ERD differences to each of the three conditions

4.5.3.2.3 Late Epoch

Table 35: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	31.94 (43.89)	42.51 (22.96)
	Still Hand	42.23 (23.45)	37.87 (31.40)
	Moving Hand	46.40 (34.68)	36.72 (31.55)
High Alpha	**Moving Balls**	12.69 (52.72)	28.45 (30.48)
	Still Hand	18.36 (37.76)	25.14 (23.81)
	Moving Hand	37.71 (26.15)	35.29 (20.45)
Low Beta	**Moving Balls**	8.50 (28.06)	21.27 (15.74)
	Still Hand	16.60 (15.32)	14.34 (16.83)
	Moving Hand	24.57 (18.57)	15.53 (29.24)

Low Alpha (8-10 Hz)

There was no main effect of type of stimuli and no interactions between type of stimuli and group (*ps* > .342) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

A significant main effect was found for type of stimuli, $F(2,50) = 5.50$, $p = .007$. Pairwise comparisons revealed significant differences between the still hands (M=22.28, SE=6.23) and moving hands (M=37.15, SE=4.80) conditions with more ERD elicited to the moving hands condition (mean difference = -14.88, p=.005, CI(95%) -25.60 - -4.15). Pearson's correlations were conducted to investigate the relationship between the self-reported measures of empathy and ERD elicited from the moving hands condition. A positive significant correlation was found between high alpha ERD elicited by the moving hand condition and the EQ ($r = .39$, $n = 30$, $p = .034$), indicating that the higher the ERD, the higher the score on the EQ.

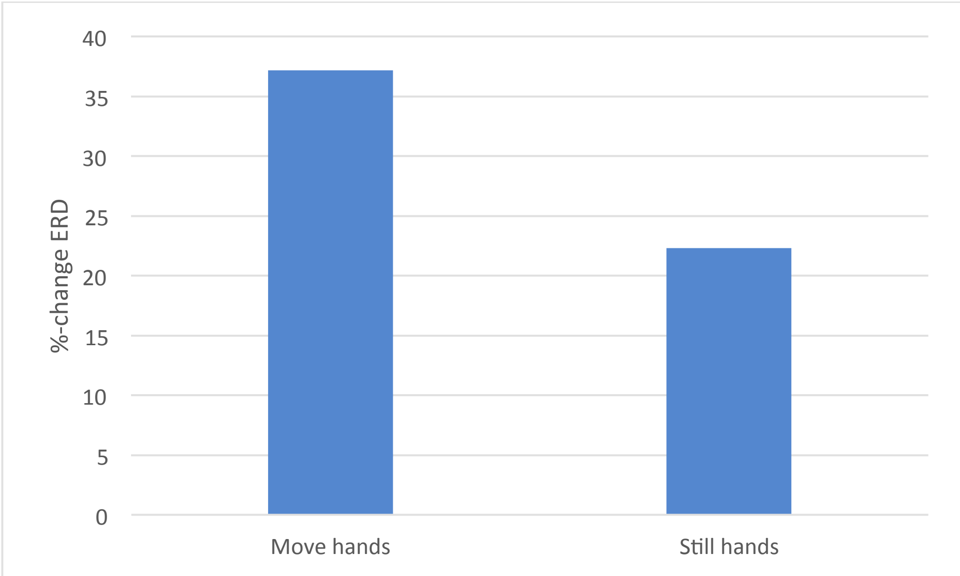

Figure 32: Chart showing ERD differences to the moving hands and still hands conditions

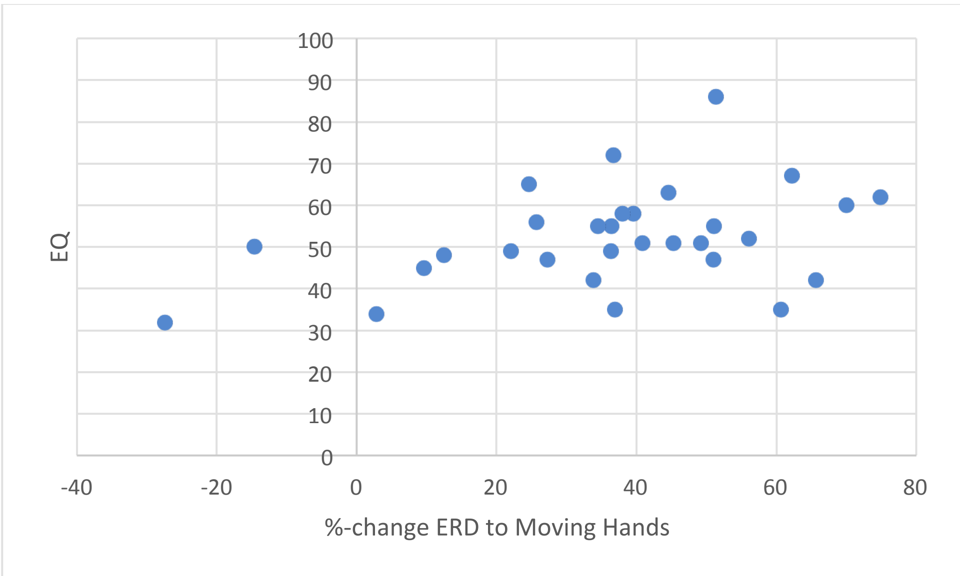

Figure 33: Chart showing positive correlation between EQ and ERD elicited by the moving hands condition

Low Beta (12.5-16 Hz)

There was no main effect of type of stimuli, F (2,50) = 1.11, p > .05. However, an interaction between type of stimuli and group was found: F (2,50) = 3.33, p = .044. A significant linear trend was found for this interaction (F(1,25) = 4.85, p = .037) showing that the difference between the moving balls (M=8.50, SE=7.01) and moving hand (M=24.57, SE=4.64)) condition in the control group was different than the difference between the moving balls (M=21.27, SE=4.21) and moving hand (M=15.53, SE=7.81) conditions for the meditator group. Paired *t*-tests were used to examine differences in ERD elicited by the moving balls and moving hand conditions for both groups. the difference between moving balls and moving hand were significantly different for the control group (t(15) = -2.76, p = .015), but not for the meditator group (t(13) = .783, p = .448).

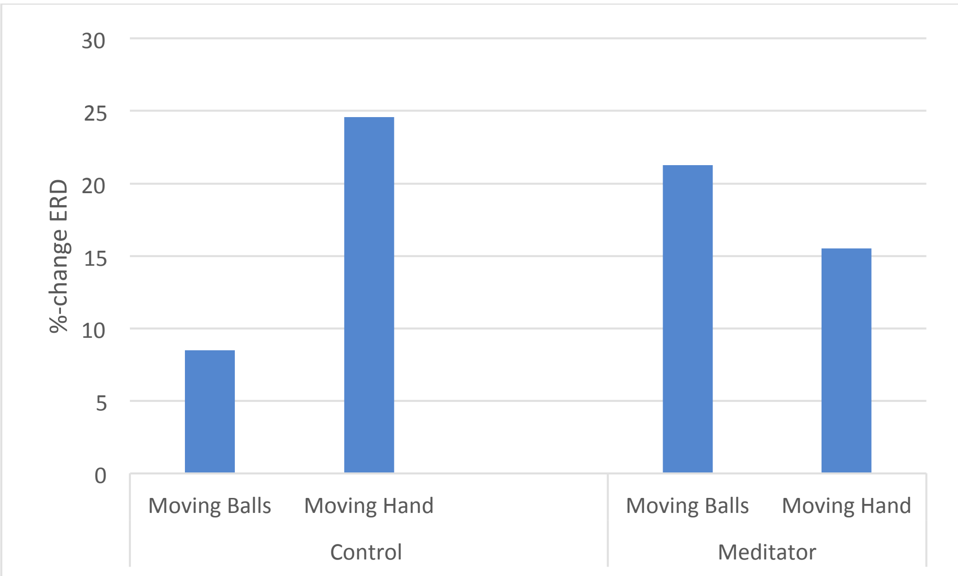

Figure 34: Chart showing ERD to moving balls and moving hands conditions for both groups

4.5.3.3 Centro-parietal (CP5, CP3, CP1, CPz, CP2, CP4, CP6)

4.5.3.3.1 Early Epoch

Table 36: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	38.50 (19.89)	27.07 (25.58)
	Still Hand	36.17 (17.76)	25.02 (29.80)
	Moving Hand	32.47 (18.83)	21.99 (25.37)
High Alpha	**Moving Balls**	13.36 (25.93)	21.09 (18.18)
	Still Hand	14.91 (16.72)	19.31 (21.39)
	Moving Hand	15.26 (22.17)	15.15 (25.88)
Low Beta	**Moving Balls**	12.90 (21.50)	12.33 (12.53)
	Still Hand	16.10 (13.81)	5.80 (16.66)
	Moving Hand	16.48 (16.59)	3.35 (32.50)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group ($ps > .260$).

High Alpha (10-12 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group ($ps > .404$).

Low Beta (12.5-16 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .258).

4.5.3.3.2 Middle Epoch

Table 37: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	44.17 (28.72)	41.86 (26.35)
	Still Hand	36.17 (17.76)	25.02 (29.80)
	Moving Hand	50.11 (28.82)	41.90 (31.74)
High Alpha	**Moving Balls**	10.55 (44.08)	25.49 (31.07)
	Still Hand	14.91 (16.72)	19.31 (21.39)
	Moving Hand	25.23 (27.47)	34.49 (26.66)
Low Beta	**Moving Balls**	19.18 (21.25)	21.23 (15.10)
	Still Hand	16.10 (13.81)	5.80 (16.66)
	Moving Hand	26.71 (17.20)	16.94 (43.60)

Low Alpha (8-10 Hz)

A significant main effect was found for type of stimuli, $F(2,52) = 6.69$, $p = .003$. Pairwise comparisons revealed a significant difference between the still hands (M=30.35, SE=4.58) condition and the moving hand (M=45.71, SE=5.90) condition, with increased ERD for the moving hands condition (mean difference = -15.36, p=.002, CI(95%) -25.39 - -5.33). No significant correlations were found.

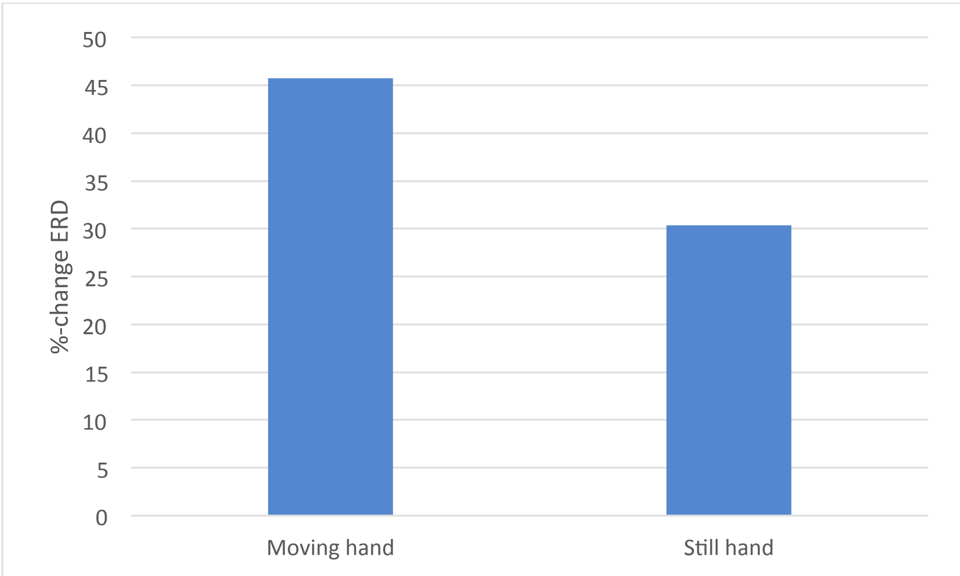

Figure 35: Chart showing ERD to the moving hands and still hands conditions

High Alpha (10-12 Hz)

A significant main effect was found for type of stimuli, $F(2,52) = 3.87$, $p = .027$. Pairwise comparisons revealed a significant difference between the still hands (M=15.81, SE=3.57) condition and the moving hand (M=29.19, SE=5.14) condition (mean difference = -13.37, p=.017, CI(95%) -24.69 - -2.05), with increased ERD for the moving hands condition. No significant correlations were found.

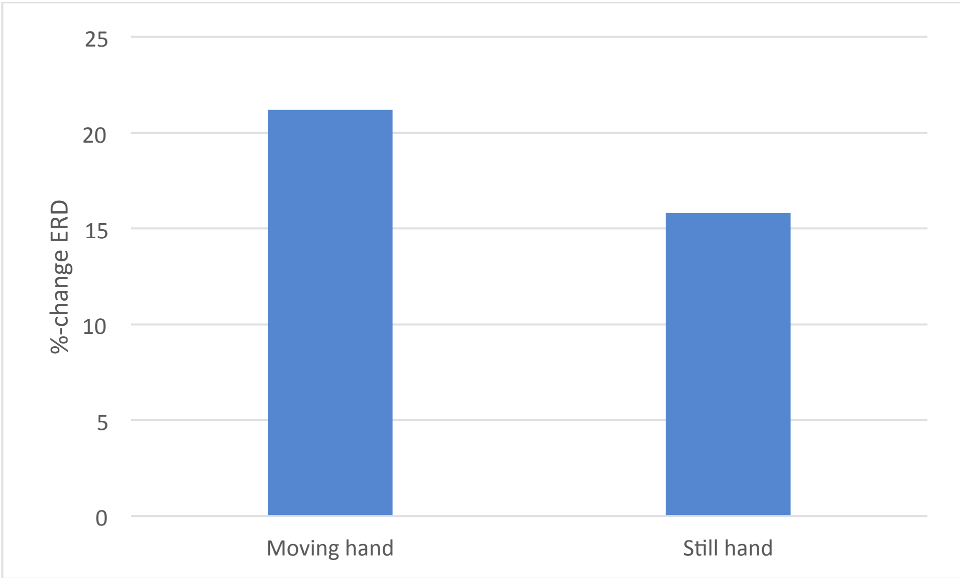

Figure 36: Chart showing ERD to both the moving hands and still hands conditions

<u>Low Beta (12.5-16 Hz)</u>

A borderline significant main effect for type of stimuli was found, $F(2,52) = 3.01$, $p = .058$. A significant quadratic trend was found in addition to this ($F(2,52) = 11.57$, $p = .002$), illustrating that ERD was higher for both the moving balls (M=21.52, SE=3.44) and moving hand (M=21.57, SE=6.22) condition than for the still hand (M=11.01, SE=2.93) condition. As mentioned above, this finding will not be discussed. No significant correlations were found.

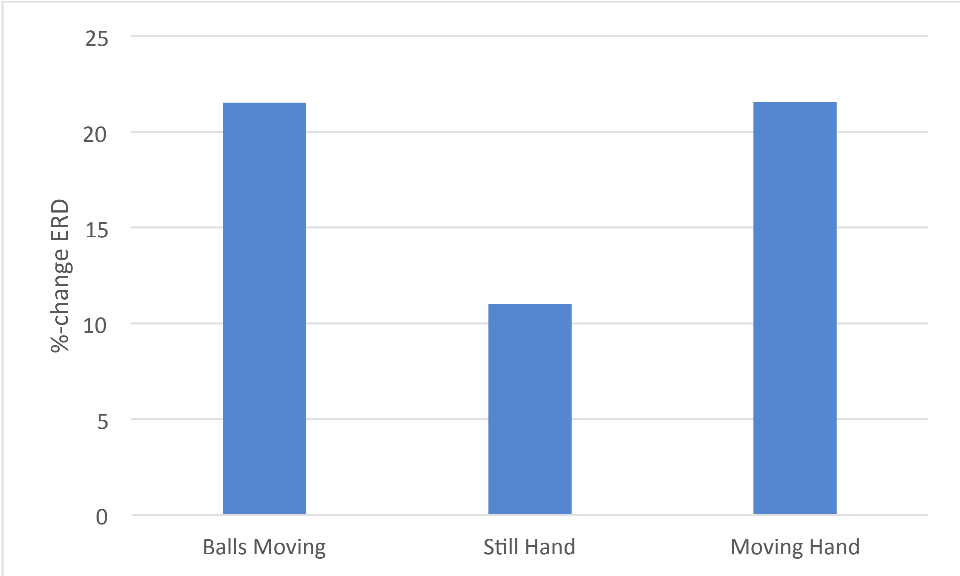

Figure 37: Chart showing ERD to each of the three conditions

4.5.3.3.3 Late Epoch

Table 38: Means and standard deviations for ERD elicited by moving balls, still hand and moving hand stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	**Moving Balls**	31.34 (41.48)	41.43 (28.60)
	Still Hand	35.70 (32.12)	42.19 (37.84)
	Moving Hand	41.14 (43.13)	36.22 (37.71)
High Alpha	**Moving Balls**	4.45 (50.70)	22.76 (37.14)
	Still Hand	13.49 (40.70)	27.55 (22.57)
	Moving Hand	29.66 (24.12)	35.41 (28.85)
Low Beta	**Moving Balls**	11.59 (26.92)	20.15 (17.82)
	Still Hand	16.63 (15.59)	17.14 (18.31)
	Moving Hand	22.70 (20.23)	21.76 (24.57)

Low Alpha (8-10 Hz)

There was no main effect of stimuli type and no interaction between stimuli type and group ($ps > .520$) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

A significant main effect was found for type of stimuli, $F(2,52) = 4.62$, $p = .014$. A significant linear contrast was also found for type of stimuli ($F(1,26) = 5.85$, $p = .023$) demonstrating a significant difference in high alpha ERD between the balls moving (M=14.75, SE=8.67) and hands moving (M=31.37, SE=5.11) conditions, with more ERD to the hand moving conditions. A significant positive correlation was found between ERD elicited by the moving hand condition and the EQ ($r = .39$, $n = 30$, $p = .034$), demonstrating that those who scored higher the score on the EQ showed greater high alpha ERD to the stimuli.

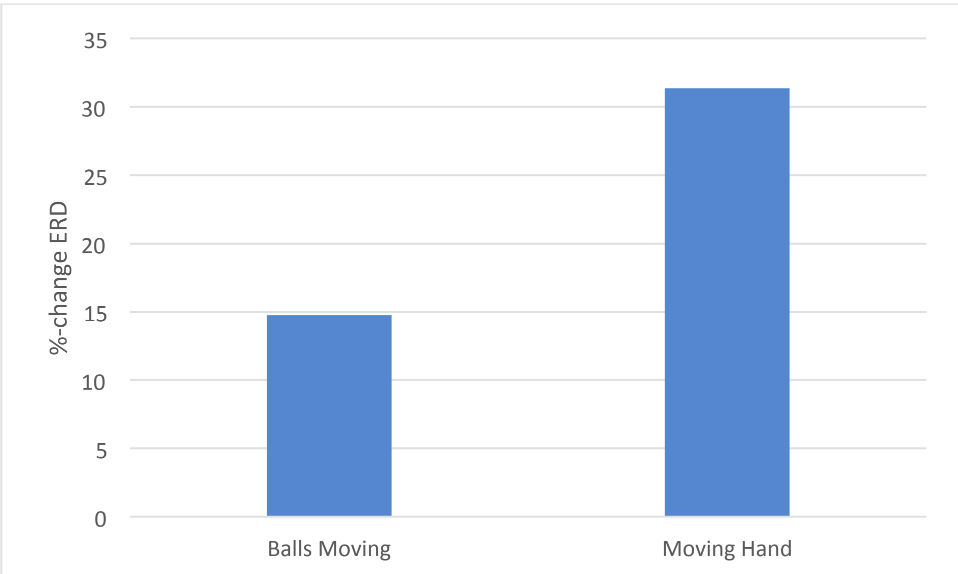

Figure 38: Chart showing ERD to both the moving balls and moving hands conditions

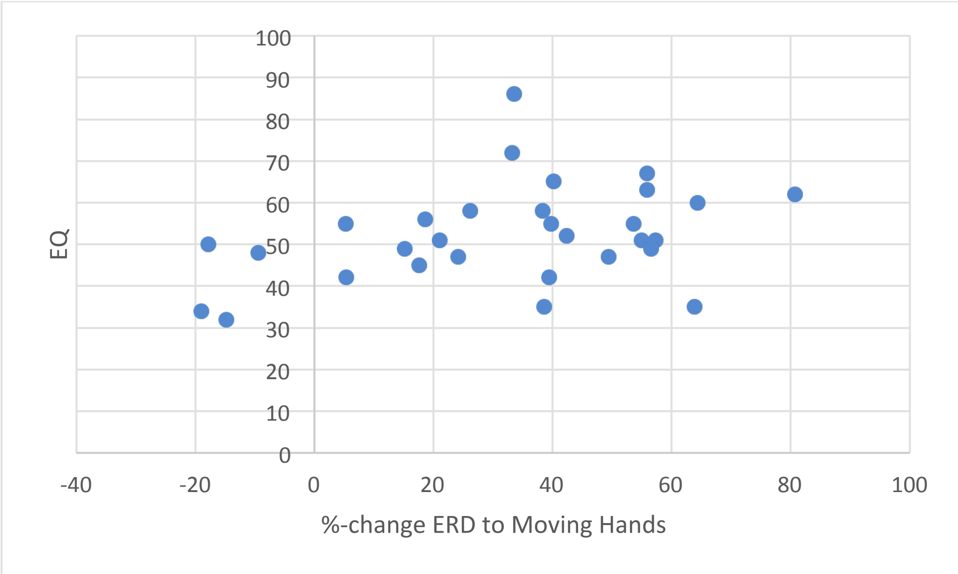

Figure 39: Chart showing positive correlation between EQ and ERD elicited by the moving hands condition

<u>Low Beta (12.5-16 Hz)</u>

There was no main effect of stimuli type and no interaction between stimuli type and group (*ps* > .369).

4.5.3.4 Interim Discussion – Moving Hands Protocol

The aim of the moving hands protocol was to examine the neural correlates of empathy by utilising a simple mirror neuron activation protocol. There were three main expectations for this protocol. Firstly, relating to between group differences we expected that if LKM has the capacity to increase a practitioner's level of empathy then we might observe this via a putative index of the mirror neuron system - higher mu ERD relative to controls. We also expected that this increased cortical excitability to be related to measures of empathy. Data in support of increased mu ERD to moving hand stimuli relative to controls was partly supported with a borderline difference in mu ERD at fronto-central regions. The difference however, was not in the expected direction with a higher relative level of mu ERD in the control group rather than the LKM group (who actually elicited ERS). The ERD exhibited by the control group is a normal finding in the literature, however the ERS that the LKM group exhibited demonstrated a non-engaged mirror system. In our pain protocol we observed a less reactive mirror system in our LKM group, and here we see the same (albeit elicited by different stimuli). The final evidence that points towards a difference in mirror neuron activity between groups was found at central regions with a different pattern of mu activation. Here we see typical mirror neuron activation in the control group (higher mu ERD to moving hands relative to moving balls), and atypical activation for our LKM group (less mu ERD to moving hands relative the moving balls). No correlations accompanied these findings. It is tentatively suggested that these findings provides partial evidence for the modulation of the mirror system by long-term practice of loving-kindness meditation, however not in the direction expected.

The second expectation was that we would find a difference in mu ERD between the still hand and the moving hand conditions, regardless of which experimental group the participants were in. This finding, whilst not strictly relevant to our hypotheses of between group differences did demonstrate the validity of the task to measure mirror neuron activation. At both central and centro-parietal (spanning both middle and late epochs) regions we see a difference in mu ERD between the moving hand and still hand conditions with higher mu ERD to the moving hand condition. The only correlations that we observe relate to mu ERD to the moving hands and the empathy quotient indicating that higher mu ERD is related to a higher score on the empathy quotient.

To summarise, we found partial evidence to support the hypothesis that practicing LKM long-term can modulate the mirror neuron system as measured by mu reactivity, however findings revealed unexpected and atypical findings - a less reactive mirror neuron system in LKM practitioners. The protocol also elicited typical findings that validated the effectiveness of the protocol at eliciting mirror neuron activity.

4.5.4 IAPS Protocol

The following presented results are of 2 x 3 x 7 mixed measures ANOVAs that were conducted to compare the main effects of the type of group (control and meditators) x stimuli valence (negative, neutral and positive) x electrode (seven electrode strip). Analysis was performed on three different epochs: early (0-1000ms), middle (1000-2000ms) and late (2000-3000ms). Analysis will focus on a) main effect of stimuli type, b) interactions between stimuli type and group, c) between-subjects effects of stimuli, and d) correlations between stimulus evoked ERD and the EQ, IRI and the four dimensions of the IRI – Perspective Taking, Empathic Concern, Fantasy and Personal Distress.

4.5.4.1 Fronto-central (FC5, FC3, FC1, FCz, FC2, FC4, FC6)

4.5.4.1.1 Early Epoch

Table 39: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	22.49 (31.33)	9.28 (30.48)
	Neutral	27.96 (22.52)	6.50 (25.83)
	Positive	21.86 (27.48)	-0.21 (41.70)
High Alpha	Negative	11.32 (27.25)	20.93 (18.75)
	Neutral	13.78 (26.73)	19.48 (20.85)
	Positive	19.92 (18.78)	12.78 (22.63)
Low Beta	Negative	14.61 (15.40)	11.14 (14.45)
	Neutral	10.45 (22.47)	6.05 (18.37)
	Positive	12.50 (16.41)	3.08 (21.94)

Low Alpha (8-10 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .081) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of type of valence, and no between-subject effects (ps > .465. A borderline significant interaction between valence and group was present, $F(2,50) = 2.96$, $p = .061$. A significant linear contrast was also observed for this interaction ($F(1,25) = 4.79$, $p = .038$), demonstrating that the difference between the negative (M=11.32, SE=6.81) and positive (M=19.92, SE=4.70) conditions for the control group are different to the difference between the negative (M=20.92, SE=5.01) and positive (M=12.78, SE=6.05) conditions for the meditator group. In order to explore this effect, *t*-tests were used in order to examine the difference between the negative and positive conditions for each group. There was no significant difference between these condition for the control group ($t(15) = -1.47$, $p = .163$). There was however a significant difference between these variables for the meditator group ($t(13) = 2.31$, $p = .038$) with more ERD elicited by the negative images. No significant correlations were found.

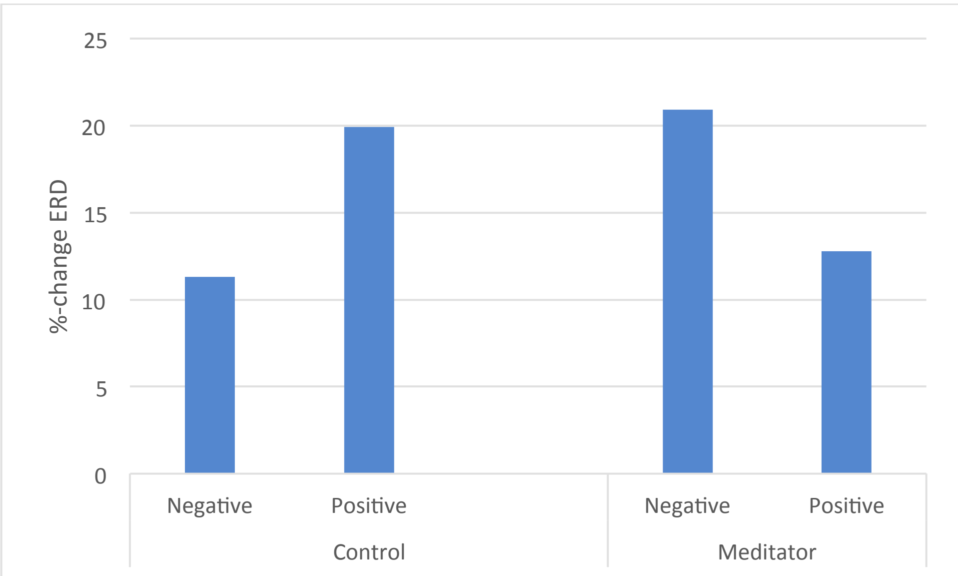

Figure 40: Chart showing high alpha ERD to negative and positive images for both groups

Low Beta (12.5-16 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .188) and consequently, no correlations were tested.

4.5.4.1.2 Middle Epoch

Table 40: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	37.20 (37.72)	37.31 (25.56)
	Neutral	38.56 (20.16)	25.56 (25.60)
	Positive	36.74 (23.24)	24.79 (32.61)
High Alpha	Negative	22.49 (35.81)	38.70 (19.53)
	Neutral	24.73 (37.00)	35.82 (18.26)
	Positive	30.99 (20.83)	29.56 (20.47)
Low Beta	Negative	26.73 (18.63)	29.94 (12.31)
	Neutral	19.55 (16.74)	21.24 (15.14)
	Positive	18.93 (20.59)	19.97 (17.27)

Low Alpha (8-10 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .237) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .127) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A significant main effect was found for type of valence, $F(2,50) = 4.89$, p = 011. There were no other significant findings of interest (*ps* > .387). Pairwise comparisons of the valence effect revealed differences between the negative (M=26.91, SE=2.90) condition and the neutral (M=19.01, SE=2.90) condition (mean difference = 7.90 p=.011, CI(95%) 1.56 - 14.24). Differences were also found between the negative (M=26.91, SE=2.90) condition and positive (M=18.30, SE=3.64) conditions (mean difference = 8.78 p=.043, CI(95%) .22 - 17.33). In all cases the highest ERD was elicited by the negative images. Four significant correlations were found. The first two between low beta ERD elicited by the negative images and the fantasy dimension of the IRI (r = .42, n = 30, p = .022), showing that higher mu ERD is associated with high fantasy scores. The second between ERD elicited by the positive images and again fantasy (r = .36, n = 30, p = .048) showing that higher mu ERD is associated with high fantasy scores. The third correlation was between ERD elicited by the positive images and the empathic concern dimension of the IRI (r = .49, n = 30, p = .006) showing that higher mu ERD is associated with high empathic concern scores. And the fourth between ERD elicited by the positive images and the personal distress dimension of the IRI (r = -.38, n = 30, p = .038) showing that higher mu ERD is associated with lower fantasy scores.

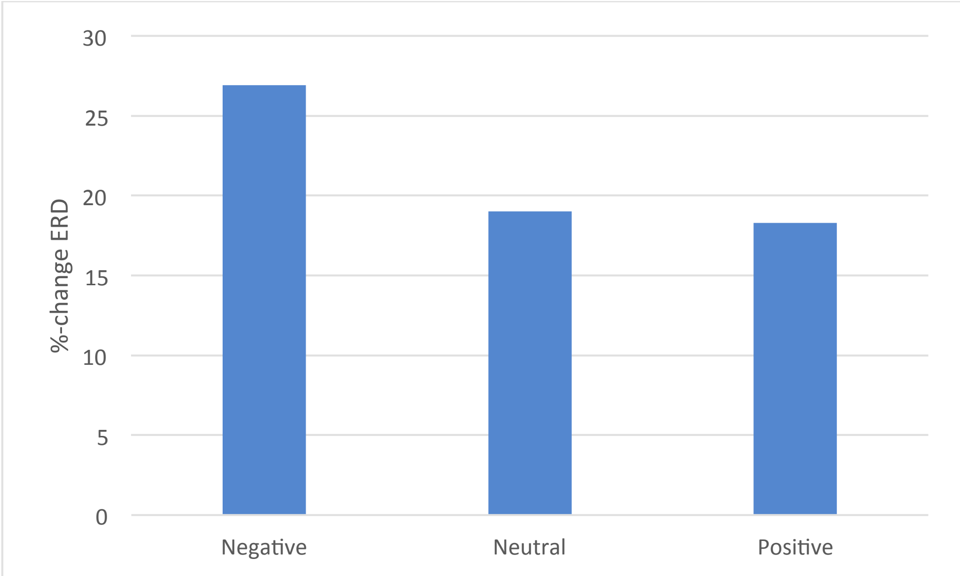

Figure 41: Chart showing ERD to each category of valence

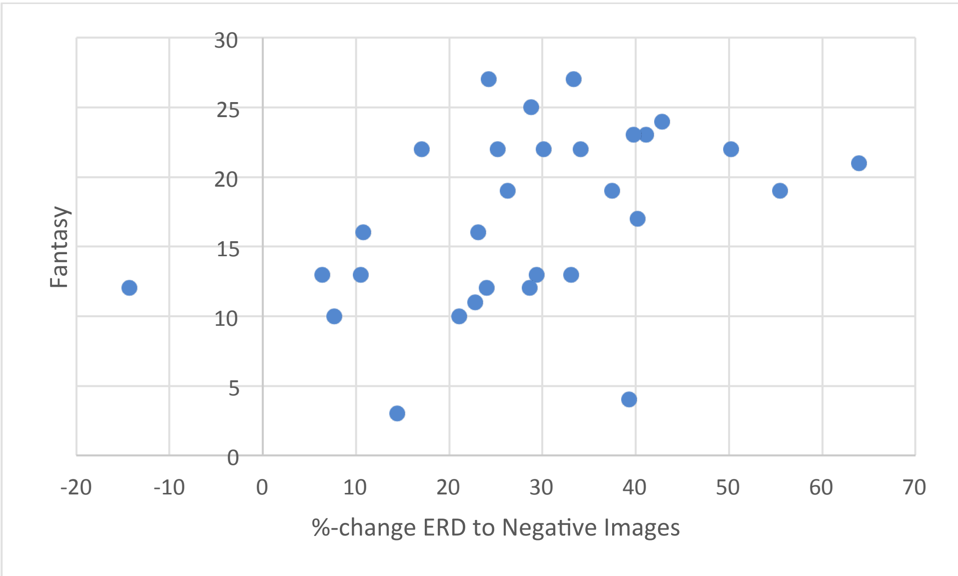

Figure 42: Chart showing positive correlation between fantasy and ERD elicited to negative images

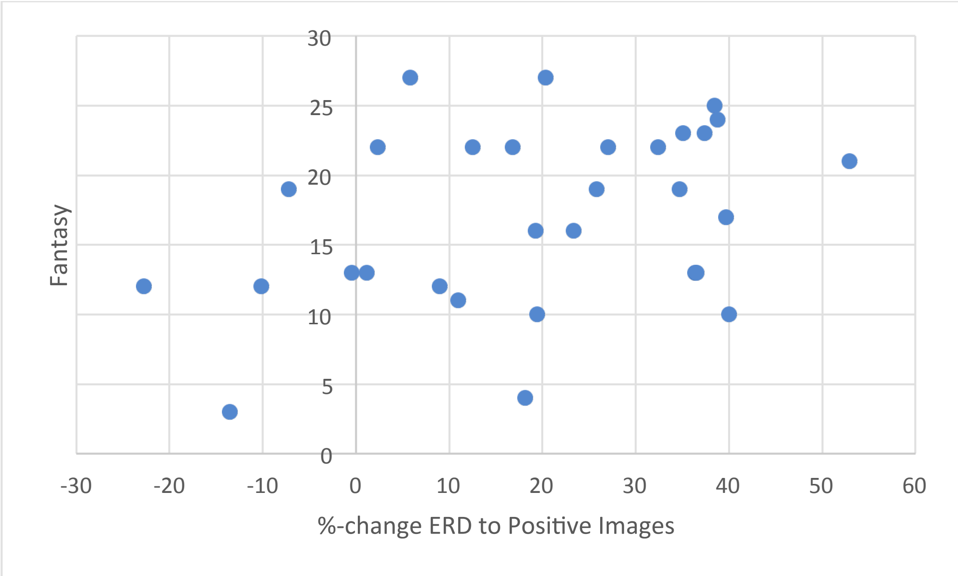

Figure 43: Chart showing positive correlation between fantasy and ERD elicited to positive images

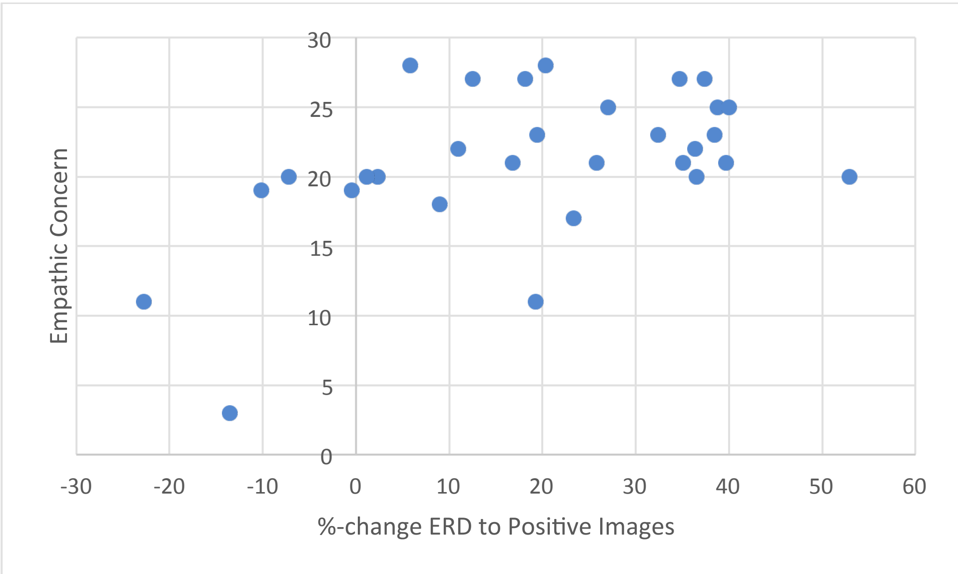

Figure 44: Chart showing positive correlation between empathic concern and ERD elicited to positive images

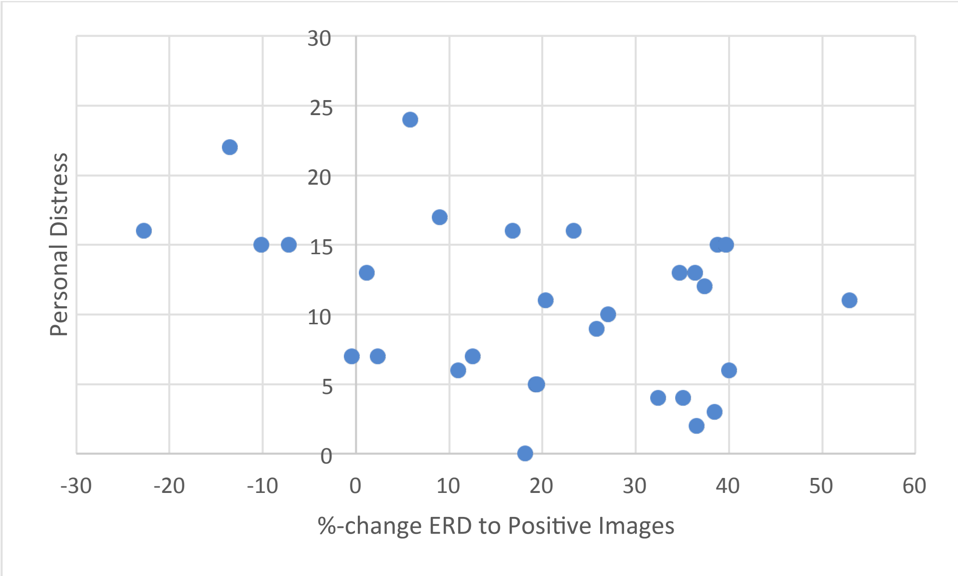

Figure 45: Chart showing negative correlation between personal distress and ERD elicited to positive images

4.5.4.1.3 Late Epoch

Table 41: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	39.26 (26.87)	37.67 (26.51)
	Neutral	29.83 (31.06)	22.98 (29.47)
	Positive	35.38 (22.48)	22.23 (35.67)
High Alpha	Negative	19.12 (38.57)	36.36 (18.97)
	Neutral	23.87 (36.91)	37.35 (18.52)
	Positive	21.64 (36.40)	29.03 (22.25)
Low Beta	Negative	27.87 (18.67)	29.52 (13.49)
	Neutral	19.72 (17.21)	22.16 (15.68)
	Positive	19.36 (18.41)	21.57 (18.53)

Low Alpha (8-10 Hz)

A borderline significant main effect was found for valence ($F(2,50) = 3.02$, $p = .058$), however pairwise comparisons revealed no significant differences (*ps* > .095). There was no significant interaction between valence and group and no between-subjects effects (*ps* > .527).

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .064) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

As in the middle epoch, a significant main effect was found for type of valence, $F(2,50) = 3.77$, $p = .030$. Pairwise comparisons revealed a significant difference between ERD elicited by the negative (M=26.96, SE=3.06) images and neutral (M=19.73, SE=3.14) images (mean difference = 7.22 p=.034, CI(95%) .44 - 14.00). A borderline difference was also found between the negative (M=26.96, SE=3.06) images and the positive (M=18.56, SE=3.42) images (mean difference = 8.40 p=.058, CI(95%) -.21 - 16.99). In all cases, low beta ERD was higher to the negative images. A significant positive correlation was found between ERD elicited by the negative images and the fantasy dimension of the IRI ($r = .42$, $n = 30$, $p = .020$), such that higher mu ERD is associated with higher fantasy scores.

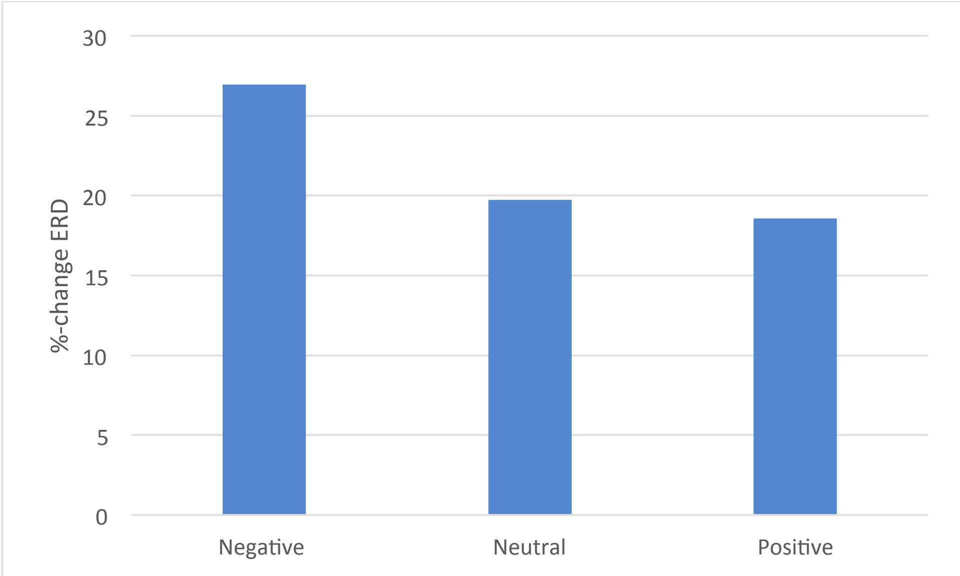

Figure 46: Chart showing ERD elicited to each category of valence

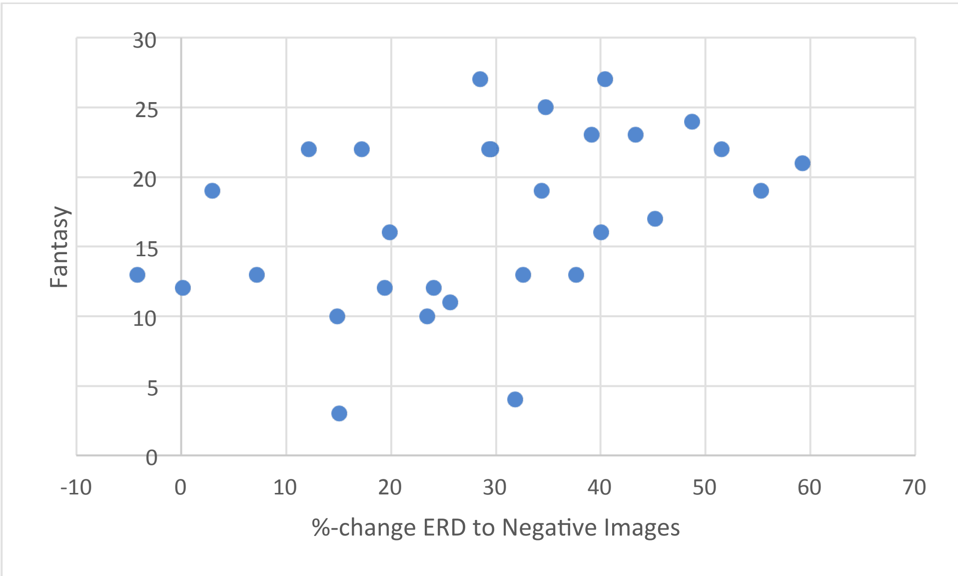

Figure 47: Chart showing positive correlation between fantasy and ERD elicited to the negative images

4.5.4.2 Central Electrodes (C5, C3, C1, Cz, C2, C4, C6)

4.5.4.2.1 Early Epoch

Table 42: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	21.29 (32.20)	11.58 (31.67)
	Neutral	21.00 (18.85)	8.27 (20.82)
	Positive	22.10 (30.19)	0.43 (34.70)
High Alpha	Negative	5.79 (31.37)	10.45 (21.19)
	Neutral	-0.80 (33.43)	13.65 (22.06)
	Positive	10.09 (19.82)	10.07 (25.31)
Low Beta	Negative	13.30 (17.16)	8.09 (16.36)
	Neutral	8.85 (24.63)	4.27 (20.34)
	Positive	14.21 (18.82)	-1.75 (27.94)

Low Alpha (8-10 Hz)

There was no main effect of valence, no significant interaction between valence and group and no between-subjects effects (*ps* > .085) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .094). A borderline significant quadratic trend was found for valence x group ($F(1,26) = 4.19$, $p = .051$) demonstrating that for the control group, the difference between the average of the emotional stimuli (negative + positive) compared to the neutral stimulus was different to that for the meditator group. Showing that whereas the meditator group had an increased response (larger high alpha ERD) to neutral stimuli (compared to emotional ones), the control group had a decreased response (almost nil).

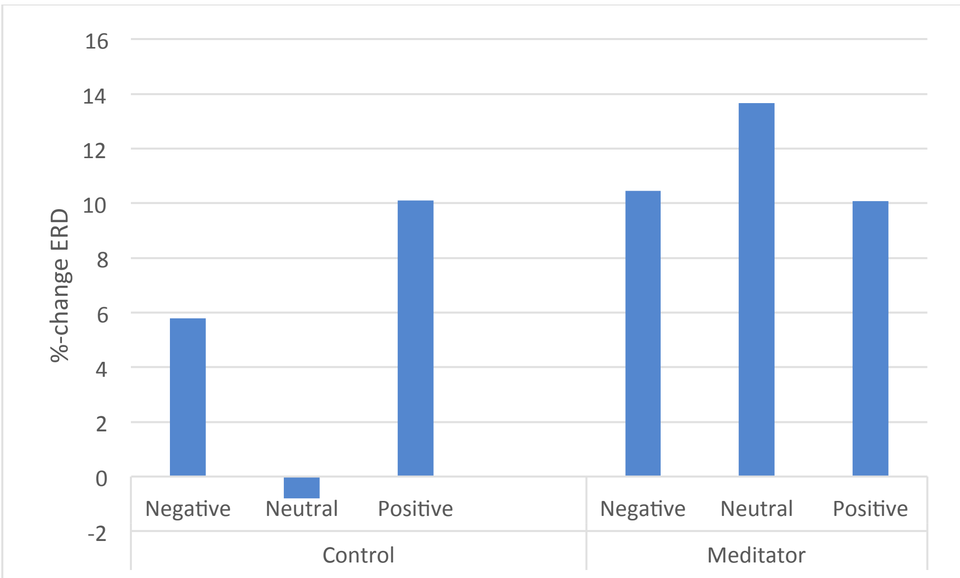

Figure 48: Chart showing ERD to each category of valence for both groups

Low Beta (12.5-16 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .137) and consequently, no correlations were tested.

4.5.4.2.2 Middle Epoch

Table 43: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	39.09 (41.13)	39.07 (23.72)
	Neutral	34.86 (19.62)	26.97 (22.96)
	Positive	39.14 (22.23)	25.73 (29.57)
High Alpha	Negative	13.93 (41.65)	27.52 (21.97)
	Neutral	14.52 (34.24)	27.51 (16.85)
	Positive	20.89 (18.90)	24.85 (27.39)
Low Beta	Negative	24.00 (21.45)	27.76 (13.32)
	Neutral	19.66 (16.89)	18.93 (16.13)
	Positive	19.38 (17.37)	16.72 (20.04)

<u>Low Alpha (8-10 Hz)</u>

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .270) and consequently, no correlations were tested.

<u>High Alpha (10-12 Hz)</u>

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .172) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A significant main effect was found for type of valence, $F(2,52) = 3.26$, $p = .046$. A significant linear contrast for valence ($F(1,26) = 6.08$, $p = .021$) indicated that there was a significant difference between ERD elicited by the negative images (M=25.75, SE=3.27) and positive images (M=18.13, SE=3.36), with more ERD elicited to the negative images. Two significant positive correlations were found. The first between ERD elicited to the positive images and the fantasy dimension of the IRI ($r = .42$, $n = 30$, $p = 021$), such that higher mu ERD is associated with higher fantasy scores. The second between ERD elicited to the positive images and the empathic concern dimension of the IRI ($r = .51$, $n = 30$, $p = 004$) such that higher mu ERD is associated with higher empathic concern scores. There was no interaction between valence and group and no between-subjects effects ($ps > .578$).

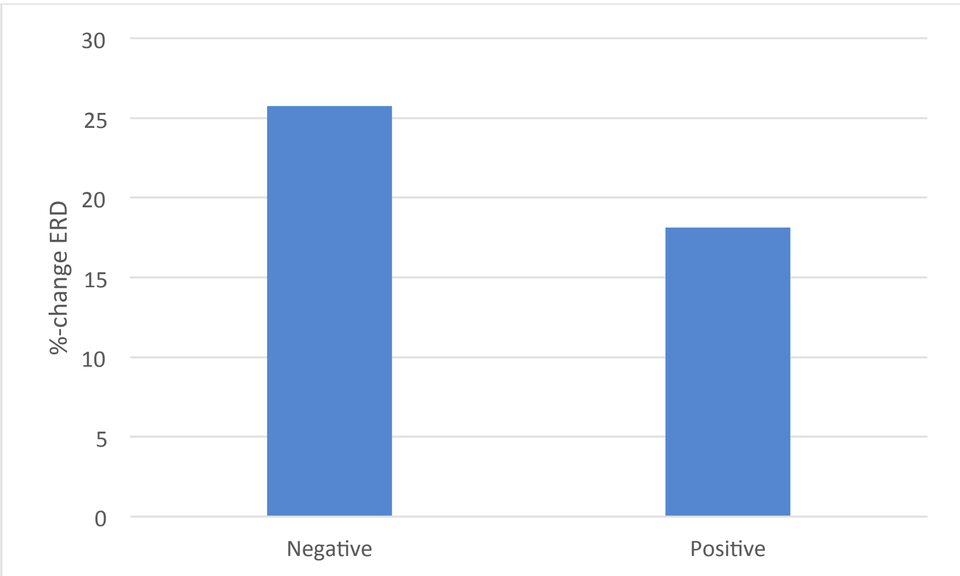

Figure 49: Chart showing ERD to both negative and positive images

Figure 50: Chart showing positive correlation between fantasy and ERD elicited to positive images

Figure 51: Chart showing positive correlation between empathic concern and ERD elicited to positive images.

4.5.4.2.3 Late Epoch

Table 44: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	39.47 (29.65)	37.80 (27.26)
	Neutral	23.92 (29.19)	22.96 (25.23)
	Positive	35.34 (24.17)	24.90 (32.70)
High Alpha	Negative	10.72 (45.94)	25.42 (22.31)
	Neutral	10.87 (36.81)	28.06 (17.54)
	Positive	15.33 (25.90)	28.35 (22.16)
Low Beta	Negative	23.86 (19.36)	26.75 (15.97)
	Neutral	18.46 (19.38)	20.85 (14.55)
	Positive	20.32 (18.70)	18.21 (20.50)

Low Alpha (8-10 Hz)

A significant main effect was found for type of valence, $F(2,52) = 6.05$, $p = .004$. Pairwise comparisons revealed that there was a significant difference in ERD between observation of the negative (M=40.63, SE=5.23) images and the neutral (M=23.46, SE=5.38) images, with more ERD elicited for negative images (mean difference = 17.18 p=.005, CI(95%) 4.77 – 29.59).

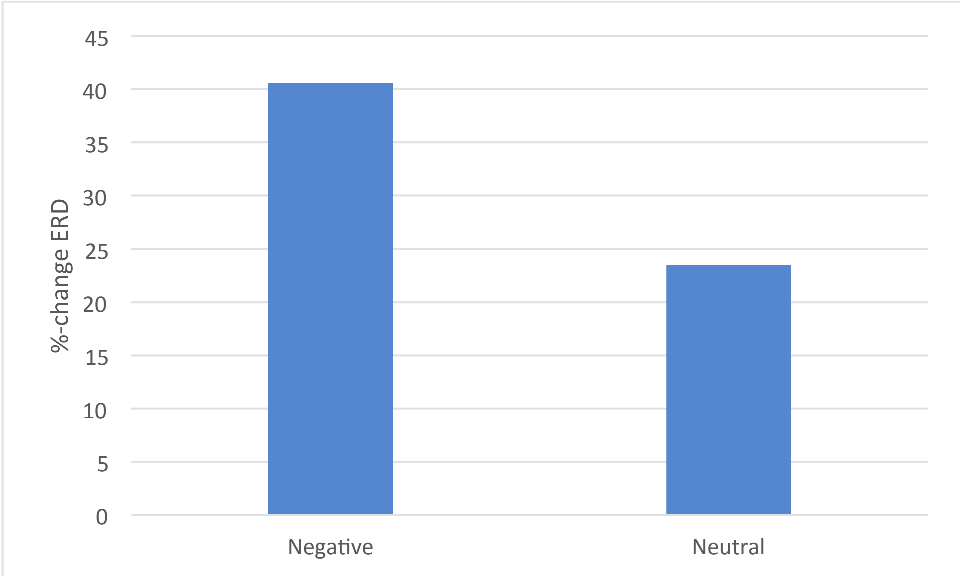

Figure 52: Chart showing ERD to both the negative and neutral images

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .064) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .175) and consequently, no correlations were tested.

4.5.4.3 Centro-parietal (CP5, CP3, CP1, CPz, CP2, CP4, CP6)

4.5.4.3.1 Early Epoch

Table 45: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	25.90 (31.15)	14.87 (30.74)
	Neutral	28.09 (21.03)	11.62 (25.61)
	Positive	30.84 (27.04)	8.19 (26.40)
High Alpha	Negative	11.70 (27.55)	11.08 (33.32)
	Neutral	4.58 (29.81)	13.81 (24.69)
	Positive	15.27 (18.70)	7.09 (27.21)
Low Beta	Negative	17.96 (26.72)	10.69 (20.71)
	Neutral	16.41 (31.03)	4.95 (16.55)
	Positive	20.64 (19.43)	4.62 (23.98)

Low Alpha (8-10 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .067) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of type of valence, and no between-subjects effect (*ps* > .598). As for the central electrodes, a significant valence by group interaction was found however

($F(2,52) = 3.70$, $p = .031$). A significant quadratic trend illustrated this ($F(1,26) = 6.09$, $p =$ 020), showing again that for the control group, the difference between the average of the emotional stimuli (negative + positive) compared to the neutral stimulus was significantly different to that for the meditator group. This shows that whereas the meditator group had an increased response (larger high alpha ERD) to neutral stimuli (compared to emotional ones), the control group had a decreased response (almost nil).

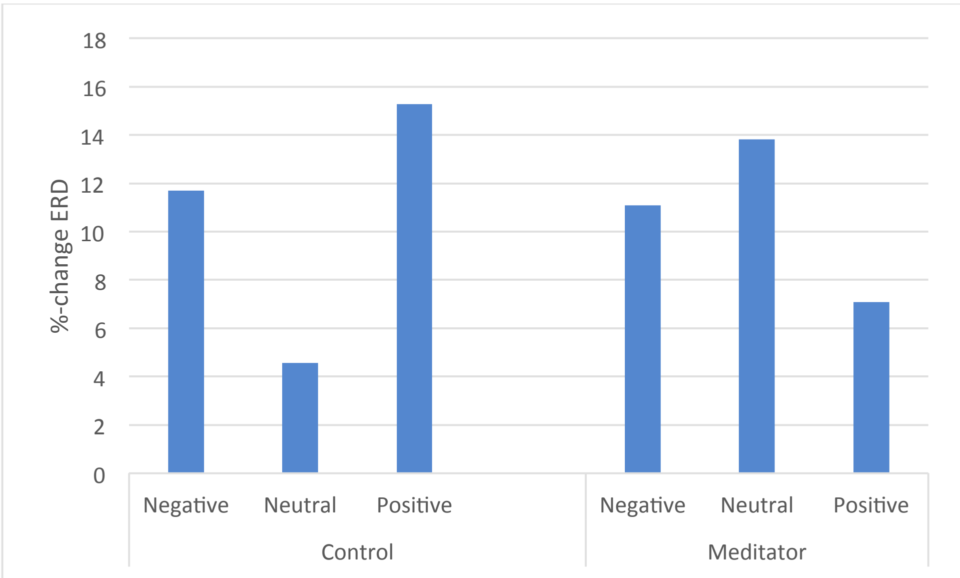

Figure 53: Chart showing ERD to each category of valence for both groups

<u>Low Beta (12.5-16 Hz)</u>

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .129) and consequently, no correlations were tested.

4.5.4.3.2 Middle Epoch

Table 46: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	38.33 (60.70)	45.56 (21.76)
	Neutral	38.16 (25.95)	34.27 (19.16)
	Positive	39.66 (30.05)	34.62 (21.46)
High Alpha	Negative	18.61 (47.89)	31.75 (25.32)
	Neutral	19.27 (32.64)	29.06 (16.47)
	Positive	22.55 (21.53)	25.97 (22.50)
Low Beta	Negative	27.70 (27.07)	33.58 (12.21)
	Neutral	23.45 (19.74)	20.06 (13.82)
	Positive	25.51 (14.33)	23.65 (12.41)

Low Alpha (8-10 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .604) and consequently, no correlations were tested.

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .285) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A significant main effect was found for type of valence, $F(2,52) = 3.31$, $p = .044$, however pairwise comparisons for this effect were not significant ($ps > .126$). No interactions between valence and group and no between-subjects effects were found ($ps > .442$) and consequently, no correlations were tested.

4.5.4.3.3 Late Epoch

Table 47: Means and standard deviations for ERD elicited by negative, neutral and positive stimuli

		Control Mean (SD)	Meditators Mean (SD)
Low Alpha	Negative	39.92 (45.25)	44.52 (25.11)
	Neutral	29.23 (39.76)	26.38 (29.03)
	Positive	35.83 (38.38)	34.39 (20.09)
High Alpha	Negative	11.82 (49.80)	32.56 (24.05)
	Neutral	14.54 (34.27)	23.40 (22.46)
	Positive	20.66 (22.85)	28.90 (32.71)
Low Beta	Negative	29.04 (24.91)	34.22 (8.36)
	Neutral	22.12 (23.18)	20.73 (12.41)
	Positive	25.93 (15.77)	34.23 (15.13)

Low Alpha (8-10 Hz)

A borderline main effect of valence was found ($F(2, 52) = 2.93$, $p = .062$). Pairwise comparisons showed that there was a significant difference between ERD elicited by the negative (M=42.26, SE=6.65) images and the neutral (M=27.19, SE=6.85) images (mean difference=16.07 *p*=.044, CI(95%) .352 – 31.79). No significant correlations were found.

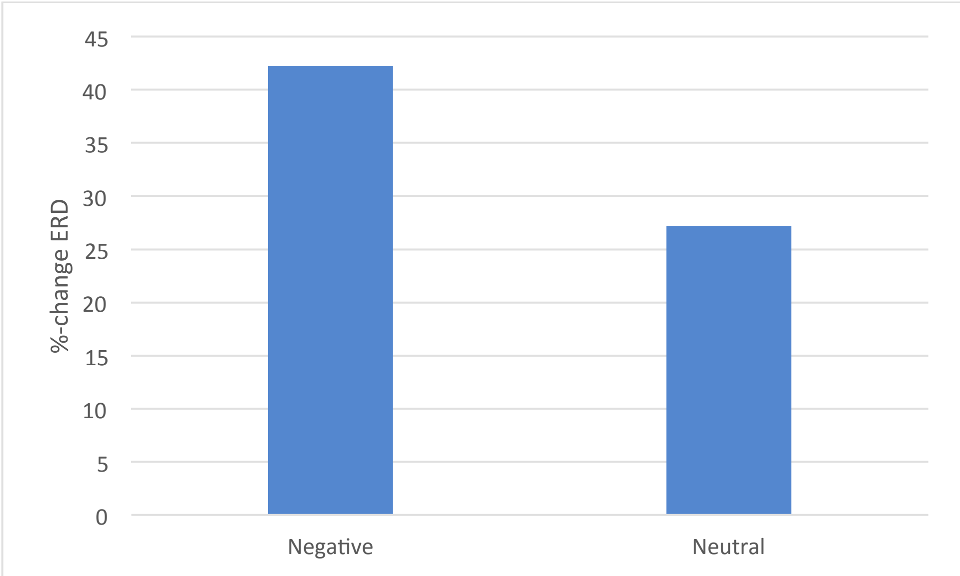

Figure 54: Chart showing ERD to both the negative and neutral images

High Alpha (10-12 Hz)

There was no main effect of valence, no interaction between valence and group and no between-subjects effects (*ps* > .379) and consequently, no correlations were tested.

Low Beta (12.5-16 Hz)

A significant main effect was found for type of valence, $F(2,52) = 5.00$, $p = .010$. Pairwise comparisons found that there was a difference between the ERD of the negative (M=32.36, SE=3.48) images and the neutral (M=21.71, SE=3.58) images, with more ERD to the negative images (mean difference=10.65 *p*=.016, CI(95%) 1.69 – 19.61). No significant correlations were found.

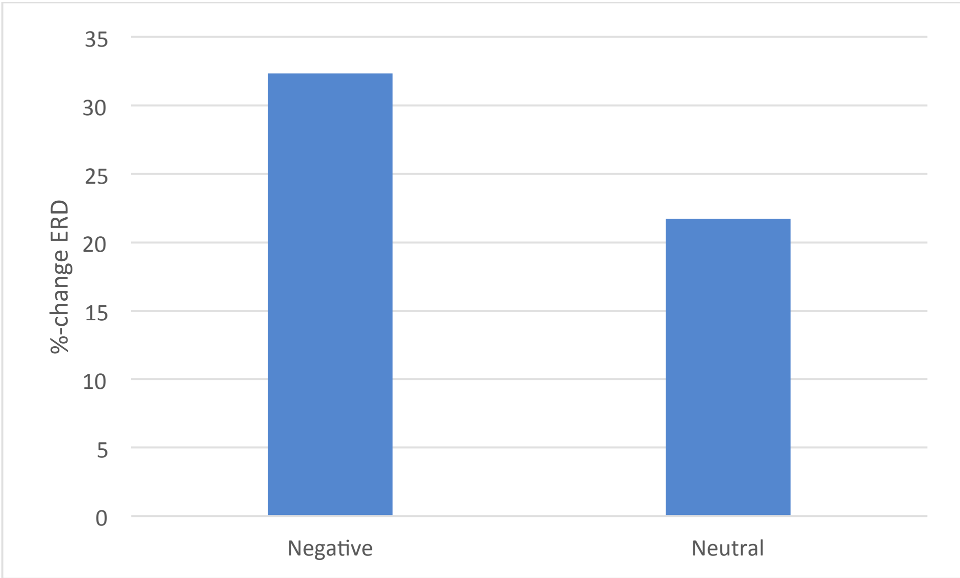

Figure 55: Chart showing ERD to both the negative and neutral images

4.5.4.4 Interim Discussion – IAPS Protocol

The aim of the IAPS protocol was to examine whether any between group differences in mirror neuron activation as measured by mu reactivity would be sensitive to emotional images of differing valence (positive, negative and neutral). It was expected that long-term practice of LKM would process emotional images differently and would be less effected by negatively valenced stimuli (Sobolewski, et al., 2011). Between group differences were indeed observed in our sample. The following findings were observed in the early epoch of the images in the high alpha bandwidth. A linear contrast was demonstrated at fronto-central regions which showed a different pattern of cortical activation between the negative and positive images between both groups. For the control group we see higher mu ERD elicited by the positive images relative to the negative - this pattern is reversed for the LKM group. At central regions, we find a quadratic effect replaces the linear one. Here we see again a different pattern of activation in that for the control group we see less activation to the neutral images relative to the two emotional image types (positive and negative), and for the LKM group we see a higher level of activation to neutral compared to the emotional images. We found no associations between these findings and empathy. These findings support the hypothesis that practicing LKM long-term can alter the manner in which emotional images are processed in that the LKM group exhibit a less varied reaction to emotional stimuli compared to control participants.

The second pertinent finding was discovered at the middle and late epoch of the images in the low beta frequency. In general, we find a difference in cortical excitability in the perception of valence. These findings are either expressed as pairwise comparisons, or linear contrasts. In all instances, we find higher ERD to the negative images, and lowest to the positive. It is here that we also find significant correlations with measures of individual levels of empathic traits. Starting at fronto-central regions in the middle time epoch, we observe four correlations, three of them positive in direction, and one negative. Of the three positive, one was between ERD elicited by the negative images and scores on fantasy, one between ERD elicited by the positive images and fantasy, and the final between positive images and empathic concern. In each of these instances higher cortical excitability is associated with a higher score on the respective measure of empathy. The negative correlation was between the positive images and the personal distress dimension of the IRI and demonstrated that lower cortical excitability was associated with higher scores. When we move into the later time epoch we only find one correlation, a positive one between negative images and fantasy. When we move to central regions we find two positive correlation at the middle time epoch, with scores on fantasy and empathic concern correlating with the positive images. No correlations are found in the late time epoch, nor at centro-parietal regions.

To summarise, it is argued that we have found evidence of a different pattern of cortical activation between our LKM and control group, with the LKM group demonstrating less variability in their cortical reactions to the different valence of images compared to the control group. It is also argued that this difference has resulted from the long-term practice of LKM. With a lack of significant correlations related to these findings, we cannot state that these differences are related to empathy in any specific manner. What is clearer is that there is a general mid to late discrimination of affect that is associated with empathy. It is possible however that these associations became more pronounced due to the increased statistical power of the whole sample as opposed to the smaller split sample.

4.6 Chapter Discussion

The aim of study 2 was to investigate whether the long-term practice of LKM can cause measurable, observable differences in self-report measures of empathy and in the EEG as expressed in the mu bandwidth. This investigation comprised of three experimental protocols: a pain protocol, a moving hands protocol and an IAPS protocol. It was thought that by introducing three different protocols we could gain a better understanding both of any advantage there may be in practicing loving-kindness meditation relating to empathy and/or any changes in brain oscillatory activity associated with the human mirror neuron system.

4.6.1 Self-report Empathy Differences

The first point to consider is the lack of a statistical difference in self-report measures of empathy (as measured by the empathy quotient and the interpersonal reactivity index). It was expected that if the long-term practice of LKM were to increase ones empathy then this may be detectable in our self-report measures. We hypothesised that we would find significant differences in empathy between the LKM and control groups, however this strictly speaking was not the case. It is important to note however that despite this lack of a statistical difference, we did observe higher scores for the empathy quotient, empathic concern and personal distress in the LKM group. It is heartening to see that this difference is going in the expected direction, even if the difference is not significant.

4.6.2 Pain Protocol

There was an expectation of finding meaningful group differences in mu ERD upon the observation of others in pain or not in pain (portrayed through needles pricking skin and Q-tips stimulating skin respectively). It was expected that long-term practitioners of LKM would demonstrate different patterns of cortical excitability compared to a group who had no experience in the technique. Whilst between group differences in perception of painful images were not found, interesting group differences were still observed. This group difference was expressed through a general difference in cortical excitability, regardless of the type of stimuli in that the LKM group exhibited less mu ERD than the control group. As to why long-term LKM practitioners would exhibit less mu ERD to these stimuli is uncertain, however previous research has demonstrated that meditators (both novices and experts) appraise physically noxious pain experiences as less painful than those with no meditative experience (Brown & Jones, 2010; Zeidan et al., 2011). It is therefore speculated that the present findings could indicate evidence to suggest a less reactive experience of pain for the LKM group. Although this explanation should be treated warily due to the effect being present for pooled stimuli rather than just for the painful images. Another and possibly more probable explanation for the decreased hMNS activation relative to the control group can be found in the neural efficiency hypothesis first mentioned in the last chapter relating to finding in the emotional sound protocol. It could be speculated that if long-term practice of LKM can indeed make a person more skilled at expressing empathy then this increase in empathic skill might be expressed through mu oscillations leading to less mu ERD in expert meditators relative to controls. The second finding illustrated that there was more mirror activity being elicited by images of the mouth being pricked than to images of the foot being pricked, and more to images of the foot being stimulated by the Qtip than to images of the hand being stimulated by the Qtip. It is speculated that the lips would be more sensitive to the pain of being pricked by a needle than a foot being pricked. It is also speculated that participants could recognise that a foot could be more ticklish (by the soft Q-tip) than the hand. The final finding demonstrated that there was more mirror activity elicited by the foot and mouth images than to the hand images. Again, this could be an issue of participants understanding that the mouth and foot are more sensitive to stimulation than the hand.

4.6.3 Moving Hands Protocol

Evidence to support the idea of meaningful group differences being elicited by a classic mirror neuron activation protocol (moving hands protocol) was not strong. Having said this, evidence was found expressed as increased mirror neuron activity elicited to the moving hands condition in the control group than to the LKM group (who demonstrated ERS rather than ERD). Other evidence demonstrated a between group difference in mirror neuron activity when comparing excitability between moving hands and moving balls conditions. In both cases we see a different level of mirror neuron activity between groups, however there is more activity being expressed by the control group rather than the LKM group. Here we see some evidence of between group differences, and that there is something causing the meditator sample to perform differently at the neuronal level. Whilst it is possible that this is due to the practice of LKM, there is a possibility that it could be down to other factors, not investigated. What is interesting, is that these group differences are similar to those seen in the pain protocol, in that the LKM group appears to show reduced hMNS activation compared to the control group. This is further evidence to imply a that long-term practice of LKM can cause a less reactive hMNS. As mentioned above, this might again relate to the neural efficiency hypothesis. Other non-group related findings demonstrate typical mirror neuron findings. The main pattern being that we observe increased mirror neuron activity to a moving rather than to a still hand, which is similar to findings by others in the field (e.g. Oberman, et al. 2005; Puzzo, Cooper, Vetter & Russo, 2010; Puzzo, Cooper, Cantarella S, & Russo 2011). Finally we find a logical correlation, between mirror neuron activity to the moving hand condition and the EQ, however this is a typical finding in the mirror neuron and empathy literature and is not strictly relevant here.

4.6.4 IAPS protocol

In the first two protocols, we observed evidence to suggest that long-term practice of LKM can elicit potentially meaningful differences in mu ERD compared to control groups. Evidence for group differences were also found in our IAPS protocol, where we observed a difference in the pattern of activation elicited by the images. At fronto-central regions we see that there is more mu activity to the negative images relative to the positive images in the LKM group. This pattern is reversed for the control group who have more mu activity to the positive images. As we move to central and centro-parietal regions we see a different pattern of activation which potentially implied a less variable mirror system in the LKM group in contrast to the controls who potentially had a more reactive mirror system in response to the emotional images (positive and negative) than to the neutral images. Past research has implied that meditators are able to process emotional images differently to non-meditators, with meditators being less effected by negative images (Sobolewski, et al., 2011). It is argued here that long-term practice of LKM has indeed led to our meditators processing emotional images differently to our control group. Finally, whilst not relating to group differences, we see a difference in mu activation in general to each of the types of images. In all instances we see that there is increased activity to the negative images and generally the least to the positive images. These findings are similar to that of Cesarei and Codispoti (2011) who report higher alpha ERD to negatively valenced images (such as mutilated bodies, human and animal attack) and lower alpha ERD to neutral images (such as animals, faces and people). However they also found high levels of alpha ERD to positive images (such as erotic couples, nude images and babies) whilst we found a similar level of ERD as in the neutral images. As the focus of this chapter is on between group differences, we shall not go into depth regarding this finding.

4.6.5 Concluding Comments

The aim of this chapter was to explore between group differences in mirror neuron activation by introducing a wide range of stimuli. Despite a lack of a significant difference between self-report measures of empathy, we did find that scores for the empathy quotient, empathic concern and personal distress were higher in the LKM group. We found between group differences in each of the experimental protocol which are argued to be meaningful and relate to the practice of LKM. There appears to be a fairly clear thread running through the data of each of these protocols that demonstrates long-term practice of LKM can lead to a less reactive mirror neuron system. This less reactive mirror system could be explained by the neural efficiency hypothesis which states that experts exert less neural activity at a task than novices do. The lack of any correlational evidence relating to the group differences is a shame and limits our interpretation that our findings are related to empathic processes.

In the following chapter we continue our investigations into individual differences in empathy by exploring recent findings by Carney, Cuddy and Yapp, (2010). Carney and colleagues found evidence to support the idea that adopting a high-power posture (i.e. an open, expansive and dominant posture) can raise both feelings of power and levels of testosterone. There is evidence that demonstrates that those with higher levels of testosterone are less empathic (Bos, Hofman, Hermans, Montoya, Baron-Cohen & van Honk, 2016). Evidence also suggests that there may be a link between feelings of power and empathy (Hogeveen, Inzlicht & Obhi, 2014). Thus in the next chapter we will explore the effect of three different postures on feelings of power and empathy as measured by mu suppression.

Chapter 5: Posture, Power and Empathy

"Do what I do. Hold tight and pretend it's a plan!" - The 11th Doctor (Matt Smith)

5.1 Introduction

The final topic of interest to this thesis will be power, posture, empathy and how they relate to each other. Within this chapter we will look at why posture and feelings of power might be of great relevance to someone's ability to behave in an empathic manner. We will also begin by briefly discuss the putative role that testosterone might play in this relationship and the arguments for and against.

Box 1: A brief testosterone primer.

Testosterone is one of various steroid hormones. In males, most testosterone is produced by Leydig cells in the testes; the remainder of this androgen being produced by the cortex of the adrenal gland (Neave, 2008). Testosterone is also present in females, however to a lesser extent. In females, testosterone is produced by the ovaries with the remainder by the adrenal gland. Increased testosterone generation if found during the middle of a female's menstrual cycle. There are three main peaks of testosterone generation in males during healthy development. The first being between 10 and 18 weeks? during gestation. The second around week 8 after birth, this can last between 4-5 months. The final peak occurs during puberty. These androgens are responsible for male primary sexual characteristics such as his reproductive system. During puberty, the hormone is responsible for secondary sexual characteristics such as beard growth, increased organ size and dominant behaviour.

Testosterone is relevant in the context of this thesis (but not directly investigated) as high levels of testosterone have been found to lead to aggressive acts, both within humans and animals (Mazur & Booth, 1998). Further research into testosterone has found that a high testosterone level is associated with violence and delinquency (Dabbs & Morris, 1990). Mazur and Booth however note that the relationship between testosterone and aggression it might not be clear-cut, as dominance does not need to be achieved through aggression. Aggressive acts tend not to lend themselves to the understanding and sharing of the feelings of others.

In relation to testosterone literature, Bos, Hofman, Hermans, Montoya, Baron-Cohen & van Honk (2016) suggested that testosterone can have an impact upon empathy, specifically by affecting a person's speed in correctly identifying an emotion that is being portrayed in an experimental task called the RMITE test. The RMITE is a task in which a person is required to identify the emotion that is being portrayed by only looking at the eye region of a face. Bos and colleagues, took 16 female participants and tested them on two separate occasions. They completed the RMITE whilst having their brain scanned once having received a dose of testosterone and once having received a placebo dose. During the placebo condition, it was found that the inferior frontal gyrus (IFG) was activated during the RMITE task. The IFG is a region which has been found to be important when making judgements about the mental states of others based upon the eye regions (Dal Monte, et al 2014) and is also implicated in the human mirror neuron system (Pineda, 2008). When looking at the effects of testosterone, it was found that on a behavioural level, participants took significantly longer to correctly identify the emotion that the eye region portrayed. On an imaging level, it was found that connectivity between the IFG and two other areas, the anterior cingulate gyrus and the supplementary motor area were significantly reduced. This study shows the potential connection between testosterone and empathy in that a large dose of testosterone appears to significantly reduce a person's ability to identify the emotions of others.

Further evidence linking testosterone to empathy finds Hermans, Putman and van Honk (2006) manipulating testosterone levels in order to investigate facial mimicry with the expectation that administration of testosterone would negatively impact facial mimicry.

Participants were given a sublingual dose of either testosterone or a placebo and testing commenced four hours later. Facial EMG was measured as participants observed two second clips of happy, neutral and angry facial expressions. Results supported their expectation that testosterone would impair dynamic facial mimicry as measured by facial EMG with significantly decreased activity in the corrugator supercilii muscle and a near significant decrease in activity in the zygomatic major muscle.

Of interest to the current study, testosterone has been shown to be modulated by posture which in turn can lead to increased feelings of power (Carney, Cuddy & Yap 2010). In their paper, the authors demonstrate that posing in an open (expansive) posture causes behavioural and neuroendocrine change in participants when compared with a closed (withdrawn) posture. Open postures can be described as those postures which enlarge the physical profile of a person, in other words - making oneself larger, often in an attempt to become or seem more dominant. A closed posture on the other hand is the act of making oneself less noticeable, decreasing one's physical profile. There is an association between individuals who enter into a closed posture and the corticoid cortisol - the "stress hormone" (Carney et al., 2010). Previous research had found that those that are in power, display lower levels of cortisol and increased levels of testosterone (Abbot et al. 2003). Carney et al., investigated the role that both low and open postures had on 42 participants on a decision making task. Participants were randomly assigned to either the high power or low power posture which they held for one minute. Testosterone saliva samples were taken before the posture and then after a decision-making task (which consisted of a simple gambling task). It was found that open poses elevated testosterone levels when compared to closed poses. It was found that low power poses caused a decrease in testosterone. In terms of the gambling task, it was found that open posers focused on the reward meaning that they took more of a risk. Importantly, open posers also reported feeling more powerful. The potential implications of this research are interesting. The idea that adopting a specific posture for a relatively short amount of time (1 minute in the case of the above research) can alter a persons behavioural, psychological and physiological responses clearly has large implications. In related research Yap and colleagues (2013) conducted research examining whether expansive postures that are imposed upon participants by the environment (such as a large driver seat compared to a small driver seat) can lead to dishonest behaviour. Over a course of four studies (both laboratory and field based) the authors found that participants who adopted an expansive posture were more likely to take part in dishonest deeds such as stealing money, cheating on a test and committing traffic violations. This could be explained by Keltner, Gruenfeld and Anderson (2003) who found that power can activate our behavioural approach system which leads people to focus on rewards and behave in a self-interested manner. In response to the findings in the posture literature, Ranehill et al. (2015) conducted a replication study with some additions. They used a participant base of 200 people and added two additional behavioural tasks on top of the single gambling task that Carney and colleagues used: a risk taking task in the loss domain and a willingness to compete task. Similarly to the Carney study, Ranhill and colleagues found that participants in the open pose condition felt (on average) more powerful than those it the low power pose condition. However, Ranehill and colleagues found no effect of posture on risk taking, or to levels of testosterone or cortisol. Thus two of the three main findings from Carney and colleagues (2010) were not replicated and the results highlight the possibility that posture may not effect levels of testosterone and cortisol. This turned a previously interesting finding into a widely debated controversy.

Since 2016, we see a definite shift in the power pose literature. Whilst the Ranehill, et al. (2015) paper provides strong evidence for the lack of an effect of open poses on the increased generation of testosterone, we also see Carney changing her stance on the phenomena of power posting. Carney makes it clear in her online commentary on the power pose controversy that based on recent evidence and evaluation of the possible confounds of the original paper, she does not now believe that power posing per se is a real phenomena (Carney, 2016). However, despite Carney's statements, there appears to be no evidence to refute the finding that those in the open poses reported feeling more powerful, as this finding was replicated in the Ranehill study. Indeed, Cuddy (one of the other authors on the original 2010 paper) stands by their findings (Singal & Dahl, 2016). If increased power (as manipulated by power-posing) can lead to an increase in self-interested behaviour (as in Yap, et al., 2013) then we might be able to draw a link between power and empathy. Clark (1980) states that he sees the concept of empathy as an opposite force to power and that "Power and empathy may be seen as conflicting or counterbalancing dynamics in the individual's struggle for some sort of equilibrium in his or her interaction with others" (Clark, 1980, pg188). A more concrete link between power and empathy comes from a TMS investigation of power altering the way the brain responds to others (Hogeveen, Inzlicht & Obhi, 2014). In their study Hogeveen and colleagues first prime their participants feelings of power by asking them write about a situation in which they were under the power of another (closed essay), what happened the day before the study (neutral) and a situation when they had power over another (open). This was followed by a baseline condition in which corticospinal excitability was determined whilst observing a fixation cross. In the final phase participants observed clips of hands squeezing a ball (action observation block) and had TMS pulses delivered at the maximum point of squeeze intensity. The authors found that those who were primed to feel higher levels of power experienced lower levels of motor resonance (relative to the baseline condition) as measured by motor evoked potentials. The concept of motor resonance (the activation of similar brain networks upon the observation of another performing an action) is important here as it is thought to be implemented by the mirror neuron system.

Based on the above information, we start see a link between power and empathy. We also see controversy in the power-posing literature. The aim of the present study is to investigate these issues by exploring: whether open posers self-report higher feelings of power in comparison to closed posers and to a control posture and if any differences in feelings of power causes both behavioural and cortical differences in empathy. In order to investigate potential differences in empathy as a result of power-posing, we exposed participants to three protocols: the reading the mind in the voice, the RMITE and the pain protocol. The reading the mind in the voice protocol was used in order to establish whether there were any group differences in empathy (both behavioural and cortical) prior to the power-posing intervention. The remaining tasks were used in order to assess any behavioural and cortical changes after the power-posing. Based on the literature, it was expected that we would find higher self-reported feelings of power in the open group relative to the closed and control groups. We also expected to find differences in empathic accuracy and in mirror neuron activation between the three groups with the open posers having decreased empathic accuracy and a decreased level of mu ERD relative to the closed and control group.

5.2 Method Section

5.2.1 Participants

Forty-seven participants from the University of Essex took part, all volunteering with the possibility of winning a £50 Amazon voucher.

5.2.2 Stimuli

Self-report measures

Both the Empathy Quotient and the Interpersonal Reactivity Index were used (see page 62 for further information).

The Reading the Mind in the Eyes Protocol

The RMITE (Baron-Cohen & Jolliffe, 1997) is a test that requires participants to judge the emotion of a person based on information from only being able to see their eye-region. Typically, the participant is presented with the eye region of a face and then is required to choose from four possible emotions. The task is said to tap in to the ability of a person to understand the mental state of another (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001).

The Reading the Mind in the Voice Protocol

The reading the mind in the voice protocol (MIV; Rutherford, Baron-Cohen & Wheelwright, 2002) is another test that assesses a person's ability to identify the emotions and mental states of others. The test requires participants to listen to a series of short audio clips that features people expressing an emotion and then make a judgement as to the emotional state of the speaker.

Pain Protocol

The pain protocol was again used (see Chapter 3) however, it was shortened by removing the foot and mouth images due to body location not being an important variable. This resulted in a total of 56 trials which consisted of 28 images of hands being pricked by a needle and 28 images of hands being stimulated by a Q-tip.

5.2.3 Procedure

After explaining the general procedure of the study and obtaining informed consent, participants began by completing the EQ and the IRI on a Windows PC as the EEG cap was fitted. The experimental procedure always began with the Reading the Mind in the Voice task which consisted of 25 trials. The task began with an instruction screen which explained that a series of audio clips would be presented and that after each clip the participant would be required to make a choice as to the emotion that the speaker was portraying. A single trial consisted of 1) the presentation of an audio clip (which varied in duration from 1128ms to 3179ms) and 2) the presentation of a screen which listed four numbered emotions of from which the participant was required to choose the emotion that most closely represented the one portrayed. Once the choice was made, the next trial began until all 25 trials were complete. EEG were continuously recorded during this process, however was only of interest as the audio was playing.

Next came the posture phase. The purpose of this phase was to investigate whether posture can affect empathy on a behavioural and neuronal level. Participants were randomly assigned to either an open, closed or a control posture group. The open posture required participants to sit back with their arms behind their head and legs spread – increasing their physical profile. The closed posture required participants to lean forwards so their torso was closer to their thighs rest their arms crossed on their legs – this decreased their physical profile. The control posture required participants to sit in a neutral position, simply upright with arms resting on their legs. Participants sat in this posture for three minutes while they watched a short video clip. The video clip was simply a filler until the time had expired and was taken from the television program Doctor Who.

After the three minutes had expired, participants were given three questions to assess how they felt. These questions were: How confident do you feel? How powerful do you feel? How comfortable do you feel. These questions were used as a subjective measure of the effect of the posture. These questions were followed by two EEG protocols: the RMITE and the pain protocol - the presentation of which were counterbalanced across participants. The RMITE protocol consisted of a total of 36 trials. The task began with an instruction screen which explained that a series of images of eye-regions would be seen and that after the image the participant would be required to make a choice as to the emotion that was being portrayed in the eye-region. Each trial consisted of 1) an image of an eye region which remained for 3000ms and 2) the presentation of a screen that contained four numbered emotions from which the participant had to choose via the keyboard. Once an option had been chosen, the next trial began until all 36 trials were complete. The pain protocol was identical to the previous two studies, however to prevent an over long procedure was shortened so that only hand images remained. In total, there were 56 trials, half of which depicted a painful situation and the other half a non-painful situation.

5.2.4 EEG Data Acquisition

As page 65

5.2.5 EEG Data Preparation

Once acquired, the continuous data files were visually inspected for noisy data blocks and bad electrodes. Noisy blocks were manually highlighted to be rejected from further analysis. Faulty electrodes were marked as ‘bad’ and therefore rejected from further analysis also. Eye-movement artefacts were then rejected according to methods described by Croft & Barry (2000). All data were re-referenced to a common average reference. Remaining artefacts exceeding ± 75 mV were automatically rejected in an automatic rejection sweep before event-related desynchronization / synchronization (ERD/S) was computed using event-related band-power transform in Neuroscan Edit 4.4 (Compumedics, Melbourne, Australia). EEG bandwidths of interest were prepared in alpha and low beta (13 – 20 Hz).

Alpha was further split into two sub-bands: low (8 - 10 Hz) and high (10 - 12 Hz) because functions associated with each end of the alpha spectrum differ (Klimesch et al., 2007; Petsche, Kaplan, von Stein, & Filz, 1997; Aftanas & Golocheikine, 2001). Electrodes of interest included those overlying the premotor cortex and supplementary motor area (FC5, FC3, FC1, FCz, FC2, FC4, FC6), those overlying the motor cortex (C5, C3, C1, Cz, C2, C4, C4, C6) and finally those over the sensory area (CP5, CP3, CP1, CPz, CP2, CP4, CP4, CP6).

All data for the pain protocol were epoched from -500 to 2250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 2000 ms) was calculated using the formula adapted from Pfurtscheller and colleagues (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999): ERD% = (R−A) / R × 100, where R = power in the reference interval and A = power in the active or task phase. Using this formula ERD is expressed as positive values and ERS as negative. For the MIV protocol, all data were epoched from -500 to 1200 and trimmed 250 from each end to remove filter warm-up artefacts and the averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 1000 ms) was calculated using the formula above. Finally, all data for the RMITE protocol were epoched from -500 to 3250 ms and trimmed 250 ms from each end to remove filter warm-up artefacts and then averaged. Percentage change between the reference period (-250 to 0 ms) and active period (0 To 3000 ms) was calculated using the same formula as above.

5.3 Results

5.3.1 Pre-posture Phase - Behavioural Analysis

The first experimental protocol to be used was the Reading the Mind in the Voice. This protocol was used in order to ascertain where there were any differences in our sample relating to empathic accuracy at both the behavioural, and the neuronal level prior to the posture manipulation. It was hoped that there would be no difference in behavioural accuracy or ERD/S in the mu bandwidth. As can be seen from table 48 below, there appears to be very little difference in performance of this task. This was verified with a one-way ANOVA ($F(2,44) = .31$, $p = .738$).

Table 48: Mean and Standard Deviation of Accuracy in the Mind in the Voice Task for Each Group

Group	Mean (Standard Deviation) Accuracy
Open	60.24 (11.18)
Closed	61.60 (15.48)
Control	57.87 (13.04)

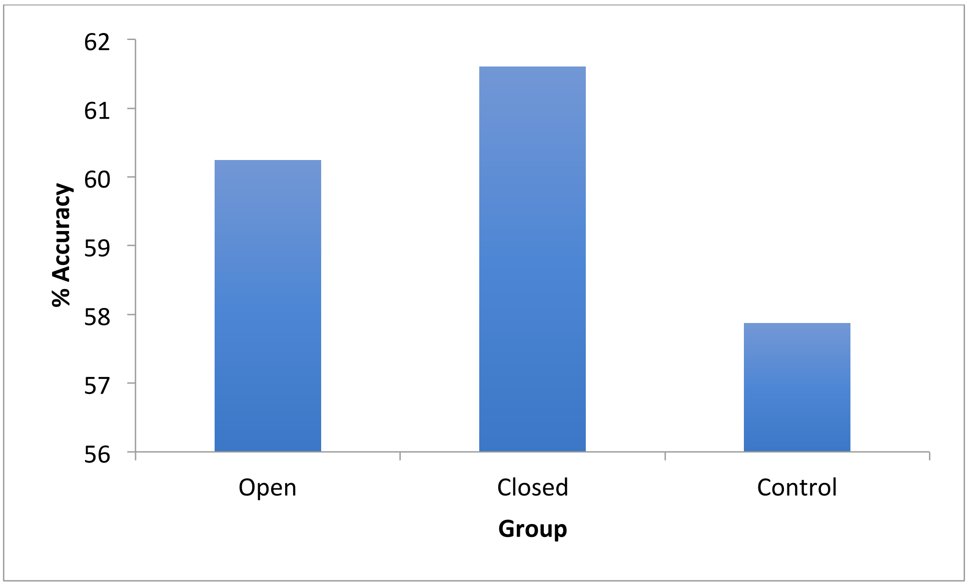

Figure 56: *Mean accuracy score for the mind in the eyes task for each group*

5.3.2 Pre-posture Phase - EEG Analysis

A 7 (electrode) x 3 (group) mixed ANOVA was run in order to investigate differences in ERD/S resulting from listening to the emotional audio clips. Results are organised by region and then by band. Analysis will focus on 1) interactions between electrode and group, 2) independent samples *t*-tests as follow-up tests (if necessary), 3) one-sample *t*-tests comparing ERD/S to zero and 4) correlations between significant mu desynchronisation/synchronisation and measures of empathy. The main effect of electrode will be reported, however are not of direct relevance to our hypotheses. Tests investigating significant levels of ERD/S (analysis 3) were conducted to ascertain whether the task elicits significant mirror activity due to an inextensive level of research on the matter.

5.3.2.1 Fronto-central Regions

Low Alpha

There was no significant main effect of electrode and no interaction between electrode and group (*ps* > .179).

High Alpha

There was no significant main effect of electrode and no interaction between electrode and group (*ps* > .439).

Low Beta

A significant main effect of electrode was observed ($F(6,252) = 2.49$, $p = .023$), however there was no significant interaction between electrode and group ($F(12,252) = 1.14$, $p = .331$).

5.3.2.2 Central Regions

Low Alpha

A significant main effect of electrode was observed ($F(6,246) = 2.80$, $p = .012$), however there was no significant interaction between electrode and group ($F(12,246) = 1.26$, $p = .246$).

High Alpha

A significant main effect of electrode was observed (*F*(6,246) = 4.27, *p* < .001), however there was no significant interaction between electrode and group (*F*(12,246) = 1.39, *p* = .172).

Low Beta

No significant main effect of electrode was observed (*F*(6,246) = .92, *p* = .482), however a significant interaction between electrode and group was observed (*F*(6,246) = 2.13, *p* = .016). In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each C-strip electrode. A significant group difference was found at electrode C4 between the open (M=-17.43, SE=6.86) and closed (M=3.05, SE=6.50) groups (1000 samples, *p* = .38), with the open group exhibiting ERS and the closed group exhibiting ERD. A significant group difference was also found at electrode C6 between the closed (M=.32, SE=5.46) and control (M=-17.98, SE=4.94) groups (1000 samples, *p* = .018), with the open group exhibiting ERD and the control group exhibiting ERS. In addition to a difference in mu activation between the open and closed group at the C4 electrode, there was also evidence of significant mu synchronisation for the open group (*t*(16) = -2.24, *p* = .040). Significant mu synchronisation was also found for the control group at C6 (*t*(14) = --3.60, *p* = .003). Finally, three positive correlations were observed, two at the C4 electrode and one at the C6 electrode. At C4 we find a correlation between mu synchronisation in the open group and Perspective Taking (*r* = .53, DF = 17, *p* = .027), and between mu desynchronisation in the closed group and Perspective Taking (*r* = .56, DF = 13, *p* = .049). At C6 we find a correlation between mu desynchronisation and Perspective Taking in the closed group (r = .67, DF = 13, p = .012).

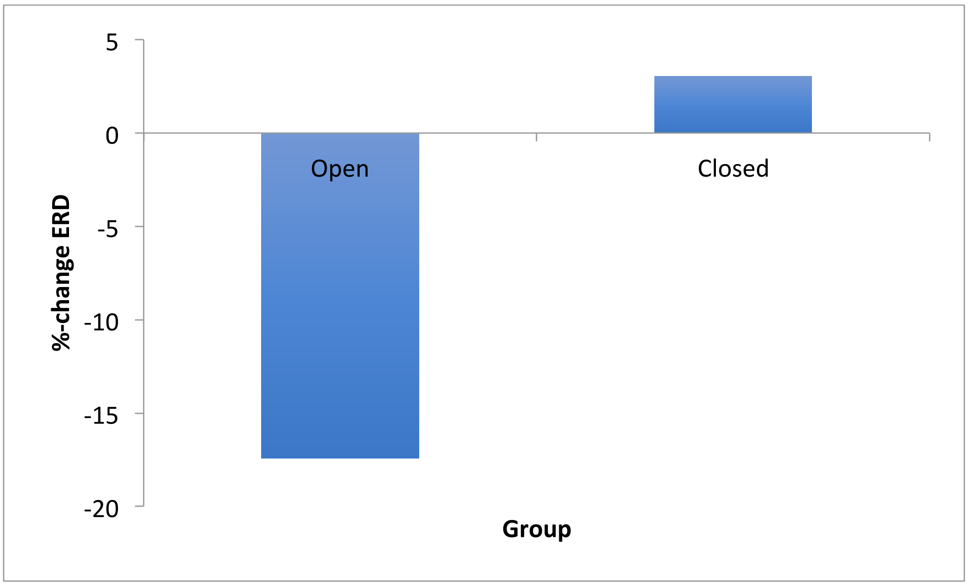

Figure 57: Difference in mu activation at the C4 electrode

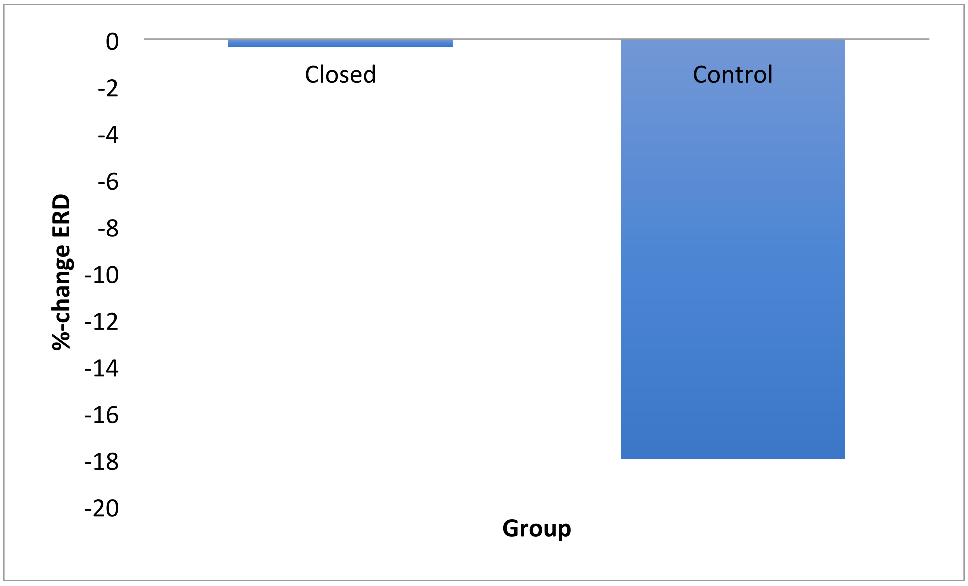

Figure 58: Difference in mu activation at the C6 electrode

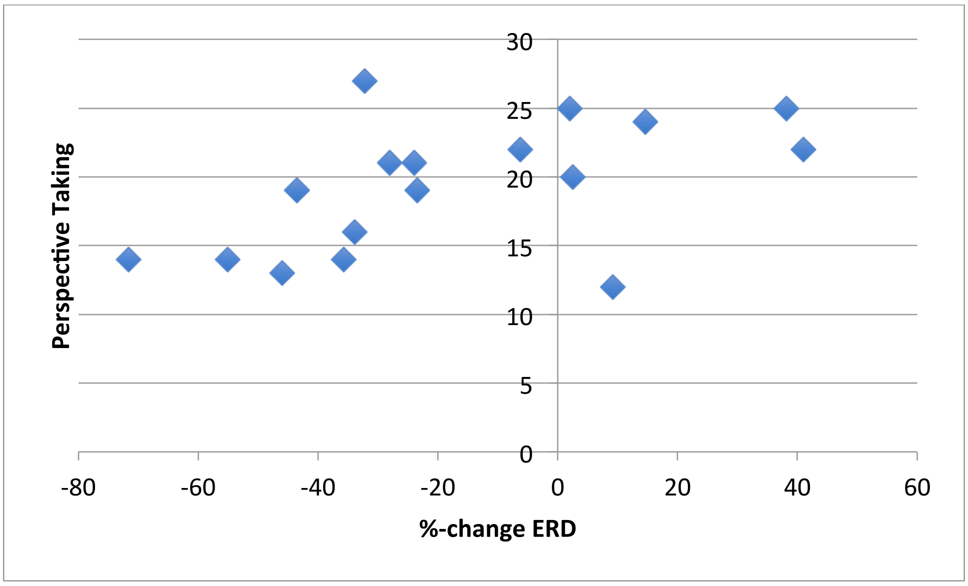

Figure 59: Positive correlation between mu synchronisation of the open group and perspective taking at C4 electrode

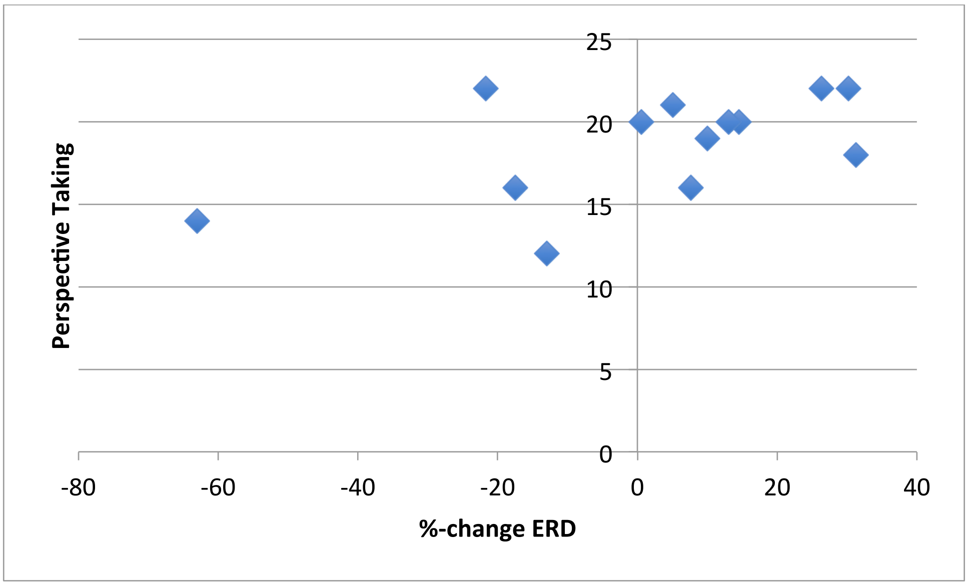

Figure 60: Positive correlation between mu desynchronisation of the closed group and perspective taking at C4 electrode

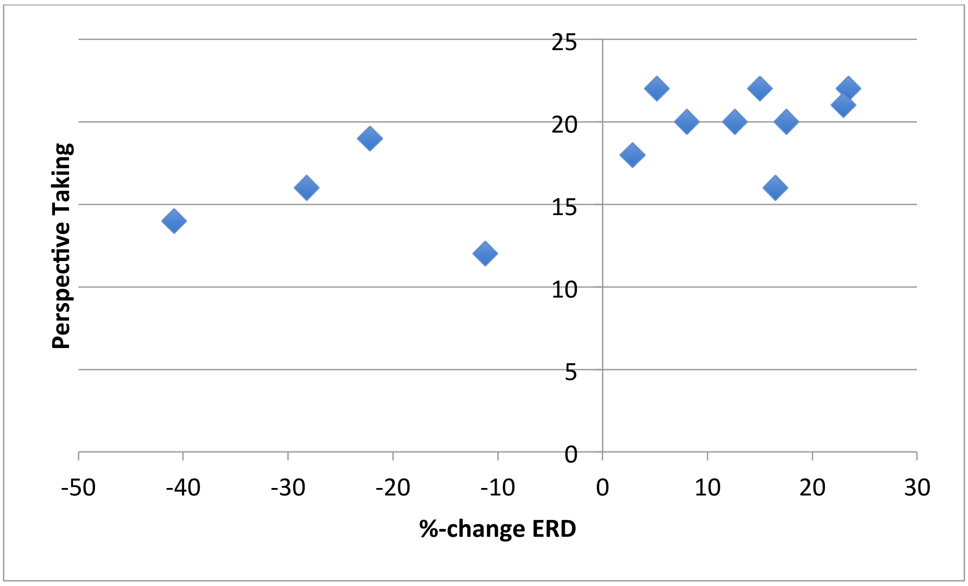

Figure 61: Positive correlation between mu synchronisation of the closed group and Perspective Taking at C6 electrode

5.3.2.3 Centro-parietal Regions

Low Alpha

A significant main effect of electrode was observed ($F(6,252) = 3.63$, $p = .002$), however there was no significant interaction between electrode and group ($F(12,252) = 1.37$, $p = .183$).

High Alpha

A significant main effect of electrode was observed ($F(6,252) = 4.17$, $p = .001$), however there was no significant interaction between electrode and group ($F(12,252) = 1.48$, $p = .129$).

Low Beta

There was no significant main effect of electrode and no interaction between electrode and group (*ps* > .233).

5.3.3 Interim Discussion - Mind in the Voice

The aim of running a pre-posture test was to ascertain whether any between group differences existed prior to the posture intervention. At the behavioural level, we observed no differences in accuracy with the Mind in the Voice task and found performance at around 60%. This lack of a group difference in accuracy is a positive finding as any potential difference in behavioural performance in the post-posture task can be used to imply the effectiveness of the posture in altering ones empathic accuracy. In terms of differences in ERD/S, we were also hoping for no between group differences, this however was not the case. We found a difference in mu activation at two electrodes at the central region with participants who will come to be in the open group exhibiting both a difference in mu activity and significant ERS at the C4 electrode. We also observed a difference in mu activity expressed as significant ERS at C6 for those who will go on to form the control group. Whilst we have significant ERS it is important to note that we found no ERD which, as mentioned, is associated with mirror system activation, and in turn empathy. This in itself is a positive finding as we hoped to find no group difference in mirror system activation prior to the posture. However, it is concerning that group differences were found in our EEG measures, even before any experimental manipulation had taken place. This added-noise in our sample is not unusual but does require us to be more conservative in our interpretation of our post-manipulation results. The final thing to be noted is that we found associations between both the synchronisation and desynchronisation and the perspective taking dimension of the IRI. Whilst not present in the control group, we found that at the C4 electrode higher scores on perspective taking were associated with more positive amplitudes (indicative of ERD). At the C6 electrode the only association was in the closed group and perspective taking, however the interpretation remained the same.

5.3.4 Post-posture Phase - Self-Report Measures of Posture

Directly after the posture phase, participants were asked to report on how powerful, confident and comfortable they felt. There was an expectation that those assigned to the open posture would rate higher on feelings of power and confidence than those in the closed and control groups. As can be seen from table 49 below, the mean values do not differ greatly. The only differences of note were a borderline difference between the comfort rating of the open and control group ($t(30) = -2.02$, $p = .053$) and a significant difference between the comfort rating of the closed and control group ($t(27) = -3.47$, $p = .002$) with the closed group rating themselves as the least comfortable. There were no other group differences (*ps* > .189).

Table 49: Means (standard deviations) of post posture questions

	Power	Confidence	Comfort
Open	2.29 (.59)	3.00 (.71)	2.18 (.88)
Closed	2.36 (1.08)	2.71 (.83)	1.79 (.70)
Control	2.07 (.88)	2.73 (.70)	2.80 (.86)

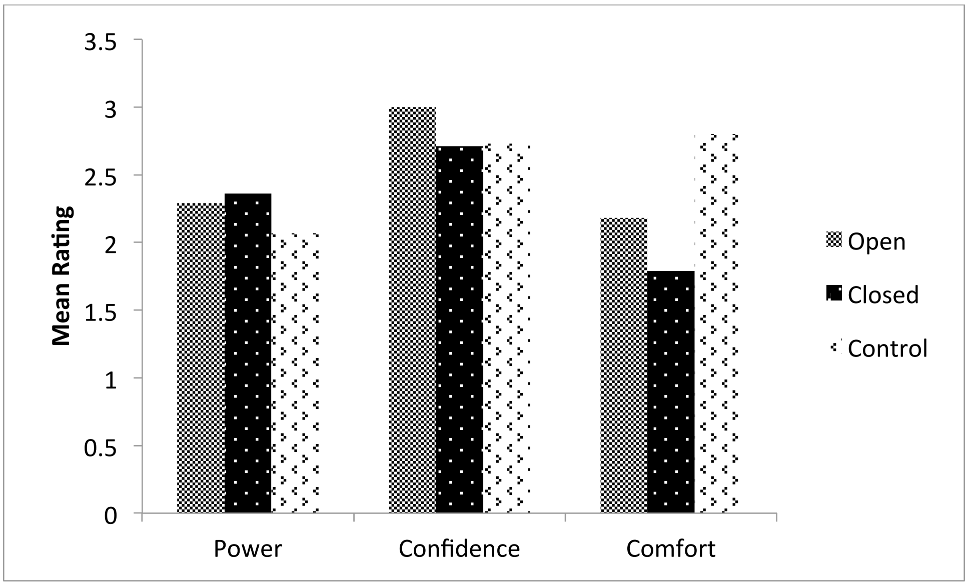

Figure 62: Mean ratings of power, confidence and comfort for each group

5.3.5 Post-posture Phase – Reading the Mind in the Eyes Behavioural Analysis

The final behavioural task to be reported is the RMITE test. This test was administered in order to ascertain whether the posture affected a putative index of empathic accuracy. It was expected that if adopting a more open posture had a negative effect on empathy then we should observe less task accuracy in the open group when compared to the closed and control group. Looking at table 50 below, the opposite seems to be true, with a higher accuracy score for the open group. Independent-samples *t*-test revealed a significant difference between the accuracy of the open and closed groups ($t(30) = 2.46$, $p = .020$), with the open group performing better than the closed group. There were no group differences in accuracy between either the open and control groups ($t(30) = 1.46$, $p = .155$) or the closed and control groups ($t(28) = -1.33$, $p = .193$).

Table 50: Mean and Standard Deviation of Per cent Accuracy in the Mind in the Eyes Task for Each Group

Group	Mean (Standard Deviation) Accuracy
Open	72.29 (14.46)
Closed	60.87 (11.43)
Control	65.93 (9.29)

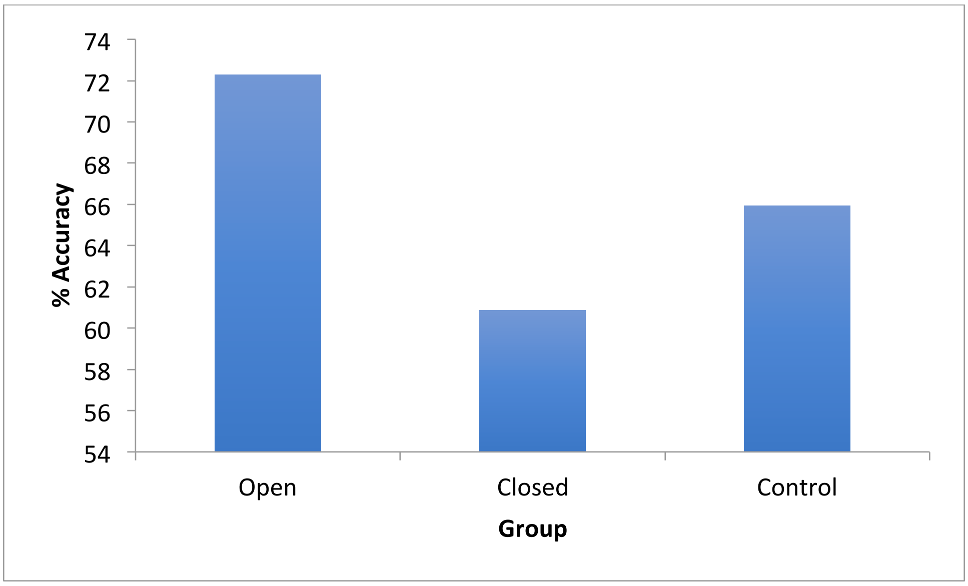

Figure 63: Mean accuracy score for the mind in the voice task for each group

5.3.6 Post-posture Phase – Reading the Mind in the Eyes EEG Analysis

A 7 (electrode) x 3 (group) mixed ANOVA was run in order to investigate differences in ERD/S resulting from observing emotional expressions. Results are organised first by region, then by time epoch and finally by band. Analysis will focus on 1) interaction between electrode and group, 2) independent samples *t*-tests as follow-up tests (if necessary), 3) one-sample *t*-tests comparing ERD/S to zero and 4) correlations between significant mu desynchronisation/synchronisation and measures of empathy. Main effect of electrode will be reported, however are not of interest. Tests investigating significant levels of ERD/S (analysis 3) were conducted to ascertain whether the task elicits significant mirror activity due to an inextensive level of research on the matter.

5.3.6.1 Fronto-central channels

5.3.6.1.1 Early Epoch

Low Alpha

There was no significant main effect of electrode and no interaction between electrode and group (*ps* > .066).

High Alpha

There was a borderline main effect of electrode ($F(6,240) = 2.13$, $p = .051$), however there was no significant interaction between electrode and group ($F(12,240) = 1.34$, $p = .199$)

Low Beta

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .128).

5.3.6.1.2 Middle Epoch

Low Alpha

There was a significant main effect of electrode ($F(6,240) = 2.23$, $p = .041$), however there was no interaction between electrode and group ($F(12,240) = .507$, $p = .909$).

High Alpha

There was a significant main effect of electrode ($F(6,240) = 2.50$, $p = .023$), however there was no interaction between electrode and group ($F(12,240) = .752$, $p = .699$).

Low Beta

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .550)

5.3.6.1.3 Late Epoch

Low Alpha

There was a significant main effect of electrode ($F(6,240) = 3.53$, $p = .002$), however there was no interaction between electrode and group ($F(12,240) = .58$, $p = .861$).

High Alpha

There was a significant main effect of electrode ($F(6,240) = 3.06$, $p = .007$), however there was no interaction between electrode and group ($F(12,240) = .61$, $p = .832$).

Low Beta

There was a borderline significant main effect of electrode ($F(6,240) = 2.10$, $p = .053$), however there was no interaction between electrode and group ($F(12,240) = .69$, $p = .761$).

5.3.6.2 Central channels

5.3.6.2.1 Early Epoch

Low Alpha

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .133).

High Alpha

There was a significant main effect of electrode ($F(6,252) = 4.85$, $p < .001$), and a significant interaction between electrode and group was also found ($F(12,252) = 1.81$, $p = .047$). In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each C-strip electrodes. A significant group difference in ERD/S was found between the open (M=2.69, SE=7.25) and closed (M=-32.91, SE=15.43) groups at the C4 electrode (1000 samples, $p = .045$), with the open group exhibiting ERD, while the closed group exhibited ERS. A final significant group difference in ERD/S was found between the open (M=4.83, SE=7.75) and control (M=-17.52, SE=7.79) groups at the C6 electrode (1000 samples, p =

.040), with the open group again exhibiting ERD and the control group exhibited ERS. In addition to the significant difference in ERD/S at C4, we also found significant mu synchronisation for the closed group ($t(14) = -2.17$, $p = .048$). We also observed significant mu synchronisation in the control group at the C6 electrode ($t(14) = -2.31$, $p = .036$). No significant correlations were found between ERD/S and self-report measures of empathy.

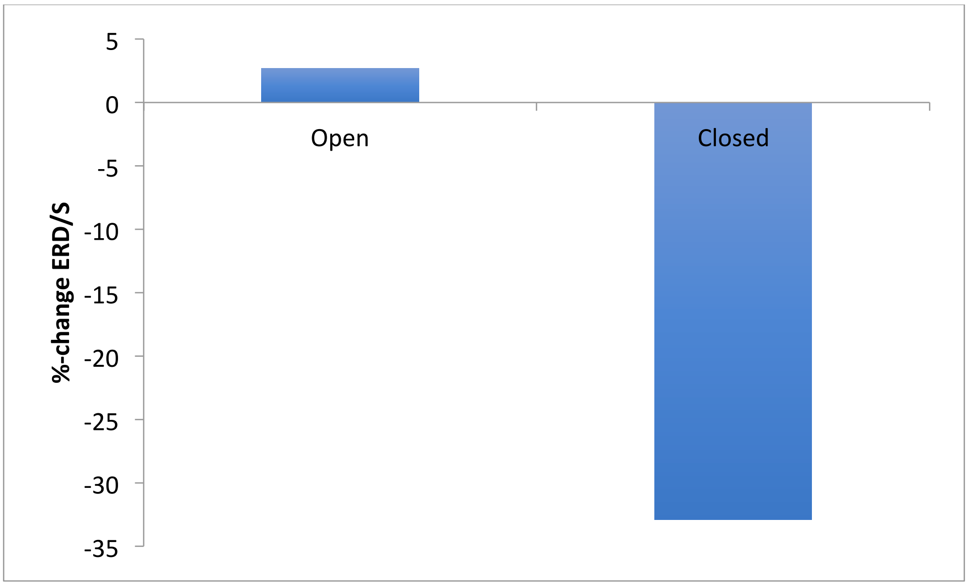

Figure 64: Difference in mu activation at the C4 electrode

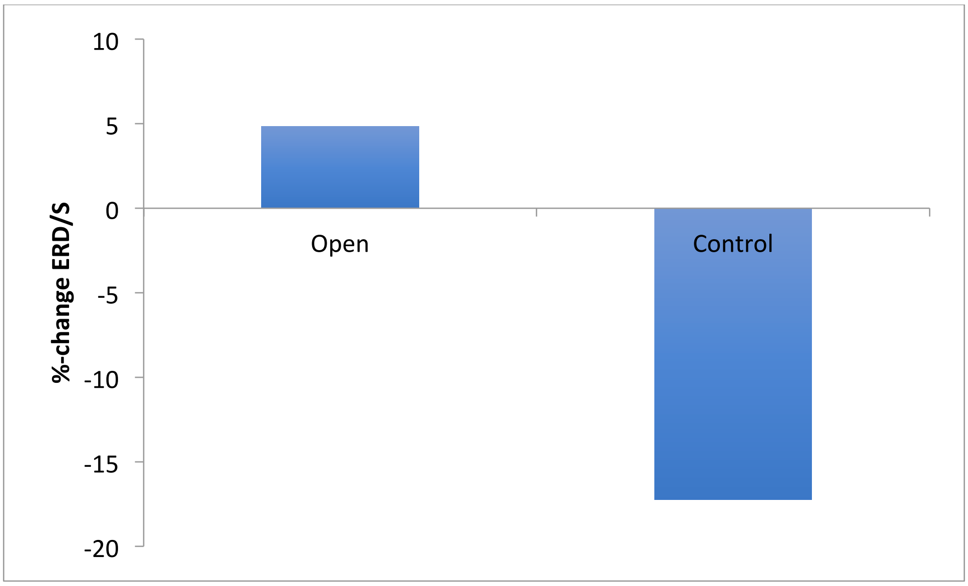

Figure 65: Difference in mu activation at the C6 electrode

Low Beta

There was a significant main effect of electrode ($F(6,252) = 2.37$, $p = .030$), however there was no significant interaction between electrode and group ($F(12,252) = .59$, $p = .852$).

5.3.6.2.2 Middle Epoch

Low Alpha

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .114).

High Alpha

There was a significant main effect of electrode ($F(6,252) = 5.84$, $p < .001$), however there was no significant interaction between electrode and group ($F(12,252) = 1.46$, $p = .140$).

Low Beta

There was a significant main effect of electrode ($F(6,252) = 2.93$, $p = .008$), however there was no significant interaction between electrode and group ($F(12,252) = .669$, $p = .781$).

5.3.6.2.3 Late Epoch

Low Alpha

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .349).

High Alpha

There was a significant main effect of electrode (F(6,252) = 4.06, p = .001), however there was no significant interaction between electrode and group (F(12,252) = .95, p = .497).

Low Beta

There was a significant main effect of electrode (F(6,252) = 4.06, p = .001), however there was no significant interaction between electrode and group (F(12,252) = .95, p = .497).

5.3.6.3 Centro-parietal channels

5.3.6.3.1 Early Epoch

Low Alpha

There was no significant main effect of electrode (F(6,246) = 1.39, p =.217). There was however, a significant interaction between electrode and group (F(12.246) = 1.97, p = .028).

In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each CP-strip electrodes. No significant group differences were observed (*ps* > .097).

High Alpha

There was no significant main effect of electrode, and no significant interaction between electrode and group (*ps* > .687).

Low Beta

There was no significant main effect of electrode ($F(6,246) = 1.23$, $p = .294$), there was however a significant interaction between electrode and group ($F(12,246) = 3.02$, $p = .001$). In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each CP-strip electrodes. A significant group difference in ERD/S was found between the open (M=-13.07, SE=9.29) and closed (M=9.92, SE=6.04) groups at the CPz electrode (1000 samples, $p = .049$), with the open group exhibiting ERS and the closed group exhibiting ERD. No other group differences were observed. There was no significant mu synchronisation or desynchronisation. No significant correlations were observed.

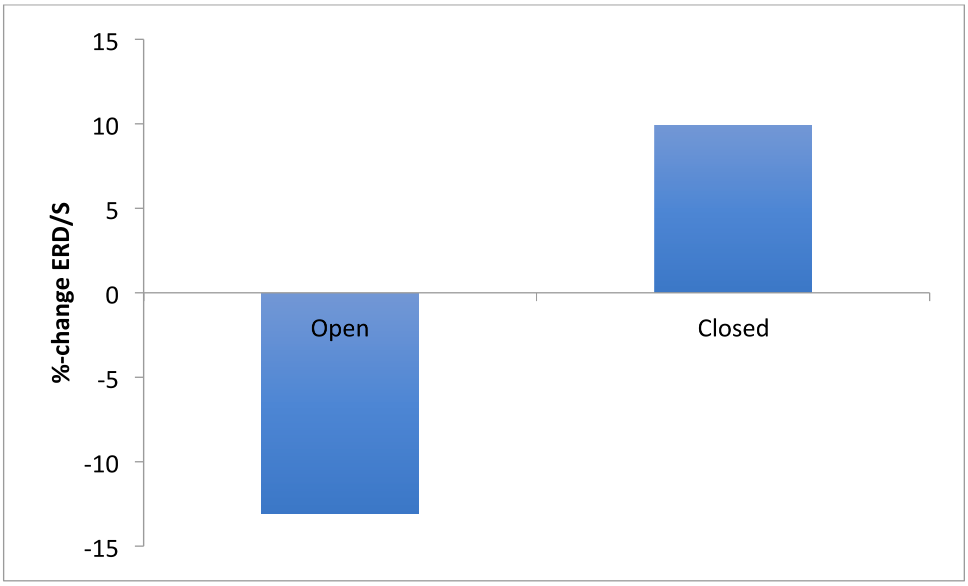

Figure 66: Difference in mu activation at the CPz electrode

5.3.6.3.2 Middle Epoch

Low Alpha

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .414).

High Alpha

There was a significant main effect of electrode ($F(6,246) = 2.56$, $p = .020$), however there was no significant interaction between electrode and group ($F(12,246) = .796$, $p = .655$).

Low Beta

There was no significant main effect of electrode ($F(6,246) = .490$, $p = 815$), there was however a significant interaction between electrode and group ($F(12,246) = 2.75$, $p = .002$). In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each CP-strip electrodes. A significant group difference in ERD/S was found between the open (M=-13.68, SE=9.24) and closed (M=16.21, SE=6.95) groups at the CPz electrode (1000 samples, $p = .012$), with the open group exhibiting ERS and the closed group exhibiting ERD. A significant group difference in ERD/S was also found between the open (M=-11.80, SE=8.59) and control (M=13.24, SE=6.57) groups at the CP1 electrode (1000 samples, $p = .030$), with the open group exhibiting ERS and the control group exhibiting ERD. In addition to the group difference at CPz, we also observed significant mu desynchronisation in the closed group. No other significant mu synchronisation or desynchronisation was observed. No significant correlations were observed.

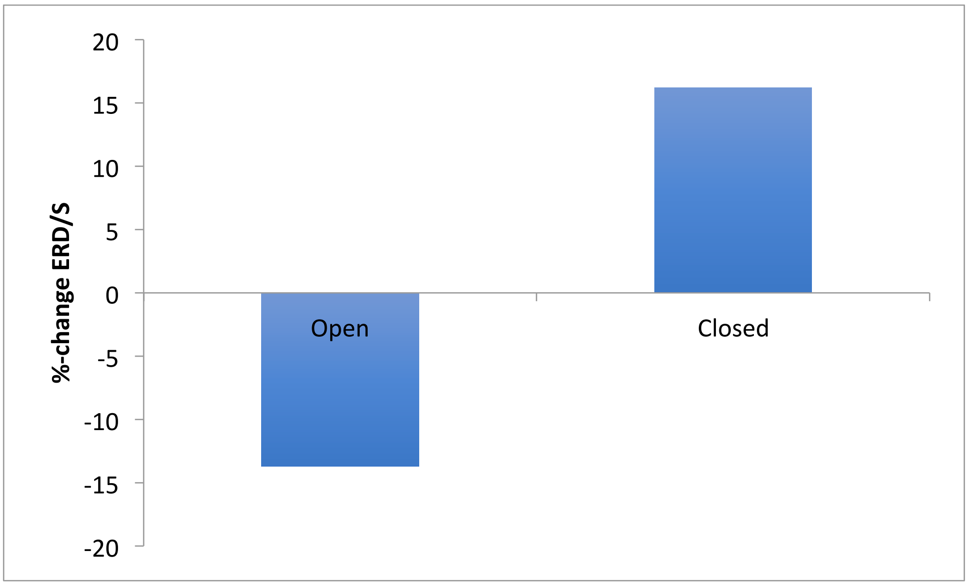

Figure67: Difference in mu activation at CPz electrode

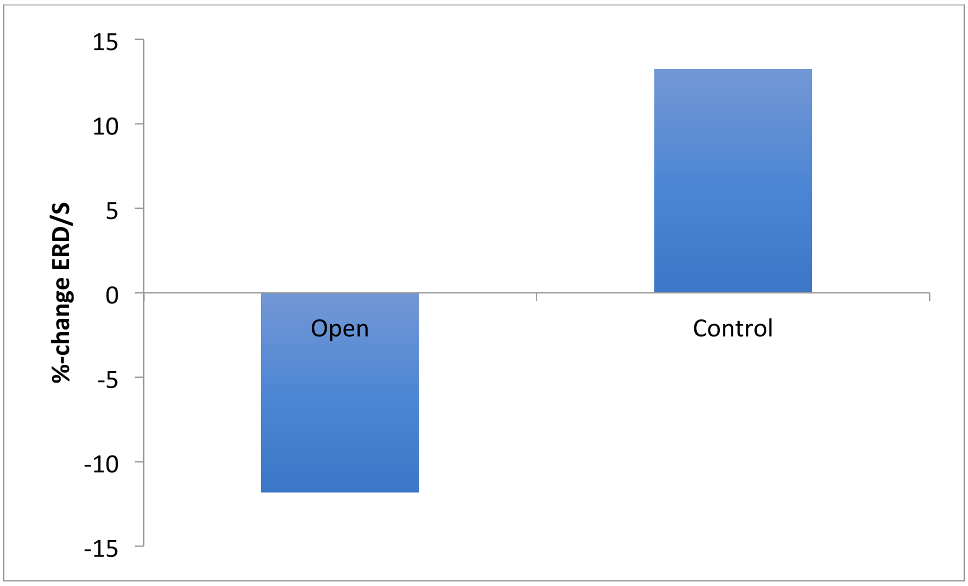

Figure 68: Difference in mu activation at CPz electrode

5.3.6.3.3 Late Epoch

<u>Low Alpha</u>

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .364).

<u>High Alpha</u>

There was no significant main effect of electrode and no significant interaction between electrode and group (*ps* > .180).

Low Beta

There was no significant main effect of electrode ($F(6,246) = 1.48$, $p = .185$), there was however a significant interaction between electrode and group ($F(12,246) = 2.28$, $p = .009$). In order to investigate this interaction and compensate for multiple comparisons, a bootstrap for independent samples *t*-test was performed examining group differences of ERD/S for each CP-strip electrodes. A significant group difference in ERD/S was found between the open (M=-3.26, SE=7.13) and closed (M=23.29, SE=6.65) groups at the CPz electrode (1000 samples, $p = .017$), with the open group exhibiting ERS and the closed group exhibiting ERD. A between group difference in ERD/S was also found between the open (M=-3.26, SE=7.13) and control (M=16.22, SE=4.67) groups at the CPz electrode (1000 samples, $p = .032$), again with the open group exhibiting ERS and the control group exhibiting ERD. In addition to these group differences, we found significant mu desynchronisation in both the closed ($t(14) = 3.49$, $p = .004$) and control ($t(14) = 3.45$, $p = .004$) groups. No significant correlations were observed.

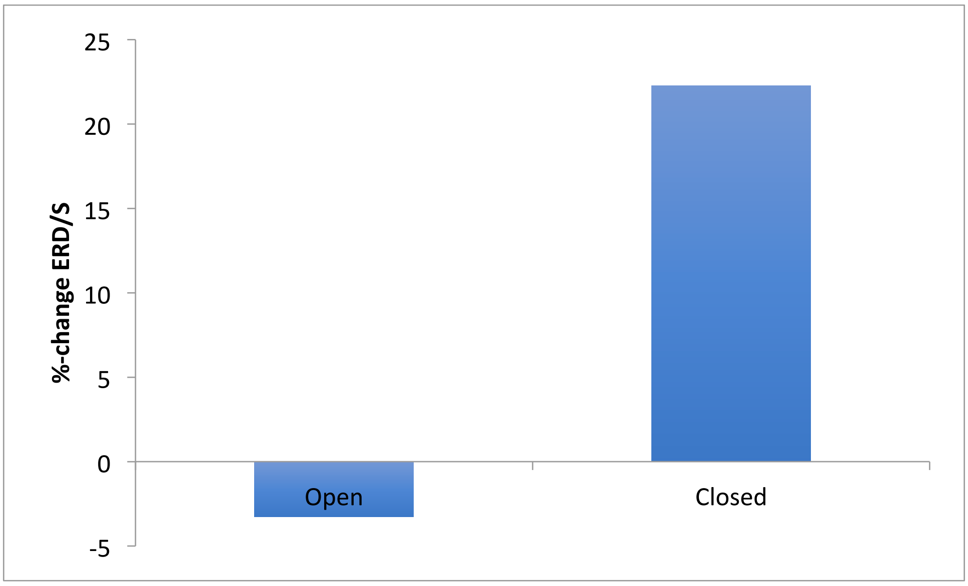

Figure 69: Difference in mu activation at the CPz electrode

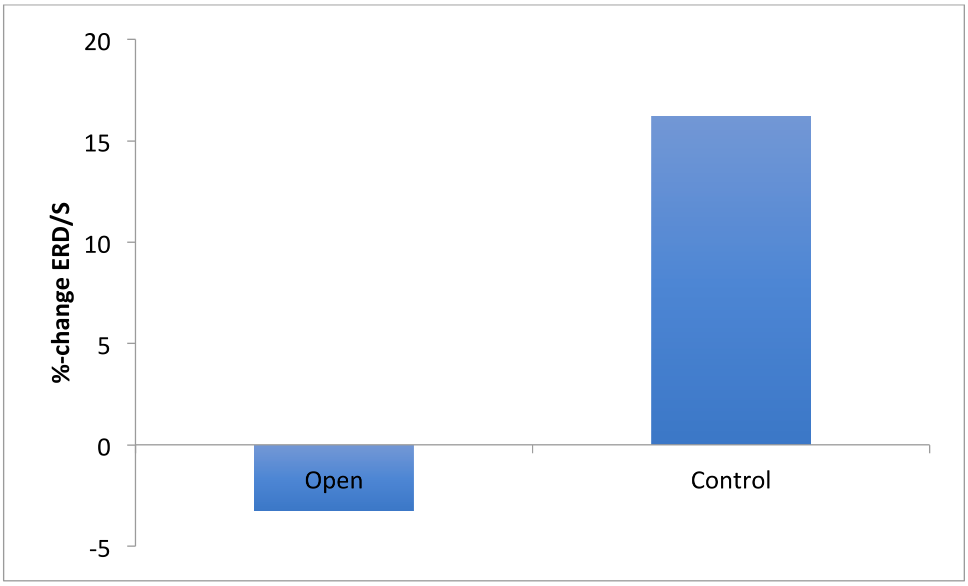

Figure 70: Difference in mu activation at the CPz electrode

5.3.7 Interim Discussion – Effects of Posture on the Reading the Mind in the Eyes Test

It was expected that adopting an open posture would result in increased feelings of power and confidence as measured by a self-report scale. The data did not support this assumption. Whilst previous research suggested that we would observe increased feelings of power as the result of adopting a open pose (Carney, et al. 2010; Ranehill, et al. 2015), it is possible that any potential effect of the posture might not have been consciously noticeable to the participant due to the suggestion that the ability to consciously identify altered states relies on higher cortical processes (Hermans, et al. 2006). The only difference that was found was in the measure of comfort, with the closed group reporting that they were significantly less comfortable in the posture than the open and control groups. Following this, we look at the accuracy of each group in the mind in the eyes task. It was initially expected that we would find a significantly poorer performance in the open group when compared with the closed and control group. Again, this was not the case, perhaps not surprising seeing as the open group did not report feeling more powerful and confident in the prior measure. Interestingly (and contrary to our hypothesis) we found that the open group performed statistically better than the closed group on the RMITE task, with no significant difference between the open group and the control group. This appears to suggest that adopting this supposed ‘power-pose’ led to the counter-intuitive finding of increased empathic ability in this group.

In terms of EEG findings, it was originally expected that we would find group differences in mu activation. This expectation was due to research which has shown that open posing can increase feelings of power (Carney, Cuddy & Yap 2010; Yap et al., 2013; Ranehill et al., 2015) and that power can have a detrimental effect on empathy (Hogeveen, et al., 2014). This was thought to be reflected in both a difference in mu activity and also in significant mu desynchronisation in the between the open group and the closed and control groups. It was finally hoped that we would discover an association between mu activity and self-report measures of empathy as this could strengthen our argument that any changes in cortical excitability (as measured by mu) are related to empathic processes. Two main findings will now be discussed. The first finding relates to a significant difference in mu activity at two central electrodes in the high alpha bandwidth in the early time epoch. The difference was found between the open group and closed groups and also the open and control groups. In both of these instances we also find significant mu synchronisation for both the closed and control groups, but not a significant level of mu desynchronisation for the open group. If the open posture were to have a detrimental effect on emotional processing then we would not expect to find a significant level of mu desynchronisation for the open group, so in this sense the results seem logical and to fit that hypothesis. It was however also expected to find a significant level of mu desynchronisation for the closed group, however instead of this, we find a significant level of mu synchronisation. Indeed, the significant difference between open and closed groups in this bandwidth potentially points towards greater hMNS activation in the open posture group. Again, this is contrary to our hypotheses but in-line with our behaviour findings.

Moving on to the second set of findings, we find ourselves looking at the centro-parietal region and the low beta bandwidth. These findings which span all time epochs demonstrate a difference in mu activity between both the open and closed groups and the open and control groups. In every instance, we see a pattern which illustrates mu synchronisation for the open group and mu desynchronisation for both the closed and control groups. This appears to be in stark contrast to the high alpha finding but better fits with our hypothesis that adopting an open posture will negatively effect empathic processing at a neural level, and that we will see increased mu activity in the closed group. At the middle and late time epochs we also find significant levels of mu desynchronisation in the closed and control group. These findings lend evidence to the idea that whilst posture did not appear to affect feelings of power or confidence on a conscious or behavioural level, it may have at the neuronal level, with both the closed and control group eliciting mu desynchronisation and the open group exhibiting mu synchronisation which is an indicator of a non-engaged neural system. What is particularly interesting is the difference between the high alpha and low beta findings (in terms of the direction of the groups' event-related band-power changes). It hints at a crucial difference between the mu bandwidths (low alpha, high alpha, low beta) in terms of their functional significance. Such observations have been made before in the literature (e.g. Hari & Salmelin, 1997) but without accompanying correlations with behaviour in our study, these differentiations cannot be clarified.

5.3.8 Post-posture Phase - Pain Protocol EEG Analysis

A 2 (stimuli) x 7 (electrode) x 3 (group) mixed ANOVA was run in order to investigate differences in ERD/S resulting from observing painful versus non-painful images. Results are organised first by region, then by time epoch and finally by band. Analysis will focus on 1) main effect of stimuli and interactions between stimuli and group, 2) one-sample *t*-tests comparing ERD/S to zero and 3) correlations between significant mu desynchronisation/synchronisation and measures of empathy.

5.3.8.1 Fronto-central channels

5.3.8.1.1 Early

<u>Low Alpha</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .140).

High Alpha

Whilst there was no main effect of stimuli (*F*(1,39) = .51, *p* = .478), there was an interaction between stimuli and group (*F*(2,39) = 3.51, *p* = .040). A significant linear contrast demonstrated that the difference between open (Mean=5.08, SE=8.77) and control (Mean=24.95, SE=8.77) group ERD elicited by the painful images, differs from the ERD elicited by the open (Mean=12.32, SE=7.15) and control (Mean=13.93, SE=7.15) group upon observing the non-painful images. We find that upon observing painful images, the open group elicits less ERD than the control group. When participants observe the non-painful images there is no real observable difference between the ERD of the open and control groups. To further demonstrate the lack of mirror activity in the open group, we find no significant mu desynchronization (*t*(15) = .94, *p* = .358) in response to the painful images. In the control group, on the other hand we do find evidence of mu desynchronization (*t*(14) = 4.41, *p* = .001). Whilst we might have expected the closed group to empathise more to the painful images, no evidence was found (*t*(14) = 1.95, *p* = .072). To investigate group differences further, correlations were run between ERD elicited to the stimuli and self-report measures of empathy. A Significant positive association were found for those in the open group, between painful images and fantasy (*r* = .52, n = 16, *p* = .038). Another association was found for those in the closed group, between non-painful images and perspective taking (*r* = .54, n = 14, *p* = .045). Finally, for the control group, three significant associations were found: one between painful images and fantasy (*r* = .55, n = 14, *p* = .041), one between painful images and empathic concern (*r* = .60, n = 14, *p* = .022) and the final one between non-painful images and empathic concern (*r* = .59, n = 14, *p* = .028). In all cases, a higher score on the measure of empathy is associated with higher levels of ERD.

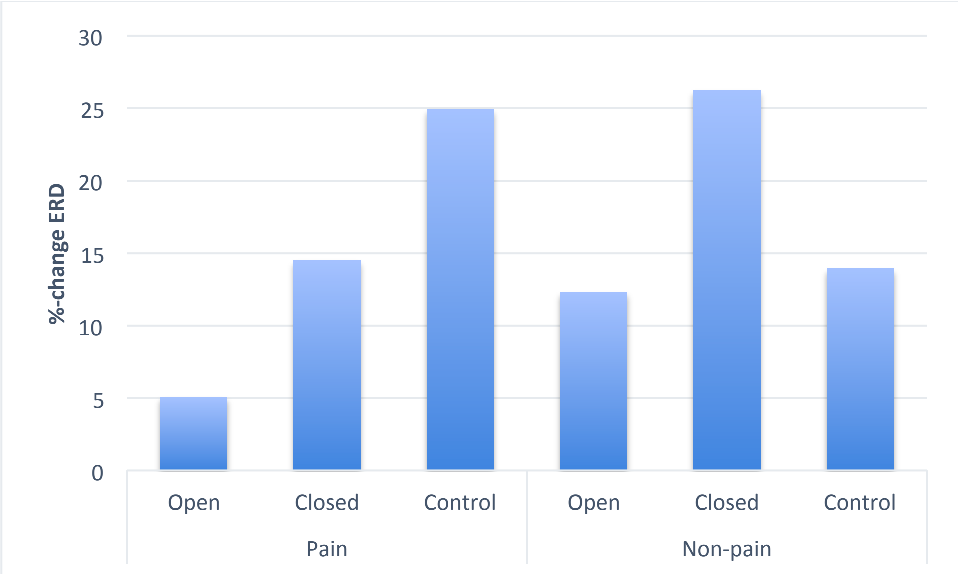

Figure 71: ERD for each group elicited by both painful and non-painful images

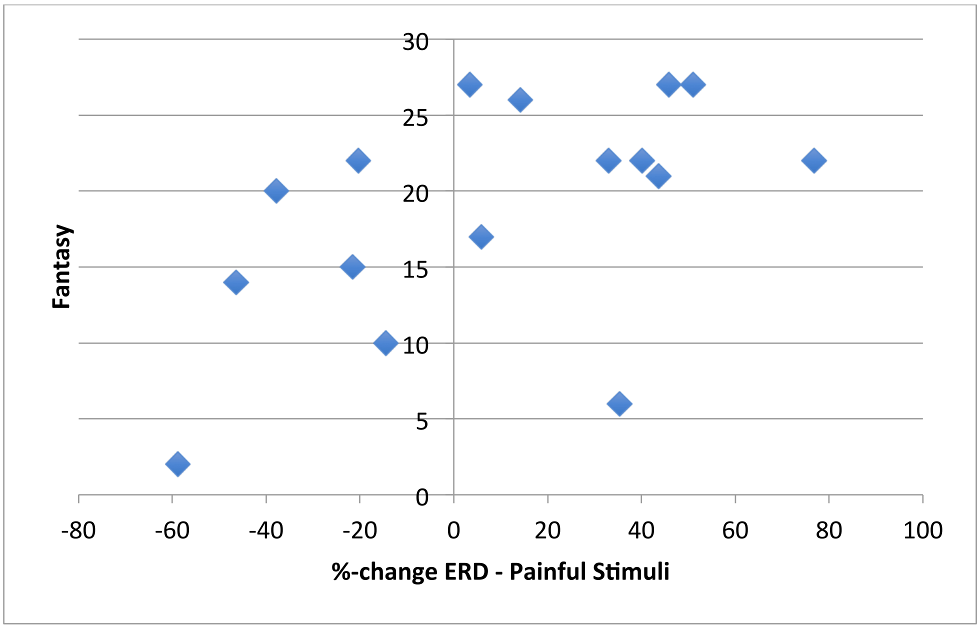

Figure72: Positive correlation between ERD to painful images and fantasy scores for the open group

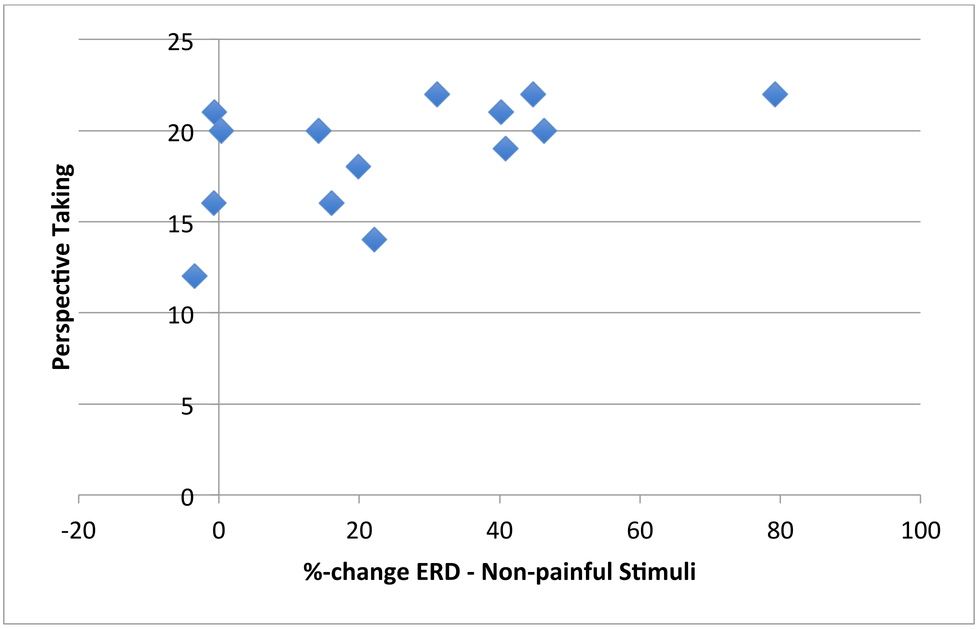

Figure 73: Positive correlation between ERD to non-painful images and perspective taking scores for the closed group

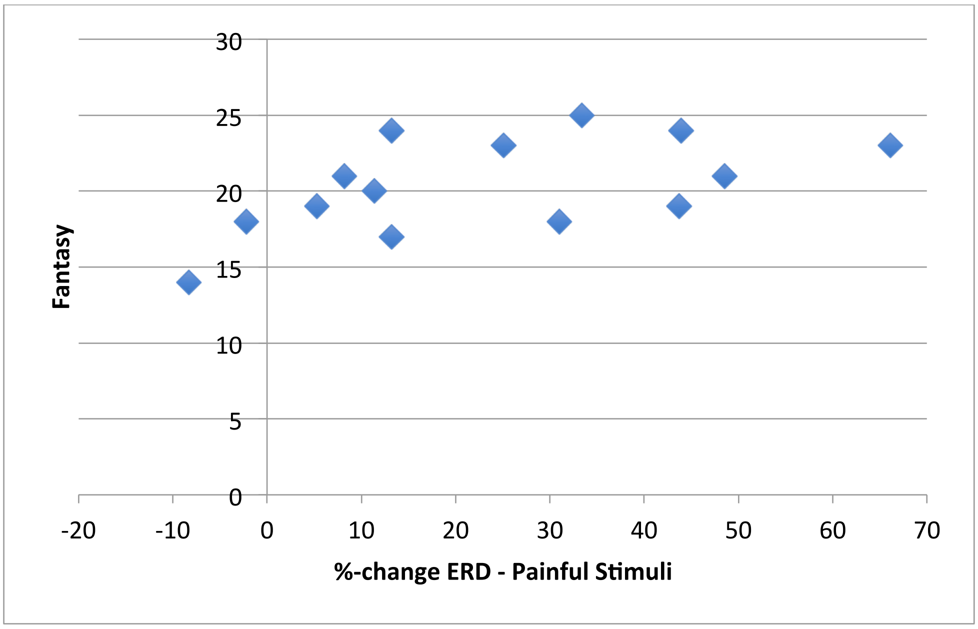

Figure 74: Positive correlation between ERD to painful images and fantasy scores for the control group

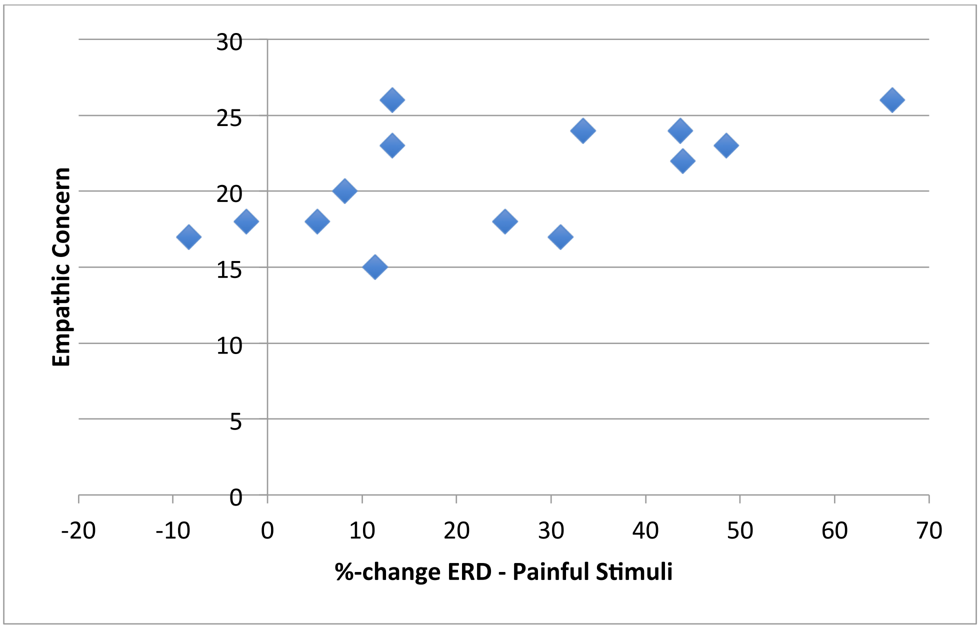

Figure 75: Positive correlation between ERD to painful images and empathic concern scores for the control group

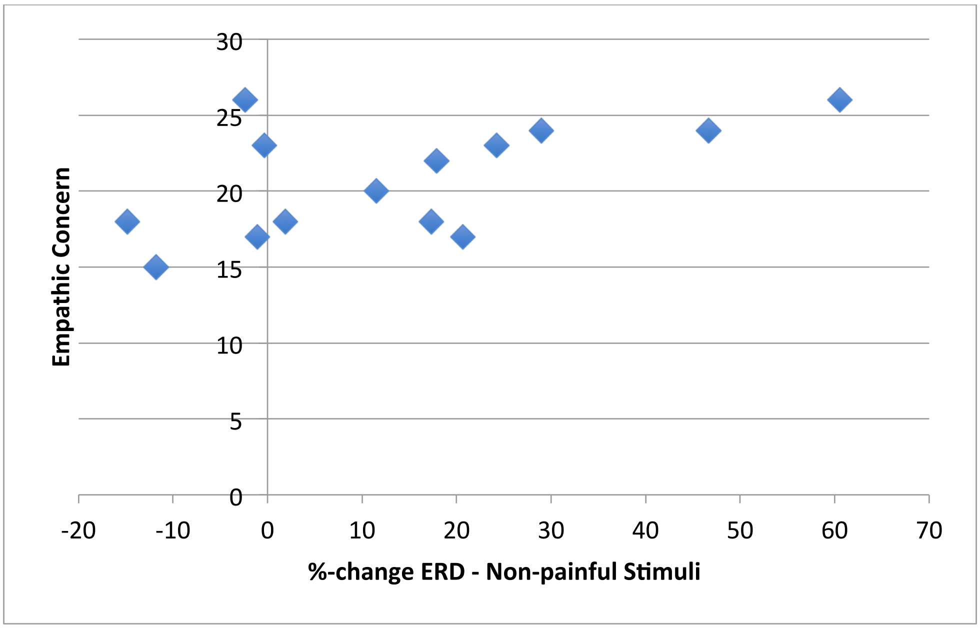

Figure 76: Positive correlation between ERD to non-painful images and empathic concern scores for the control group

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group ($ps > .153$).

5.3.8.1.2 Middle

Low Alpha

A main effect of stimuli was found ($F(1,39) = 5.78$, $p = .021$), demonstrating that there was a difference in mu activation between observing the painful (M=30.87, SD=3.63) and non-painful (M=19.87, SE=4.96) images, with more ERD elicited by the painful images. Both the painful and non-painful images elicited significant mu desynchronization ($t(45) = 9.49$, $p < .001$ and $t(45) = 4.70$, $p < .001$ respectively). There was no stimuli by group interaction ($F(2,39) = 2.46$, $p = .099$). No significant correlations were found.

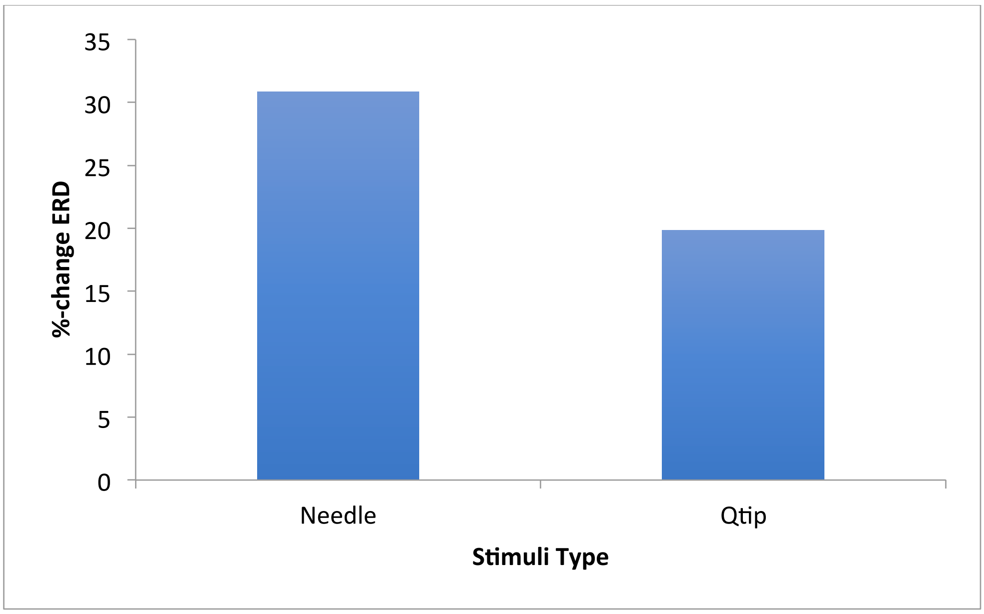

Figure 77: Difference in mu activation between painful and non-painful images

High Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .345).

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .398).

5.3.8.1.2 Late

Low Alpha

A main effect of stimuli was found ($F(1,37) = 4.59$, $p = .039$), demonstrating that there was a difference in mu activation between observing the painful (M=25.05, SE=4.08) and non-painful (M=15.48, SE=4.19) images, with more ERD elicited by the painful images. Both the painful and non-painful images elicited significant mu desynchronization ($t(45) = 6.27$, $p < .001$ and $t(45) = 2.04$, $p = .047$ respectively). A single significant correlation was found between non-painful images and the empathy quotient ($r = .37$, n = 43, $p = .016$) showing that the higher one's EQ score, the more low alpha suppression when observing the non-painful stimuli.

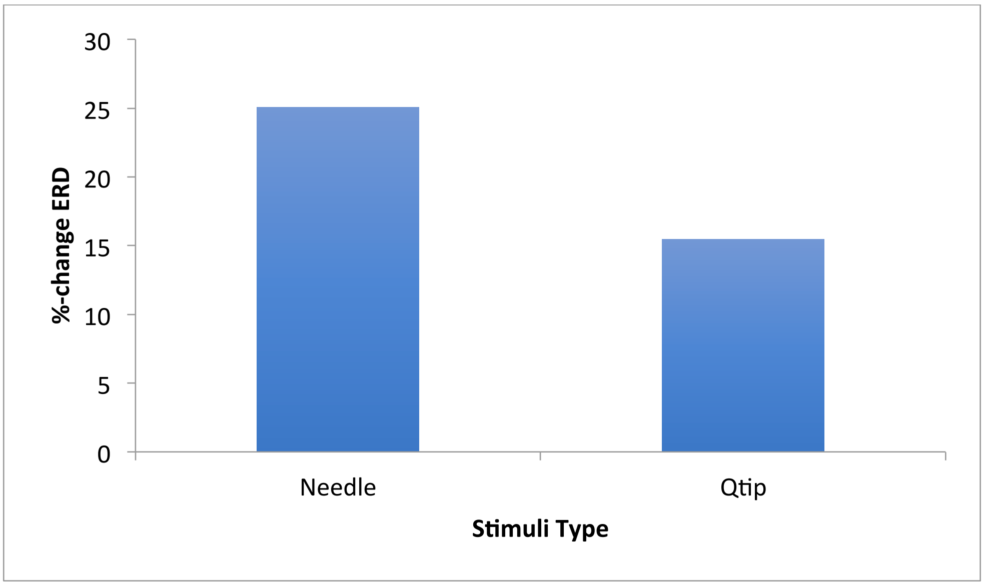

Figure 78: Difference in mu activation between painful and non-painful images

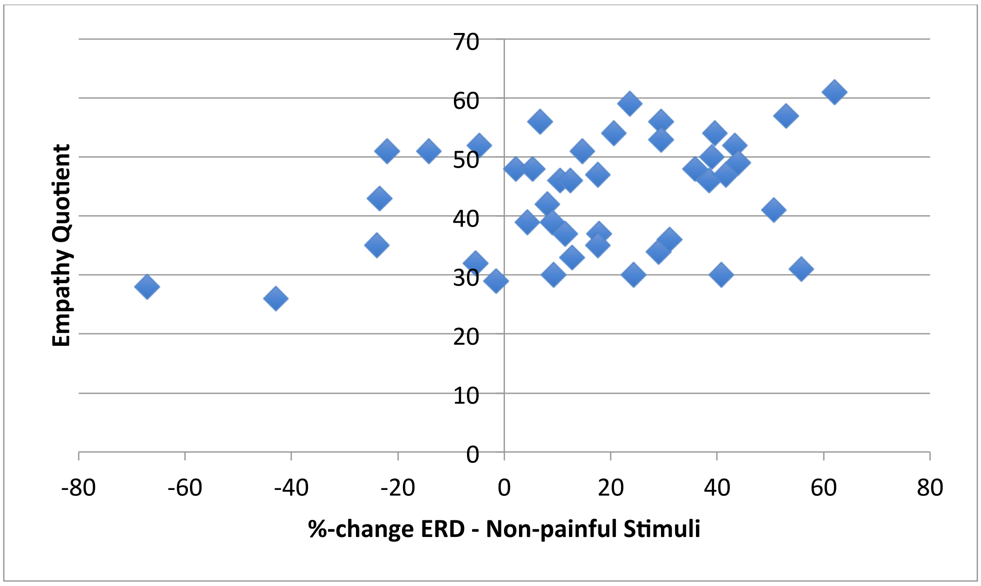

Figure 79: Positive correlation between non-painful images and the empathy quotient

High Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .532).

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .673).

5.3.8.2 Central channels

5.3.8.2.1 Early

Low Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .151).

High Alpha

A main effect of stimuli was found ($F(1,41) = 6.19$, $p = .017$), demonstrating a difference in mu activation between the observation of non-painful images (M=5.09, SE=6.34) in relation to the painful images (M=16.08, SE=3.65), with higher ERD to the non-painful images. There was no interaction between stimuli and group ($F(2,41) = 1.99$, $p = .150$). Significant mu desynchronization was found for the observation of the non-painful images ($t(45) = 4.87$, $p < .001$) but not for the painful images ($t(45) = 1.16$, $p = .253$) indicating that observation of the non-painful images resulted in significant mirror activity. Three significant correlations were found between ERD and self-report measures of empathy. The first correlation was between painful images and fantasy ($r = .48$, n = 44, $p = .001$). The second between non-painful images and the empathy quotient ($r = .33$, n = 45, $p = .026$). The final correlation was between the non-painful images and perspective taking ($r = .30$, n = 44, $p = .047$). In all instances, higher score on the measures of empathy is associated with more ERD.

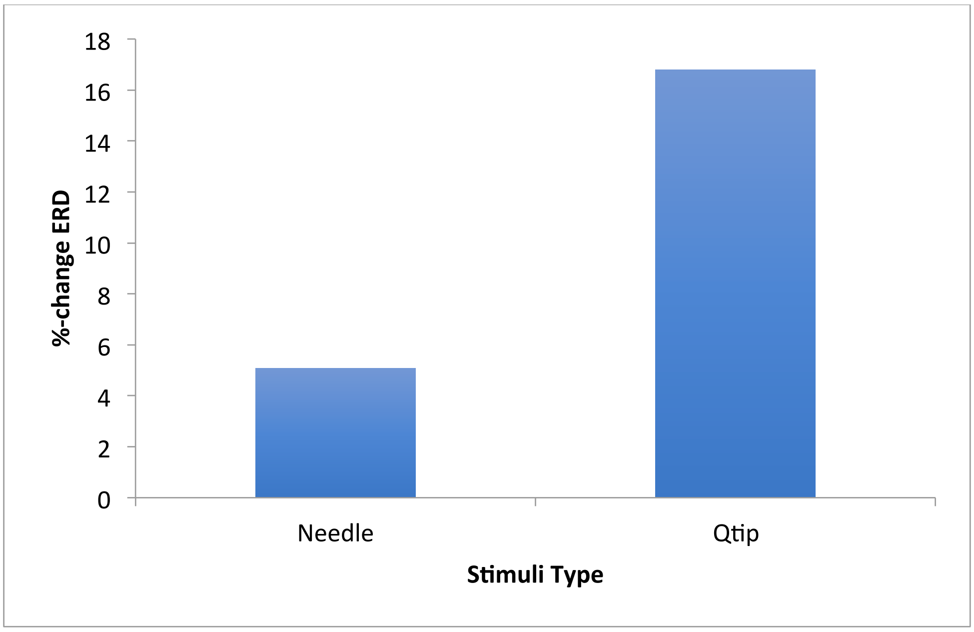

Figure 80: Difference in mu activation between painful and non-painful images

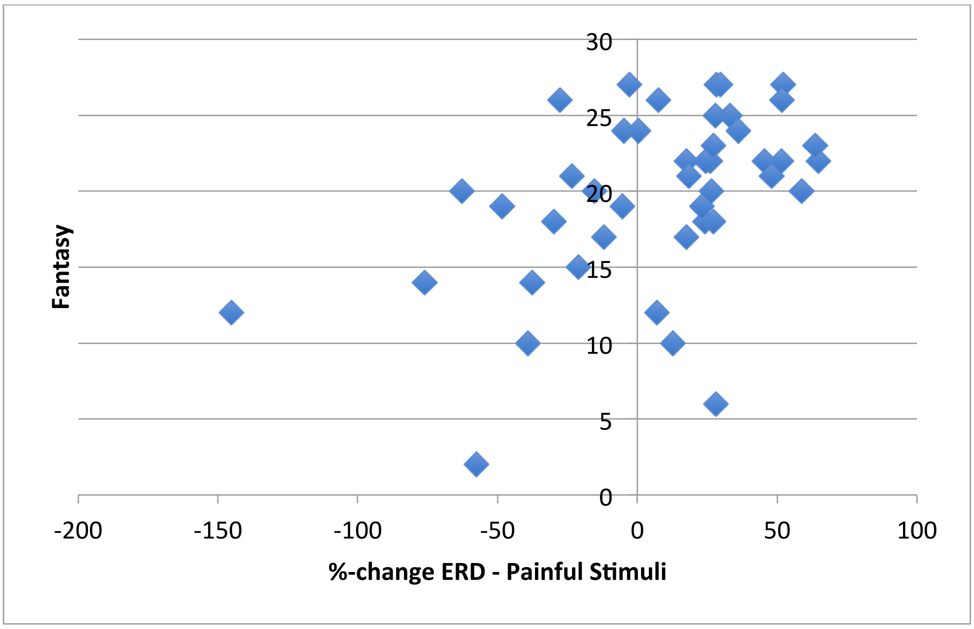

Figure 81: Positive correlation between painful images and fantasy

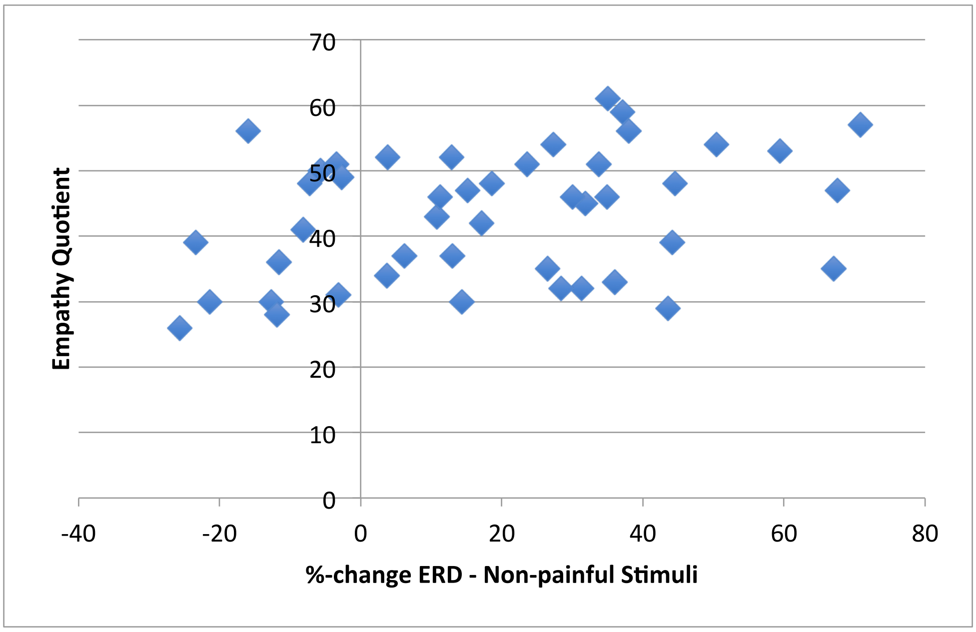

Figure 82: Positive correlation between painful images and the empathy quotient

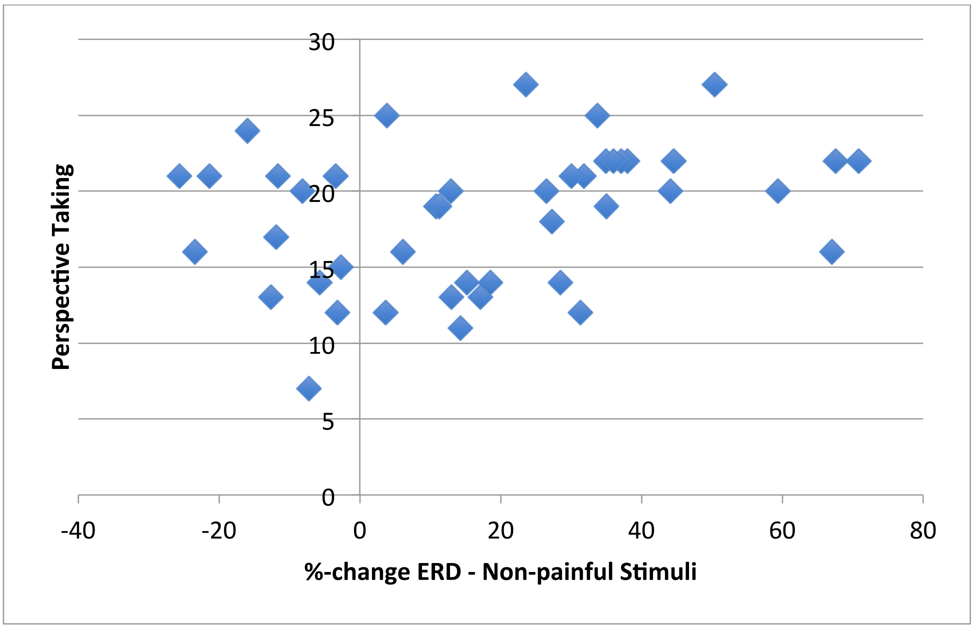

Figure 83: Positive correlation between non-painful images and perspective taking

<u>Low Beta</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .336).

5.3.8.2.2 Middle

<u>Low Alpha</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .117).

High Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .345).

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .398).

5.3.8.2.3 Late

Low Alpha

A main effect of stimuli was found ($F(1,41) = 4.38$, $p = .043$), demonstrating that there was a difference in mu activation between observing the painful (M=21.34, SE=3.87) and non-painful (M=12.14, SE=5.08) images, with more ERD elicited by the painful images. Both the painful and non-painful images elicited significant mu desynchronization ($t(45) = 6.04$, $p < .001$ and $t(45) = 2.70$, $p = .010$ respectively). No significant correlations were found.

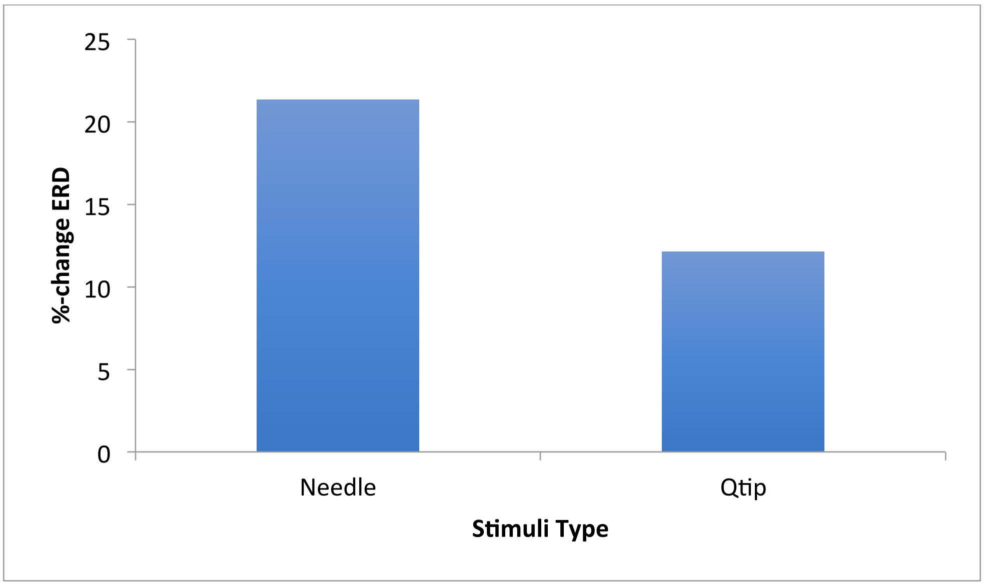

Figure 84: Difference in mu activation between painful and non-painful images

<u>High Alpha</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .503).

<u>Low Beta</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .821).

5.3.8.3 Centro-parietal channels

5.3.8.3.1 Early

Low Alpha

A main effect of stimuli was found ($F(1,41) = 4.33$, $p = .044$), demonstrating a difference in mu activation between the observation of the painful images (M=37.63, SE=4.27) and the non-painful images (M=30.74, SE=4.90), with more ERD being elicited by the painful images. There was no interaction between stimuli and group ($F(2,41) = .48$, $p = .623$). Both painful and non-painful images elicited significant mu desynchronization ($t(45) = 8.71$, $p < .001$ and $t(45) = 6.75$, $p < .001$ respectively). One significant association was found between the non-painful images and the empathy quotient ($r = .30$, n = 45, $p = .049$), with a higher score on the empathy quotient being associated with more ERD.

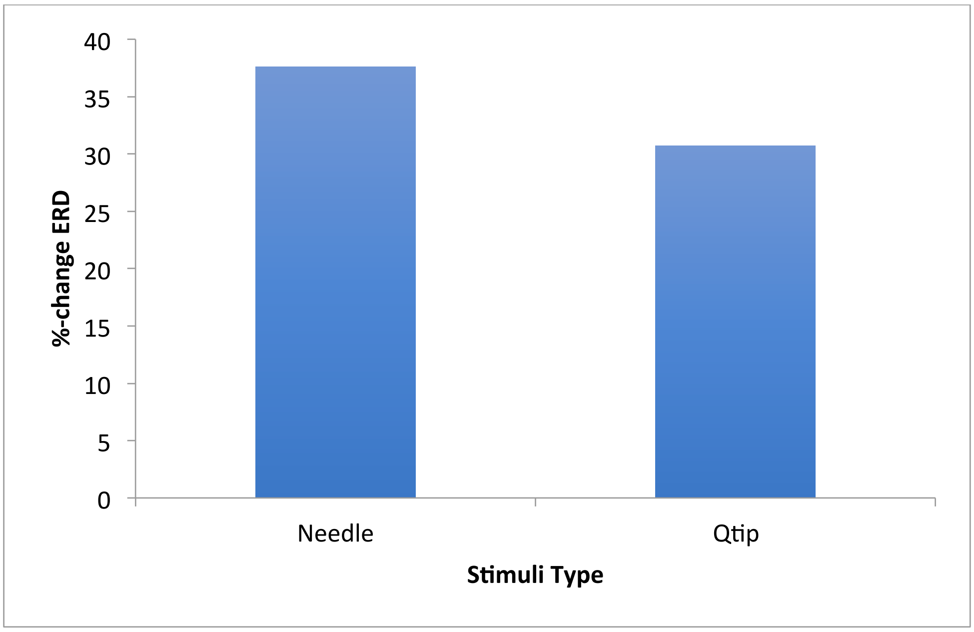

Figure 85: Difference in mu activation between painful and non-painful images

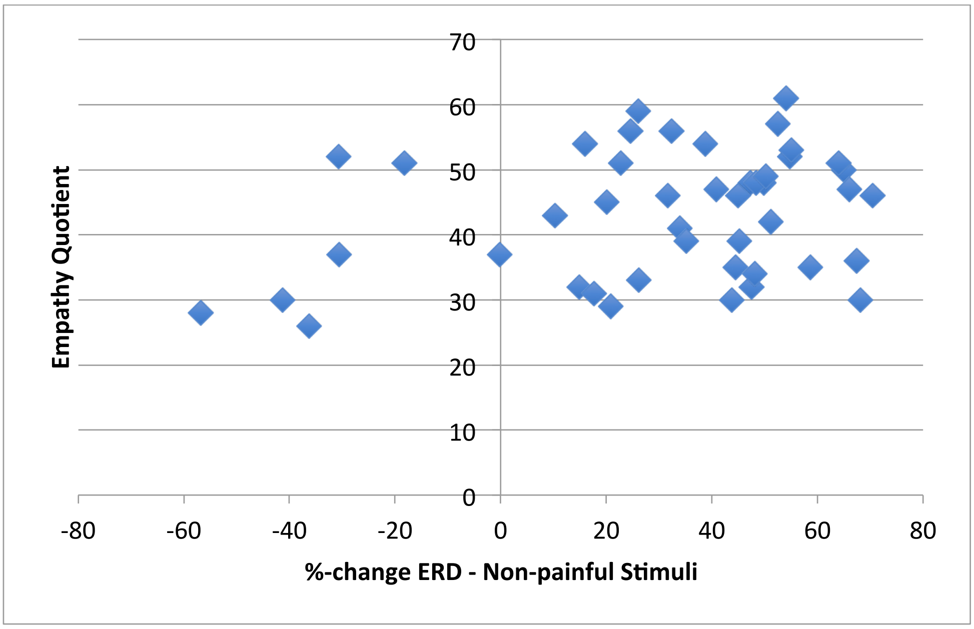

Figure 86: Positive correlation between non-painful images and the empathy quotient

<u>High Alpha</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .179).

<u>Low Beta</u>

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .178).

5.3.8.3.2 Middle

<u>Low Alpha</u>

A main effect of stimuli was found (F(1,40) = 7.89, p = .008) demonstrating a difference in mu activation between the painful (M=35.76, SE=3.24) and non-painful (M=23.60, SE=4.98)) images, with increased ERD to the painful images. Both painful images and non-painful images also elicited significant mu desynchronization (t(44) = 11.74, p < .001 and t(44) = 4.99, p < .001 respectively). There was no interaction between stimuli and group (F(2,40) = 1.82, p = .176). Two significant correlations were found between the painful images and the empathy quotient (r = .31, n = 45, p = .042) and between the non-painful images and the empathy quotient (r = .35, n = 45, p = .018).

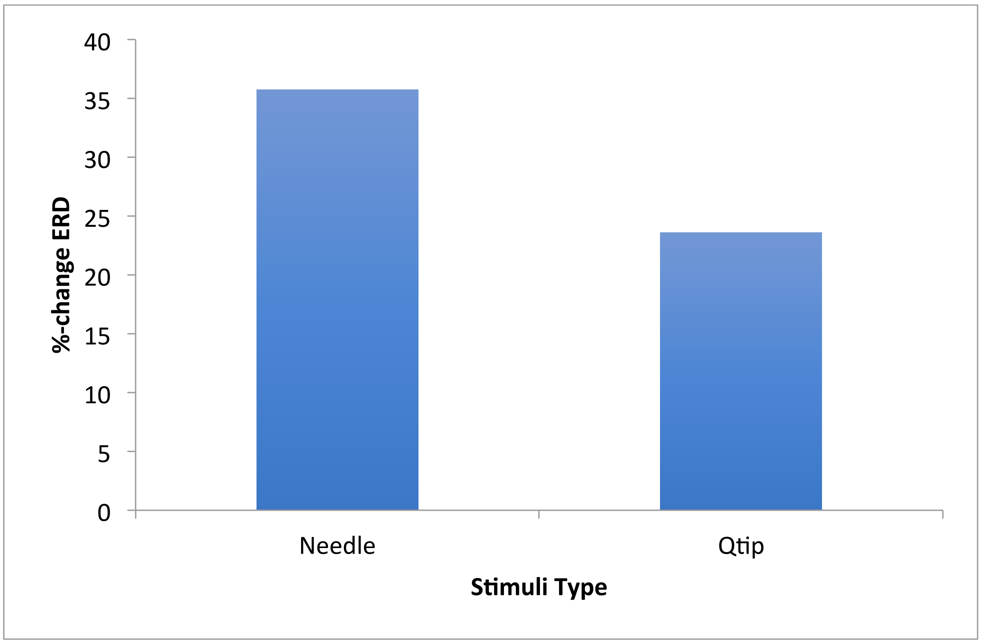

Figure 87: Difference in mu activation between painful and non-painful images

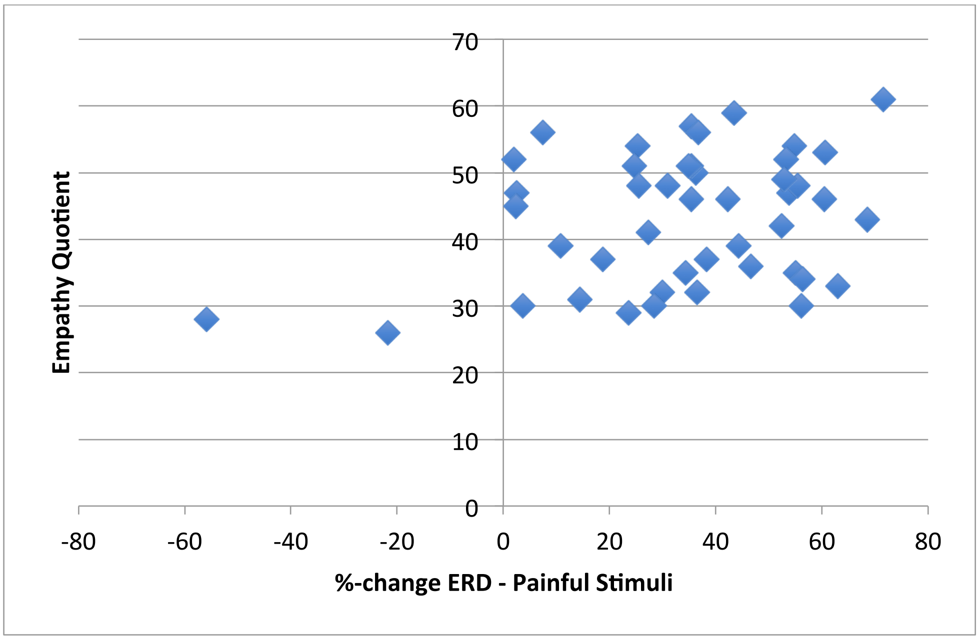

Figure 88: Positive correlation between painful images and the empathy quotient

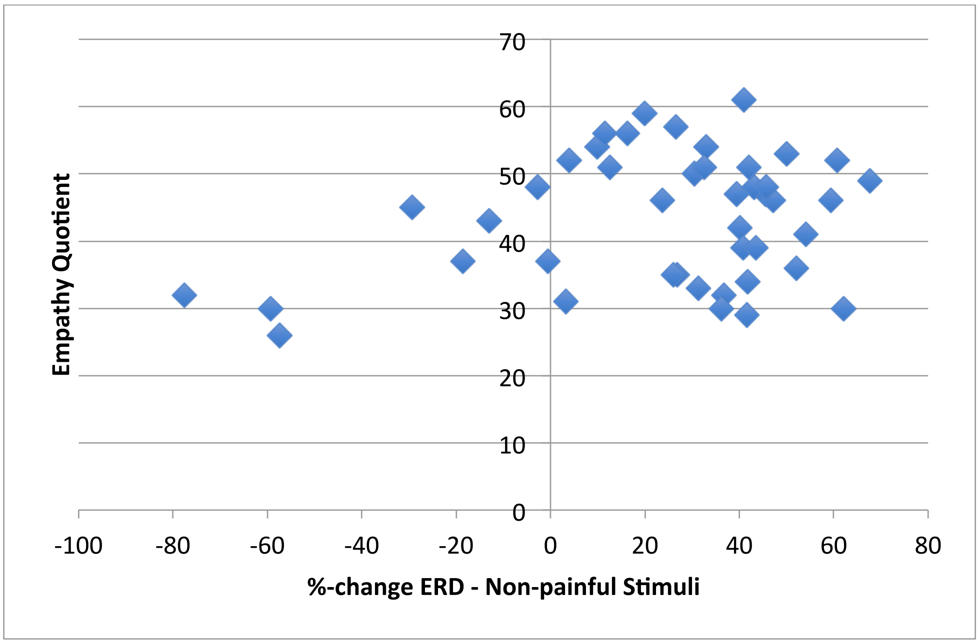

Figure 89: Positive correlation between non-painful images and the empathy quotient

High Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .259).

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .176).

5.3.8.3.2 Late

Low Alpha

A main effect of stimuli was found ($F(1,41) = 7.79$, $p = .008$) demonstrating a difference in mu activation between the painful (M=27.30, SE=3.78) and non-painful (M=14.37, SE=4.38) images, with increased ERD to the painful images. Both painful images and non-painful images also elicited significant mu desynchronization ($t(45) = 7.80$, $p < .001$ and $t(45) = 3.49$, $p = .001$ respectively). There was no interaction between stimuli and group ($F(2,37) = .12$, $p = .879$). A significant correlation was found between the painful images and the empathy quotient ($r = .32$, n = 44, $p = .038$).

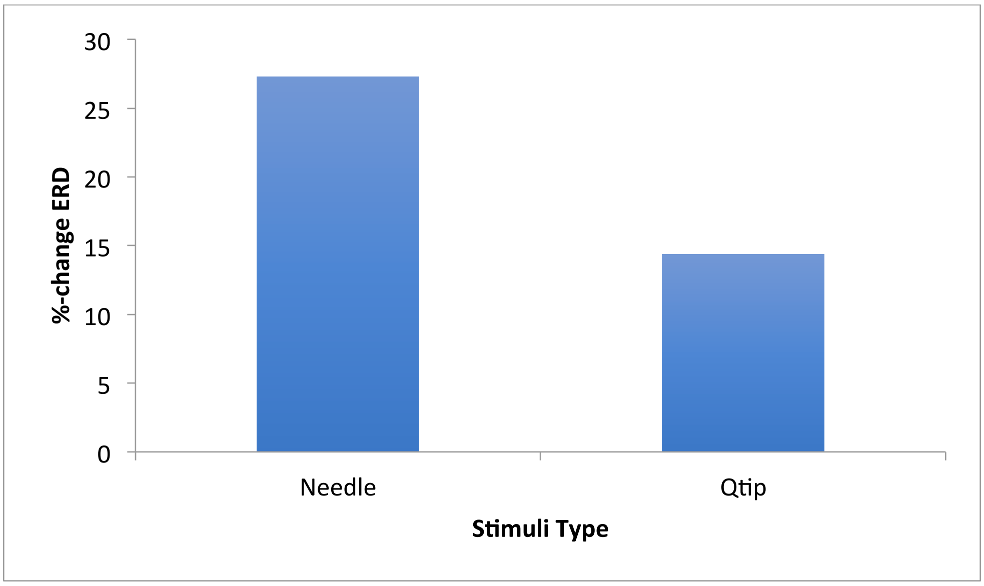

Figure 90: Difference in mu activation between painful and non-painful images

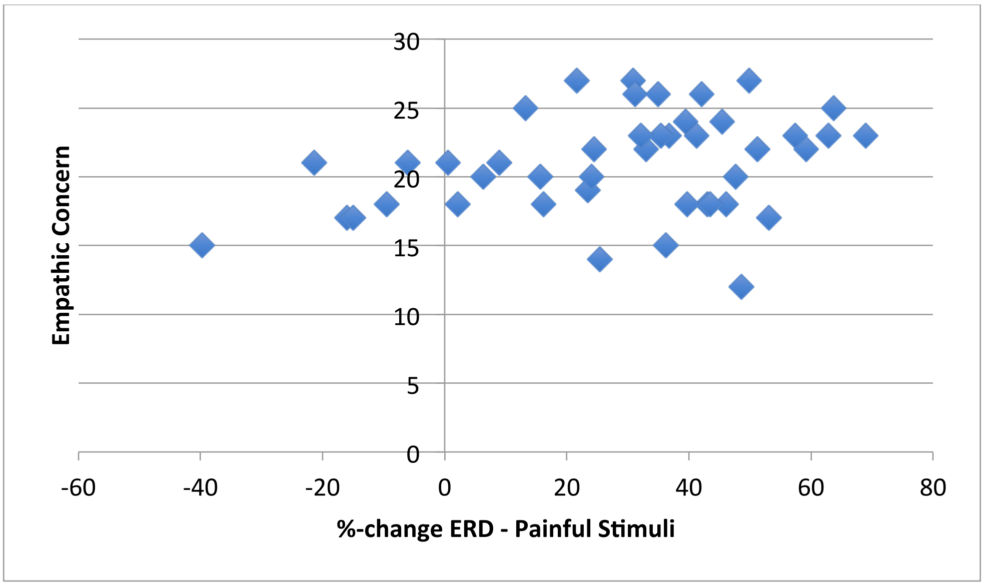

Figure 91: Positive correlation between painful images and the empathic concern

High Alpha

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .623).

Low Beta

There was no main effect of stimuli and no interaction between stimuli and group (*ps* > .332).

5.3.9 Interim Discussion - Pain protocol

The aim of utilising the pain protocol in this study was to investigate the effect of posture on the perception of others in pain. If an open posture were to temporarily affect someone's ability to empathise with another then we might see this expressed as a decrease in power in the mu bandwidth when comparing ERD of the open group to that of the closed and control group. Likewise, it would be logical to assume a higher level of mu desynchronisation in the closed group when observing painful images when comparing them to the open group. It was finally hoped that we would observe logical correlations between self-report measures of empathy and mu activity.

Three main findings will now be discussed. The first pertains to the only evidence of a group difference in mu activity, which was observed in the high alpha range. At fronto-central regions, in the time early time epoch, we found a significant interaction between stimuli and group. This difference was revealed in a linear contrast which demonstrated that the difference in mu activation elicited by the painful images between the open and control groups differed to the difference in mu activation elicited by the non-painful images between the open and control groups. Essentially, we found less mu desynchronisation in the open group than in the control group when observing others in pain; when we look at ERD to the non-painful images we see little difference. This could indicate less engagement of the mirror neuron system for those in the open group when seeing others in pain compared to other groups.

The second main finding pertains to differences in mu activation dependent only on the stimuli. In every time epoch and in nearly every region (except at the centro-parietal strip in the middle time epoch) we see a difference in mu activation between observation of the painful and non-painful images in the low alpha range. In all but one instance, we see an increased level of ERD to the painful images rather than to the non-painful images. In that one instance we see the reverse being true. The findings of a higher level of ERD to the painful images is indicative that the protocol was having the intended effect and matches the results from the pain protocol in study one, however this effect was not as widely observed there as it is here. This finding was absent, however, from the results of the pain protocol in study two.

The third main finding related to the significant correlations. Firstly, relating to the group differences found in the early time epoch at fronto-central regions in the high alpha range, we see five significant positive correlations. For the open group we see only one, which is between the painful images and the fantasy dimension of the IRI. It is uncertain as to how relevant the fantasy construct is in this situation as the task requires the participants to image how the people in the image feels; this (one assumes) would relate more to perspective taking and empathic concern than fantasy. For the closed group we see one correlation, between the non-painful images and perspective taking. This association between non-painful images and perspective taking was also found in study one, however in that instance it was a negative association. No correlations were observed between images in the pain protocol and measures of empathy for study two. The present correlation implies that participants in the closed group had an improved ability to spontaneously adopt the psychological view of the people in the non-painful images. The final three correlations were found in the control group. The first was between painful images and fantasy. As mentioned above, this does not seem to be a logical association and may require more investigation. The second correlation appears to be more logical with an association between painful images and empathic concern. It seems that those who were in the control group were able to exhibit feelings of concern for those being pricked by the needle in the painful images. Having said that, we see the same association for non-painful images also, which appears less logical. The remaining correlations are associated with ERD elicited to painful and non-painful images. At fronto-central regions we find a correlation between the empathy quotient and the non-painful images. As we move on to central regions we find an association between the painful images and fantasy, and between non-painful images and the empathy quotient and perspective taking. Moving on to centro-parietal regions we find correlations between painful images and the empathy quotient and empathic concern and between the non-painful images and the empathy quotient. We see two logical correlations at centro-parietal regions with participants' ability to express empathic concern for others correlating with ERD to the painful images. Finding a correlation between the EQ and painful images is also makes sense. These centro-parietal effects and correlations may relate to the parietal lobe's functional ability to detect the sense of touch, therefore we could be observing a 'mirrored touch' aspect of empathy.

5.4 Chapter Discussion

The aim of this study was to investigate whether power-posing for a short period of time can affect a person’s level of empathy in both a behavioural and EEG sense. Previous posture research has demonstrated somewhat conflicted findings, however research has suggest that adopting a open pose can at least raise the posers feelings of power (Carney, Cuddy & Yap 2010; Yap et al., 2013; Ranehill et al., 2015).

In order to investigate the potential behavioural and EEG effects of posture, we first tested whether any group differences were present prior to the commencement of the posture. The hope here was to not find any difference in either, as this would provide stronger evidence than any post-posture differences could be attributable to the posture itself. Looking at the behavioural data, we see no significant difference in performance in the mind in the voice task. In terms of the EEG data, group differences in mu activation were found at central regions. Whilst differences were found between the open and closed group at one electrode and between the closed and control group at another, there was no evidence of significant levels of ERD, therefore these differences do not appear to be associated with the engagement of the mirror system. It is therefore concluded that there was neither evidence of behavioural differences or meaningful EEG differences as they relate to hMNS activation. However, as mentioned above, the very fact that were some limited EEG differences between groups prior to the experimental manipulation does mean that extra caution needs to be applied when interpreting the post-manipulation data.

After the posture manipulation had taken place, three checking questions were administered to participants. These were used to assess their subjective feelings of power, confidence and comfort. Based on previous findings (Carney et al. 2010; Ranehill et al. 2015) we expected to find increased subjective feelings of power and confidence in the open group, compared to the closed and control groups. This however was not observed, with the only group difference being in the comfort dimension, with the closed group being less comfortable than the open or control groups. This was not expected and goes against the above research. A lower comfort score for the closed group might potentially reflect the discomfort experienced by making oneself smaller, bent down yet still having to raise ones head to see the three minute video clip. Even though not significantly different from the other two groups, the mean confidence rating for the open group is highest indicating that there might be cause for further research. Whilst we have not observed a self-reported effect of the posture, we now move on to examine whether any group differences can be observed in the arguably more sensitive behavioural and EEG measures of the RMITE task and in the EEG of the pain task.

First, we examine the behavioural data for the mind in the eyes task. If the open posture impairs empathic accuracy, then we should observe a decrease in performance in the mind in the eyes task by the open group. This was not found, in fact the opposite was found, as the open group performed statistically better in this task than those in the closed group. This interesting finding may be explained by research that has found that individuals who are more powerful are better able to focus on a task and therefore improving the pursuit of their goals (Guinote, 2007). Moving on to the EEG data for this task, we find group differences in the central and centro-parietal regions. The effects present at central regions were found in the high alpha range and are expressed as a difference in mu activation between the open and closed groups and the open and control groups. In all instances, we see a small amount of (non-significant) ERD in the open group, and a significant level of mu synchronisation for both the closed and the control groups. Event related synchronisation has been found by some to signify cortical idling (Pfurtscheller, 1992; Pfurtscheller & Neuper, 1994; Pfurtscheller, Stancák & Neuper, 1996; Pfurtschellera, Lopes & da Silva, 1999). Whilst we see some ERD related to the open group, indicating some mirror activation for the open group, it is not a significant level of activation. The effects present at centro-parietal regions were found in the low beta range and are expressed as a difference in mu activation between the open and closed groups and between the open and control groups. In all instances we see the open group expressing mu synchronisation and the closed and control groups expressing mu desynchronisation - this is the reverse of the high alpha findings. In almost every case we find significant levels of ERD in the control and closed groups, indicating activation of the mirror neuron system, however no significant levels of ERS for the open group, again, possibly indicating an idling system. Interestingly, no correlations were observed here again reducing any inferences we can make that the mu ERD is related to empathic processes.

Finally, we examine the EEG data from the pain protocol. The least widespread but only evidence of group differences were found at fronto-central regions in the early time epoch in the high alpha range. Here we see that each group has a different pattern of mirror neuron activity based on the observation of the painful and non-painful images. There appears to be not much difference in ERD to non-painful images between the open and control groups (indicating similar levels of mu ERD being elicited by the non-painful images), but a fairly big difference between the ERD to painful images for the same groups (indicating less mirror neuron activity to painful images in the open posers relative to the control group). This latter finding is interesting as we predicted that those adopting a open pose would demonstrate less empathy relative to controls and this is the case. We also find further evidence to strengthen our argument as we also see an association between mu ERD to painful images in the control group and empathic concern, however this association is missing for the open posers. The most widespread discovery was a sample wide discrimination between the painful and non-painful images in the low alpha range (similar to both study 1 and 2). We find this effect at each scalp region, especially at the late time epoch. Alongside these differences, we see significant associations with some of our measures of empathy. For mu ERD to painful images we see associations with empathic concern, the EQ and fantasy. For mu ERD to non-painful images we see correlations with the EQ and perspective taking. The correlations associated with the painful images seem fairly intuitive (although perhaps not so much with the fantasy dimension) as we might expect one to empathise with another in pain. The correlations associated with the non-painful images are perhaps less intuitive (especially with the EQ), however we could posit that participants were attempting to take the perspective of the people who were being stimulated by the Q-tip as they might be less sure of what that would feel like compared to a needle – the Q-tip could perhaps be seen as a more novel stimulus. In study 1 we saw a correlation between Q-tip images and perspective taking, although it was a negative in direction.

To summarise, in this chapter we set out to explore power-posing and in specific to ascertain whether adopting a open pose for three minutes would leave to a self-reported change in feelings of power which would also manifest meaningful changes in both behavioural and cortical measures of empathy. The only self-reported group difference was found in how comfortable the participants felt immediately after the posture. In terms of behavioural changes, counter to predictions the open group performed statistically better. In terms of cortical differences, in the reading the mind I the eyes task we found partial evidence to suggest higher mu ERD in the control/closed group relative to the open group. For the pain protocol we found evidence to suggest that the open group elicit less mirror neuron activation to observing another in pain relative to the control group. All in all we see evidence to suggest that whilst the posture intervention seemed to not impact feelings of power, we did observe meaningful difference in the EEG suggesting that those in the open group exhibit less mu ERD empathy relative to the control and closed group.

Chapter 6: General Discussion

"We're all stories, in the end. Just make it a good one, eh?" - The 11th Doctor (Matt Smith)

6.1 Thesis aims

The primary aim of this thesis was to expand upon the neuroscientific and behavioural literature surrounding empathy; an important social construct which helps us to understand how others are feeling which in turn can facilitate helping behaviour. The focus of our analysis is on the activation of the human mirror neuron system which has been found to be a putative neural index of empathy. This investigation spans three experimental chapters, each one focusing on multiple investigations with the aim to expand our understanding of the hMNS and empathy.

6.2 Studies recap

6.2.1 Study 1

The aims of the first study were to a) lay the groundwork for the next two studies, b) replicate studies investigating mirror neuron activation to painful stimuli, and c) expand upon the auditory mirror neuron literature. In order to achieve the above aims, we examined participants' activity in the mu bandwidth in relation to two EEG protocols: a pain protocol and an emotional sounds protocol and correlated them with two measures of empathy: the empathy quotient (EQ) and the interpersonal reactivity index (IRI). Past research has found hMNS activation in relation to the observation of painful images (Cheng, et al., 2008; Tang, et al., 2009; Perry, et al., 2010) while less conclusive correlations were found between mu suppression and two components of empathy - perspective taking (Cheng et al., 2008) and personal distress (Yang, et al., 2008).

6.2.1.1 Pain Protocol

We created our own pain protocol expanding upon examples from the literature, in an attempt to both replicate and to build upon past findings. A significant difference in mu activation was found between conditions (painful and non-painful) at centro-parietal regions (i.e. over somatosensory cortex). This effect lasted for almost two-thirds of the duration of the presentation of the images and was found in the high alpha bandwidth (10-12Hz). As expected, painful images elicited more ERD than non-painful images. As with past research, an association was also found with self-reported measures of empathy. In this instance however, the association was a negative one between the non-painful images and the perspective taking dimension of the IRI. This unexpected result demonstrated that those who scored higher on the ability to take on the perspective of others elicited less mu activation than those who were not as proficient. On one hand, these results demonstrate typical findings (difference in mu desynchronisation between painful and non-painful images), on the other hand we see no association between painful images and empathy. Whilst this negative correlation between mu activity and perspective taking seems counter-intuitive, one explanation can be found through the neural efficiency hypothesis. The neural efficiency hypothesis posits a link between expertise and brain activation, in that those who are more experienced at a task often show lower brain activation. For example, Del Percio et al. (2009) tested two hypotheses 1) that expert athletes (compared to non-athletes) would elicit reduced cortical activation in the preparation phase immediately before the task commenced, and 2) that optimal performance in athletes (in this case high score shots) would be related to low cortical activation. In relation to the first hypothesis it was found that the expert athletes elicited lower low and high alpha band power than the non-athletes when preparing to engage with the task, therefore supporting the first hypothesis. Regarding the second hypothesis, the authors found that expert athletes elicited larger high alpha amplitudes when they made high scoring shots than when they performed low scoring shots, this effect was not observed for the non-athletes. Similar results were observed by Babiloni, et al. (2009) when they tested whether 1) expert rhythmic gymnasts would experience reduced cortical activation when observing and judging sporting actions of other gymnasts than non-athletes, and 2) that a good judgement in expert athletes would be associated with a low cortical activation. In relation to the first hypothesis it was found that expert athletes elicited lower amplitude low and high alpha band ERD than the non-athlete group. For the second hypothesis, higher amplitude high frequency alpha ERD was observed when the experts made a high judgement error (judgement error = difference between judgement score by the trainer and the athlete) compared to when they made a low judgement error. Both studies providing evidence that lower cortical resources are utilized when one is more proficient at a task. It is proposed therefore, that this might be an explanation for the negative association found in this protocol.

6.2.1.2 Emotional Sounds Protocol

There has been a lack of research investigating hMNS activation to emotional sounds. To date, the focus of auditory mirror neurons has been on action-related sounds for primates and piano sequences for humans. To this author’s knowledge, the association between the hMNS and emotional sounds has not been extensively investigated. In order to fill this gap and to expand our knowledge on the multi-modal nature of mirror neurons we exposed our participants to two emotional sound conditions and one control sound condition (pink noise). If the hMNS resonates with emotional sounds and we find an association between the resulting activity and measures of empathy then this could provide additional evidence of the role of auditory mirror neurons in the perception of emotionally sounds (specifically laughing and crying). Possible evidence to support mirror neuron reactivity to emotional sounds was found. At each electrode region (fronto-central, central and centro-parietal) in the low beta bandwidth, we found mu ERD was higher to the crying than to the laughing sounds. Interestingly, whilst the crying sounds elicited ERD and therefore it is argued - mirror system activation, the laughing sounds only ever elicited ERS; it is unclear what this may reflect, however perhaps implies a non-engaged mirror neuron system. This finding could also provide evidence to imply the lack of a need for the mirror system to be engaged with positive-valanced emotional sounds – however this is highly speculative. In terms of associations between mirror neuron activation and empathy, effects were present at both fronto-central and central regions. At fronto-central regions we see an association between mu ERD elicited by the crying sound and perspective taking (this also exists at central regions) and between ERS elicited by the laughing sound and perspective taking. Whilst the presence of these negative correlations strengthens our argument about this activity relating to empathic processes it must be noted that they are negative in direction again. The neural efficiency hypothesis might be applicable here also. It should also be noted that the pink noise control condition elicited the highest level of ERD, which was not expected and may introduce a confounding element to the findings. Kohler, et al., (2002) found that a control noise (white noise) elicited no excitatory response, however their study tested monkeys and not humans. Whilst event-related cortical studies in relation to aversive sounds are not well documented, research by Czigler, Cox, Gyimesi and Horvath (2007) demonstrated that ERP amplitudes were more negative than everyday sounds. Whilst these findings do not translate directly to the present study, it is possible evidence that the pink noise sound would not be an ideal control sound to use in future, as several participants reported it as aversive.

The second main finding was again found at all regions, but this time in the low alpha band. Here we find no significant differences between the laughing and crying sounds (which in this instance both elicited ERD), but instead between the two emotional sounds and the pink noise sound which again elicits the most ERD. No associations were found with empathy here, implying perhaps that unlike the above findings these are not related to empathic processes and instead reflect simple auditory mechanisms.

The results from the first study of the thesis were promising, and imply both the engagement of the human mirror neuron system in response to both painful stimuli and to emotional sounds. Whilst evidence for an association with measures of empathy is not conclusive, a strong association with perspective taking is present in both protocols (pain and emotional sound).

6.2.2 Study 2

The aim of the second study was to examine the effect of long-term practice of loving-kindness meditation (LKM) on both levels of empathy and activation of the mirror neuron system. It has been suggested that training in LKM can improve one's empathic abilities (Dalai Lama & Cutler, 1998; Cho, et al., 2018). There is however there is a lack of strong empirical evidence to support this beside the anecdotal, although brain imaging studies have found that meditation can strengthen areas responsible for empathic processes (Ruby & Decety, 2004; Singer, et al. 2004; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008; Lutz, Greischar, Perlman, & Davidson, 2009). In order to test this hypothesis, both long-term practitioners of LKM and participants with no meditative experience were exposed to three experimental protocols. Mirror neuron activation was examined in relation to a pain protocol (brought forward from the first study), a standard mirror neuron activation protocol and finally an emotional image protocol (International Affective Picture System), results were correlated with measures of empathy. To begin, we examined between-group differences in empathy in order to see if the groups did indeed differ with respect to self-report measures of empathy. Whilst no statistically significant group differences were found, it is important to highlight the fact that mean values for the empathy quotient, empathic concern and personal distress were higher in the LKM rather than the control group. Even without the significant difference, it appears as though the LKM group had slightly higher empathic abilities than the control group. Perhaps with a larger sample size, we would see the differences becoming significant; however, recruiting large numbers of experienced LKM practitioners is problematic and was unfortunately, beyond the scope of the present study.

6.2.2.1 Pain Protocol

The most relevant and interesting finding was a group difference in mu ERD in the low alpha band, regardless of stimuli type. Across stimuli, we find less mirror neuron activation in the LKM group than we do in the control group. As stated, in the literature increased mu activation is seen as a more engaged mirror neuron system, therefore in this instance we can also assume that our LKM group's mirror neuron system is less reactive to the stimuli (both painful and non-painful combined). This finding seems particularly interesting as we expected a group difference (although it was not certain how this would be expressed). It is unlikely (based on the literature) that the LKM group (who are expert meditators) have a "deficit" in empathy (whether expressed by self-report measures or in cortical processing) as they actively engage in developing their ability to feel compassionate loving-kindness to others. Further research is desirable on this matter as through the lower cortical excitability of the LKM group we might again be seeing evidence in support of the neural efficiency hypothesis.

In non-group-related findings we see an effect of body location (regardless of whether the location was stimulated by the needle of the Qtip) at central regions. Here we see more low beta ERD to both the foot and the mouth images at the middle epoch rather than to the hand. This effect changes slightly in the late epoch, with the only difference being between the hand and foot locations. As to why we observed increased mirror activity to the images of the foot and mouth (and later just the foot) than to the hand is uncertain. However, it is possible that it is simply a function of the area of somatosensory cortex given over to these body parts. Consulting the cortical homunculus (see figure 92 below) we see that the hand has the most cortical representation, followed by the mouth and then the foot (tucked into the longitudinal fissure).

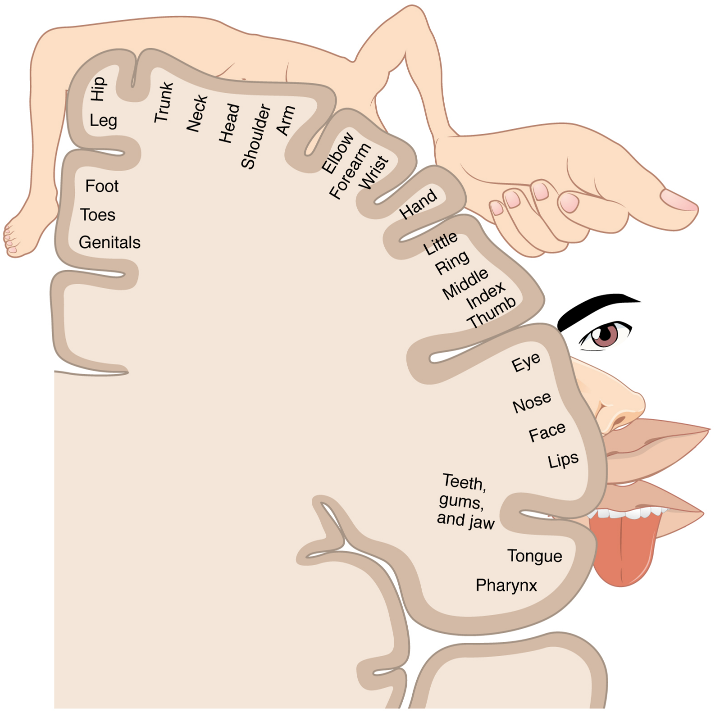

Figure 92: Image of the cortical homunculus, representations of foot, hand and mouth are of interest.

The final non-group-related effect relates to an interaction between stimuli type and body location. Here we see a different pattern of low alpha ERD for body location that is dependent on whether the types of images were painful or non-painful. With the painful images, we see increased ERD to both the hand and mouth location and less to the foot. The reverse pattern was found for the non-painful images, with the foot images eliciting more ERD than the hand and mouth. Unlike the effect of body location (mentioned above), this makes more sense when we look at the painful ERD response as we see more ERD to both the hand and the mouth, which have more cortical representation than the foot. Whilst not significantly different, the pattern of activation indicated more engagement of the mirror system to hands and mouths in pain than to the foot in pain. However the reverse is true when the body locations are not experiencing painful stimulation (Qtip) where we see more engagement of the mirror system to the feet, perhaps a novelty factor (e.g. ticklishness) is at play. However, ass the focus of this study is on differences in mirror system activation and empathy between the LKM and control group, this finding, whilst potentially interesting, is not strictly relevant to this thesis.

6.2.2.2 Moving Hands Protocol

The moving hands protocol is a "traditional" mirror neuron activation protocol witch has been found to elicit the hMNS in previous studies (Oberman, et al. 2005; Puzzo, Cooper, Vetter & Russo, 2010; Puzzo, Cooper, Cantarella S, & Russo 2011). Evidence for group differences in mu activation from a simple mirror neuron activation protocol were found, both in the low beta band. The first, an interaction between stimuli and group over fronto-central regions demonstrated a borderline group difference in mu activation when perceiving the clips of hands moving. Here we observed mu ERD for the control group, but ERS for the LKM group. Thus arguably, we have engagement of the mirror neuron system in the control group in relation to seeing a hand move, however the system is not engaging in the same way in the meditators. This might indicate a possible interesting effect of practicing LKM and will be discussed in the limitations and future directions section below. The second indication of a between-group difference in mu activation comes in the form of a linear contrast at central regions. Here we observed a group difference in the pattern of mu activation for the moving balls and moving hands stimuli. For the control group, we see a traditional finding, with increased mu activity for the moving hand stimuli and less for the moving balls stimuli. For the LKM group however, we see an atypical response with less mu activation for the moving hand stimuli. For both of these effects we found no association with empathy. Again, we find an atypical response in the LKM group that could be due to the neural efficiency hypothesis as meditators needing to exert as much mental effort as the control group.

The second prominent finding relates to a traditional finding in the mirror neuron literature. In the middle epoch at both central and centro-parietal regions we see a difference between low and high alpha ERD to moving balls and moving hand stimuli, with more mu ERD to the moving hand. This effect is also present in late epochs, however there, mu ERD expressed is expressed in the high alpha band. Correlations were observed between EQ and high alpha ERD elicited by the moving hand stimuli at the late epoch at central and centro-parietal regions. This finding indicated that those with higher mirror activation to the moving hands stimuli also had higher scores on the EQ. Whilst this finding is not strictly relevant to our thesis, it does provide evidence of the validity of the task.

6.2.2.3 IAPS Protocol

Evidence of between-group effects were found in relation to our emotional image protocol. These effects were present at all electrode groups (fronto-central, central and centro-parietal) and were expressed as high alpha ERD in the early epoch. At fronto-central regions we observed a difference in the pattern of mu activation (a linear contrast) in that we saw more mu activity to the positive images rather than the negative ones in the control group, the opposite being true for the LKM group. At central regions (and continuing to centro-parietal regions) this effect changed to a quadratic contrast, with the control group demonstrating more mu activity to the negative and positive images rather than to the neutral images (which actually elicits mu synchronisation). That pattern is reversed in the LKM group with more mu activity to the neutral images and a similar amount to the negative and positive images. No association between mu activation and empathy was found for these effects, perhaps indicating no direct link with empathy as measured by the EQ or IRI. Whilst a clear difference in the pattern of mu activation is being observed here, further research is needed in order to decipher the meaning. What we seem to be observing in the LKM group is less mu reactivity to the stimuli (especially between the negative and positive stimuli) when compared to the control group whose pattern of mu activation appears to be more varied.

The second set of findings relates to a difference in mu activation between each of three stimuli types (negative, neutral and positive) in the low beta band. At fronto-central locations we find a difference in mu ERD between negative and neutral stimuli types and also between negative and positive. Here we see higher mu ERD to the negative images and lower mu ERD to the positive. As we move to central and then centro-parietal regions we see a similar effect with higher mu ERD to the negative images. So, we are observing a similar effect at both high alpha and low beta bands, but one aspect stands out: we observe correlations only between low beta ERD and empathy. At fronto-central regions in the middle epoch, we see three positive associations between mu ERD to the positive images and fantasy, negative images and fantasy, and positive images with empathic concern (higher empathy scores associated with higher mu activation). The final association at the middle epoch was a negative one between positive images and personal distress (higher personal distress scores associated with less mu activation). At the late epoch at fronto-central regions we see one positive association between negative images and fantasy. Finally moving on to central regions we see two positive associations between positive images and fantasy and between positive images and empathic concern. Remember, we observed no correlation in the low alpha band. Whilst it is a shame that we found no group based associations, it is interesting that we found multiple ones here, although it must be noted that there is a possibility of type-1 error due to multiple correlations being run.

6.2.3 Study 3

6.2.3.1 Pre-posture Findings

The aim of study three was to investigate the effect of posture (high and closed posing and a control posture) on self-reported feelings of power and how such power-posing might affect both behavioural measures and neural correlates of empathy. Before the posture phase began, pre-test behavioural and EEG data were taken. This was to ascertain whether any between group effects were present before the intervention (so that these could be accounted for). Behavioural data was gathered from the Reading the Mind in the Voice task, results demonstrated that there was no difference between the accuracy of the three groups. Although some unexpected EEG difference were found they are not relevant to the hypotheses.

6.3.2.2 Post-posture Findings

After the posture phase participants recorded their feelings of power, confidence and comfort. There was an expectation that those assigned to the open pose would feel more powerful and more confident than those in both the closed and control posture (as in Carney, et al. 2010; Ranehill, et al. 2015). This was not the case however, with the only significant difference being between the measure of comfort with the closed posers being the least comfortable. It is interesting to note however that the highest rating for feelings of confidence were reported by the open posers. Whilst not significantly higher than the other two groups, it is at least in an expected direction. In order to attempt to gain a more detailed picture of any possible effects of the posture on empathic accuracy and on mu activity, we examined both behavioural and EEG data from the RMITE test and EEG data from a pain protocol.

Firstly, we will consider the behavioural results from the RMITE test. Unexpectedly, we see a better accuracy score for those in the open posing group and the lowest for those in the closed posing group. These findings do not fit with our hypothesis that power-posing will increase feelings of power and lead to a decrease in empathy. One possible argument for this finding comes from Guinote (2007) who found that those who had been primed to feel more powerful were more focused at achieving a goal than those with low power. Moving on to our EEG findings for the RMITE protocol we see two different effects. At central regions in the high alpha band we see a difference in mu activity between the open and closed groups and between the open and control groups. In both cases we see a low amount of mu ERD in the open group (this cannot attest to the idea of the mirror system being engaged) and a high level of ERS for the other two groups. This pattern changes at centro-parietal regions where the effect shifts to the low beta band. Here we observe a significant level of mu ERD in the closed and control groups relative to the ERS expressed by the open group. So, whilst we found significant differences in mirror neuron activation between groups, we also found conflicting findings between the central and centro-parietal regions with findings in the latter regions fitting with the hypothesis of decreased mirror neuron activity being associated with the open group. No significant correlations were found associated with these effects however, which as always limits our interpretations that this activity I linked to empathic processing.

Finally in relation to our pain protocol we observed two main effects. The only group related effect came in the form of a linear contrast in the high alpha band at fronto-central regions. Here we saw a different pattern of mu ERD dependent on whether the images were classified as painful or non-painful. For the painful stimuli we see a lower level of mu ERD in the open group relative to the control group and for the non-pain group very little difference in the level of mu ERD. It seem that being faced with panful images leads to increased mirror neuron activity for those in the control posture, and significantly less for those who had adopted the open pose. This finding provides evidence to suggest that posture has had an effect on empathy as measures by the EEG. To strengthen this argument we also find a logical association between mu ERD for the control group and empathic concern, a correlation which is absent in the open group. The final effect was one which was also present in study 1 (but absent from study 2)– a difference in mu ERD between the painful and non-painful conditions. In low alpha (at all electrode regions) we see a higher level of mu ERD to the painful images relative to the non-painful. In addition to this effect we see correlations we see positive correlations between both painful and non-painful conditions and the EQ. So not only are we finding more mirror neuron activity to painful images but we also see an association with empathy.

6.3 Limitations and future directions

6.3.1 Study One

One potential issue regarding the pain protocol was that no behavioural measures were taken (e.g. participants ratings of perceived pain). Obtaining more information about the images could have been useful, and that information could have been used in order to investigate findings further, for example correlating perceived pain intensity with mirror neuron activity. However it should be stated that it is fairly typical for mirror neuron studies to not contain a behavioural aspect. Despite this potential issues, one strength of using the same pain protocol for each study in this thesis (aside from a modified version in study three) is that we were able to compare differences and similarities in the results. Whilst the emotional sounds protocol appeared to be effective in eliciting mirror neuron activity, we also found the highest level of mu activation in relation to our control sound (pink noise). Similar to the suggestions above, it would have been useful to obtain ratings for each sound that could then have been used to dissect the effects that were found.

6.3.2 Study Two

Ideally an equal sample size would have been preferable, however this was beyond the scope of the study. Despite this, it was argued that meaningful group differences were observed. Whilst our meditator sample were defined as loving-kindness meditators, it should be noted that many of them practiced this along-side mindfulness meditation. It was also beyond the scope of our study to find a large enough group of participants who only practiced LKM. It is possible, however that the effects that we observed are partly attributable to the dual practice. Arguably, the most effective means to investigate possible empathic benefits of practicing LKM would be to conduct a longitudinal study. This could be achieved by creating two groups: a LKM group and a control group (possibly a waiting group). In the first phase, baseline empathy, behavioural and EEG measures would be taken. Following this, participants would be assigned to either the LKM or the waiting group. The LKM group would receive detailed instructions and support in practicing LKM, whilst the control group could be instructed on basic deep breathing exercises. Groups would practice their assigned tasks for a specified amount of time and then be tested on multiple occasions (possible three or four). A common theme running through study two is the atypical results found for the LKM group for each protocol. As mentioned earlier, this may be due to the neural efficiency hypothesis. This is possible due to the LKM group having many years of experience with the task (whilst not reported here, in excess of one year). It would be interesting to investigate this. This could be achieved as part of the longitudinal design mentioned above.

6.3.3 Study Three

Despite the design of our study attempting to account for any behavioural and EEG differences in empathy prior to the power-posing intervention, it would perhaps be far better to pre-screen participants beforehand. That way we could choose participants who showed little to no difference in empathy. In terms of the power-posing phase, participants in the present study were asked to adopt the pose for three-minutes in length which differs from the literature in which one-minute is the usual length. It is possible that the three-minute duration led to participants in the closed group to feel uncomfortable. The choice of the video clip was in hindsight possibly not ideal. A clip from the BBC television show Doctor Who was chosen, but might not have been as neutral in content as it could have been. In fact many participants recognised it and seemed to enjoy it. Post-posture, participants were required to complete the power, confidence and comfort scale. There is a possibility that they responded in relation to how the video clip made them feel rather than how they felt at that moment in time regardless of the clip. The inclusion of the moving hand protocol use in study 2 might have yielded interesting results as it is a traditional mirror neuron activation protocol. This could have been presented both before and after the posture phase in order to examine group difference. Finally, relating to the potential duration of the poser-posing phase, it is uncertain as to how long the effect might last. This is relevant due to the fact that participants completed two protocols after this phase and whether any effect would last through two protocol is questionable.

6.4 An Ideal Protocol to Measure the Neural Correlates of Empathy?

Within this thesis, six protocols have been used in order to attempt to gain a better understanding of the neural correlates of empathy. Whilst past research has demonstrated that empathy is a multi-faceted construct, a question has perhaps been raised as to whether there is an "ideal" protocol for measuring the neural correlates of empathy. It should be noted that being a multi-dimensional construct, it is unlikely that one "ideal" task can measure each dimension of empathy effectively whilst also maintaining a strong association with a neural marker. Past research has demonstrated this, as has this thesis. At the simplest level of measuring empathy we have various well established and reliable questionnaires such as the EQ and IRI. These questionnaires, whilst useful, merely provide us with a numerical value which represents a persons' level of empathy. When considering neural markers of empathy, the task becomes arguably more difficult. Inconsistent findings in the literature seem to be focused around associations between neural markers of empathy and empathy questionnaires. This is a near impossible challenge as not only do researchers need a task that successfully taps into the specific construct(s) that they wish to measure, but they also need to find a common significantly associated neural marker for said constructs. For the sake of simplicity we shall consider this question in the context of empathy being a multidimensional approach (as per Davis's IRI). What follows should be considered a think piece and therefore treated as such.

Showing participants images of people in pain in an attempt to elicit an empathic neural reaction is very common in the literature. This is probably the most logical type of protocol for this purpose as what could be better at eliciting an empathic reaction than seeing another suffering in some manner? Pain protocols generally appear in the literature in two forms, light tactile (e.g. needle vs. cotton) and more visceral (e.g. a knife about to cut a hand vs. a knife cutting a vegetable). The light tactile protocol was adopted in this thesis due to the ease of creation of the stimuli and the frequency that the protocol is used in the literature. More visceral protocols whilst not necessarily less common, focus less on mu suppression and more on event-related potentials (e.g. Fan & Han, 2008; Han, Fan & Mao, 2008, Li & Han, 2010; Meng, Hu, Shen, Yang, Chen, Huang & Jackson, 2012 and Meng, Jackson, Chen, Hu, Yang, Su & Huang, 2013). These protocols could be seen however as more ecologically valid, as they contain images of "real life" hazards. Also being more visceral, could theoretically result in a stronger neural activation. Despite this, there is a distinct lack of a correlation between these neural markers and subjective measures of empathy. This lack of correlational evidence even with more visceral protocols of course raises questions as to the validity of even these tasks of reliably evoking neural mechanisms of empathy. That being said, the lack of mu ERD studies examining the more visceral reaction to pain stimuli opens up the possibility of discovering a reliable relationship. However in this researchers opinion, this might be overly optimistic.

To conclude, until the times comes where a protocol reliably measures the neural correlate of empathy arguably the most effective protocol to date is the simple mirror neuron activation protocol (moving hands protocol). This task has been shown to effectively elicit the mirror neuron system (through mu desynchronisation). This neural activation has also found to be localised in areas that are important for empathic processing by utilising various neuroscience methodologies. Whilst the lack of ecological validity might be an issue for some researchers, it must be said that such studies are not attempting to encourage the participant to imagine how another feels, simply to activate areas of the brain associated with empathic processing.

6.5 Final Summary and Concluding Statements

Over the course of these three large studies we have discovered that empathy is not always an easy clear-cut topic to study. We have however found evidence to suggest that mu activity is an effective neural index of mirror neuron activity and one which correlates with self-report measures of empathy (albeit not immediately intuitive at times). There seems to be clear evidence that practicing LKM can alter activity in the mirror neuron system in relation two three different but related protocols, although further research is needed in order to compensate for some methodological flaws in the study. Finally whilst we did not find that those who were primed to feel more powerful reported this, possible evidence for reduced empathic processing was found in the EEG.

“…we’re all capable of the most incredible change. We can evolve while still staying true to who we are. We can honour who we’ve been and choose who we want to be next.” - The 13th Doctor (Jodie Whittaker)

References

Abbot, D. H., Keverne, E. B., Bercovitch, F. B., Shiverly, C. A., Mendoza, S. P., Saltzman, W., Snowdon, C. T., Ziegler, T. E., Banjevic, M., Garland, T. & Sapolsky, R. M. (2003). Are subordintes always stressed? A comparative analysis of rank differences in cortisol levels among primates. *Hormones and Behaviour, 43*, 67-82.

Akturk, A. O., & Sahin, I. (2011). Literature Review on Metacognition and its Measurement. *Pocedia - Social and Behavioural Sciences, 15*, 3731-3736.

Allee, W., Callias, N., & Lutherman C. . (1939). Modification of the social order in flocks of hens by the injection of testosterone propionate. *Physiological Zoology, 117*, 904-911.

Altschuler, E. L., Vankov, A., Hubbard, E. M., Roberts, E., Ramachandran, V. S. & Pineda, J. A. (2000). Mu wave blocking by observation of movement and its possible use as a tool to study theory of other minds. *Society for Neuroscience Abstracts, 26*.

Andrewes, D. (2004). *Neuropsychology: From Theory to Practice*. New York: Psychology Press.

Arnstein, D., Cui, F., Keysers, C., Maurits, N. & Gazzola, V. (2011). Mu-Suppression during Action Observation and Execution Correlates with BOLD in Dorsal Premotor, Inferior Parietal, and SI Cortices. *The Journal of Neuroscience, 31*, 14243-14249.

Avenanti, A., Bueti, D., Galati, G. & Aglioti, S. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nature Neuroscience, 8*, 935-960.

Babiloni, C., Babiloni, F., Carducci, F., Cincotti, F., Cocozza, G., Del Percio, C., Moretti, D.V. & Rossini, P.M. . (2002). Human Cortical Electroencephalography (EEG) Rhythms during the Observation of Simple Aimless Movements: A High-Resolution EEG Study. *NeuroImage, 17*, 559-572.

Baker, D., Hunter, E., Lawrence, E., Medford, N., Patel, M., Senior, C., Sierra, M., Lambert, M.V., Phillips, M.L. & David, A. S. (2003). Depersonalisation Disorder: clinical features of 204 cases. *British Journal of Psychiatry, 182*, 428 - 433.

Barker, A. T., Jalinous, R. & Freeston, I.L. (1985). Noninvasive magnetic stimulation of human motor cortex. *Lancet, 2*, 1106-1107.

Baron-Cohen, S., Wheelwright, S.,. (2004). The Empathy Quotient: An Investigation of Adults with Asperger Syndrome or High Functioning Autism, and Normal Sex Differences. *Journal of Autism and Developmental Disorders, 34*, 163-175.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y. & Plumb, I. (2001). The 'Reading the mind in the eyes' test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychiatry and Psychiatry, 42*, 241 - 252.

Baron-Cohen, S. J., T. (1997). Another Advanced Test of Theory of Mind: Evidence from Very High Functioning Adults with Autism or Asperger Syndrome. *Journal of Child Psychiatry and Psychiatry, 38*, 813-822.

Batson, C. D., Early, S. & Salvarani, G. (1997). Perspective Taking: Imagining how another feels versus imagining how you would feel. *Personality and Social Psychology Bulletin, 23*, 751-758.

Blair, R. J. R. (1995). A cognitive developmental approach to morality; investigating the psychopath. *Cognition, 57*, 1 - 29.

Blair, R. J. R. (2005). Responding to the emotions of others: Dissociating forms of empathy through the study of typical and psychiatric populations. *Consciousness and Cognition, 14*, 698-718.

Bodhi, B. (2005). *In the Buddha's Words*

Bos, P. A., Hofman, D., Hermans, E.J., Montoya, E.R., Baron-Cohen, S. & van Honk, J. (2016). Testosterone reduces functional connectivity during the 'Reading the Mind in the Eyes' Test. *Psychoneuroendocrinology, 68*, 194-201.

Botvinick, M., Jha, A.P., Bylsma, L.M., Fabian, S.A., Solomon, P.E. & Prkachin, K.M. (2005). Viewing facial expressions of pain engages cortical areas involved in the direct experience of pain. *NeuroImage, 25*, 312-319.

Bowlby, J. (1978). Attachment theory and its theraputic implications. *Adolescent Psychiatry, 6*, 5-33.

Braadbart, L., Williams, J. & Waiter G. (2013). Do mirror neuron areas mediate mu rhythm suppression during imitation and action observation? *International Journal of Psychophysiology, 89*, 99-105.

Bradley, M. M., & Lang, P. J. (1994). Measuring Emotion: The Self-assessment Manikin and the Semantic Differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49-59.

Brown, C. A., & Jones, A. K. P. (2010). Meditation experience predicts less negative appraisal of pain: Electrophysiological evidence for the involvement of anticipatory neural responses. *Pain, 150*(3), 428-438. doi:10.1016/j.pain.2010.04.017

Brown, K. W. R., R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*, 822-848.

Buccino, G., Binkofski, F., Fink, G., Fadiga, L., Fogassi, L., Gallese, V., Seitz., Zilles, K., Rizzolatti, G. & Freund, H. (2001). Action Observation Activates Premotor and Parietal Areas in a Somatotopic Manner: an fMRI Study. *European Journal of Neuroscience, 13*, 400 - 404.

Bufalari, I., Aprile, T., Avenanti, A., Di Russo, F. & Aglioti, S. (2007). Empathy for Pain and Touch in the Human Somatosensory Cortex. *Cerebral Cortex, 17*, 2553-2561.

Burton, D. (2004). *Buddhism, Knowledge and Liberation*. Hampshire: Ashgate.

Carney, D. (2016). My position on "Power Poses". Retrieved from http://faculty.haas.berkeley.edu/dana_carney/pdf_my%20position%20on%20power%20poses.pdf

Carney, D. R., Cuddy, A. J. C., & Yap, A, J. (2010). Power Posing: Brief Nonverbal Displays Affect Neuroendocrine Levels and Risk Tolerance. *Psychological Science, 21*, 1-6.

Carson, J. W., Keefe, F.J., Lynch, T.R., Carson, K.M., Goli, V., Fras, A.M. & Thorp, S.R. (2005). Loving-Kindness Meditation for Chronic Low Back Pain. *Journal of Holistic Nursing, 23*, 287-304.

Chawla, J. (2016). Motor Evoked Potentials. Retrieved from http://emedicine.medscape.com/article/1139085-overview

Cheng, Y., Lin, C., Liu, H., Hsu, Y., Lim, K., Hung, D. & Decety, J. (2007). Expertise Modulates the Perception of Pain in Others. *Current Biology, 17*, 1708-1713.

Cheng, Y., Yang, C., Lin, C., Lee, P. & Decety, J. (2008). The perception of pain in others suppresses somatosensory oscillations: A magnetoencephalography study. *NeuroImage, 40*, 1833-1840.

Cho, H., Noh, S., PArk, S., Ryu, S., Misan, V. & Lee, J. (2018). The development and validation of the Lovingkindness-Compassion Scale. *Personality and Individual Differences, 124*, 141-144.

Clark, K. (1980). Empathy: A Neglected Topic in Psychological Research. *American Psychologist, 35*, 187-190.

Cochin, S., Barthelemy, C., Lejeune, B., Roux, S. & Martineau, J. (1998). Perception of motion and qEEG activity in human adults. *Electroencephalography and Clinical Neuroscience, 107*, 287 - 295.

Cochin, S., Barthelemy, C., Roux, S. & Martineau, J. (1999). Observation and execution of movement: similarities demonstrated by quantified electroencephalograpy. *European Journal of Neuroscience, 11*, 1839 - 1842.

Cohen-Seat, G., Gastourt, H., Faure, J. & Heuyer, G. (1954). Etudes experimentales de l'activite nerveuse pendand la projection cinematographique. *Rev. Int. Filmol., 5*, 7-64.

Crawcour, S., Bowers, A., Harkrider, A., & Saltuklaroglu, T. (2009). Mu wave suppression during the perception of meaningless syllables: EEG evidence of motor recruitment. *Neuropsychologia, 47*(12), 2558-2563. doi:10.1016/j.neuropsychologia.2009.05.001

Croft, R. J. B., R.J. (2000). Removal of ocular artifact from the EEG: a review. *Neurophysiologie Clinique/Clinical Neurophysiology, 30*, 5-19.

Crowne, D. P. M., D. (1960). A new scale of social desirability independent of psychopathology. *Journal of Consulting Psychology, 24*, 349 - 354.

Dabbs, J. M., & Morris, R. (1990). Testosterone, Social-Class, and Antisocial-Behavior in a Sample of 4,462 Men. *Psychological Science, 1*(3), 209-211. doi:DOI 10.1111/j.1467-9280.1990.tb00200.x

Davis, M. H. (1980). A Multidimensional Approach to Individual Differences in Empathy. *JSAS Catalog of Selected Documents in Psychology, 10*, 85 - 102.

Davis, M. H. (1996). *Empathy: A social psychological approach*: Westview Press.

Decety, J., & Ickes, W. (2009). *The Social Neuroscience of Empathy*. London: MIT Press.

Decety, J., Chaminade, T., Grezes, J. & Meltzoff, A. N. (2002). A PET exploration of the neural mechanisms involved in reciprocal imitation. *NeuroImage, 15*, 265 - 272.

Decety, J., Chen, C. Harenski, C. & Kiehl, K.A. (2013). An fMRI study of affective perspective taking in individuals with psychopathy: imagining another in pain does not evoke empathy. *Frontiers in Human Neuroscience, 7*, 1-12.

Depue, R. A., & Morrone-Strupinsky, J. V. (2005). A neurobehavioural model of affiliative bonding: Implications for conceptualizing a human trait of affiliation. *Behavioural and Brain Sciences, 28*(3), 313-395.

di Pellegrino, G., Fadiga, L., Fogassi, L., Gallese, V. & Rizzolatti, G. (1992). Understanding motor events: a neurophysiological study. *Experimental Brain Research, 91*, 176-180.

Dymond, R. (1950). Personality and empathy. *Journal of Consulting Psychology, 14*, 343 - 350.

Enticott, P. G., Kennedy, H.A., Bradshaw, J.L., Rinehart, N.J. & Fitzgerald, P.B. (2011). Motor corticospinal excitability during the observation of interactive hand gestures. *Brain Research Bulletin, 85*, 89-95.

Eslinger, P. J. (1998). Neurological and Neuropsychological bases of empathy. *European Neurology, 39*, 193-199.

Fadiga, L., Fogassi, G., Pavesi, G. & Rizzolatti, G. (1995). Motor Facilitation During Action Observation: A Magnetic Stimulation Study. *Journal of Neurophysiology, 73*, 2608 - 2611.

Farrell, F. S., & McGuinness, M.Y. (2003). Effects of pubertal anabolic-androgenic steroid (AAS) administration on reproductive and aggressive behaviours in male rats. *Behavioural Neuroscience, 117*, 904-911.

Fecteau, S., Pascual-Leone, A., Zald, D. H., Liguori, P., Theoret, H., Boggio, P. S., & Fregni, F. (2007). Activation of prefrontal cortex by transcranial direct current stimulation reduces appetite for risk during ambiguous decision making. *Journal of Neuroscience, 27*(23), 6212-6218. doi:10.1523/Jneurosci.0314-07.2007

Fogassi, L., Ferrari, P., Gesierich, B., Rozzi, S., Chersi, F. & Rizzolatti, G. (2005). Parietal Lobe: From Action Organisation to Intention Understanding. *Science, 308*, 662-667.

Fredrickson, B. L., Cohn, M.A., Coffey, K.A, Pek, J. & Finkel, S.M. (2008). Open Hearts Build Lives: Positive Emotions, Induced Through Loving-Kindness Meditation, Build Consequential Personal Resources. *Journal of Personality and Social Psychology, 95*, 1045-1062.

Gallese, V., Fadiga, L., Fogassi, L. & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain, 119*, 593-609.

Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences, 2*(12), 493-501. doi:Doi 10.1016/S1364-6613(98)01262-5

Gastaut, H. J. B., J. (1954). EEG changes during cinematographic presentation. *Electroencephalogr. Clin. Neurophysiol., 6*, 433-444.

Gazzola, V., Aziz-Zadeh, L., & Keysers, C. (2006). Empathy and the somatotopic auditory mirror system in humans. *Current Biology, 16*(18), 1824-1829. doi:10.1016/j.cub.2006.07.072

Goldman, R., Stern, J., Engel,. J. & Cohen, M. (2012). Simultaneous EEG and fMRI of the alpha rhythm. *Neuroreport, 13*, 2487-2492.

Gordon, R. M. (1995). Sympathy, simulation and the impartial spectator. *Ethics, 105*, 727-742.

Grezes, J., Armony, J.L., Rowe, J. & Passingham, R.E. (2003). Activations related to “mirror” and “canonical” neurones in the human brain: an fMRI study. *NeuroImage, 18*, 928 - 937.

Gutsell, J. N., & Inzlicht, M. (2010). Empathy constrained: Prejudice predicts reduced mental simulation of actions during observation of outgroups. *Journal of Experimental Social Psychology, 46*(5), 841-845. doi:10.1016/j.jesp.2010.03.011

Hari, R., & Salmelin, R. (1997). Human cortical oscillations: a neuromagnetic view through the skull. *Human cortical rhythms, 20*, 44-49.

Hari, R., Salmelin, R., Makela, J.P., Salenius, S., & Helle, M. (1997). Magetoencephalographic cortical rhythms. *International Journal of Psychophysiology, 26*, 51-62.

Hatfield, E., Cacioppo, J. T. & Rapson, R. . . (1994). *Emotional contagion*. New York: Cambridge University Press.

Hermans, E. J., Putman, P. & van Honk, J. (2006). Testosterone administration reduces empathic behaviour: A facial mimicry study. *Psychoneuroendocrinology, 31*, 859-866.

Herzog, H. A., Betchart, N. S. & Pittman, R. B. (1991). Gender, sex role orientation, and attitudes towards animals. *Anthrozoos, 4*, 184-191.

Hobson, H. M., & Bishop, D. V. M. (2017). The interpretation of mu suppression as an index of mirror neuron activity: past, present and future. *Royal Society Open Science, 4*(3). doi:ARTN 16066210.1098/rsos.160662

Hodes, R. L., Cook, E. W., & Lang, P. J. (1985). Individual-Differences in Autonomic Response - Conditioned Association or Conditioned Fear. *Psychophysiology, 22*(5), 545-560. doi:DOI 10.1111/j.1469-8986.1985.tb01649.x

Hoffman, M. L. (1977). Sex differences in empathy and related behaviors. *Psychological Bulletin, 84*, 712-722.

Hoffman, M. L. (2000). *Empathy and Moral Development*. Cambridge: Cambridge University Press.

Hoffman, S. G., Grossman, P. & Hinton, D.E. (2011). Loving-Kindness and Compassion Meditation: Potential for Psychological Interventions. *Clinical Psychological Review, 31*, 1126-1132.

Hofmann, S., Grossman, P. & Hinton, D. (2011). Loving-kindness and compassion meditation: Potential for psychological interventions. *Clinical Psychological Review, 31*, 1126-1132.

Hogeveen, J., Inzlicht, M. & Obhi, S. (2014). Power Changes How the Brain Responds to Others. *American Psychological Association, 143*, 755-762.

Hommel, B. (1997). Interactions between stimulus-stimulus congruence and stimulus-response compatibility. *Psychological Research, 59*, 248 - 260.

Hsee, C. K., Hatfield, E. & Carlson, J. G. (1990). The Effect of Power on Susceptibility to Emotional Contagion. *Cognition and Emotion, 4*, 327 - 340.

Hucherson, C. A., Seppala, E.M. & Gross, J.J. (2008). Loving-Kindness Meditation Increases Social Connectedness. *Emotion, 8*, 720-724.

Hunsinger, M., Livingston, R., & Isbell, L. (2013). The Impact of Loving-Kindness Meditation on Affective Learning and Cognitive Control. *Mindfulness, 4*, 275-280.

Hutcherson, C. A., Seppala, E. M., & Gross, J. J. (2008). Loving-Kindness Meditation Increases Social Connectedness. *Emotion, 8*(5), 720-724. doi:10.1037/a0013237

Iacoboni, M. (2008). The role of premotor cortex in speech perception: Evidence from fMRI and rTMS. *Journal of Physiology-Paris, 102*(1-3), 31-34. doi:10.1016/j.jphysparis.2008.03.003

Iacoboni, M., Molnar-Szakacs, I., Gallese, V., Buccino, G., Mazziotta, J., & Rizzolatti, G. (2005). Grasping the Intentions of Others with One's Own Mirror Neuron System. *Plos Biology, 3*(3), 529-535.

Iacoboni, M., Woods, R.P., Brass, M., Bekkering, H., Mazziotta, J.C. & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science, 286*, 2526 - 2428.

Ickes, W. (1993). Empathic accuracy. *Journal of Personality, 61*, 587-610.

Jackson, P. L., Meltzoff, A. N. & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeroImage, 24*, 771-779.

Jasper, H. H. (1958). The ten twenty electrode system of the international federation. *Electroencephalography and Clinical Neurophysiology, 10*, 371-375.

Jeannerod, M. (1994). The Representing Brain: Neural Correlates of Motor Intention and Imagery. *Behavioural and Brain Sciences, 17*, 187 - 245.

Johnson, D. P., Penn, D.L., Fredrickson, B.L., Kring, A.M., Meyer, P.S., Catalino, L.I. & Brantley, M. (2011). A pilot study of loving-kindness meditation for the negative symptoms of schizophrenia. *Schizophrenia Research, 129*, 137-140.

Keltner, D., Gruenfeld, D. H., & Anderson, C. (2003). Power, approach, and inhibition. *Psychological Review, 110*(2), 265-284. doi:10.1037/0033-295x.110.2.265

Keysers, C., Kohler, E., Umilta, M.A., Nanetti, L. Fogassim L. & Gallese, V. (2003). Audiovisual mirror neurons and action recognition. *Experimental Brain Research, 153*, 628-636.

Khvatskaya, Y. L., M. F. (2016). Motor Empathy in Individuals With Psychopathic Traits: A Preliminary Study. *Journal of Personality Disorders, 30*, 613-632.

Killingsworth, A., M. & Gilbert, T., D. (2010). A Wandering Mind is an Unhappy Mind. *Science, 330*(6006), 932.

Kohler, E., Keysers, C., Umilta, L.F., Gallese, V. & Rizzolatti, G. (2002). Hearing Sounds, Understanding Actions: Action Representation in Mirror Neurons. *Science, 297*, 846-848.

Kohler, W. (1929). *Gestalt psychology*. New York: Liveright.

Koshino, Y., & Isaki, K. (1896). Familial occurrence of the mu rhythm. *Clinical Electroencephalography, 17*, 44-50.

Koski, L., Iacoboni, M., Dubeau, M., Woods, R.P. & Mazziotta, J.C. (2003). Modulation of corticalactivity during different imitative behaviors. *Journal of Neurophysiology, 89*, 460 - 471.

Krebs, D. (1975). Empathy and Altruism. *Journal of Personality and Social Psychology, 32*(6), 1134-1146. doi:Doi 10.1037//0022-3514.32.6.1134

Lama, D. C., H.C. (1998). *The art of happiness: A handbook for living*. New York: Riverhead Books.

Lamm, C., Nusbaum, H. C., Meltzoff, A. N., & Decety, J. (2007). What Are You Feeling? Using Functional Magnetic Resonance Imaging to Assess the Modulation of Sensory and Affective Responses during Empathy for Pain. *PloS One, 2*(12). doi:ARTN e129210.1371/journal.pone.0001292

Lawrence, E. J., Shaw, P., Baker, D., Baron-Cohen, S. & David, A.S. (2004). Measuring empathy: reliability and validity of the Empathy Quotient. *Psychological Medicine, 34*, 911 - 924.

Leung, M., Chan, C.C.H., Yin, J., Lee, C., So, K. & Lee, T.M.C. (2013). Increased gray matter volume in the right angular and posterior parahippocampal gyri in loving-kindness meditators. *SCAN, 8*, 34-39.

Lipps, T. (1903). Einfühlung, innere Nachahmung und Organenempfindungen. *Revue Philosophique de la France Et de l'Etranger, 56*, 660-661.

Luciano, C., & Wilson, K. (2008). An Experimental Test of a Conitive Defusion Exercise: Coping with Negative and Positive Self-Statements. *The Psychological Record, 58*, 623-640.

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), 1-10.

Lutz, A., Greischar, L., Perlman, D.M. & Davidson, R.J. (2009). BOLD signal in insula is differentially related to cardiac function during compassion meditation in experts vs. novices. *NeuroImage, 47*, 1038-1046.

Mascaro, J. S., Rilling, J. K., Negi, L. T., & Raison, C. L. (2013). Compassion meditation enhances empathic accuracy and related neural activity. *Social Cognitive and Affective Neuroscience, 8*(1), 48-55. doi:10.1093/scan/nss095

Mazur, A. B., A. (1998). Testosterone and dominance in men. *Behavioural and Brain Sciences, 21*, 353-397.

McCall, C., & Singer, T. (2012). The animal and human neuroendocrinology of socail cognition, motivation and behaviour. *Nature Neuroscience, 15*(5), 681-688.

McDougall, W. (1908/1928). *An introduction to social psychology*. London: Methuen.

Mehrabian, A. E., N. (1972). A measure of emotional empathy. *Journal of Personality, 40*.

Melamed, B. G., Cook, E. W., Cuthbert, B. N., Mcneil, D. W., & Lang, P. J. (1989). Emotional Imagery and the Differential-Diagnosis of Anxiety. *International Journal of Psychophysiology, 7*(2-4), 311-312. doi:Doi 10.1016/0167-8760(89)90249-3

Meng, J., Hu, L., Shen, L., Yang, Z., Chen, H., Huang, X. & Jackson, T. (2012). Emotional primes modulate the responses to others' pain: an ERP study. *Experimental Brain Research, 220*, 277-286.

Meng, J., Jackson, T., Chen, H., Hu, L., Yang, Z., Su, Y. & Huang, X. (2013). Pain perception in the self and observation of others: An ERP investigation. *NeroImage, 72*, 164-173.

Merton, P. A. M., H.B. (1980). Stimulation of the cerebral cortex in the intact human subject. *Nature*.

Monte, O. D., Schintu, S., Pardini, M., Berti, A., Wassermann, E.M., Grafman, J. & Krueger, F. (2014). The left inferior frontal gyrus is crucial for reading the mind in the eyes: Brain lesion evidence. *Cortex, 58*, 9-17.

Moore, A., Gorodnitsky, I., & Pineda, J. (2012). EEG mu component responses to viewing emotional faces. *Behavioural Brain Research, 226*(1), 309-316. doi:10.1016/j.bbr.2011.07.048

Muthukumaraswamy, S. D., Johnson, B. W., & McNair, N. A. (2004). Mu rhythm modulation during observation of an object-directed grasp. *Cognitive Brain Research, 19*(2), 195-201. doi:10.1016/j.cogbrainres.2003.12.001

Neave, N. (2008). *Hormones and Behaviour*. Cambridge.

Nelson, H. E. W., J. (1982). *The National Adult Reading Test (NART)*. Windsor: Wilson.

Niedermeyer, E., Goldszmidt, A., & Ryan, D. (2004). "Mu rhythm status" and clinical correlates. *Clinical Eeg and Neuroscience, 35*(2), 84-87. doi:Doi 10.1177/155005940403500206

Oberman, L. M., Hubbard, E.M., McCleerly, J.P., Altschuler, E.L., Ramachandran, V.S. & Pineda, J.A. (2005). EEG evidence for mirror neuron dysfunction in autism spectrum disorders. *Cognitive Brain Research, 24*, 190-198.

Oberman, L. M., Ramachandran, V.S. & Pineda, J.A. (2008). Modulation of mu suppression in children with autism spectrum disorders in response to familiar or unfamiliar stimuli: The mirror neuron hypothesis. *Neropsychologia, 46*, 1558-1565.

Ochsner, K. N., & Gross, J. J. (2008). Cognitive Emotion Regulation: Insights From Social Cognitive and Affective Neuroscience. *Current Directions in Psychological Sciance, 17*(2), 153-158.

Perry, A., & Bentin, B. (2009). Mirror activity in the human brain while observing hand movements: A comparison between EEG desynchronization in the mu range and previous fMRI results. *Brain Research, 1282*, 126-132.

Perry, A., & Bentin, B., Bartal, I., Lamm, C. & Decety, J. (2010). "Feeling" the pain of those who are different from us: Modulation of EEG in the mu/alpha range. *Cognitive, Affective, & Behavioural Neuroscience, 10*, 493-504.

Pfurtscheller, G., Stancak, A., & Neuper, C. (1996). Event-related synchronization (ERS) in the alpha band - an electrophysiological correlate of cortical idling: A review. *International Journal of Psychophysiology, 24*, 39-46.

Pineda, J. A. (2005). The functional significance of mu rhythms: Translating "seeing" and "hearing" into "doing". *Brain Research Reviews, 50*, 57-68.

Pineda, J. A., Allison, B. Z., & Vankov, A. (2000). The Effects of Self-Movement, Observation, and Imagination on Mu Rhythms and Readiness Potentials (RP's): Toward a Brain-Computer Interface (BCI). *IEEE Transactions on Rehabilitation Engineering, 8*(2), 219-222.

Preston, S. D. d. W., F. B. M. (2002). Empathy: Its ultimate and proximate bases. *Neuroscience, 27*, 169 - 192.

Preston, S. D. d. W., F. B. M. (2017). Only the PAM explains the personalized nature of empathy. *Nature REviews: Neuroscience*.

Puzzo, I., Cooper, N.R., Cantarella, S. & Russo, R. (2011). Measuring the effects of manipulating stimulus presentation time on sensorimotor alpha and low beta reactivity during hand movement observation. *NeuroImage, 57*, 1358-1363.

Ramnani, N., & Owen, A. (2004). Anterior Prefrontal Cortex: Insights into Function from Anatomy and Neuroimaging. *Nature, 5*, 184-194.

Ranehill, E., Dreber, A., Johannesson, M., Leiberg, S., Sul, S. & Weber, R. (2015). Assessing the Robustness of Power posing: No Effect on Hormones and Risk Tollerance in a Large Sample of Men and Women. *Association for Psychological Science*, 1-4.

Raz, A., & Buhle, J. (2006). Typologies of attentional networks *Neuroscience, 7*, 367-379.

Rizzolatti, G., & Arbib, M. A. (1998). Language within our grasp. *Trends in Neurosciences, 21*(5), 188-194. doi:Doi 10.1016/S0166-2236(98)01260-0

Rizzolatti, G., Fadiga, L., Gallese, V. & Fogassi, L. . (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research, 3*, 131 - 141.

Rizzolatti, G., Fadiga, L., Matelli, M., Bettinardi, V., Perani, D. & Fazio, F. (1996). Localization of cortical areas responsive to the observation of hand grasping movements in humans: a PET study. *Experimental Brain Research*.

Rizzolatti, G., Fogassi, L. & Gallese, V. (2001). Neurophysiological mechanism underlying the understanding and imitation of action. *Nature REviews: Neuroscience, 2*, 661-670.

Rizzolatti, G., Gentilucci, M., Camarda, R. M., Gallese, G., Luppino, M. & Fogassi, L. (1990). Neurons related to reaching-grasping arm movements in the rostral part of area 6. *Experimental Brain Research, 82*, 337-350.

Rizzolatti, G. C., L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience, 27*, 169 - 192.

Rizzolatti, G. C., R., Fogassi, L., Gentilucci, M., Luppino, G. & Matelli, M. (1988). Functional organisation of inferior area 6 in the macaque monkey. *Experimental Brain Research, 71*, 491-507.

Ruby, P. D., J. (2004). How would you feel versus how do you think she would feel? A neuroimaging study of perspective-taking with social emotions. *Journal of Cognitive Neuroscience, 16*, 988-999.

Rutherford, M. D., Baron-Cohen, S. & Wheelwright, S. (2002). Reading the Mind in the Voice: A Study with Normal Adults and Adults with Asperger Syndrome and High Functioning Autism. *Journal of Autism and Developmental Disorders, 32*, 189-194.

Shonin, E., Van Gordon, W., Compare, A., Zangeneh, M. & Griffiths, M.D. (2015). Buddhist-derived loving-kindness and compassion meditation for the treatment of psychopathology: A systematic review. *Mindfulness, 6*, 1161-1180.

Simon, J. S., A. (1969). Processing Auditory Information: Interference From An Irrelevant Cue. *Journal of Applied Psychology, 53*, 433-435.

Simpson, J. A. (1990). Influence of attachment styles on romantic relationships. *Journal of Personality and Social Psychology, 59*(5), 971-980.

Singal, J. D., M. (2016). Here is Amy Cuddy's Response to Critiques of Her Power-Posing Research. Retrieved from https://www.thecut.com/2016/09/read-amy-cuddys-response-to-power-posing-critiques.html

Singer, T. (2012). The past, present and future of social neuroscience: A European perspective. *NeuroImage, 61*, 437-449.

Singer, T., Critchley, H., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences, 13*(8), 334-340.

Singer, T., & Lamm, C. (2009). The Social Neuroscience of Empathy. *Year in Cognitive Neuroscience 2009, 1156*, 81-96. doi:10.1111/j.1749-6632.2009.04418.x

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J. & Frith, C.D. (2004). Empathy for pain involves the affective but not the sensory components of pain. *Science, 303*, 1157-1162.

Sobolewski, A., Holt, E., Kublik, E., & Wrobel, A. (2011). Impact of meditation on emotional processing-A visual ERP study. *Neuroscience Research, 71*(1), 44-48. doi:10.1016/j.neures.2011.06.002

Spencer, H. (1855). *The Principles of Psychology*. London: Longman, Brown, Green and Longmans.

Stotland, E. (1969). *Exploritory investigations of empathy* (Vol. 4). New York: Academic Press.

Sur., S. S., V. (2009). Event-related potential: An overview. *Industrial Psychiatry Journal, 18*, 70-73.

Taylor, N. S., T. (2005). Empathy and attitudes to animals. *Anthrozoos, 18*, 18-27.

Titchener, E. (1909). *Experimental psychology of the thought processes.*: Macmillan.

Wesson, D. W. M., M.Y. (2006). Stacking anabolic androgic steroids (AAS) during puberty in rats: a neuroendocrine and behavioura assessment. *Pharmacology, Biochemistry and Behaviour, 83*, 410-419.

Wingfied, J. C. (1984). Androgens and mating systems: testosterone-induced polygyny in normally monogamous birds. *Auk, 101*, 665-671.

Wispe, L. (1986). The distinction between sympathy and empathy: To call forth a concept, a word is needed. *Journal of Personality and Social Psychology, 50*, 314 - 321.

Woodruff, C. C., Martin, T., & Bilyk, N. (2011). Differences in self- and other-induced Mu suppression are correlated with empathic abilities. *Brain Research, 1405*, 69-76. doi:10.1016/j.brainres.2011.05.046

Yang, C., Decety, J., Lee, S., Chen, C. & Cheng. Y. (2009). Gender differences in the mu rhythm during empathy for pain: An electroencephalagraphic study. *Brain Research, 1251*, 176-184.

Yap, A. J., Wazlawek, A. S., Lucas, B. J., Cuddy, A. J. C., & Carney, D. R. (2013). The Ergonomics of Dishonesty: The Effect of Incidental Posture on Stealing, Cheating, and Traffic Violations. *Psychological Science, 24*(11), 2281-2289. doi:10.1177/0956797613492425

Zahn-Waxler, C., Robinson, J. L. & Emde, R. N. (1992). The development of empathy in twins. *Developmental Psychology, 28*, 1038-1047.

Zilioli, S., Caldbick, E. & Watson, N.V. (2013). Testosterone reactivity to facial display of emotions in men and women. *Hormones and Behaviour, 65*, 461-468.

Zilioli, S., Ponzi, D., Henry, A. & Maestripieri, D. (2015). Testosterone, Cortisol and Empathy: Evidence for the Dual-Hormone Hypothesis. *Adaptive Human Behaviour and Psysiology, 1*, 421-433.