COMENIUS UNIVERSITY IN BRATISLAVA

FACULTY OF MATHEMATICS, PHYSICS AND INFORMATICS

VICARIOUS SENSORIMOTOR ACTIVATION AND DISPOSITIONAL EMPATHY

Master's Thesis

2019

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COMENIUS UNIVERSITY IN BRATISLAVA

FACULTY OF MATHEMATICS, PHYSICS AND INFORMATICS

VICARIOUS SENSORIMOTOR ACTIVATION AND DISPOSITIONAL EMPATHY

Master's Thesis

Study Programme: Cognitive Science

Field of Study: 2503 Cognitive Science

Department: Department of Applied Informatics

Supervisor: RNDr. Barbora Cimrová, PhD.

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2019

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THESIS ASSIGNMENT

Name and Surname: Mgr. Xenia-Daniela Poslon
Study programme: Cognitive Science (Single degree study, master II. deg., full time form)
Field of Study: Cognitive Science
Type of Thesis: Diploma Thesis
Language of Thesis: English
Secondary language: Slovak

Title: Vicarious Sensorimotor Activation and Dispositional Empathy

Annotation: Embodied approach to social cognition suggests that the central aspect to the understanding of others relies on the activation of neural structures involved in our own personally experienced actions, bodily states, and emotions. Vicarious sensorimotor resonance, i.e. brain activation resulting from observing other people's actions or sensations, is believed to contribute to the neural underpinnings of empathy. The aim of the thesis is to further explore the associations between the vicarious electroencephalography (EEG) brain oscillatory activity, resulting from resonant responses of sensorimotor cortex to the pain and touch of others, and empathy as a personality trait.

Aim: The thesis will assess the relationship between event-related desynchronization (ERD) and synchronization (ERS) of sensorimotor mu and beta rhythms with self-report measure of dispositional empathy.

Literature: Keysers, C., Kaas, J. H., & Gazzola, V. (2010). Somatosensation in social perception. Nature Reviews Neuroscience, 11(6), 417-428.
Riečanský, I., Paul, N., Kölble, S., Stieger, S., & Lamm, C. (2014). Beta oscillations reveal ethnicity ingroup bias in sensorimotor resonance to pain of others. Social cognitive and affective neuroscience, 10(7), 893-901.

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ZADANIE ZÁVEREČNEJ PRÁCE

Meno a priezvisko študenta: Mgr. Xenia-Daniela Poslon
Študijný program: kognitívna veda (Jednoodborové štúdium, magisterský II. st., denná forma)
Študijný odbor: kognitívna veda
Typ záverečnej práce: diplomová
Jazyk záverečnej práce: anglický
Sekundárny jazyk: slovenský

Názov: Vicarious Sensorimotor Activation and Dispositional Empathy
Sprostredkovaná senzorimotorická aktivácia a dispozičná empatia

Anotácia: Podľa zástancov ukotveného prístupu v sociálnej kognícii, základným aspektom, umožňujúcim porozumenie iným ľuďom, je aktivácia nervových štruktúr sprostredkúvajúcich aj naše vlastné prežívanie činností, pocitov a emócii. Predpokladá sa, že táto sprostredkovaná senzorimotorická aktivácia, t.j. mozgová aktivácia vznikajúca pri pozorovaní činností alebo pocitov iných ľudí, prispieva k neurálnym základom empatie. Cieľom tejto práce je preskúmať, či existuje súvislosť medzi empatiou, ako osobnostnou črtou, a medzi sprostredkovanými mozgovými osciláciami EEG, vznikajúcimi v dôsledku rezonančnej odpovede sensorimotorickej kôry pri pozorovaní dotyku a bolesti u iných ľudí.

Cieľ: Cieľom záverečnej práce je zanalyzovať vzťah medzi seba-výpoveďovou dispozičnou empatiou a na udalosť viazanou (event-related) desynchronizáciou (ERD) a synchronizáciou (ERS) senzorimotorických oscilácii mí a beta rytmu.

Literatúra:
Keysers, C., Kaas, J. H., & Gazzola, V. (2010). Somatosensation in social perception. Nature Reviews Neuroscience, 11(6), 417-428.
Riečanský, I., Paul, N., Kölble, S., Stieger, S., & Lamm, C. (2014). Beta oscillations reveal ethnicity ingroup bias in sensorimotor resonance to pain of others. Social cognitive and affective neuroscience, 10(7), 893-901.

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Dátum schválenia: 31.01.2017

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vedúci práce

Declaration

I hereby declare that I elaborated this diploma thesis independently using the cited literature.

Bratislava, 2019

Acknowledgment

I would like to express my endless gratitude to my supervisor, RNDr. Barbora Cimrová, PhD., not only for her counsel concerning the present thesis, but also for her continuous support and mentoring throughout my entire journey in the world of cognitive science. I would also like to thank my consultant, MUDr. Igor Riečanský, PhD., for giving me an opportunity to be a part of this bigger research project, and his close guidance thought the past year. Finally, I owe thanks to all the people at the University of Vienna that have contributed to this project in the past.

ABSTRACT

Embodied approach to social cognition suggests that the central aspect to the understanding of others relies on the activation of neural structures involved in our own personally experienced actions, bodily states, and emotions. Vicarious sensorimotor resonance, i.e. brain activation resulting from observing other people's actions or sensations, is believed to contribute to the neural underpinnings of empathy. Two electroencephalography (EEG) studies measuring resonant responses of sensorimotor cortex to the pain and touch of others were conducted to further explore the associations between the vicarious oscillatory activity and individual differences in empathy. The aim was to assess the relationship between event-related desynchronization (ERD) and synchronization (ERS) of sensorimotor mu and beta rhythms and behavioral measures of dispositional empathy. In study 1, participants (N = 37) observed videos showing hands being either penetrated with needle or touched with a cotton swab. The stimuli were presented on a monitor placed in front of the participants. In study 2 (N = 30), identical stimuli were used, but were presented horizontally on a monitor placed over the participant's hand, in order to increase bodily self-attribution of the target hand. In both studies, participants filled out the Interpersonal Reactivity Index (IRI) questionnaire, measuring four dimensions of empathy: Perspective Taking, Fantasy scale, Empathic Concern, and Personal Distress. Event-related spectral power modulation (ERD/ERS) was assessed for each subject within the frequency bands of 7-12 Hz (mu) and 13-30 Hz (beta) over sensorimotor cortex. The results showed significant mu and beta ERD following the perception of stimuli. Even though studies involved different setup, we didn't find any statistically significant differences in the perception of stimuli between these two conditions. Finally, we observed weak associations between certain IRI subscales and mu and beta ERD evoked with the perception of painful hand treatment. Mu ERD was predicted by the participants' self-reported tendency to experience distress when witnessing the suffering of others, while individuals with higher tendency to feel empathic concern for others also showed stronger beta ERD. Possible interpretation of these results is discussed, as well as several directions for future research.

Keywords: empathy, pain, sensorimotor response, personality

ABSTRAKT

Podľa zástancov ukotveného prístupu v sociálnej kognícii, základným aspektom, umožňujúcim porozumenie iným ľuďom, je aktivácia nervových štruktúr sprostredkúvajúcich aj naše vlastné prežívanie činností, pocitov a emócii. Predpokladá sa, že táto sprostredkovaná senzorimotorická aktivácia, t.j. mozgová aktivita vznikajúca pri pozorovaní činností alebo pocitov iných ľudí, prispieva k neurálnym základom empatie. Cieľom práce bolo preskúmať, či existuje súvislosť medzi osobnostnými rozdielmi v empatii a medzi sprostredkovanými mozgovými osciláciami EEG. Do analýzy boli začlenené dáta z dvoch EEG experimentov, zameraných na oscilácie vznikajúce v dôsledku rezonančnej odpovede sensorimotorickej kôry pri pozorovaní dotyku a bolesti u iných ľudí. V prvom experimente, participanti (N = 37) pozorovali videá statických rúk, ktorých sa buď dotkla vatová tyčinka (nebolestivá podmienka) alebo boli pichnuté ihlou (bolestivá podmienka). Tieto podnety boli prezentované štandardne, na obrazovke, ktorá sa nachádzala na stole pred participantmi. V druhom experimente (N = 30) boli použité rovnaké podnety, ale tentokrát boli zobrazené na obrazovke, ktorá sa nachádzala v horizontálnej polohe, nad rukou participanta. Participanti v obidvoch podmienkach vyplnili škálu interpersonálnej reaktivity, merajúcu štyri dimenzie empatie: preberanie perspektívy, empatický záujem, osobná nepohoda, a fantázia. Pre každého participanta bola vypočítaná spektrálna analýza EEG signálu (ERD/ERS) nad senzorimotorickou kôrou, v rámci frekvenčných pásiem 7-12 Hz (mí) a 13-30 Hz (beta). Výsledky ukázali signifikantnú mí a beta desynchronizáciu vznikajúcu v dôsledku percepcie podnetov. Napriek tomu, že v rámci experimentov bolo použité iné nastavenie podnetov, medzi nimi sme nenašli žiadne štatisticky významné rozdiely vo vnímaní podnetov. V poslednom rade, výsledky ukázali slabé asociácie medzi určitými dimenziami dispozičnej empatie a medzi mí a beta desynchronizáciou vyvolanou percepciou bolesti. Mí desynchronizácia bola predikovaná individuálnou tendenciou prežívať nepohodu pri pozorovaní utrpenia iných. Na druhej strane, participanti s vyššou tendenciou prežívať empatický záujem o iných, tiež preukázali silnejšiu beta desynchronizáciu. V závere práce diskutujeme možné interpretácie týchto výsledkov a poskytujeme návrhy a pripomienky pre budúci výskum v tejto oblasti.

Kľúčové slová: empatia, bolesť, sensorimotorická aktivácia

Contents

Introduction

"Not even one's own pain weighs so heavy as the pain one feels with someone, for someone, a pain intensified by the imagination and prolonged by a hundred echoes."

― Milan Kundera, The Unbearable Lightness of Being

How do we know what other people around us think and feel? As I am writing this text, I imagine what it would be like for a reader to read these lines. This ability helps me express my thoughts so that they are understood by the reader just the way I intend them to be understood. Yet, this is just a minor example of this impressive ability our mind is capable of. On everyday basis, we meet and interact with other humans on this planet, we do so effortlessly and, in most cases, quite successfully. How is that so?

This question has troubled many philosophers and psychologists over the years, but recently, it has caught the attention of neuroscientists. There have traditionally been two approaches that attempted to explain our 'mind-reading' abilities: theory-theory and simulation theory (Apperly, 2008). According to theory-theory, people use 'lay' theories when inferring on other's mental states, theories that provide us with information about general way that people usually think and feel. To the contrary, simulation theory proponents believe that we understand the internal states of others by simulating actions, states and feelings using our own mental apparatus. Recent advances in social neuroscience have supported the idea behind simulation theory and inspired the embodied approach to social cognition[1] (Gallese & Sinigaglia, 2011).

[1] Embodied cognition – "according to its advocates in philosophy of mind and cognitive neuroscience, this notion usually means that many features of cognition are causally or even constitutively related to the physical body and the bodily actions of an agent" (Gallese & Sinigaglia, 2011, p. 512)

In the present thesis, we aim to explore the neural correlates of our empathic abilities. We will focus on the sensorimotor resonance in our brain that is elicited when observing other people in pain, and we will examine how it might be related to individual differences in empathic reactivity. We will try to do so through the lens of interdisciplinarity. Empathy research is not strictly limited to clinical and developmental psychologists anymore – today it also spurs the attention of social and personality psychologists, cognitive psychologists, philosophers and cognitive-affective neuroscientists, making way to a truly interdisciplinary study (Ickes & Decety, 2009).

In the following section, we will first review and discuss about the various concepts related to empathy, that have sometimes been used synonymously not just in public discourse, but in scientific literature as well. Secondly, we will introduce the shared network hypothesis of social cognition and focus more closely on neural correlates of empathy for pain. Finally, we will present the research aim, hypotheses, and research questions that have guided the present study.

1.1 Empathy: A Quest for an Inclusive Definition

Half a century before the term 'empathy' was coined, Walt Whitman wrote: "I do not ask the wounded person how he feels, I myself become the wounded person" (*Song of Myself*, 1855/1965, p. 159). Even though the concept was far from novel, and poets had written about it for centuries before, the terminology itself surprisingly originated in art, entering the modern lexicon as late as the beginning of the twentieth century. Striving to make sense of why art moves us, the word 'empathy' was first used to capture the act of projecting oneself into a work of art. Lipps described this state in 1903 using the German term 'Einfühlung', which was later translated by Tichener in 1909 into the expression we widely use today – 'empathy' (as cited in Batson, 2009).

Despite the fact that this phenomenon has been studied for decades, there is no agreement yet in the research community what the term ‘empathy’ stands for. Many different authors use it in various ways - sometimes as an umbrella term for both the ‘affective’ component of experiencing another’s person emotion and feelings of sympathy or concern for the other, or on the other hand, what some might understand as more ‘cognitive’ components – inferring on what others think and feel, the ability to take perspective of others, having theory of mind, or mentalizing. As Singer and Lamm (2009) note, “there are almost as many definitions of empathy as there are researchers in the field” (p. 82).

However, thanks to the recent higher interest of scholars in this phenomenon, there have finally been some efforts to distinguish among the various states that contribute to the experience of empathy. In order to fully understand and study this concept, we need to reflect on the range of different meanings it has been given so far. For this reason, Batson (2009) tried to map and describe all the conceptually distinct phenomena that have been previously labelled as empathy. According to him, the quest for a definition of empathy can be narrowed down to two main questions: how can people know what other people are thinking and feeling, and how this knowledge (or these feelings) drive a person to respond ‘prosocially’[2] to another human being?

In order to answer these questions, Batson made a review of eight different “things called empathy”. The first concept he describes is the *1) knowledge of another person’s internal state*, such as his thoughts and feelings. Some authors have defined this as ‘cognitive empathy’, ‘empathic inference’, ‘theory of mind’ or ‘mentalizing’ (Ickes, 2009). Regarding this ability, Ickes has introduced the term ‘empathic accuracy’, referring to the level of success one has in inferring on what others think and how do they feel. The several following concepts could be also considered as a general ability of perspective taking, even though Batson makes a clear distinction between them: *2) imaging what is another thinking or feeling* (as opposed to

[2] Prosocial (adjective) – “Relating to or denoting behaviour which is positive, helpful, and intended to promote social acceptance and friendship.” (English Oxford Dictionary, 2018)

knowing), *3) projecting oneself into another's situation*, and *4) imaging how one would think and feel in the other's place*.

Another concept that is often assumed to be related to empathy, and is central to the focus of our study, is *5) the matching neural responses* of observer and the observed person, in terms of motor mimicry or imitation. Hatfield et al. (1993) define mimicry as the tendency to automatically synchronize one's movements with the facial expressions, vocalizations, postures, and movements with those of another person.

In this sense, Batson refers to one of the frequently cited theories in this field – Preston and de Waal's (2002) fairly comprehensive model of empathy. According to these authors, the various approaches to empathy and their distinctions "have been overemphasized to the point of distraction" (p.2), and in order to unify these approaches, the concept needs to be reinterpreted more broadly. They proposed a theory that views empathy as a superordinate category, consisting of subclasses of all the phenomena that are (allegedly) based on the same mechanism and cannot be separated from one another, such as sympathy, emotional contagion, helping behaviour, etc. Their theory is based on the Perception-Action Model (PAM), according to which, observing another person automatically results in matching the other's neural state. Since perception and action rely on some of the same neural circuits, thanks to activated matching neural representation, one can understand the other's internal state by feeling what the other feels. However, when considering the ability of 'knowing' what others think and feel, this model seems to underestimate the role of memory and declarative knowledge, a critique which was pointed out by several authors (Batson, 2009; Singer et al. 2004).

On the other hand, Batson emphasizes that matched perceptual neural representations do not necessarily lead to feelings. For this reason, he differentiates between matching neural responses (concept 5) and *6) feeling the same emotion as the other person feels.* Some authors refer to this tendency as 'emotional contagion' (Hatfield, Rapson & Le, 2009). However, there is no consensus on how much the emotion of the observer needs to be matched with the observed emotion – whether it should be identical or just similar to a certain level (and considering there would be considerable difficulties in determining whether the emotion is similar enough). One could certainly attempt to measure this with the magnitude of the physiological response, but physiological matching still doesn't testify whether the observer's response does not evoke qualitatively different emotion.

One of the most famous studies in early development of empathy aimed to elicit emotional contagion in newly born babies (Sagi & Hoffman, 1976). They exposed babies with recorded sound of another baby crying. Compared to the young participants presented with sounds of an artificial nonhuman cry, or with no sounds, babies that heard authentic new-born cry tended to cry significantly more. Even though many authors interpret this as evidence for our innate empathic distress reaction, Batson (2009) argues that there are many alternative, more probable explanations, such as the fact that the infants might have cried in reaction to hearing another infant cry in order to attract the mother's attention to themselves.

Yet another concept similar to this phenomenon is *7) feeling distress when observing another person's suffering*, what some authors define as 'personal distress' (e.g. Davis, 1983). Batson highlights that this state is qualitatively different than feeling distressed *as the other* (related to the concept 6) or feeling distressed *for the other* (concept 8, below); it should rather be labelled as feeling distressed *by the other*. However, we are once more faced with a challenge: if, hypothetically, matching neural or some other physiological response from perceiving another's suffering elicits personal distress, should this type of distress be considered as an aspect of empathy at all? Or rather as a consequence of experiencing empathy? In our view, a person might be 'selfishly' distressed when witnessing another's pain without experiencing empathy. For instance, personal distress could be a result of panic from the mere sight of the blood. For this reason, Singer and Lamm (2009) argue that empathy essentially depends upon self-other distinction – having awareness of whether the source was triggered by the other, or simply lies within ourselves. According to them, personal distress is purely self-centred response. In the same line of reasoning, they suggest that neither mimicry, not emotional contagion, are sufficient or necessary for the experience of empathy as full-blown emotion.

The final concept reviewed by Batson is *8) 'feeling for' another person who is suffering*. This concept is the one most related to the phenomena often confused in general public (and sometimes even scientific literature) with the term empathy – that is, 'sympathy' or 'compassion'. Davis (1983) defines this state as other-oriented feelings of concern for the other and labels it as 'emphatic concern'. Once more, Singer and Lamm (2009) argue that, due to the fact that the experience of sympathy is oriented to the other, it should be considered as a distinct phenomenon. In their view, affective sharing is necessary for the experience of empathy ('feeling with' compared to 'feeling for').

Coming back to the two questions mentioned at the beginning, personal distress and empathic concern are the only two phenomena out of those reviewed that are not direct sources of our understanding what others think and feel. They explicitly provide an answer to the second question – what motivates humans to act with the aim to relieve the other person of their suffering? There is general agreement among researchers that personal distress, as unpleasant experience, leads to avoidance, while feeling empathic concern motivates us to relieve others from their suffering (Batson, 2009).

It is important to note that there is one more phenomenon that Batson doesn't include in his review, but it's sometimes considered in the empathy literature. It is the tendency to imaginatively transpose oneself into fictional situations in books, movies, or plays, by identifying strongly with their characters. Interestingly, Davis (1983) considers this state as one of the four aspects of individual differences in empathy, and it is also central to the Fantasy-Empathy (FE) Scale of Stotland et al. (1978). This concept might be partly related to projecting oneself into another's situation, as described by Batson.

In this section, we've provided a brief review of some of concepts related to empathy. To sum up, when studying empathy, it is important to keep all of these key concepts in mind and, as researchers, we need to make clear which phenomenon (or phenomena) we are focusing on. Additionally, even though each of these concepts refers to a different psychological phenomenon, and they most likely have different neural paths, we need to be aware that they most frequently occur simultaneously, or at least consecutively. For example, motor mimicry may give help us understand what the other is thinking or feeling, and this knowledge may motivate us to act with sympathy or compassion towards the other. For this reason, studying empathy remains a challenge for scholars. We need to seek to understand how these different phenomena relate to each other as well.

Since the aim of our work is to examine empathy from the lens of social neuroscience, we will adopt the definition of empathy most often cited in this field: “We “empathize” with others when we have (1) an affective state (2) which is isomorphic to another person’s affective state, (3) which was elicited by observing or imagining another person’s affective state, and (4) when we know that the other person’s affective state is the source of our own affective state” (De Vignemont & Singer, 2006, p. 435).

In the next part, we will introduce the shared representations hypothesis central to the embodied cognition approach and fundamental for our research aim.

1.2 Empathy as Shared Representations

The shared network hypothesis was inspired by recent neuroscientific findings, and it is currently considered to be the dominant approach in social cognitive neuroscience. The central to this theory is the idea that “we come to understand the actions, sensations, and emotions of others by the activation of neural representations corresponding to those states” (Singer & Lamm, 2009, p. 84). This hypothesis has encouraged many authors to claim that the root of our social interaction lies in our capacity to take another person’s perspective by simulating their mental activity using our own mental apparatus (e.g. Keysers & Gazzola, 2006).

This is consistent with the simulation theory as explanation to our social cognition, which suggests that people simulate perceptions and actions with their sensory and motor systems without actually moving, but simply by observing or imagining somebody else executing movement or experiencing certain sensations. One of the models supporting this theory is also

Preston and de Waal's Perception Action Model (2002), according to which, when one observes or imagines another person in a particular state, it automatically activates one's neural representation of that state.

The two major neuroscientific streams supporting this idea were based on the discovery of mirror neurons and the succeeding compelling evidence brought by studies investigating empathy for pain. In the following part, we will introduce and review evidence for the existence of mirror neuron system in humans.

1.2.1 The Mirror Neuron System

Mirror neurons were initially discovered in monkey's ventral premotor cortex, known as F5 area. These neurons were found to discharge both when macaque monkeys perform an action and when they observe a similar action made by someone else (Rizzolatti et al. 1996). It was already known that these neurons discharge selectively during goal-related hand movements such as grasping, holding, or manipulating, however, Rizzolatti et al. (1996) found that a special subset of these neurons discharge when the monkey observes meaningful hand movements made by the experimenter, thus naming them "mirror" neurons. The neurons fired when an experimenter manipulated objects, for example placed or took away objects from a table, or grasped food from another experimenter. The authors suggested that F5 area in monkeys consists of observation/execution matching system - when the monkey observes a motor action that is similar to its movement repertoire, the action is automatically retrieved, either executed, or only represented in the motor system.

Moreover, Ferrari et al. (2003) showed the mirror responses of F5 neurons that motorically coded mouth actions. The neurons became active during the execution and observation of mouth actions related to ingestive functions (grasping, sucking or breaking food), but they were mostly triggered by the communicative mouth gestures, such as lip smacking, while several also fired when monkeys made communicative gestures. These findings inspired the idea that this system is involved in communicative functions in primates.

Initial experiments supported the hypothesis that the mirror neuron system exists in humans as well (Fadiga et al. 1995). Fadiga and collaborators (1995) found that during the observation of various actions, a selective increase of motor evoked potentials occurred in the muscles that the subjects usually use for producing them. Moreover, it has been hypothesized that Broca's area is responsible for this system in humans. This area is typically associated with human speech production, but some authors believe that it's homologous to the monkey's F5 area (e.g. Rizzolatti et al. 1996; Nishitani et al. 2005). Later neurophysiological and brain imaging studies provided more evidence that the mirror neuron system might present in humans (see Fabbri-Destro & Rizzolatti, 2008).

Since then, there has been a great number of studies driven by these initial findings. The growing empirical support inspired scholars to extend this notion to primate's mind-reading abilities – theory of mind. Several authors argue that our capacity to understand other people's mental states evolved from this execution/observation matching system (e.g. Gallese & Goldman, 1998). There is also evidence that children with autism spectrum disorder lack this ability (e.g. Baron-Cohen et al. 1985). Hence, the excitement from the discovery of the mirror neurons initiated many assumptions about its possible role in action understanding, imitation, theory of mind, empathy, autism, and communication (see Rizzolatti & Fabbri-Destro, 2010).

Naturally, the theory about the existence of this system in humans and its many newly assigned functions didn't go unnoticed by the critics. For example, Dinstein et al. (2008) expressed concern with the lack of ability to assess movement selectivity in the studies conducted on human subjects. They concluded that "the study of mirror neurons and the 'human mirror system' in particular has been characterized by much speculation and relatively little hard evidence" (p. 18). Hard evidence is particularly hard to obtain in this case, single cell recordings are still impossible in healthy individuals. Borg (2007), on the other hand, argued that the theory comes in a disguised form of *behaviorism*, since it states that a "specific intention (and attributing it to others) is a matter of one's motor system being disposed to fire in a specific way" (p. 17).

However, the criticism didn't discourage scientists to hypothesize about the importance of the mirror neuron system. Ramachandran (2000) went as far as describing the mirror neurons as "the driving force behind the great leap forward in human evolution" (p. 7).

1.2.2 Empathy for Pain

Interestingly, years before the discovery of mirror neurons in monkeys, researchers found that electroencephalogram (EEG) mu oscillations were supressed when people observe, execute, or imagine a movement (Gastaut & Bert, 1954). Later results from fMRI studies also indicated that similar brain regions are activated in action execution and observation (e.g., Keysers & Gazzola, 2009), however they are not homologous to the mirror neuron regions in the macaque brain (Keysers et al., 2013).

Observation of pain is a common model paradigm in social cognitive neuroscience research. The reason for using pain in eliciting empathic responses is because it is quite easily manipulated and was proven to lead to fruitful results (e.g. Decety & Lamm, 2006; de Vignemont & Singer, 2006; Singer & Leiberg, 2009). On the other hand, the neural correlates of pain are already relatively well understood (McCall & Singer, 2013), making it easier to interpret brain imagining results. The majority of these studies have shown that observing pain activates part of the neural network that is typically activated when we experience pain ourselves, therefore supporting the shared network hypothesis.

There are two different methods that researchers use to manipulate and elicit empathy for pain, known as picture-based and cue-based stimuli (McCall & Singer, 2013). Picture-based method uses the observation of images or videos to evoke empathic responses. For example, participants may observe a video of needle penetrating a hand (Avenanti et al., 2010), or an image of a face expression of an individual experiencing pain (Saarela et al.,2006). On the other hand, cue-based stimuli use observation of actual people going through a painful experience, thus increasing their ecological validity. In one such fMRI study, Signer et al. (2004) measured brain activity while participants experienced a painful stimulus themselves and compared it to the one elicited when they received a signal indicating that their partner was experiencing a similar pain stimulus. They showed that part of the neural network associated with affective qualities of pain contributed to mediating empathy, but not the one associated with sensory qualities.

This initial finding supported the idea that some parts of the brain regions known as pain matrix (Derbyshire 2000), typically involved in the firsthand experience of pain, are also activated when participants experience empathy for pain. The pain matrix consists of anterior cingulate cortex, the thalamus, the insula, and the primary somatosensory cortex. Recently, new evidence has emerged showing that when we observe someone else experiencing pain, brain areas associated with somatosensory processing can also become activated (Bufalari & Ionta, 2013). In one electroencephalography (EEG) study, the amplitude of even-related potential (ERP) P45, typically occurring in primary somatosensory cortex, was modulated by observing a needle penetrating another person's hand (Bufalari et al., 2007). This finding was supported by an fMRI study, which found activation in primary somatosensory cortex after participants witnessed of another person's painful hand treatment (Lamm & Decety, 2008).

However, these findings should be treated with caution. Even though brain imagining methods provide exciting evidence, most of the non-invasive neuroscientific measures are indirect and correlative, which means that the measured brain activity might have simply occurred simultaneously with the processing of empathy (Lamm & Majdandžić, 2015). Additionally, given the low spatial resolution of fMRI we cannot deduce that the exact same neurons are firing.

Nevertheless, taken all into consideration, empathy for pain seems to be a useful paradigm in measuring empathic brain responses. For this reason, in our study we decided to employ this method to measure EEG oscillations associated with empathy. The following section briefly introduces our experimental design and the aim of the study.

1.3 Research Aim

Previous research has shown that observation of pain activates the similar parts of the brain that are typically associated when experiencing pain first-hand. This effect was also observed in somatosensory cortices, when the painful treatment is directed at the somatosensory aspects of the painful experience (Bufalari & Ionta, 2013). The aim of the present thesis was to further examine vicarious[3] sensorimotor activation associate with witnessing another person's painful hand treatment. Two experiments were conducted in which participants observed videos of hand being either pierced with a needle or touched with a cotton swab, while their brain activity was measured with electroencephalography (EEG). The experiments differed in the experimental setup of the stimuli: in the conventional setup, participants observed stimuli on the monitor in front of them, while in the overlap setup, their hand was placed under the monitor in order to stimulate a variation of a rubber hand illusion (RHI; Botvinick & Cohen, 1998), aimed to increase bodily hand attribution of the target hand.

Our analysis focused on event-related spectral power modulation (synchronization and desynchronization) of mu (7 – 12 Hz) and beta (13 – 30 Hz) rhythms. Mu and beta frequencies are spontaneous rhythmic oscillations, typically occurring over sensorimotor cortex and modulated in a response to somatosensory and motor processing (Niedermeyer, 2005). They are known to occur at the onset of stimulation involving somatosensory processing as well as during both imagination and execution of movements. Avanzini et al. (2012) showed that modulation of sensorimotor mu and beta rhythms is also associated when participants experience somatosensory stimulation or movements vicariously. In terms of empathy for pain,

[3] Vicarious (adjective) – "Felt or experienced by watching or reading about someone else doing something, rather than by doing it yourself" (English Oxford Dictionary, 2018).

Perry et al. (2010) observed that mu and beta suppression was elicited when participants observed pictures of painful hand treatment.

We were also interested to assess the neural correlates of empathy as a personality trait. In previous research, there were several studies reporting correlation of the empathic response in the brain with individual differences in empathy. For example, Jabbi et al. (2007) showed that brain acitivty in anterior insular cortex was positively correlated with self-reported empathy. Additionally, Singer et al. (2004) found significant association between the activation level in the ACC and the left insula resulting from empathy for pain and the participants' self-reported tendency to experience empathic concern (measured by IRI scale, Davis, 1980). However, the evidence on the relationship between anatomical and functional features of empathy is still quite limited (Bufalari & Ionta, 2013).

1.3.1 Hypotheses

H1: We assume that mu and beta event-related desynchronization will be significantly stronger in Study 2 (overlap condition), compared to the Study 1 (conventional condition), due to the manipulation that is expected to increase bodily hand attribution.

H2: We assume that the perception of stimuli will result in significantly increased mu and beta event-related desynchronization, compared to the baseline pre-stimulus period.

H3: We assume that there will be increased mu and beta event-related desynchronization when participants observe painful hand treatment, compared to the non-painful one. (Perry et al. 2010)

1.3.2 Research Questions

RQ1: Is there a relationship between mu and beta event-related desynchronization and dispositional empathy?

> *RQ1.1:* Is there a relationship between mu and beta event-related desynchronization and Emotional Concern scale?
>
> *RQ1.2:* Is there a relationship between mu and beta event-related desynchronization and Perspective Taking scale?
>
> *RQ1.3:* Is there a relationship between mu and beta event-related desynchronization and Personal Distress scale?
>
> *RQ1.4:* Is there a relationship between mu and beta event-related desynchronization and Fantasy scale?

Methods

The present research is part of a bigger ongoing project at the Social, Cognitive and Affective Neuroscience Unit, Department of Basic Psychological Research and Research Methods, at the Faculty of Psychology, University of Vienna. Data used for the present thesis were collected in two separate experimental studies.

2.1 Research Sample

The studies were conducted in line with the ethical standards and each participant signed an informed consent before taking part in the experiment. Participants were made aware that their participation is voluntary and that they can withdraw from the experiment at any time. All participants received either course credit or monetary reward for study participation. The participants were right-handed and had normal or corrected-to-normal vision. None of the participants had a history of neurological or psychiatric disorders, traumatic head injury, irregular medication use, or abuse of psychotropic drugs.

Study 1 consisted of 69 participants, divided into the experimental and the control condition. In the main experimental condition, 37 individuals participated. Since one of the aims of the research was to examine ethnicity bias in empathy, participants in this condition observed naturalistic videos, consisting of Caucasian-white and African-black hands. As a control for ethnicity bias, 32 participants in the control condition observed violet colored versions of the same stimuli. Similarly, Study 2 consisted of 30 participants in the main experimental condition and 26 participants in the control condition, using the identical versions of the stimuli as Study 1. Considering that were not interested in ethnicity bias with respect to the aim of the present research, we used data only from the main experimental condition of both studies. The demographic data of the research sample selected for the present analysis is shown in the Table 1.

Table 1 – Demographic Data of the Participants

Group	No. of Participants	Age Range	Mean Age	Gender
Study 1	37	19 - 36	23.7	20F/17M
Study 2	30	20 - 39	24.5	16F/13M

2.2 Procedure and Data Collection

All participants were tested individually. The research was carried out in a darkened acoustically attenuated EEG recording room. The experiments consisted of collection of EEG data and the subsequent collection of questionnaire data. The participants performed all tasks in solitude and there was no direct or indirect observation by the experimenters, in order to avoid biasing participants' behavior in any way.

Participants were seated in a comfortable chair in front of a computer. In Study 1, the stimuli were presented on a monitor placed in front of the participants ("conventional setup"). The distance to the monitor was 1 m. In study 2, the stimuli were presented on a monitor placed over the participants' right hand ("overlap" setup) in order to increase bodily self-attribution of the target hand. This setup was inspired by a rubber hand illusion (RHI). In a typical RHI manipulation, watching a rubber hand being stroked synchronously with one's own unseen hand causes the rubber hand to be attributed to one's own body (Botvinick & Cohen, 1998). A previous pilot experiment showed that the bodily self-attribution was stronger in the overlap setup compared with the conventional setup. Apart from this manipulation, the two studies were identical in every other aspect. Therefore, we decided to use the data from both studies and treat them as independent experimental groups. From this point, we will refer to the Study 1 as the conventional setup condition, and the Study 2 as overlap setup condition.

2.3 Stimuli

Experiment stimuli consisted of short videos that were developed and provided by Avenanti et al. (2010). Stimuli were presented using E-Prime 2.0 (Psychology Software Tools, Inc., Sharpsburg, PA, USA). The videos depicted a right hand in a first-person perspective either penetrated by a needle syringe (pain condition) or touched by a cotton swab (no-pain condition). The conditions also differed in the ingroup/outgroup manipulation, presenting either a white or black hand (resulting in 4 different conditions: white/black, pain/no-pain). However, since the focus of the present research was not on the ethnicity bias, but on empathy in a broader sense, the data were pooled from both of these conditions. There were 240 trials in total (60 trials for each of the experimental conditions).

Figure 1 shows the sequence and the timing of stimuli within one trial. The duration of one trial was 4500 ms. The trial sequence began with a white fixation cross on black background (duration randomly varied between 1500 and 2000 ms), followed by an initial static display of a hand for a duration of 1500 ms. The static hand was followed by the video showing the dynamic hand treatment in terms of motion of a needle or a cotton swab, (duration = 1500 ms). After the needle or the cotton swab had reached their final position, a static display of this last frame of the video was shown for a duration of 1500 ms. Trials of stimuli presentation were grouped into 6 blocks of 40 trials each, with trials of all conditions randomized. Between these blocks, participants could take a break and continue with the experiment when ready. On average, the data collection lasted approximately 25 minutes.

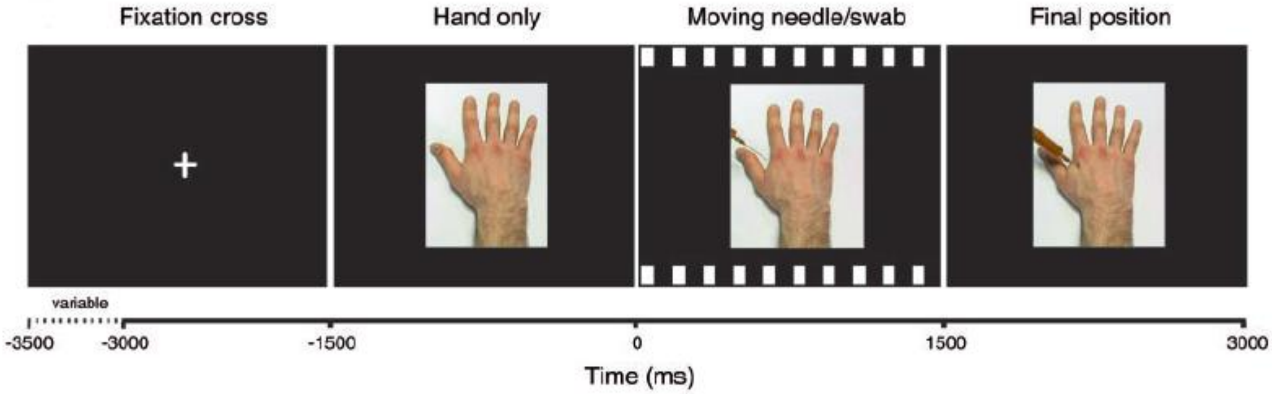

Figure 1 – Time sequence of the visual stimuli used in the experiments

There were several measures taken in order to avoid confounds. To minimize habituation, the color of the cotton swab and the size of the needle were randomized (colors of the cotton swabs used: white, light yellow, light blue; sizes of the needles used: small, medium, large). The hands were shown from a first-person (egocentric) perspective, in order to minimize the additional sensorimotor responses that would have likely been activated during spontaneous mental rotation (Kosslyn et al., 1998). The hand holding the needle or the cotton swab was not visible and the shown hands were fully static, since observing the movements performed by others also results in stronger activation of the sensorimotor cortex (Hari et al., 1998).

2.4 Measures of Dispositional Empathy

After the collection of EEG data, the participants were administered the German version of the Interpersonal Reactivity Index (IRI; Davis, 1980, 1983; Paulus, 2009), well established and frequently used measure of individual differences in empathy. According to Davis (1980, 1983), empathy consists of a set of separate but related constructs. The questionnaire contains four seven-item subscales, each measuring a separate aspect of empathy. The Perspective Taking (PT) scale measures the reported ability to spontaneously take the perspective of others and to see things from their point of view in everyday life (e.g. “Before criticizing somebody, I try to imagine how I would feel if I were in their place.”). The Empathic Concern (EC) scale is used to assess the tendency to experience other-oriented feelings of sympathy or compassion (e.g. “Other people's misfortunes do not usually disturb me a great deal.” – reversed). The Personal Distress (PD) scale refers to the tendency to experience distress or discomfort oneself when observing others in need (e.g. “When I see someone who badly needs help in an emergency, I go to pieces.”). The final, Fantasy Scale (FS) scale, measures the tendency to imaginatively transpose oneself into fictional situations and characters (“After seeing a play or movie, I have felt as though I were one of the characters.”). All items are measured on a 5-point Likert scale (Likert, 1932). See Appendix 1 for the original version of the questionnaire in English.

2.5 EEG Recording

Prior to the presentation of stimuli, the elastic EEG cap was placed on the participant’s head and the degassed electrode gel was applied with skin gently scratched to ensure the impedances of all individual electrodes were kept below 2 kΩ (tested by using an impedance meter f.Zickler GmbH, Pfaffstätten, Austria). Data were recorded from 59 equidistantly positioned silver/silver chloride (Ag/AgCl) electrodes according to the montage M10 (f. Easycap GmbH, Herrsching, Germany). The reference electrode for scalp potentials recording was placed over processus mastoideus on the right side (later digitally re-referenced to the linked mastoids on both sides). The ground electrode was located above the nasion. EEG was registered by using a Neuropax amplifier (f. Neuroconn, Ilmenau, Germany) in the range DC-600 Hz with a sampling frequency at 2000 Hz. In order to record eye blinks and eye movements, four periocular electrooculographic (EOG) electrodes were attached above and below the right eye and at the canthi of both eyes by using disposable sticky rings.

2.6 EEG Processing

EEG data were processed using the open source EEGLAB toolbox (Delorme and Makeig, 2004) under the commercial software MATLAB (The Mathworks, Massachussetts, MA, USA). The EEG signal was first down-sampled to 256 Hz and re-referenced to linked mastoids (an average from left and right mastoid reference). Next, it was digitally filtered in the range with a high-pass filter on 0.1 Hz and a low-pass filter on 80 Hz. Thorough visual inspection of the data was carried on in order to check the data for large artifacts and contaminated segments containing severe artifacts were rejected. Subsequently, an independent component analysis (ICA) was performed for each subject individually to detect components of clear separable artifactual sources, such as eye blinks, horizontal and vertical eye movements, muscle activity or electrocardiographic activity. Such components were removed from the data and only segments containing clear EEG signal continued to further analysis.

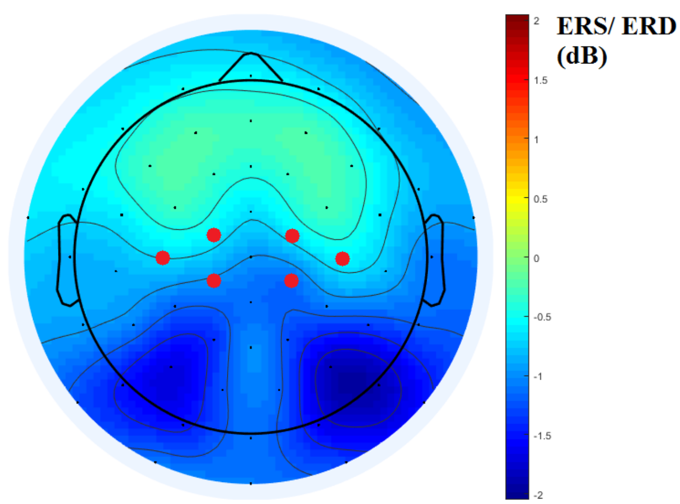

Figure 2 – Topographic map of mean beta ERD/ERS (dB) during observation of hand treatment in study 1. Highlighted are sensors overlying the sensorimotor cortex (FC1, C3, CP1; FC2, C4, CP2), which were selected for the analysis.

After data pre-processing, EEG signals were transformed to reference-free scalp current source density (CSD) using CSD toolbox (Kayser, 2009), which provides a MATLAB implementation of a spherical spline algorithm to compute current source density (CSD) estimates for surface potentials. Sensors overlying left and right sensorimotor cortex were selected as region of interest (ROI). Six channels over frontal, central and centro-parietal sites on both sides were chosen (Fig. 2). Even though the experimental design might have resulted in stronger ERD in the contralateral hemisphere, no such effects were found in the previous analyses of the Study 1 data (Riečanský et al., 2015). It was also noted previously that mu and beta ERD do not have to necessarily show lateralization during sensorimotor stimulation (Pfurtscheller, 1989; McFarland et al., 2000). Other studies reported a bilateral suppression following the observation of movement, with no significant difference between hemispheres (e,g, Muthukumaraswamy & Johnson, 2004; Avanzini et al., 2012). Therefore, we decided to use the data from both left and right sensorimotor cortex pooled.

Signals from selected channels were sequenced into epochs, starting from 500 ms prior to the onset of the initial visual stimuli (initial hand perception at time = - 2000 ms, see above Fig. 1) and ending with the termination of visual stimulation (time = 3000 ms, see above Fig. 1). Time-frequency decomposition of CSD was calculated on each epoch using fast Fourier transform (FFT) to a 500 ms wide Hanning-tappered window oversampled twice by using zero padding and moving over the signal in 500 evenly separated steps (Delorme & Makeig, 2004) for each trial separately. According to Delorme and Makeig (2004). Compared with wavelet analysis, FFT preserves equally good time resolution at all frequencies. Next, event-related spectral perturbation (i.e. power modulation) – synchronization (ERS) and desynchronization (ERD) was computed separately for each participant, experimental condition, time point, electrode and frequency.

2.7 Statistical Analysis

For the statistical analysis, we calculated mean ERD/ERS within the mu (7 – 12 Hz) and beta (13 – 30 Hz) frequency bands, averaged within ROI. In the conventional setup (Study 1), one participant's mean ERD/ERS value was found to be considerably different from the total sample distribution. This outlier was excluded from the subsequent statistical analysis. In the overlap setup (Study 2) one participant was similarly excluded from the sample due to excessive artifacts in the EEG recordings. The final sample thus consisted of 36 and 29 participants in each condition respectively. Other occasional outliers in within-subject variable (pain/ no-pain), including behavioral data, were winsorized (Dixon & Yuen, 1974), i.e. extreme values were limited to the observations above the 5th percentile and below the 95th percentile.

Statistical analyses were then performed by means of general linear model using IBM SPSS Statistics (using Type III Sum-of-squares method) and R package nlme (Pinheiro, Bates, DebRoy & Sarkar, 2018). Data visualization was performed using MATLAB and R code (package ggplot2, Wickham, 2016). Further description of statistical models will be discussed in the following Results section.

Results

3.1 Behavioural Data

Participants' self-reported dispositional empathy was measured by the Interpersonal Reactivity Index (IRI; Davis, 1980, 1983). Table 2 shows participants' mean scores for each IRI scale. Since empathy is considered to be a multidimensional psychological construct, according to Davis (1983) the subscales should be treated and analysed independently, not as a single empathy score. Participants' mean scores for the Empathic Concern subscale were slightly below average norm value (20.35, SD ± 4). Mean scores for the rest of the scales were within norm values (Davis, 1980).

Table 2 – Interpersonal Reactivity Index Subscale Mean Scores

		Empathic Concern	Perspective Taking	Personal Distress	Fantasy Scale
Study 1	Mean	15.36	15.09	12.19	14.46
	N	36	35	36	35
	Std. Deviation	1.659	2.254	2.436	2.241
Study 2	Mean	15.24	15.34	11.28	14.97
	N	29	29	29	29
	Std. Deviation	2.799	3.518	3.217	2.822
Total	Mean	15.31	15.20	11.78	14.69
	N	65	64	65	64
	Std. Deviation	2.222	2.874	2.826	2.513

When it comes to subscales intercorrelations (see Table 3), the results showed that there were significant positive relationships between Empathic Concern and Perspective Taking scales (r = .366, p = .003) and Empathic Concern and Fantasy scale (r = .245, p = .049).

Perspective Taking scale also showed significant positive relationship with the Fantasy scale ($r = .508$, $p < .001$).

Table 3 – Intercorrelations of the Interpersonal Reactivity Index Subscales

		Empathic Concern	Perspective Taking	Personal Distress	Fantasy Scale
Empathic Concern	Pearson Correlation	1	.366**	.232	.245*
	Sig. (2-tailed)		.003	.063	.049
	N	65	65	65	65
Perspective Taking	Pearson Correlation	.366**	1	-.114	.508**
	Sig. (2-tailed)	.003		.370	.000
	N	65	65	65	63
Personal Distress	Pearson Correlation	.232	-.114	1	.192
	Sig. (2-tailed)	.063	.370		.129
	N	65	65	65	65
Fantasy Scale	Pearson Correlation	.245*	.508**	.192	1
	Sig. (2-tailed)	.049	.000	.129	
	N	65	65	65	65

**. Correlation is significant at the 0.01 level (2-tailed).

3.2 EEG Data

We first assessed whether the experimental stimuli, i.e. perception of hand videos, modulated the sensorimotor mu and beta oscillations. Figure 3 shows grand mean event-related spectral power modulation (ERD/ERS) from all participants (data pooled from both studies: N = 65), averaged across both treatment conditions (pain/touch), across sensors overlying sensorimotor cortex. As highlighted in Fig. 3, the hand perception following the hand treatment elicited a prominent event-related desynchronization (ERD) of mu and beta rhythms. We observed a set of distinguishing EEG oscillatory changes over time. First prominent ERD occurred at the initial perception of hand prior to the beginning of treatment (time = –1500 ms), after which it gradually decreased in magnitude. ERD increased again when the participants observed the hand intervention with needle or cotton swab (time = 0 ms). The magnitude of ERD had changed once more after the needle or swab reached its final position (time = 1500 ms), gradually decreasing (decrease being slightly stronger in the beta than in the mu frequency band). At times – 1500 ms and 300 ms, upon the hand onset and the onset of the intervention, we can also notice event-related synchronization (ERS) of delta waves (0.5 – 3.5 Hz), supersimposed with theta (4 – 7 Hz) response. Delta and theta oscillatory responses are typically involved in perception and signal detection (Güntekin & Başar, 2016).

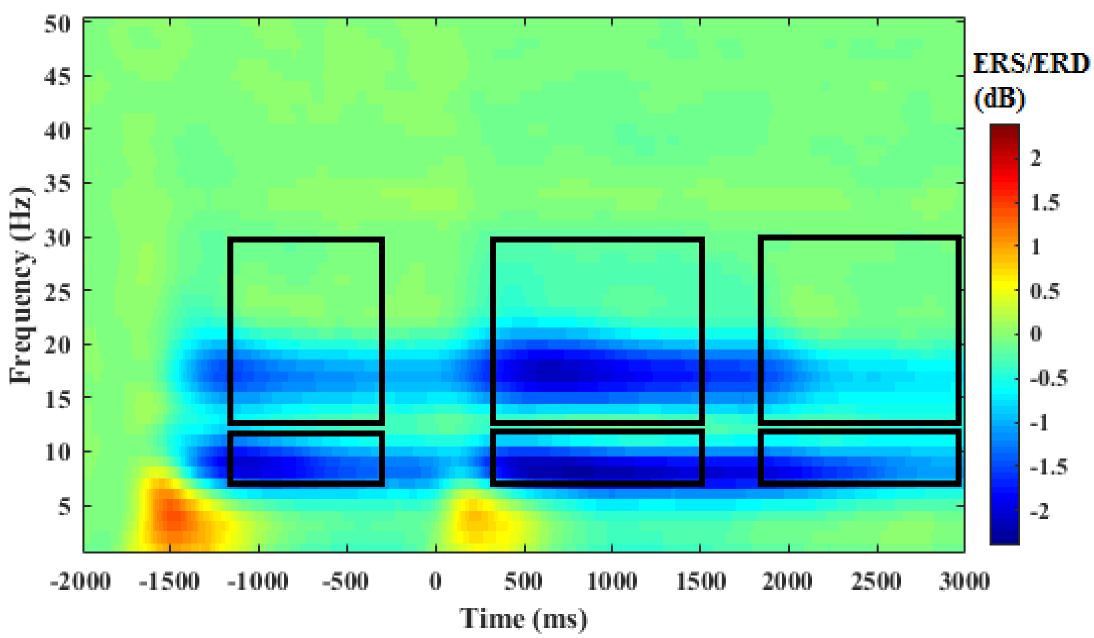

Figure 3 - Grand mean ERS/ERD from all subjects of both studies (N = 65), averaged across 6 sensors overlying sensorimotor cortex. Rectangles highlight the time windows chosen for the statistical analysis.

Given these patterns, we selected the following time windows for the statistical analysis: – 1200 ms to – 300 ms, to assess the effects of perception of the hand prior to the hand treatment; 300 ms to 1500 ms, to assess the effects of observing the dynamic hand treatment (pain or touch); and 1800 ms to 3000 ms, for the perception of hand treatment final static endpoint (Fig. 2). Mean ERD/ERS were separately calculated within these time windows for both frequency bands of interest (mu 7–12 Hz and beta 13–30 Hz), across sensors overlying sensorimotor cortex.

3.3 Difference Between the Two Setups: Conventional and Overlap

H1: We assume that mu and beta event-related desynchronization will be significantly stronger in Study 2 (overlap condition), compared to the Study 1 (conventional condition), due to the manipulation that is expected to increase bodily hand attribution.

To examine whether there were differences between the two experimental setups, we first ran the independent samples T-tests comparing each time window for each frequency band separately, irrespective of the hand treatment condition. Tables 4 and 5 show mean mu and beta ERD/ERS in all three time windows, across both conditions, respectively. Surprisingly, mean values of the overlap setup seem to show weaker both mu and beta ERD/ERS.

Table 4 – Mean Mu ERD/ERS (7-12 Hz)

Time Window	Condition	N	Mean	Std. Deviation
Initial Hand Perception	Conventional Setup	36	-1.436850	1.1197327
	Overlap Setup	29	-1.111359	.8365191
Hand Treatment	Conventional Setup	36	-1.311481	1.9301298
	Overlap Setup	29	-1.341041	1.1449970
Static Final Position	Conventional Setup	36	-1.071258	1.6081861
	Overlap Setup	29	-.907203	.7549035

Table 5 – Mean Beta ERD/ERS (13-30 Hz)

Time Window	Condition	N	Mean	Std. Deviation
Initial Hand Perception	Conventional Setup	36	-.519192	.5299572
	Overlap Setup	29	-.433110	.3411113
Hand Treatment	Conventional Setup	36	-.782042	.7067715
	Overlap Setup	29	-.745334	.4119860
Static Final Position	Conventional Setup	36	-.352825	.6000019
	Overlap Setup	29	-.320310	.3548931

However, the results of the independent T-tests showed that here were no statistically significant differences in the hand perception, movement perception, nor final static position perception between the two conditions (Tables 6 and 7). Therefore, the results did not confirm our hypothesis and the observed effect of weaker values in the overlap condition could have had probably occurred due to the sampling error.

Table 6 – Mu ERD/ERS (7-12 Hz) Independent Samples T-tests

Time Window	t	df	Sig. (2-tailed)
Initial Hand Perception	-1.3	63	.198
Hand Treatment	.077	58.342	.939
Static Final Position	-.542	51.911	.591

Table 7 – Beta ERD/ERS (13-30 Hz) Independent Samples T-tests

Time Window	t	df	Sig. (2-tailed)
Initial Hand Perception	-.792	60.316	.431
Hand Treatment	-.248	63	.805
Static Final Position	-.261	57.881	.795

3.4 Perception of Stimuli

H2: We assume that the perception of stimuli will result in significantly increased mu and beta event-related desynchronization, compared to the baseline pre-stimulus period.

Next, we were interested to see whether the perception of stimuli significantly modulated mu and beta event-related desynchronization. Tables 8 and 9 show mean mu and beta ERD/ERS in pre-stimulus baseline and all three time windows, in both conditions. As we can see from the tables 8 and 9, the perception of stimuli shows lower ERD values in both mu and beta frequency bands, indicating stronger oscillatory desynchronization.

Table 8 - Mean Mu ERD/ERS (7-12 Hz)

Condition		Pre-stimulus baseline	Initial Hand Perception	Hand Treatment	Static Final Position
Conventional Setup	Mean	-.058033	-1.436850	-1.311481	-1.071258
	N	36	36	36	36
	Std. D.	.2818301	1.1197327	1.9301298	1.6081861
Overlap Setup	Mean	.003983	-1.111359	-1.341041	-.907203
	N	29	29	29	29
	Std. D.	.1664817	.8365191	1.1449970	.7549035
Total	Mean	-.030365	-1.291631	-1.324669	-.998065
	N	65	65	65	65
	Std. D.	.2377568	1.0091618	1.6158955	1.2924546

Table 9 - Mean Beta ERD/ERS (13-30 Hz)

Condition		Pre-stimulus baseline	Initial Hand Perception	Hand Treatment	Static Final Position
Conventional Setup	Mean	-.052247	-.519192	-.782042	-.352825
	N	36	36	36	36
	Std. D.	.1164346	.5299572	.7067715	.6000019
Overlap Setup	Mean	-.066617	-.433110	-.745334	-.320310
	N	29	29	29	29
	Std. D.	.1006802	.3411113	.4119860	.3548931
Total	Mean	-.058658	-.480786	-.765665	-.338318
	N	65	65	65	65
	Std. D.	.1090896	.4542666	.5897240	.5022393

3.4.1 Perception of Hand Prior to the Hand Treatment

To confirm our observation that the initial perception of hand modulated sensorimotor mu and beta oscillations (compared with the pre-stimulus baseline period) and examine whether the modulation happened to be stronger in the overlap setup, we calculated mixed analysis of variance (mixed ANOVA) with the between-subject variable condition (conventional vs overlap). The statistical analysis confirmed that the perception of hands elicited a significant suppression of both mu ($F(1, 63) = 42.39$, $p < .001$, effect size: $\eta 2 = .15$) and beta frequency bands ($F(1, 63) = 125.795$, $p < .001$, effect size: $\eta 2 = .42$), compared with the baseline. However, the interaction between condition and the changes in both mu and beta oscillatory activity was non-significant ($p = .184$; $p = .224$, respectively).

3.4.2 Perception of the Hand Treatment

Similarly, perception of hand treatment (moving needle/cotton swab) elicited statistically significant decrease of mu ($F(1, 63) = 8.793$, $p = .004$, effect size: $\eta 2 = .04$) and beta rhythms ($F(1, 63) = 69.676$, $p < .001$, effect size: $\eta 2 = .31$), compared with the baseline. Similarly, we didn’t find a significant interaction between conditions and oscillatory modulation ($p = .978$; $p = .933$).

3.4.3 Perception of Static Final Position

As we have observed in the previous time windows, the perception of final static position has also showed a statistically significant suppression of both mu ($F(1, 63) = 19.071$, $p < .001$, effect size: $\eta 2 = .07$) and beta rhythms ($F(1, 63) = 40.277$, $p < .001$, effect size: $\eta 2 = .2$). Again, there were no statistically significant differences in the oscillatory decrease between the two conditions (mu: p = .467; beta: p = .704).

3.5 Difference Between Painful and Non-Painful Stimuli

H3: We assume that there will be increased mu and beta event-related desynchronization when participants observe painful hand treatment, compared to the non-painful one (touch).

We were also interested to see whether observation of pain elicited stronger oscillatory response compared to observation of touch. Since painful and non-painful stimuli were present in two time windows (hand treatment and final static position), we calculated the mean values from both time windows pooled. Tables 10 and 11 show mean mu and beta desynchronization in within-subject variable hand treatment across these two time windows. As we can see from the tables, observation of pain resulted in lower both mu and beta ERD values.

Table 10 – Mean Mu ERD/ERS (7-12 Hz) for Painful and Non-Painful Stimuli

Condition		Observation of Touch	Observation of Pain
Conventional Setup	Mean	-1.252136	-1.322797
	N	36	36
	Std. Deviation	1.7625931	2.0042280
Overlap Setup	Mean	-1.091521	-1.303876
	N	29	29
	Std. Deviation	.8758486	.9829499
Total	Mean	-1.180477	-1.314355
	N	65	65
	Std. Deviation	1.4286639	1.6185044

Table 11 – Mean Beta ERD/ERS (13-30 Hz) for Painful and Non-Painful Stimuli

Condition		Observation of Touch	Observation of Pain
Conventional Setup	Mean	-.596964	-.646878
	N	36	36
	Std. Deviation	.6168067	.7204766
Overlap Setup	Mean	-.536707	-.690797
	N	29	29
	Std. Deviation	.3796523	.4637318
Total	Mean	-.570080	-.666472
	N	65	65
	Std. Deviation	.5215645	.6151769

We calculated mixed ANOVA with the within-subject variable hand treatment (pain vs touch) and between-subject variable condition (conventional vs overlap), to see whether there was any difference between the conditions as well. The results confirmed that in both mu and beta frequency bands, observation of pain was followed by significantly stronger ERD (mu: $F(1, 63) = 18.463$, $p < .001$, effect size: $\eta 2 = .07$; beta: $F(1, 63) = 11.321$, $p = .001$, effect size: $\eta 2 = .003$). Even though the mean difference between painful and non-painful treatment was higher in the overlap condition, indicating that this type of manipulation might have elicited stronger empathic response, this interaction turned out to be statistically non-significant (mu: $p = .780$; beta: $p = .094$).

3.6 Relationships Between Vicarious Sensorimotor Activation and Dispositional Empathy

RQ1: Is there a relationship between mu and beta event-related desynchronization and dispositional empathy?

In order to examine the relationships between vicarious sensorimotor activation and self-reported individual measures in emphatic reactivity, we first analysed the two conditions separately.

For initial examination of the relationships between the selected variables, we ran correlational analyses. Since we were interested in the relationship between the empathic response and self-reported empathy, we checked for the variables that involved observation of needle penetration or touch with cotton swab: hand treatment time window and static final position (pain and touch pooled) and observation of pain and touch separately (averaged across both time windows).

3.6.1 Conventional Setup (Study 1)

Table 12 shows results of the correlational analysis of the relationship between mu ERD and IRI questionnaire subscales. The results indicate that there is a significant negative relationship between Personal Distress scale and mu ERD in the final static hand position window (r = -.337, p = .045), and both observation of pain and touch separately (r = -333, p = .047; r = -.348, p = .038), meaning that higher self-reported score of personal distress in emergency situations is associated with stronger mu desynchronization during observation of pain and touch.

Table 12 – Results of the Correlational Analysis (Mu ERD) – conventional setup

		Hand Treatment	Final Position	Observation of Pain	Observation of Touch
Empathic Concern	Pearson Correlation	-.154	-.280	-.219	-.244
	Sig. (2-tailed)	.370	.098	.199	.152
	N	36	36	36	36
Perspective Taking	Pearson Correlation	-.070	-.055	-.111	-.047
	Sig. (2-tailed)	.686	.750	.519	.787
	N	36	36	36	36
Personal Distress	Pearson Correlation	-.300	**-.337***	**-.333***	**-.348***
	Sig. (2-tailed)	.075	**.045**	**.047**	**.038**
	N	36	36	36	36
Fantasy Scale	Pearson Correlation	-.201	-.212	-.229	-.216
	Sig. (2-tailed)	.239	.213	.179	.207
	N	36	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The relationship between beta ERD and questionnaire scales is shown in the Table 13. The results showed significant inverse relationship between both selected time windows (*r* = -.372, *p* = .026; *r* = -392., *p* = .018) as well as observation of pain and touch separately (*r* = -.409, *p* = .013; *r* = -.347, *p* = .024) and participants' Empathic Concern scores. There was also significant negative correlation between observation of touch and Personal Distress scale (*r* = -.367, *p* = .028), but in the case of observation of pain the relationship was only marginal (*p* = .055). Finally, we found significant inverse relationship between the Fantasy Scale and hand treatment time window (*r* = -.366, *p* = .028) as well as observation of pain (*r* = -.338, *p* = .044), while the observation of touch showed only marginally significant correlation (*p* = .051).

Inverse correlations were expected since lower ERD values indicate stronger sensorimotor desynchronization. However, it's important to note that, in the case of both mu and beta frequency windows, most of the correlations above showed only weak to moderate effect.

Table 13 – Results of the Correlational Analysis (Beta ERD) – conventional setup

		Hand Treatment	Final Position	Observation of Pain	Observation of Touch
Empathic Concern	Pearson Correlation	**-.372***	**-.392***	**-.409***	**-.374***
	Sig. (2-tailed)	**.026**	**.018**	**.013**	**.024**
	N	36	36	36	36
Perspective Taking	Pearson Correlation	-.088	.035	-.064	-.039
	Sig. (2-tailed)	.609	.838	.711	.821
	N	36	36	36	36
Personal Distress	Pearson Correlation	-.301	-.320	-.322	**-.367***
	Sig. (2-tailed)	.074	.057	.055	**.028**
	N	36	36	36	36
Fantasy Scale	Pearson Correlation	**-.366***	-.258	**-.338***	-.328
	Sig. (2-tailed)	**.028**	.129	**.044**	.051
	N	36	36	36	36

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.6.2 Overlap Setup (Study 2)

Surprisingly, when we ran the correlational analyses with the selected variables from the overlap setup, we didn't find any significant relationships apart from one case: mean mu event related desynchronization in the final position time window showed significant negative relationship with Perspective Taking scale (r = -.391, p = .036). This finding is also unexpected since data from the conventional setup showed no relationships with this scale, and neither mu nor beta ERD. Tables 15 and 16 show the results of the correlational analysis for mu and beta frequency bands, respectively.

Table 15 – Results of the Correlational Analysis (Mu ERD) – overlap setup

		Hand Treatment	Final Position	Observation of Pain	Observation of Touch
Empathic Concern	Pearson Correlation	.058	-.109	.065	-.067
	Sig. (2-tailed)	.766	.575	.740	.729
	N	29	29	29	29
Perspective Taking	Pearson Correlation	-.223	**-.391***	-.254	-.325
	Sig. (2-tailed)	.245	**.036**	.183	.086
	N	29	29	29	29
Personal Distress	Pearson Correlation	.310	.219	.294	.260
	Sig. (2-tailed)	.102	.253	.121	.173
	N	29	29	29	29
Fantasy Scale	Pearson Correlation	-.218	-.330	-.262	-.276
	Sig. (2-tailed)	.255	.081	.169	.147
	N	29	29	29	29

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 16 – Results of the Correlational Analysis (Beta ERD) – overlap setup

		Hand Treatment	Static Final Position	Observation of Pain	Observation of Touch
Empathic Concern	Pearson Correlation	.108	.041	.156	.076
	Sig. (2-tailed)	.577	.834	.420	.694
	N	29	29	29	29
Perspective Taking	Pearson Correlation	-.177	-.206	-.241	-.162
	Sig. (2-tailed)	.359	.283	.208	.402
	N	29	29	29	29
Personal Distress	Pearson Correlation	.259	-.008	.146	.098
	Sig. (2-tailed)	.175	.968	.451	.612
	N	29	29	29	29
Fantasy Scale	Pearson Correlation	.042	-.110	-.058	-.039
	Sig. (2-tailed)	.829	.572	.767	.841
	N	29	29	29	29

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

3.7 Regression Analysis

To confirm our observation of the relationships between the selected variables, we ran the regression analysis with the data from conventional setup. We first calculated simple linear regressions for each identified ERD as dependent variable, and IRI subscale scores as predictor variable. Since we were interested in the brain activity resulting from empathic response, we selected data from the painful treatment condition.

In the case of mu ERD, significant regression equation was found ($F(1,34) = 4.235$, $p = .047$), with an R^2 of .111. Participants' mu had therefore ERD decreased -.274 for each point of the Personal Distress scale, meaning that one's self-reported tendency to experience personal distress when witnessing the suffering of others predicts his or her empathic response in terms of mu oscillations following the observation of pain (Figure 4).

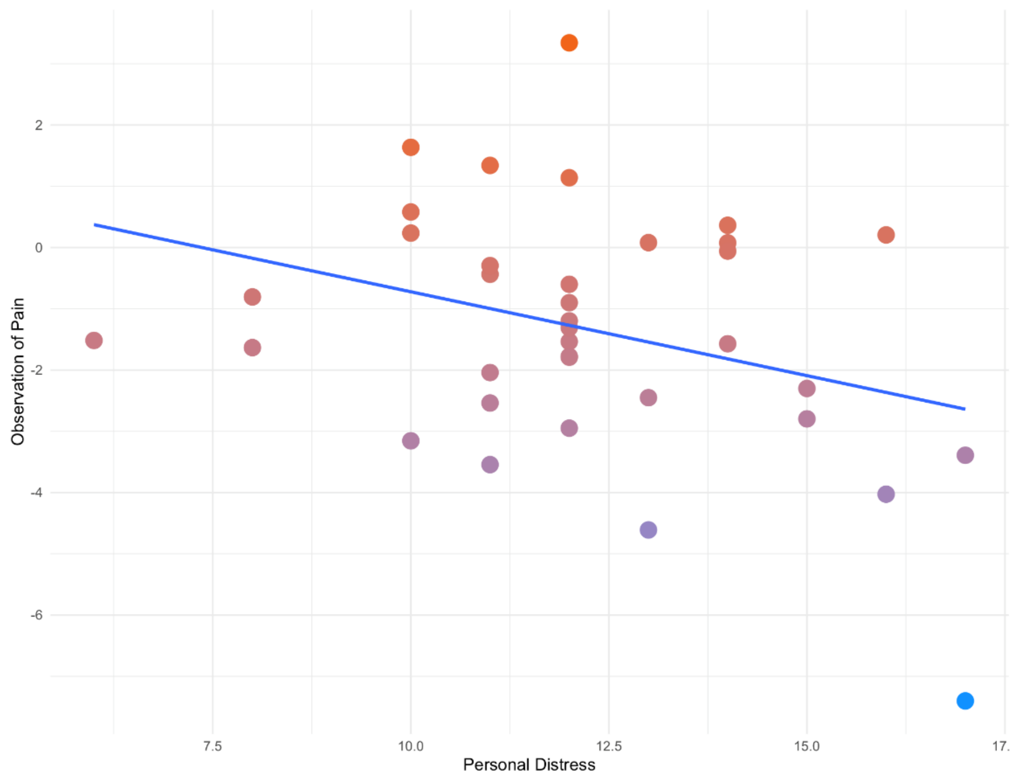

Figure 4 - Scatterplot showing the relationship between participants' scores in Personal Distress scale and mu ERD following the observation of painful stimuli

On the other hand, beta ERD was found to be significantly predicted by participants' scores in Empathic Concern scale ($R^2 = .167$, $F(1,34) = 6.833$, $p = .013$). Beta ERD had decreased -

.178 for each point of the Empathic Concern scale, indicating that participants' individual differences in empathic concern for others seems to predict beta event-related desynchronization elicited by perceiving a painful hand treatment stimulus (Figure 5). Similar results were found for Fantasy Scale, i.e. participants' self-reported tendency to transpose themselves into fictional characters predicted their beta ERD following the observation of painful stimulus (R^2 = .114, $F(1,34)$ = 4.388, β = -.338, p = .044; see Figure 6). However, running multivariate analysis with both scales as predictors did not yield any significant results, confirming that the IRI subscales should be treated as separate empathy constructs. It is also important to note that all the observed relationships were relatively weak in this sample.

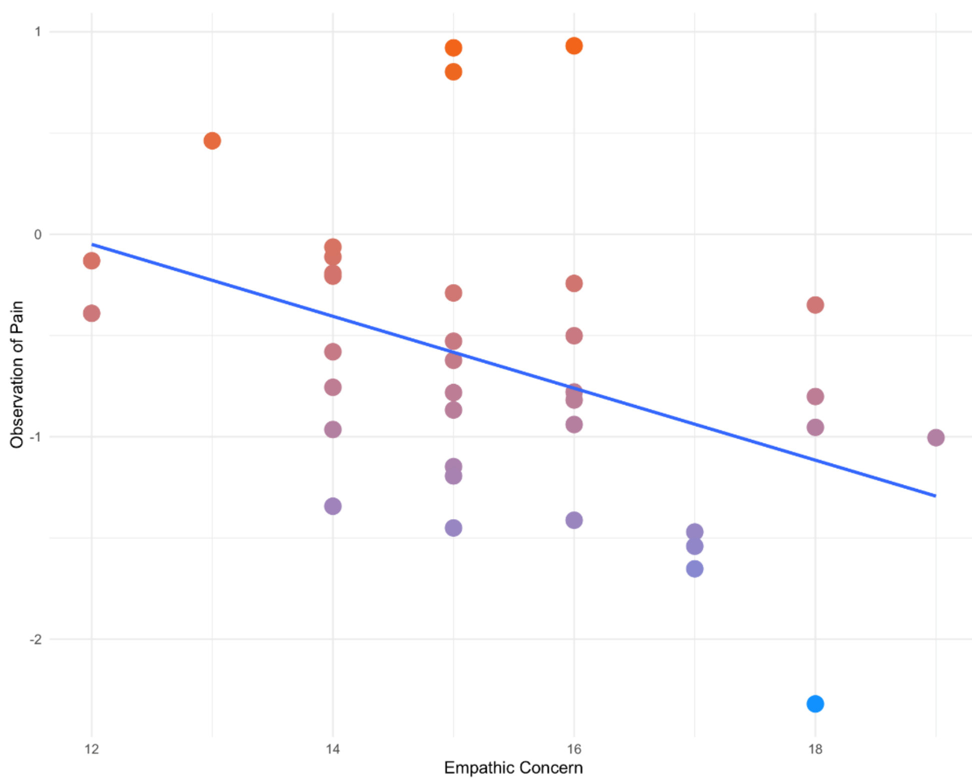

Figure 5 - Scatterplot showing the relationship between participants' scores in Empathic Concern scale and beta ERD following the observation of painful stimuli

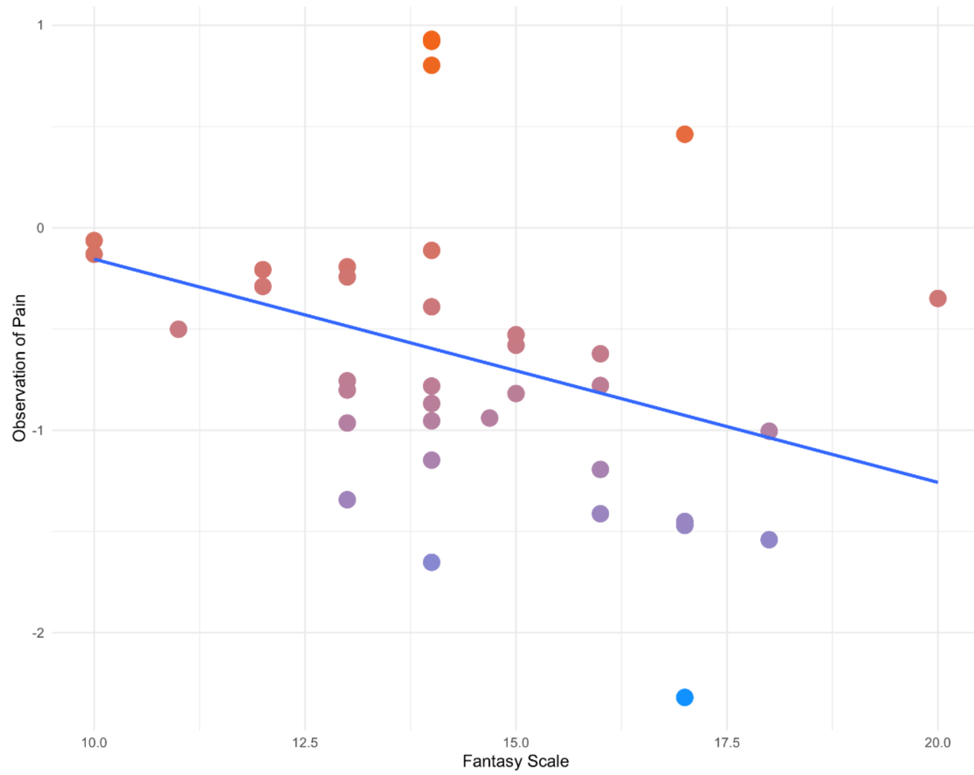

Figure 6 - Scatterplot showing the relationship between participants' scores in Empathic Concern scale and beta ERD following the observation of painful stimuli

Discussion

In this section, we will attempt to interpret the results of our research. We will discuss what implications the results of this study may bring considering the theoretical review of empathy, and some potential limits of our research. Finally, we will reflect on the possible future directions in this field, and how can we, as empathy researchers, contribute to solving some of the real-world problems in our society.

4.1 Interpretation of Results

The present research aimed to examine resonant sensorimotor activation following the vicarious perception of painful hand treatment. We were interested to learn whether different setup of stimuli contributes to modulating somatosensory desynchronization. Finally, our goal was to explore the relationship between the empathic response of brain oscillations and self-reported individual differences in empathic traits.

In two experiments, participants observed videos of hand being either penetrated by a needle or touched with a cotton swab. Participants' brain activity was measured with EEG during the presentation of stimuli. After the experiments, participants filled out Interpersonal Reactivity scale (IRI; Davis, 1980, 1983). First of all, behavioral results showed several significant subscale intercorrelations. Empathic Concern scale positively correlated with both Perspective Taking and Fantasy scale. These results are in line with Davis (1980), who observed similar relationships in a large representative sample of the population. On the other hand, he found that Perspective Taking and Fantasy scale are essentially unrelated. On the contrary, our data showed significant correlation between these two scales. This discrepancy might support the notion of Davis (1980), who argued that one's score on a particular subscale should not be a reliable predictor of scores on the other scales, suggesting relative independence of the scales. Overall, despite these correlations, it seems that IRI subscales should be treated separately, not as a single empathy score.

Next, we analyzed EEG data using spectral analysis of event-related changes. The analysis showed noticeable event-related desynchronization (ERD) of both mu (7 – 12 Hz) and beta (13 – 30 Hz) rhythms time-locked to the perception of stimuli across sensors overlying sensorimotor cortex. Three time windows were selected for statistical analysis: initial hand perception, dynamic hand treatment, and static final position. Statistical analysis confirmed significant desynchronization of both mu and beta frequency bands in the observed time windows compared to the baseline pre-stimulus period. Furthermore, as we hypothesized, observation of pain elicited significantly stronger mu and beta ERD compared to the observation of touch. These results are in line with Perry et al. (2010) and they support the previous findings suggesting that witnessing another's pain modulates activity in brain regions typically associated with one's own somatosensory perception (Bufalari & Ionta, 2013).

We expected to find significant differences between the two experimental setups, due to the fact that the overlap setup manipulation (stimuli on a horizontal monitor above participant's hand) aimed to increase bodily hand attribution of the stimuli (Botvinick & Cohen, 1998). Thus, we hypothesized that this manipulation would elicit stronger mu and beta ERD, compared to the conventional setup (stimuli on the monitor in front of the participant). Surprisingly, there was no statistically significant difference between the two setups in the perception of stimuli. These results indicate that the positioning of the stimuli presumably does not affect resonant brain activity. One possible interpretation could be that the vicarious somatosensory activation was already extremely prominent with the conventional setup of stimuli, creating a floor effect, in the case of which there couldn't have been stronger values of oscillatory ERD in the overlap setup.

Finally, we aimed to explore the relationship between somatosensory ERD associated with empathic response, resulting from observation of painful hand treatment, and dispositional measures of empathy. We found that participants' self-reported scores in Personal Distress scale predicted their mu ERD in response to painful stimuli. This result is highly intuitive –

participants' tendency to experience distress when witnessing others in emergency situations seems to be associated with their biological neural response to vicarious painful stimulation. On the other hand, beta ERD was predicted by both Empathic Concern scale and Fantasy scale (although separately). As expected, higher values in IRI scores were associated with lower values of ERD, indicating stronger desynchronization. This might imply that participants with higher tendency to express concern for others in need also experience higher somatosensory resonance to other's pain, suggesting potential interplay between the two mechanisms of empathy. The association between the brain activity in pain matrix resulting from vicariously experiencing pain and the empathic concern scores was also found by Singer et al. (2004). Interestingly, in the case of our study, these effects were observed only in the Study 1 data (conventional setup). In the case of Study 2 (overlap setup), there were essentially no associations found. This unexpected result may be explained by the lower research sample (N = 29).

Based on our results, is seems that beta suppression in response to vicarious painful stimulation showed more associations with the other constructs related to empathy. This was expected considering the findings from Study 1 (Riečanský et al., 2015), which showed significant interaction between beta ERD and IRI subscales, as well as stronger beta ERD when participants observed white (ingroup) compared to black (outgroup) hands, associated with ethnicity bias in empathy. However, even though we observed some statistically significant relationships, it's important to note that the effect sizes were relatively weak in our sample.

4.2 Limitations of Our Study

There are several limits of our study. First of all, even though this type of stimuli is common in neuroscientific research of empathy, their ecological validity is questionable. For this reason, cue-based stimuli are certainly a better choice in measuring empathy, although it is far more challenging to conduct this type of experiment involving actual people. Undoubtedly, this is one of the main challenges in social cognitive neuroscience. We need to find a way to separate different aspects of empathy in order to test them experimentally, however, limiting the empathic response to controlled laboratory environment brings its drawbacks. It is important to note that the full experience of empathy involves many other factors. Even though the shared network hypothesis has gained a lot of empirical support recently, we should not underestimate the top-down influence of memory, declarative knowledge, as well as means of communication on our ‘mind-reading’ abilities. Thanks to the increasing accessibility of brain imagining methods, soon we will be able to measure brain activity in real time social interaction. It is indeed an exciting time for social cognitive neuroscience.

Secondly, due to the small sample size, we did not explore the gender differences in empathy. Due to gender stereotypes, it is believed that women have higher empathic abilities than men and tend to express more concern for others. Many studies have found significant differences in men and women when it comes to various aspects of empathy. For example, Davis (1980, 1983) reported women displaying higher scores than men in each of the four IRI subscales. In a similar experimental design to our study, Yang et al. (2009) found that females had stronger mu suppressions than males when observing painful as well as non-painful stimuli.

However, a meta-analytic study conducted by Ickes, Gesn and Graham (2000) showed that this effect might be caused by demand characteristics (in studies were participants were aware that empathy as such is measured) and reflected in females’ motivation to outperform men in these types of tasks due to general gender stereotypes. Furthermore, Klein and Hodges (2001) confirmed that gender differences in empathic accuracy might be caused by motivation differences by paying both sexes for the success on the task, which not only improved the empathic abilities in both groups, but also removed any differences between their performance.

Since studies above showed clear motivational influences on participants’ manifested empathy, it is important to note that IRI questionnaire might also be accompanied with certain limits. Participants might have been influenced to report more socially desirable answers. For this reason, future research should employ performance-based behavioral measure, rather than self-report questionnaire. For example, the test of empathic accuracy developed by Ickes (2009) measures participants' actual success in inferring the specific content of other people's thoughts and feelings in certain situations. As a matter of fact, self-report measures of dispositional empathy were found not to be correlated with the performance on empathic accuracy task (Davis & Kraus, 1997).

4.3 Implications for Future Research

Even though the manipulation in the overlap condition hasn't led to any significant differences in the perception of hands that we have expected, nor the empathic neural response to pain, future studies should further explore how different setups influence people's perception and empathic response. Setups that increase bodily attribution of the target stimuli may help us gain deeper insight into the processes behind empathy. If the theory behind shared neural networks proves to be true, we can influence our empathic response by bridging the gap between the self and the other. For example, using virtual reality setups may help us project easier into the 'shoes' of another person. There have already been some efforts of improving social skills of people with autistic spectrum disorders with virtual reality (Parsons & Mitchell, 2002).

On the other hand, an art director, Chris Milk, has already started to explore the power of perception in empathy by making virtual reality films in a Syrian refugee camp (2015). He believes that seeing virtual reality videos of people suffering in some other part of the world might bring us just a little bit closer to them. Dehumanization of various minority groups, such as refugees, is one of the main problems in intergroup relations (Haslam, 2006). A pilot study has already tested the effects of this video (Schutte & Stilinović, 2017). They have found that the virtual reality experience resulted in greater engagement, leading to higher level of empathy for the refugee girl in the video. As a social psychologist, it is my personal goal to combat dehumanization, prejudice and rising intolerance in the world, by exploring the application of various prejudice-reduction methods. Facilitating empathy with virtual reality might just lead us one step closer to improving public attitudes towards various discriminated groups.

4.4 When Does Empathy Lead to Prosocial Behavior?

The most crucial question out of all in the field of empathy research is how this vicarious brain activation influences our social behavior. More precisely, which mechanisms lead to empathic concern and subsequent prosocial behavior, and when does high personal distress result in aversion and avoidance? Several authors have pointed out that the answer may lie in emotional regulation, especially when it comes to ability to distinguish between the self and the other (e.g. Decety & Jackson, 2004; Eisenberg & Eggum, 2009; McCall & Singer, 2013). Eisenberg and Eggum (2009) have suggested that the optimal levels of arousal might be needed in order to promote other-related feelings, which may in turn motivate one to react with concern and sympathy. On the other hand, Decety and Lamm (2006) proposed that individual factors such as dispositional empathy and emotional regulation come into play with context and the level of emotional arousal elicited by the situation, in controlling whether witnessing others in need will lead to prosocial behavior or aversive personal distress. Nonetheless, Bloom (2017), in his most recent publication with a provocative title (*A Case Against Empathy*) argues that our ability to experience the suffering of others does not make us better people. He builds upon the most recent neuroscientific findings and views empathy as an irrational emotion that should not be relied on, and that instead, a more distant and rational compassion is a true path to humanity.

Future research should most certainly address this debate in more detail. For instance, the latest study conducted by Gallo and collaborators (2018) provided compelling answers to this issue. In their study, participants witnessed a confederate experiencing pain, and they were able to choose to reduce the amount of pain administered to the confederate by donating money. Not only have the participants donated more money in trials where the confederate expressed more pain, but the activity in somatosensory cortex measured by EEG predicted the amount of donated money. These findings bring hope that one day we can shed light on the question of human altruism and learn how to promote this tendency in the society.

Conclusion

The present thesis aimed to explore the relationship between the empathic response in the brain and different measures of empathy as a more stable personality trait. Even though our work contributed little to resolve the existing debates in this field, we believe that studying the mechanisms behind this phenomenon carries a great value. Every small study is a small step closer to discovery.

One of the most important applications of the research in this filed might be in education. If we learn how to improve our empathic abilities, we can train people that work in health, social service, or any other profession for that matter. Improving one's social intelligence this way can be of great benefit both to the individual himself and to the people around them. Similarly, we can learn how to help individuals that are struggling to make sense of their social worlds, such as people with autism spectrum disorder. Neil deGrasse Tyson (2011) had recently suggested that training empathy should be included in basic education. He believes that humans are not as good as they should be in their capacity to empathize with other people and animals around us. If we put an effort into teaching empathy to children, the would might truly become a better place to live in.

Few centuries ago, David Hume (1740) had suggested that empathy is the basis for all human social perception and interaction. We could not agree more. Empathy is the key element that brings people together, facilitates our mutual communication and enables cooperation. To answer the questions of how we come to know the internal state of another and how it motivates us to care about each other is of great importance for our society.

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Appendix 1 - Interpersonal Reactivity Index original questionnaire in English *(the scale type and coding are added for clarity)*

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate number on the scale at the top of the page: 1, 2, 3, 4 or 5. When you have decided on your answer, fill in the letter on the answer sheet next to the item number. Read each item carefully before responding. Answer as honestly as you can. Thank you.

<u>Answer scale</u>:

	1	2	3	4	5	
does not describe me well						describes me very well

1. I daydream and fantasize, with some regularity, about things that might happen to me. *(FS)*
2. I often have tender, concerned feelings for people less fortunate than me. *(EC)*
3. I sometimes find it difficult to see things from the "other guy's" point of view. *(PT) (-)*
4. Sometimes I don't feel very sorry for other people when they are having problems. *(EC) (-)*
5. I really get involved with the feelings of the characters in a novel. *(FS)*
6. In emergency situations, I feel apprehensive and ill-at-ease. *(PD)*
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. *(FS) (-)*
8. I try to look at everybody's side of a disagreement before I make a decision. *(PT)*
9. When I see someone being taken advantage of, I feel kind of protective towards them. *(EC)*
10. I sometimes feel helpless when I am in the middle of a very emotional situation. *(PD)*
11. I sometimes try to understand my friends better by imagining how things look from their perspective. *(PT)*
12. Becoming extremely involved in a good book or movie is somewhat rare for me. *(FS) (-)*
13. When I see someone get hurt, I tend to remain calm. *(PD) (-)*
14. Other people's misfortunes do not usually disturb me a great deal. *(EC) (-)*

15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. *(PT) (-)*
16. After seeing a play or movie, I have felt as though I were one of the characters. *(FS)*
17. Being in a tense emotional situation scares me. *(PD)*
18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. *(EC) (-)*
19. I am usually pretty effective in dealing with emergencies. *(PD) (-)*
20. I am often quite touched by things that I see happen. *(EC)*
21. I believe that there are two sides to every question and try to look at them both. *(PT)*
22. I would describe myself as a pretty soft-hearted person. *(EC)*
23. When I watch a good movie, I can very easily put myself in the place of a leading character. *(FS)*
24. I tend to lose control during emergencies. *(PD)*
25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. *(PT)*
26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. *(FS)*
27. When I see someone who badly needs help in an emergency, I go to pieces. *(PD)*
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. *(PT)*

NOTE: (-) denotes item to be scored in reverse fashion

PT = perspective-taking scale

FS = fantasy scale

EC = empathic concern scale

PD = personal distress scale