How do we process pain in others? Investigating behavioral and neural correlates of empathy

Dissertation

der Mathematisch-Naturwissenschaftlichen Fakultät
der Eberhard Karls Universität Tübingen
zur Erlangung des Grades eines
Doktors der Naturwissenschaften
(Dr. rer. nat.)

vorgelegt von
Sarah Fabi
aus Pforzheim

Tübingen
2018

Gedruckt mit Genehmigung der Mathematisch-Naturwissenschaftlichen Fakultät der Eberhard Karls Universität Tübingen.

Tag der mündlichen Qualifikation:	14.11.2018
Dekan:	Prof. Dr. Wolfgang Rosenstiel
1. Berichterstatter:	Prof. Dr. Hartmut Leuthold
2. Berichterstatter:	Prof. Dr. Barbara Kaup

Für meine lieben Eltern.

Danksagung

Dieses Dissertationsprojekt wurde durch das Landesgraduiertenstipendium des Landes Baden-Württemberg unterstützt.

Mein Dank gilt ganz besonders meinem Betreuer Prof. Dr. Hartmut Leuthold für seine Zeit, seine stets sehr hilfreichen Beiträge und die Ermöglichung dieses Dissertationsprojekts. Ich bin sehr dankbar für all die Dinge, die ich von ihm lernen durfte, vom Kritischen Literaturverständnis, über die methodischen Kenntnisse, insbesondere dem EEG, bis hin zum wissenschaftlichem Schreiben, um nur ein paar wenige zu nennen. Er hat mich im gesamten Forschungsprozess angeleitet und stand mit seiner Expertise zur Seite. Weiterhin möchte ich ihm für das sorgfältige Lesen des Manuskripts dieser Dissertation und die hilfreichen Kommentare danken.

Außerdem möchte ich Dr. Ian G. Mackenzie für seine wichtigen Beiträge zu diesem Dissertationsprojekt hervorheben. Angelika Kunkel möchte ich für ihre Einführung in das Labor der Biologischen Psychologie und die aufbauenden Gespräche danken.

Ich danke meiner Familie für ihre Liebe und den Rückhalt auch in schwierigen Phasen. Meinen Eltern möchte ich ganz besonders danken, da sie mir diesen Weg durch ihre liebevolle und bestimmte Art geebnet haben und ich ohne sie nicht so weit gekommen wäre. Meinem Mann Kai und meiner Schwester Laura danke ich für ihre wichtige Unterstützung und ihre offenen Ohren. Meiner Schwester Jeanette und ihrem Mann Benni möchte ich dafür danken, dass man sich immer auf sie verlassen kann. Und nicht zuletzt danke ich meinen Neffen Leon und Tobias, die einem immer wieder ein Lächeln auf das Gesicht zaubern.

Zusammenfassung

Im täglichen Leben sind wir häufig dem Leiden anderer ausgesetzt. Die empathische Reaktion für Schmerz und die zugehörigen Hirnareale sind bereits gut untersucht. Jedoch ist noch unklar, wie und wann empathische Bottom-up und Top-down Prozesse interagieren. Daher befasste sich die erste Forschungsfrage dieser Dissertation damit, wie wir Empathie erleben und wie der zeitliche Verlauf der zugrunde liegenden Prozesse von der Stimulusenkodierung über die Kategorisierung bis hin zur motorischen Antwort aussieht (Studie 1). Das Ziel dieser Arbeit war es weiterhin, die Einflüsse des ethnischen Hintergrunds der Zielperson auf die empathischen Prozesse zu bestimmen (Studie 2). Der zweite große Strang dieser Arbeit befasste sich mit den motivationalen Auswirkungen von Empathie, da die bisherige Forschung offen lässt, unter welchen Bedingungen Empathie in prosoziales Verhalten resultiert. Daher wurde das Auftreten von Mitgefühl (*Empathic Concern*), das eine altruistische Motivation mit sich bringt, und persönlicher Betroffenheit (*Personal Distress*), die mit einer egoistischen Motivation in Verbindung gebracht wird, untersucht (Studie 3).

Um diese Fragen genauer zu untersuchen, wurden den Versuchspersonen in Studie 1 schmerzhafte oder neutrale Bilder von Körperteilen in Alltagssituationen gezeigt. Diese bewerteten dann, ob es sich um eine schmerzhafte oder neutrale Situation handelte oder zählten, wie viele Körperteile zu sehen waren. In der Zwischenzeit wurde das EEG und die Kraft, mit der die Versuchspersonen die Antworttasten betätigten, aufgezeichnet. Studie 2 war der ersten sehr ähnlich, wobei auf den Bildern hell- und dunkelhäutige Hände zu sehen waren und die Zählaufgabe durch die Aufgabe ersetzt wurde, die Hautfarbe zu beurteilen.

In Studie 3 wurden die Versuchspersonen gebeten, den Fokus auf die andere Person zu legen, während sie Bilder von Menschen mit physischem oder psychischem Leid präsentiert bekamen. Das Mitgefühl und die persönliche Betroffenheit in einer spezifischen Situation wurden gemessen und mit anderen Faktoren in Verbindung gebracht, wie dem Affekt und der Disposition der Versuchspersonen, generell Mitgefühl und persönliche Betroffenheit zu empfinden.

Studie 1 und 2 sprachen für empathische automatische Einflüsse auf die frühe Enkodierungsstufe, spätere kontrollierte Einflüsse auf die Kategorisierungsstufe und zeigten unterschiedliche Befunde in Bezug auf die motorischen Verarbeitungsstufen. Während die Ergebnisse der Studie 1 eine Verstärkung der sensomotorischen Aktivität nach der motorischen Reaktion nahelegten, sprach Studie 2 für eine Verstärkung der sensomotorischen Aktivität vor und eine Inhibition nach der motorischen Antwort. Der ethnische Hintergrund der Zielperson beeinflusste frühe, aber nicht späte Verarbeitungsstufen. Jedoch war der Einfluss auf die späte Kategorisierungsstufe größer, je größer die individuelle implizite Präferenz für die Eigengruppe war. Motorische Verarbeitungsstufen wurden vom kulturellen Hintergrund nicht beeinflusst. Studie 3 zeigte, dass situationelle Faktoren wie die Art des präsentierten Schmerzes oder dem Affekt des Beobachters eine größere Rolle spielen als dispositionelle empathische Eigenschaften, wenn Mitgefühl und persönliche Betroffenheit hervorgerufen werden sollen.

Insgesamt liefert diese Dissertation wichtige Einblicke in den zeitlichen Verlauf automatischer und kontrollierter Prozesse, die der empathischen Antwort zugrunde liegen, ebenso wie neue Erkenntnisse bezüglich des Auftretens von Mitgefühl und persönlicher Betroffenheit.

Abstract

Experiencing pain in others is a phenomenon which we encounter regularly in everyday-life. The empathic response to pain and the involved brain regions are quite well investigated. However, it is still unclear whether and when empathic bottom-up and top-down processes influence information processing. Thus, the first research question of this dissertation thesis was how do we experience empathy and what is the time course of the underlying processes from stimulus encoding over categorization to motor execution (Study 1). A further aim was to determine the influence of the target's racial background on the empathy-related processes (Study 2). The second main strand of this work concerned the motivational consequences of empathy, because it is still an open question when empathy results in prosocial behavior. Therefore, the occurrence of empathic concern and personal distress implying an altruistic and an egoistic motivation, respectively, was investigated (Study 3).

In order to address these issues, in Study 1, participants were asked to judge the painfulness of pictures displaying body parts in painful or neutral situations or to count the displayed body parts. Meanwhile, EEG and response force were recorded. Study 2 was very similar to Study 1, but the pictures displayed fair- and dark-colored hands and the counting task was replaced by a skin color judgment task. In Study 3, situational empathic concern and personal distress to pictures of persons in physical and psychological pain were measured, while participants were asked to maintain an other-focused perspective. Then, the situational measures were related to other factors like affect and the participant's disposition to experience empathic concern and personal distress.

Study 1 and 2 indicated empathic automatic influences on the early encoding stage, later controlled influences on the categorization stage, whereas the effects on the motor processing stage varied. While the results of Study 1 revealed a facilitation of sensorimotor activity after the response, Study 2 indicated a facilitation of sensorimotor activity before the response and an inhibition after the response. The racial background of the target influenced early but not late processing stages. However, the influence on the late categorization stage increased with the individual implicit ingroup preferences. Motor processing stages were not influenced by the racial background. Study 3, on the other hand, indicated that situational factors like the type of the presented pain and the affect of the observer are substantial in evoking empathic concern and personal distress, whereas the influence of dispositional empathic traits is of less importance.

All in all, this dissertation thesis gives important insights into the time course of automatic and controlled processes underlying empathic responses, as well as into the occurrence of empathic concern and personal distress.

Table of contents

Chapter 1

Introduction

In everyday-life, we are very commonly exposed to other humans in pain. But our responses when witnessing others in physical or psychological pain vary immensely across different situations: Sometimes we experience sorrow and concern for the targets and want to help them, sometimes we feel stressed by witnessing their pain, sometimes we ignore it or distract ourselves, and on other occasions it does not affect us at all. But what are the causes for these differing responses? Is there anything similar in all empathic responses? When do we experience empathy, when does it even lead to prosocial behavior? And when are we numb to others' pain? In order to understand these issues, it is important to understand how our brain processes the information of witnessing another person in pain and how this is influenced by specific characteristics of the target, the corresponding context information and our own affective state.

Since it is essential for social interactions to comprehend another's situation, this doctoral thesis deals with the initial empathic processing, modulating factors influencing the empathic outcome, and empathic emotions that follow the initial response. In the first chapter, the theoretical background will be discussed, thereby introducing former studies concerned with empathy. In Chapter two, the objectives of this doctoral thesis will be described. Chapters three to five cover three studies concerned with the empathic influences on information processing, the modulation of these when the target's racial background is changed, and the two empathic emotions following the initial empathic processing: empathic concern and personal distress. In the last chapter, the results of these studies will be discussed and integrated into the current literature.

1.1 Different concepts of empathy

We experience empathy when we observe someone in pain, as well as when we observe a more abstract cue like painful facial expressions or even when we are told of an event in which someone was experiencing pain (McCall & Singer, 2013). Children start to show empathic responding in their second year of life (Zahn-Waxler, Radke-Yarrow, & King, 1979) and also nonhuman animals exhibit empathy (Meyza, Bartal, Monfils, Panksepp, & Knapska, 2002; Preston & de Waal, 2017). But what exactly is empathy?

According to Lamm and Majdandžić (2015), a major problem of empathy research is that there are different definitions of it and researchers claiming to investigate empathy, are often only looking at some aspects of empathy that may not be related to those investigated by other scientists, leading to contradictory results and confusion. Therefore, when studying empathy, the first important step is to recognize that there are various different definitions of empathy and to specify which concept is looked at. Batson (2009) claimed that there are eight different concepts known under the term empathy. The first concept Batson describes is the knowledge of the internal state, including thoughts and feelings, of another person who has for instance told you about a loss. The second psychological state one may experience in such a situation is a matched behavioral or neural response. Facial mimicry is a good example for this state. The matched neural response will be discussed in greater detail below. A third psychological concept related to empathy is the same (Hoffman, 1987) or a very similar (Hoffman, 2001) affective state compared to the other's affective state. This mere copy of another's affective state is often defined as emotional contagion, like in mass panics or when babies start to cry because other babies are crying (e.g., Decety & Lamm, 2006; Hatfield, Cacioppo, & Rapson, 1994; Hatfield, Rapson, & Le, 2009). It is often called affective empathy (e.g., Zahn-Waxler et al., 1992). Even though Batson did not focus on self-other differentiation when defining the different concepts of empathy, various other authors stress self-other differentiation to constitute the difference between emotional contagion and empathy (de Vignemont & Singer, 2006; McCall & Singer, 2013; Singer & Lamm, 2009). In other words, when experiencing empathy, one is aware of the fact that the other person's state was the source of the own isomorphic affective state. Coming back to Batson, the counterpart of affective empathy is cognitive empathy or perspective-taking, which can be subdivided into the fourth, fifth and sixth concept of empathy: He differentiates between projecting oneself into another's situation (what would it be like to actually be the other person?), imagining how the other is thinking and feeling (what must it be like for the other person to be in this situation?), and imagining how oneself would think and feel in the other's place (what would it be like if you yourself were in the situation of the other?). The seventh and eighth concepts take motivational consequences of the isomorphic affective state into account and are also known under the terms personal distress and empathic concern (e.g., Bernhardt & Singer, 2012; Eisenberg & Eggum, 2009). Too intensely experienced empathy, for example because of a missing self-regulation, can result in personal distress, an aversive and self-oriented response, which contains an egoistic motivation to reduce one's own suffering (Eisenberg & Fabes, 1990; Eisenberg et al., 1996; McCall & Singer, 2013). An example is being anxious about experiencing the same situation oneself in the future, or being overwhelmed by another's distress (Batson et al., 1991). The opposing concept, empathic concern, also known as compassion or sympathy can result from empathy, if experienced above some threshold (Eisenberg, Shea, Carlo, & Knight, 1991) and is characterized through other-oriented feelings that promote a motivation to relieve the other from suffering (e.g., Batson et al., 1991; Singer

& Lamm, 2009). This can then be transformed into prosocial behavior (Batson, Eklund, Chermok, Hoyt, & Ortiz, 2007).

With these different concepts of empathy in mind, empathy seems to be a response of similar feelings compared to another person in a specific affective state (Singer & Lamm, 2009). It is often preceded by mimicry or emotional contagion and followed by empathic concern or personal distress, determining whether prosocial behavior is elicited (Singer & Lamm, 2009). According to Batson (2009), empathy research can be subsumed under two main questions to which the different concepts can be related: How do we get to know the internal state of another and when do we respond with emotional care to others' suffering? The concepts of empathic concern and personal distress are more relevant for the latter question, whereas the remaining concepts are important for the former of the two questions. Because Batson criticizes that many researchers try to answer one of these questions without considering the other, I want to address both questions in this dissertation thesis. First, it will be investigated how humans experience empathy. In doing so, it is important to distinguish two main theories: the theory-theory and the simulation theory. The theory-theory view assumes that we use our lay theories of the mind in order to draw conclusions about the internal state of another person, similar to scientists. The simulation theory holds that we simulate the state of others in ourselves in order to understand what they are thinking and feeling (Batson, 2009). These theories will be discussed in the following paragraphs. Then, I will introduce approaches combining bottom-up and top-down processes and the methodology with which Study 1 and 2 aim at determining the answer to Batson's first question, that is, how we achieve the knowledge of thoughts and feelings of others or in short, how we experience empathy. Thereafter, I will introduce the theory behind Batson's second question of what leads persons to respond with care to the suffering of others. Again, scientists from different backgrounds like philosophy, social and developmental psychology tried to solve this question, this time focussing on the actions that result from the empathic response (Batson, 2009). Introducing this issue, I will first relate empathy to prosocial behavior, then focussing on the occurrence of empathic concern and personal distress because previous research suggests that empathic concern, in contrast to personal distress, leads to prosocial actions. Again, the methodology with which Study 3 tackled this question will then be presented.

1.2 Theory-theory versus simulation theory

Two important theories regarding the way to understanding another person's internal state are the simulation theory and the theory-theory (Perry & Shamay-Tsoory, 2013; Samson & Michel, 2013; Zaki & Ochsner, 2013). I will start with presenting the historically older theory-theory, followed by the simulation theory, and more recent neuroscientific findings.

1.2.1 Theory-theory

The theory-theory assumes that in order to infer the internal state of others, people use lay theories about the mind, similar to theories that scientists use in order to investigate an issue (Batson, 2009). These theories can provide information about thoughts and feelings of people in general or of persons with specific characteristics (Batson, 2009). Thus, the theory-theory stresses theory of mind (ToM) abilities, also known under the term cognitive empathy, like cognitively putting oneself in the shoes of someone else in order to understand this person's beliefs, intentions and emotions (e.g., Frith & Singer, 2008; Shamay-Tsoory, Aharon-Peret, & Perry, 2009).

While the emotional part of empathy like emotional contagion can occur very early in life, this cognitive mentalizing part of empathy has to develop during childhood (Johnson, 2003). Thus, on average, children can only solve the famous Sally-Anne test successfully from the age of three or four years onwards (Baron-Cohen, Leslie, & Frith, 1985; Wimmer &

Perner, 1983). This task tests the understanding that another person can have a belief that oneself knows is erroneous: Sally leaves a toy at a certain location A and disappears from the scene. Anne moves this toy to another location B. Participants are then asked where Sally will look for her toy when she returns. Children who do not yet have acquired higher ToM skills say that Sally will look for her toy at location B even though Sally could not have noticed that Anne has changed the location. When children are able to differentiate between the own and the other belief, they give the correct answer A. This cognitive component of empathy can be further divided into reasoning about emotions or about beliefs, thus affective and cognitive mentalizing (Brothers & Ring, 1992).

1.2.2 Simulation theory

The theory-theory views cognitive processes as isolated processes, whereas research of the last decades suggests a tight interconnection between cognitive and sensorimotor processes (Hesslow, 2002). In this vein, concepts like embodied cognition were introduced in the 1990s (Clark, 1997; Varela, Thompson, & Rosch, 1991). It was assumed that imagery was not possible without sensory mechanisms and some problem-solving tasks were taken to rely on motor structures (Hesslow, 2002). The simulation theory suggests that we simulate actions and perception with our motor and sensory systems without actually moving or perceiving anything. There are various findings of behavioral experiments that support this assumption. For example, the time to solve a simple motor task in your imagination is similar to the time it takes to execute the actual task (Decety, Jeannerod, & Prablanc, 1989). Furthermore, evidence is provided by patients with unilateral neglect syndrome who can describe only the features of one side of a square they imagine to stand in, but the other side if they change their position in their mind to the opposite side of the square (Bisiach & Luzzatti, 1978). According to this line of reasoning, we can also simulate the other's internal state in order to understand it and experience empathy (Singer & Lamm, 2009). There is neuroscientific evidence supporting a simulation theoretic account of empathy that will be discussed below: First, I will discuss mirror neuron findings in macaques that fire when observing and executing an action, followed by the introduction of shared neural networks in humans that are active when observing or experiencing pain.

Mirror Neurons

The simulation theory received support from research on mirror neurons after their discovery in the ventral premotor cortex of macaque monkeys in the 1990s (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996). Since then they have often been assumed to exist in humans as well. Mirror neurons are neurons that are firing both when the monkey is grasping an object and when the monkey observes someone else executing the same movement (Keysers, Thioux, & Gazzola, 2013). Based on the assumption that mirror neurons do exist in human brains, the perception-action model claims that we understand movements of other persons by simulating them in our brain (Preston & de Waal, 2002). In this respect, one promising study was able to apply single cell recording in human epileptic patients during a procedure to localize the origins of epileptic seizures (Mukamel, Ekstrom, Kaplan, Iacoboni, & Fried, 2010). They determined neurons that fired while executing and observing an action, providing evidence for the existence of mirror neurons in human brains. Although, it is hard to determine whether mirror neurons exist in humans because single cell recording in healthy humans is not possible, there is converging evidence from neuroscientific studies in humans. Long before the discovery of mirror neurons in monkeys, Gastaut and Bert (1954) found that mu rythms in the electroencephalogram (EEG) were blocked during the execution and the observation of an action. fMRI results also suggest that similar brain regions are active in action execution and observation (e.g., Keysers & Gazzola, 2009), even though they differ from the mirror neuron regions in the macaque brain (Keysers et al., 2013). Despite this evidence for the existence of mirror neurons in humans, the non-invasive brain imaging methods have several restrictions as will be outlined below, making it hard to draw definite conclusions.

All non-invasive, indirect measures are correlative, meaning they measure brain responses that occur simultaneously with empathy and not necessarily because of or in order to evoke empathy (Lamm & Majdandžić, 2015). Additionally, only because fMRT regions overlap when observing and executing an action, there are not necessarily the same processes involved, given the low spatial resolution of these indirect measures in comparison to single cell recordings. Each voxel is measuring the activity of thousands of neurons. Thus, from the activation of the same brain regions in fMRI one cannot deduce that the same neurons are firing (Lamm & Majdandžić, 2015).

Even if one assumes that mirror neurons exist in humans and we simulate others' actions in order to comprehend them, it still remains an open question whether mirror neurons play also an important role in the observation and understanding of affective states, namely in empathy (Preston & de Waal, 2002). Some evidence is provided by fMRI studies investigating empathy for pain that will be discussed in the following section.

Shared neural networks

It is evident that purely motor simulations are not sufficient in explaining empathic responses with its emotional aspects. The theory of shared neural networks assumes that we simulate the other's affective state in our brain by recruiting the same networks as if we would have experienced it ourselves. This assumption has been supported by recent neuroscientific studies, as will now be discussed in more detail.

Most of the time, these neuroscientific studies investigated empathy for pain (Bernhardt & Singer, 2012) because, first, pain and empathy for pain are everyday phenomena, making investigation easier, and second, the neural correlates of pain are quite well investigated (McCall & Singer, 2013). Specifically, processing pain is related to activity in the anterior cingulate cortex, the insula, the thalamus and the primary somatosensory cortex, which form the so-called pain matrix (Bushnell et al., 1999; Peyron et al., 1999; Treede, Kenshalo, Gracely, & Jones, 1999).

In order to investigate neural empathic responses to pain, two prominent paradigms were used in early fMRI studies: In the picture-based paradigm, participants were presented with pictures or videos of body parts in painful or neutral daily-life situations like a hand being cut by a knife (e.g., Jackson, Meltzoff, & Decety, 2005). In the cue-based paradigm, the presented visual stimuli were not pictures but cues that indicated whether the participant or another person was receiving a shock or a non-painful touch (e.g., Singer et al., 2004). With these two paradigms, various fMRI-studies found that some of the brain regions active during the own experience of pain (i.e., the pain matrix) were also active when watching pain in others, especially the anterior insula (AI) and the anterior and midcingulate cortices (ACC, MCC), reflecting the affective component of pain, and the primary and secondary somatosensory cortices, reflecting the somatosensory processing of pain, although these latter results were inconsistent across studies (e.g., Decety & Meyer, 2008; Gu & Han, 2007; Jackson et al., 2005; Kanske et al., 2016; Singer et al., 2004; for a review, see Lamm, Decety, & Singer, 2011). The assumption that somatosensory-motor representations are also involved in empathy for pain, has been further supported by Avenanti, Bueti, Galati, and Aglioti (2005), who investigated motor evoked potentials (MEPs) triggered by transcranial magnetic stimulation that also allow to measure motor activity, but on a peripheral level. They found a reduction of motor excitability for limbs that were observed to be painfully treated. The authors suggested that the somatic resonance was a simple form of empathy, whereas the affective component represents more complex forms. Among other things, this classification will be discussed in Study 1.

The inferential problem of the studies supporting the simulation theory is that by using fMRI, one is not able to determine the functional significance of the overlapping networks:

Lamm and Majdandžić (2015) argued that one cannot distinguish whether the shared neural networks are the route to experience similar emotions like the observed person or a mere sign of this experience. Furthermore, one cannot even state that the same neurons are active because various neuron activation patterns may lead to the same metabolic activity, as measured by fMRI (Singer & Lamm, 2009). Thus, as pointed out above, the problem is the low spatial resolution of fMRI and its correlational nature. Another problem is that the focus of previous research was almost exclusively directed to the affective state of pain, whereas we do not know whether the neural correlates of other emotions overlap when experienced and observed. Results of one fMRI study suggested that empathy for happiness is related to the activation of the vmPFC instead of the AI and the ACC (Morelli, Rameson, & Lieberman 2012), but further research is necessary to draw conclusions about empathy for other affective states than pain. Another limitation of previous studies is that it is not clear which empathic emotion is measured, because emotional contagion, empathy, personal distress, and empathic concern often occur simultaneously (Singer & Lamm, 2009). A hint that AI and ACC activation represent empathy is provided by Klimecki, Leiberg, Ricard, and Singer (2014), who found that empathy training enhances the activation of AI and ACC, whereas empathic concern training enhances the activation of areas known to be related to positive affect. Singer and Lamm (2009) stated a further more conceptual problem of the simulation models: They only take sensory-driven bottom-up processes into account but not top-down control and contextual appraisal, what appears necessary given the evidence for top-down processes influencing empathy. That is, brain responses were found to be different when additional information was given (e.g., anesthesized body parts, Lamm, Nusbaum, Meltzoff, & Decety, 2007), when participants were physicians (Decety, Yang, & Cheng, 2010), the racial background differed between the target and the observer (e.g., Wang, Wu, Liu, Wu, & Han, 2015), or when the perspective was modulated (imagine-self vs. imagine-other, Jackson, Rainville, & Decety, 2006). In comparison to the simulation theory, the theory-theory acknowledges top-down processes but disregards bottom-up processes on the other hand.

Interim summary

Until recently, the shared network hypothesis was the predominant approach in the field of empathy research, assuming that people understand others' feelings by recruiting the same networks as if they experienced the same feelings themselves. While this approach focuses on affective empathy and bottom-up processes, the theory-theory approach focuses solely on cognitive empathy and top-down processes, because it assumes that we understand the internal state of others through lay theories we have about people's minds. In order to address the problem that both theories disregard one aspect of empathic processing, in previous years, combined approaches have gained attention in empathy research. These approaches will be explained in greater detail in the next section.

1.2.3 Combined approaches

According to Lamm and Majdandžić (2015), empathy should not be divided into affective and cognitive empathy, but these processes should be acknowledged as key mechanisms in evoking empathic responses. Zaki and Ochsner (2013) also warn against considering experience sharing and mental state attribution as two isolated systems. One combined approach was suggested by Goubert, Craig, and Buysse (2009) who presume that affective sharing might be elicited automatically, but can then be modulated by higher-order cognitive factors like thoughts of the observer. Thus, Goubert et al. (2005) divide the observer's behavioral, affective and cognitive responses into bottom-up, top-down, contextual and relational factors. Under bottom-up factors that determine empathic responses, they subsume characteristics of the person in pain and pain cues. Those can be the severity of pain displayed by the other through facial expression or cries. The existence of injuries or the event itself are further examples of bottom-up factors influencing the empathic response. Top-down factors are those related to the observer, like beliefs and memory of prior experiences (Goubert & Craig, 2009; Goubert et al., 2005). It was assumed that bottom-up processes occur automatically, in the sense of not requiring attention to the pain cues, whereas the controlled top-down processes should depend on attention (Fan & Han, 2008). Based on Bargh (1994), Singer and Lamm (2009) suggested that, in contrast to controlled, automatic means without conscious and effortful processing.

Regarding the interplay of bottom-up and top-down empathic processing, de Vignemont and Singer (2006) suggested two different models: the late appraisal model and the early appraisal model (see Figure 1.1). The late appraisal model assumes that empathic responses are automatically elicited by emotional cues via a bottom-up pathway. The context is processed in parallel, thereby allowing appraisal processes to modulate the primary empathic response, representing the top-down pathway. This modulation can be an inhibition or an enhancement of the initial empathic response. In contrast, the early appraisal model assumes that the context is processed first, thereby determining whether an empathic response is elicited at all. Thus, the main difference between the two models is whether the appraisal processes only modulate the previously elicited empathic response or determine their occurrence in the first place.

An fMRI-paradigm developed by Kanske, Böckler, Trautwein, Parianen Lesemann, and Singer (2016) evokes affective and cognitive empathy within one experiment, making it possible to determine specific brain regions involved in cognitive empathy (medial prefrontal cortex, the temporoparietal junction, the posterior cingulate cortex, and the temporal poles) or affective empathy (e.g., AI, ACC). However, in order to determine whether the early or the late appraisal model is more accurate in describing empathic responses, fMRI is not the measure of choice, given its low temporal resolution and the fact that the different processes occur within hundreds of milliseconds. Thus, to test the two models with regard to the time

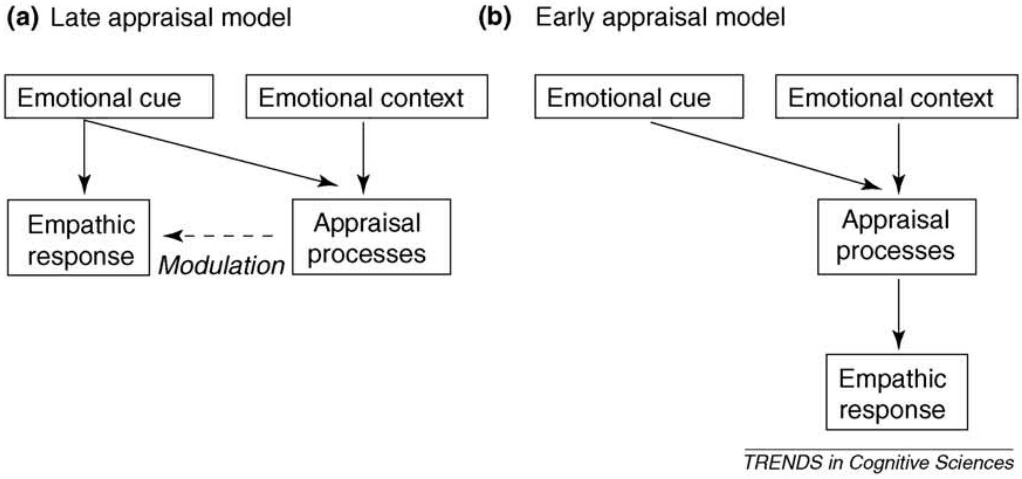


Fig. 1.1 Graphical illustration of the early and late appraisal models by de Vignemont and Singer (2006). Figure reprinted from Trends in Cognitive Sciences, 10, de Vignemont, F. & Singer, T., The empathic brain: How, when and why?, 435-441, Copyright (2006), with permission from Elsevier.

course of bottom-up and top-down processes in human empathy, a methodology with high temporal resolution and the possibility to differentiate between automatic and controlled processes is necessary. Therefore, the EEG, being a non-invasive measurement with relatively high temporal resolution, appears best suited to investigate the interplay of bottom-up and top-down processes of empathy, as will be outlined in the next sections (de Vignemont & Singer, 2006).

1.3 The time course of empathic processing

Despite the fact that numerous studies are concerned with empathy, the time course of automatic and controlled empathic processing stages from stimulus input to response output has still not been thoroughly investigated. As mentioned above, de Vignemont and Singer (2006) recommended using EEG because of its high temporal resolution in order to distinguish between the early and late appraisal model of empathic influences on mental processing stages. But also other authors like Zaki and Ochsner (2012) criticized that most of the fMRI studies did not relate brain activity to behavior and recommended focusing on other than neuroimaging methods in order to explore the temporal dynamics of these processes and to investigate links between brain and behavior. According to these authors, EEG is most suited to investigate the mental chronometry of empathic processing (Zaki & Ochsner, 2012) for two important reasons: On the one hand, EEG allows to differentiate between automatic and controlled processes, as will be explained in more detail below. On the other hand, with EEG one can reveal empathic influences on different processing stages over time.

The EEG reflects the ongoing electrical activity of the brain. There are two ways of analysing EEG data, providing different kinds of information: event-related brain potentials (ERPs) and EEG oscillations. In the next section, I will begin by explaining ERPs and their significance for investigating the time course of empathic processing. Then, I will continue with discussing EEG oscillations and their significance for examining the motor processing stage, followed by a general introduction to models of information processing. Then, studies that have already applied ERPs and EEG oscillations in order to investigate empathy will be described.

1.3.1 Event-related brain potentials (ERPs)

ERPs are voltage changes that are time- and phase-locked to a sensory, cognitive, or motor event and result from filtering and averaging procedures in order to enhance the signal-to-noise-ratio (Fabiani, Gratton, & Coles, 2007). Thus, random background noise that is not time- and phase-locked to the event is averaged out. ERPs are assumed to be generated by postsynaptic potentials of thousands of similarly oriented neurons firing simultaneously. If the orientation of different neurons is different, the electrical field potentials of neuronal cell assemblies cancel each other. Therefore, most of the ERPs we can measure at the scalp originate from cortical pyramidal cells that are oriented perpendicular to the skull (Luck, 2014).

The voltage by time function typically shows various deflections of different polarity, at different time points over specific electrodes. When segments of ERP waveforms are influenced by experimental manipulation, they are represented by theoretical constructs called ERP components. They can be defined by polarity, latency, and topography (Fabiani et al., 2007). Thus, the components are often associated with specific deflections in the voltage by time curve. There are modality-specific components that are triggered obligatorily, meaning even if the attention is drawn away from the stimulus. These are sensory components like in the visual modality the posterior P1 component, typically peaking between 100 to 130 ms after stimulus onset, and the N1 component between 130 and 200 ms (Luck, 2014). They reflect early visual processing being enlarged for attended than unattended stimuli (e.g., Hillyard & Anllo-Vento, 1998; Luck, 2014; Luck et al., 2000). Even the early posterior negativity (EPN) from 200 to 300 ms, typically found over temporo-occipital electrodes (left hemisphere: P5, P7, PO7, PO9'), can be subsumed under these components. The EPN is typically enlarged for affectively-arousing compared to neutral stimuli (e.g., Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp, Junghöfer, Weike, & Hamm, 2004). Furthermore, there also exist attention-dependent cognitive components like the P3 that is typically found over centro-parietal regions between 300 and 800 ms after stimulus onset (e.g., Donchin, 1981; Polich, 2007). The P3 is enlarged for infrequent and salient stimuli if they are relevant for the task. Emotional stimuli also elicit a larger P3 response, probably because of their salience. This component is also sometimes called P3b in order to differentiate it from the P3a, a frontally distributed component in the same time interval (Luck, 2014). Verleger, Jaskowski, and Wauschkuhn (1994) found that the P3b was elicited by infrequent but somehow expected stimuli, whereas the P3a was elicited by surprising stimuli. With the different ERP components and their automatic versus controlled nature in mind, it is obvious why ERPs are suitable to test the occurrence of bottom-up and top-down processes.

Since not only the background noise but also important information that is not time- and phase-locked to the event is cancelled out through the averaging procedure of ERPs, the time frequency analyses provides additional information as described in the next section.

1.3.2 EEG oscillations

Compared to ERPs, which reflect the averaged EEG activity time- and phase-locked to an event, power change values represent an increase or decrease in synchrony of the underlying electrophysiological activity (Roach & Mathalon, 2008). Event-related synchronizations (ERSs) or desynchronizations (ERDs) are obviously related to ERPs (Peng, Hu, Zhang, & Hu, 2012; Sochurková, Brázdil, Jurák, & Rektor, 2006; Toledo, Manzano, Barela, & Kohn, 2016), but they complement each other because ERSs/ERDs measure oscillatory activity that is not phase-locked to an event and therefore not cancelled out as in the averaging process when calculating ERPs (Gomarus, Althaus, Wijers, & Minderaa, 2006; Pfurtscheller & Da Silva, 1999). ERSs and ERDs represent power increases and decreases due to the synchronized oscillation pattern, respectively. They result from changes in parameters that control oscillatory processes in networks and are thus influenced by the dynamics of synaptic processes, the feedback loops between different brain regions, and neurotransmitter changes (Pfurtscheller & Da Silva, 1999).

One field of research, in which the analysis of EEG oscillations have been frequently applied is motor processing. Thus, EEG oscillations over the sensorimotor cortex represent its state of activation (Pfurtscheller, 1992): Decreases (ERDs) and increases (ERSs) in mu- and beta-band power (less than 30 Hz) over the sensorimotor cortex represent its excitability and inhibition, respectively. Evidence in support of this assumption has been provided, for instance, by Fonken et al. (2016) who showed that beta-band power over the motor cortex decreased during motor preparation, speaking for an increase in excitability of the motor cortex, whereas beta-band power increased when participants stopped their action, reflecting an inhibition. Results of Takemi, Masakado, Liu, and Ushiba (2013) revealed that even ERDs involved in a motor imagery task were associated with corticospinal excitability increases, similar to ERDs during actual motor responses.

In sum, ERPs and EEG oscillations allow to investigate the time course of automatic bottom-up and controlled top-down processes of empathy. Furthermore, in order to map specific ERP components to specific neural processes, as well as to investigate empathic influences on different cognitive and motor processing stages, it seems reasonable to apply an established model of information processing. Such a model will be outlined in the next section.

1.3.3 Modern mental chronometry

In cognitive psychology, parallel and serial models of information processing are distinguished (Meyer, Osman, Irwin, & Yantis, 1988). Whereas in a serial model, stages proceed in a sequential order, the stages in a parallel model happen simultaneously (Leuthold, 1994). An additional distinction is made between discrete and continuous models that assume a discrete or continuous information transmission between contingent processing stages, respectively (Leuthold, 1994).

The classical serial-discrete model assumes discrete transmission between the different processing stages between stimulus input and response output: stimulus encoding, categorization, response selection, and motor processing stages (cf. Sanders, 1990; Sternberg, 2004). In addition, Sanders (1983) assumed that an overstimulation of the arousal system leads to instant motor action without further cognitive consideration. Consequently, he proposed an arousal pathway leading from the stimulus encoding stage directly to the motor processing stage (cf. Figure 3.1).

While there exist alternatives to the serial-discrete stage model, like the cascade model suggested by McClelland (1979), it is not the goal of this dissertation thesis to investigate the different models; rather will I focus on the serial-discrete stage model as a heuristic tool for determining the potential locus of empathy-related influences on information processing.

Initially, mental chronometry used behavioral RT experiments, assuming that the RT is the sum of the time needed for each processing stage (e.g., Broadbent & Gregory, 1965, but see Eriksen & Schultz, 1979). Since it is difficult to tear the different stages apart with RTs, modern mental chronometry research applied the analysis of ERPs, because specific ERP components can be interpreted as representing different stages of information processing (e.g., Leuthold, 1994). The encoding and categorization stages are represented by different ERP components that either reflect their duration or extent.

For instance, the previously introduced sensory ERP components P1 and N1 can be taken to reflect the early stimulus encoding stage. The EPN represents somewhat later but still early differential processing of affective stimuli after their initial encoding. The later categorization stage is typically assumed to be represented by the centroparietal P3 component. EEG oscillations and response force, on the other hand, measure influences on the motor processing stage. In the next section, I will introduce studies that have already investigated empathic processing with EEG.

1.3.4 EEG studies of empathy

Several studies investigating the time course of empathy for pain compared ERP amplitudes of participants watching stimuli depicting body parts or faces in painful or neutral daily-life situations. Table 1.1 provides an overview of these studies. One of the first ERP studies on empathy for pain was conducted by Fan and Han (2008) who aimed at investigating the influence of stimulus reality and attention toward the pain dimension on empathic processing. Therefore, they presented cartoon and real pictures of body parts in painful situations, like cutting a finger, and the neutral counterpart with the body parts in the exact same arrangement but without the painful element (see Figure 1.2). Fan and Han asked their participants to judge the painfulness of the pictures or to count the body parts displayed, while recording EEG. This task manipulation allowed to draw attention towards or away from the pain dimension, respectively. After the EEG recording session, participants saw the painful pictures again and rated their pain intensity and their own self-unpleasantness during watching. RT was not significantly different between painful and neutral pictures, whereas response accuracy was lower in the painful than neutral condition. This difference was furthermore enlarged in the pain judgment compared to the counting task. Additionally, they found more positive ERP amplitudes in the painful than the neutral condition in early time intervals (P180, N240) over frontal electrodes, independent of the task but influenced by stimulus reality (cartoon versus picture). P3 amplitudes were larger in the painful than the neutral condition after 380 ms over central-parietal regions. This difference was independent of stimulus reality, but disappeared in the counting task, thus depending on the attention to the pain dimension. ERP amplitudes in the painful condition and the pain judgment task in an early time window (140-180 ms) were negatively correlated with pain intensity and self-unpleasantness ratings. Fan and Han interpreted their ERP results as reflecting early automatic bottom-up and late controlled top-down processes. Thus, in my view, these results support the late appraisal model that assumes an early empathic bottom-up response that is later on modulated by top-down mechanisms.

Subsequent ERP studies used a similar approach as Fan and Han (2008). However, as can be seen in Table 1.1, the RT and accuracy results differ across the studies. Similarly, the ERP results of Fan and Han (2008) regarding early automatic empathic processes have only been replicated by some studies (e.g., Han, Fan, & Mao, 2008), whereas others found amplitude differences in other time intervals (Decety, Yang, & Cheng, 2010; Mella, Studer, Gilet, & Labouvie-Vief, 2012; Meng et al., 2012; Sessa, Meconi, Castelli, & Dell'Acqua, 2014) or no early ERP difference at all (Lyu, Meng, & Jackson, 2014). The late controlled empathy effect has been found quite consistently over the different studies (e.g., Cheng et al., 2014;

Lyu et al., 2014). Thus, except for the late P3 difference, the studies revealed an inconsistent pattern of results, not allowing to identify whether the early or late appraisal model is more accurate in describing empathic responses.

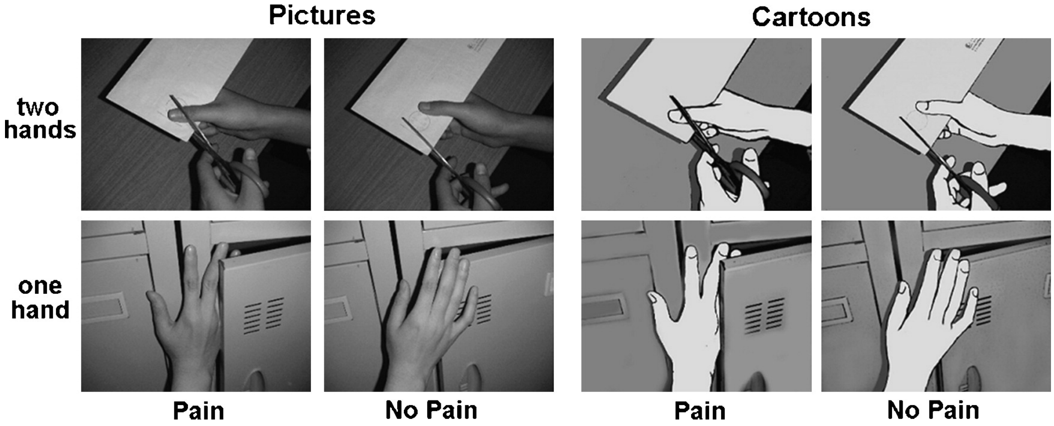


Fig. 1.2 Fotographs and cartoons of body parts in painful and neutral situations used by Fan and Han (2008). Figure reprinted from Neuropsychologia, 46, Fan, Y. & Han, S., Temporal dynamic of neural mechanisms involved in empathy for pain: An event-related brain potential study, 160-173, Copyright (2008), with permission from Elsevier.

Riečanský, Paul, Kölble, Stieger, and Lamm (2014) investigated EEG oscillations over the sensorimotor cortex to empathy-evoking stimuli and found stronger ERDs of beta oscillations (13-30 Hz) or of mu oscillations (7-12 Hz) during watching videos of hands in pain compared to neutral situations or at the static end phase of the videos, respectively. Their results were interpreted as an anticipatory sensorimotor activation, maybe in order to protect oneself from possible danger, speaking for a facilitation of movements when experiencing empathy for pain. In line with this assumption, Perry, Bentin, Bartal, Lamm, and Decety (2010) and Whitmarsh, Nieuwenhuis, Barendregt, and Jensen (2011) found stronger mu suppression over the sensorimotor cortex for painful than neutral stimuli. In contrast, other authors (Avenanti et al., 2005; Avenanti, Sirigu, & Aglioti, 2010) investigating MEPs triggered by transcranial magnetic stimulation found smaller MEP amplitudes to painful than neutral video clips. This was interpreted as an inhibition of motor responses when observing pain. Avenanti, Minio-Paluello, Sforza, and Aglioti (2009) clarified with their results that this

Table 1.1 Overview over ERP studies of empathy

Study	Participants	Stimuli	Task	Empathy-related results
Decety et al. (2010)	33 participants	Pictures of body parts penetrated by needle or Q-tip	Pain judgment for some trials	**ERPs** *N110 [90-120 ms]:* painful > neutral *P3 [360-400 ms]:* painful > neutral
Fan and Han (2008)	26 participants	Pictures of hands in painful or neutral daily-life situations and cartoons displaying the same scenes	Pain judgment + counting task	**ERPs** *P180 [140-200 ms]:* painful > neutral, task-independent *N240 [200-280 ms]:* painful > neutral, task-independent *P3 [380-500 ms]:* painful > neutral only in pain judgment task **RT** no difference between painful and neutral **Accuracy** neutral > painful, stronger in pain judgment task
Han et al. (2008)	26 participants	Pictures of hands in painful or neutral daily-life situations and cartoons displaying the same scenes	Pain judgment + counting task	**ERPs** *P180 [140-200 ms]:* painful > neutral, task-independent *N240 [200-280 ms]:* painful > neutral, task-independent *P3 [380-500 ms]:* painful > neutral only in pain judgment task **RT** Only males: neutral > painful only in pain judgment task **Accuracy** Only females: neutral > painful only in pain judgment task
Lyu et al. (2014)	28 participants	Pictures of body parts in painful or neutral daily-life situations	Pain intensity rating	**ERPs** *N1 [100-140 ms]:* no difference between painful and neutral *P3 [360-500 ms]:* painful > neutral
Mella et al. (2012)	16 adolescents + 16 adults	Pictures of hands in painful or neutral daily-life situations and cartoons displaying the same scenes	Pain judgment + counting task	**ERPs** *N110 [90-130 ms]:* neutral > painful in both tasks, but only in adolescents *N340 [340 ms]:* painful > neutral in both tasks *P3 [360-800 ms]:* painful > neutral only in pain judgment task **RT** neutral > painful only in pain judgment task **Accuracy** no difference between painful and neutral
Meng et al. (2012)	20 participants	Pictures of body parts in painful or neutral daily-life situations	Pain intensity rating	**ERPs** *N1 [90-150 ms]:* painful > neutral *P2 [200-250 ms]:* painful > neutral *N2 [230-300 ms]:* neutral > painful *P3 [360-800 ms]:* painful > neutral **RT** painful > neutral (note: rating instead of pain judgment task)
Sessa et al. (2014)	12 participants	Pictures of faces penetrated by needle or Q-tip	Pain judgment	**ERPs** *N2-N3 [280-340 ms]:* painful > neutral *P3 [400-750 ms]:* painful > neutral **RT** no difference between painful and neutral

Note. Overview over studies investigating empathy with ERPs (concerning ERPs '>' means 'more positive amplitude').

motor inhibition was limited to the left or right hand of the observer that corresponded to the hand presented in the video. One can speculate that EEG oscillations measured a general sensorimotor activation of larger muscle groups, whereas the specific muscle that is injured in the video, is inhibited in the observer as suggested by the MEP results. Another possible explanation for the differing oscillatory and MEP results is that the excitability and inhibition of the sensorimotor system may vary over time. Thus, it remains an open issue whether empathy inhibits or facilitates sensorimotor activation.

In sum, EEG studies investigating either empathic influences on affective and cognitive processing or on motor processing, revealed inconsistent results. More specifically, behavioral results differed across studies, revealing either no RT differences or shorter RTs for the neutral and sometimes for the painful condition. The early ERP difference between the painful and the neutral condition was found at different time intervals and sometimes not at all. The only ERP difference that was consistently found was in the late P3 time interval. For the painful condition, EEG oscillation and MEP results revealed a facilitation and an inhibition of sensorimotor activity, respectively, making it difficult to come up with straightforward conclusions.

1.3.5 Modulating factors

Considering empathic influences on information processing, it is further interesting to compare the empathic responses towards in- and outgroup targets. As already mentioned, we know key factors modulating the empathic response measured by EEG, like the profession (Decety et al., 2010) or the age of the participants (Cheng, Chen, & Decety, 2014; Mella et al.,2012), the relationship between the observer and the target (Leng & Zhou, 2010), or the type of perspective-taking (Li & Han, 2010). The racial background of the target is another modulating factor important for present purposes that is also viewed to be critical for the relation of empathy and morality as will be discussed below (e.g., Chiao & Mathur, 2010;

Cikara, Bruneau, & Saxe, 2011). To better understand the exact mechanisms underlying the racial bias in empathy, it is again important to determine its time course and thus the differences on the encoding, categorization and motor processing stages to be examined in Study 1.

The existing literature again can be divided into studies investigating the influence of racial background on information processing with ERPs and its influence on motor processing with EEG oscillations or MEPs. An overview over the relevant studies is presented in Table 1.2. Sessa et al. (2014) measured EEG while White participants were judging the painfulness of pictures of fair- or dark-colored faces penetrated by a needle (painful condition) or a Q-tip (neutral condition). Afterwards, the implicit racial bias was assessed by the race version of the Implicit Association Task (IAT), an experimental procedure to assess the strength of automatic associations by measuring performance speed of two categorization tasks (Greenwald, McGhee, & Schwartz, 1998; Greenwald, Nosek, & Banaji, 2003). Sessa et al. did not find any RT difference between the painful and neutral condition, but ERP results indicated more positive amplitudes for the painful than the neutral condition in the N2 - N3 time interval (280-340 ms), only for own race targets. The later P3 amplitudes were larger for the painful than the neutral condition, independent of the racial background. Nevertheless, P3 amplitudes for ingroup targets in pain over specific electrodes were associated to the IAT scores, possibly reflecting a relation between an implicit ingroup preference and the extent of the P3 response to pain. In sum, Sessa et al. assumed that the early empathic response is influenced by the racial bias and therefore only present for the ingroup, whereas the later controlled empathic response is present for both groups.

Several other studies that investigated this racial bias in empathy also found an influence on early ERP time intervals, even though the exact intervals varied strongly (Contreras-Huerta, Hielscher, Sherwell, Rens, & Cunnington, 2014; Li et al., 2015; Sessa et al., 2014; Sheng, Du, & Han, 2017; Sheng, Liu, Zhou, Zhou, & Han, 2013). One critical issue is that

Table 1.2 Overview over studies of racial bias in empathy

Study	Participants	Stimuli	Task	RBE-related Results
Contreras-Huerta et al. (2014)	21 Caucasian-Australian participants	Pictures of Asian and Caucasian faces penetrated by needle or Q-tip	Pain judgment	**ERPs** *N1 [80-140 ms]:* painful > neutral only for ingroup *P3 [450-650 ms]:* painful > neutral for both groups
Li et al. (2015)	32 Chinese participants	Pictures of Asian and Caucasian faces with neutral or painful expression	Pain judgment	**ERPs** *P2 [128-188 ms]:* painful > neutral stronger for ingroup *N2 [200-300 ms]:* painful > neutral for both groups *P3 [400-700 ms]*: painful > neutral stronger for ingroup, if mortality salience is primed **RT** neutral > painful for both groups
Sessa et al. (2014)	12 white-Caucasian participants	Pictures of black- and white-colored faces penetrated by needle or Q-tip	Pain judgment	**ERPs** *N2-N3 [280-340 ms]:* painful > neutral only for ingroup *P3 [400-750 ms]:* painful > neutral for both groups **RT** no difference between painful and neutral
Sheng et al. (2017)	26 Chinese participants	Pictures of Asian and Caucasian faces with neutral or painful expression	Judgment of orientation of filler items (scrambled faces)	**ERPs** *N170 [128-188 ms, occipitotemporal]:* no difference between painful and neutral *P2 [128-188 ms, fronto-central]:* painful > neutral only for ingroup
Sheng and Han (2012)	48 Chinese participants	Pictures of Asian and Caucasian faces with neutral or painful expression	Study 1: race judgment Study 2: race + pain judgment	**ERPs** Study 1: *P2 [128-188 ms]:* painful > neutral only for ingroup *N2 [200-300 ms]:* painful > neutral stronger for ingroup *P3 [400-700 ms]*: no difference between painful and neutral Study 2: Pain judgment task eliminated bias (attention for individual's feelings) **RT** Study 1: painful > neutral only for ingroup
Sheng et al. (2013)	16 Chinese participants	Pictures of Asian and Caucasian faces with neutral or painful expression	Race judgment	**ERPs** *P2 [128-188 ms]:* painful > neutral stronger for ingroup *N2 [200-300 ms]:* neutral > painful for both groups *P3 [400-700 ms]:* no difference between painful and neutral **RT** painful > neutral for ingroup neutral > painful for outgroup
Riečanský et al. (2015)	69 white-colored participants	Video clips of black-, white- and purple-colored hands penetrated by needle or Q-tip	--	**EEG oscillations over sensorimotor cortex** *beta ERD (moving stimuli):* painful > neutral only for ingroup *mu ERD (static endpoint):* painful > neutral for both groups
Avenanti et al. (2010)	18 white-Caucasian + 18 black-African participants	Video clips of black-, white- and purple-colored hands penetrated by needle or Q-tip	After each block: questions about videos	**Motor-evoked potentials (MEPs)** neutral > painful only for ingroup

Note. Overview over studies investigating the racial bias in empathy (RBE) with ERPs, EEG oscillations and MEPs (concerning ERPs '>' means 'more positive amplitude').

the results change with the presented stimuli: On the one hand, pictures of faces with painful compared to neutral facial expressions led to a larger frontocentral P2 amplitudes (128-188 ms), with this effect being increased or only present for own-race targets in a race judgment task (Sheng et al., 2013; Sheng & Han, 2012), the pain judgment task (Li et al., 2015; but see Sheng & Han, 2012) or without any stimulus-specific task (Sheng et al., 2017). On the other hand, faces in painful compared to neutral situations with neutral facial expressions evoked only for ingroup targets more positive amplitudes between 80 and 140 ms in the pain judgment task of one study (Contreras-Huerta et al., 2014) and a somewhat later between 280 and 340 ms after stimulus onset over frontocentral electrodes in the study of Sessa et al. (2014). Possibly, the neutral facial expression combined with the penetration of a needle seemed unrealistic to participants because usually people show painful expressions if they experience pain. Furthermore, one cannot rule out that other factors than racial background like trustworthiness of the presented faces (e.g., Stanley, Sokol-Hessner, Banaji, & Phelps, 2011; Todorov, Said, & Verosky, 2011) interacted with empathy. Another problem of all the presented studies except for one (Contreras-Huerta et al., 2014) that makes interpretation of the inconsistent results more difficult was that they investigated only one racial group of participants, most of the time Asians (see Table 1.2). Nevertheless, regarding the late P3 influence, results were consistent: The late empathic response was not differentially influenced by the target's racial background (but see Li et al., 2015).

Concerning the influence on the motor processing stage, Riečanský et al. (2014) found larger ERDs and thus greater sensorimotor activation in the beta band (13-30 Hz) to painful compared to neutral video clip stimuli of hands only for ingroup targets, but no difference in motor activation for painful stimuli depicting outgroup targets. In contrast, mu band (7-12 Hz) ERDs were larger for painful than neutral static pictorial stimuli for both skin colors, speaking for an increase of sensorimotor activation for targets of both skin colors in pain. Using MEPs, Avenanti, Sirigu, and Aglioti (2010) found an ingroup-specific motor effect, but in the opposite direction: Motor activation was inhibited for painful compared to neutral stimuli.

1.3.6 Interim summary

In order to investigate automatic bottom-up and controlled top-down empathic processes, the EEG seems to be especially suitable because of its high temporal resolution. ERPs and EEG oscillations are complementary analysis approaches that reveal information about empathic influences on the different stages of information processing. Recalling the two questions formulated by Batson (2009), we have now looked into the existing literature and the methodology in order to investigate the first question of how empathy arises. I then introduced modulating factors of empathy like the racial background of the target in order to bridge the gap between the first and the second question "When do people respond with care to others' suffering?". On the one hand, one can investigate the influences of the racial background on empathic processing and on the other hand, the results give hints as to why prosocial behavior might be missing in some occasions. This will also be discussed in the next section, where I will dive into the theoretical background of the second question. I will start with the relationship between empathy and prosocial behavior, and then introduce the concepts of empathic concern and personal distress, two phenomena that are believed to determine whether prosocial behavior is shown or not.

1.4 Empathy and its link to prosocial behavior

Regarding Batson's (2009) second question, that is, when we respond to others' suffering with care, it is obvious that empathy has often been related to prosocial behavior and altruism, like for example in the empathy-altruism-hypothesis of Batson (1987). This hypothesis assumes that the motivation to help other persons that results from empathy is purely altruistically driven. Evidence in favor of the empathy-altruism-hypothesis was provided by various studies (Batson, Duncan, Ackerman, Buckley, & Birch, 1981; Toi & Batson, 1982) which found that if the observers experience low levels of empathy and escape is easy, the probability of helping the other is very low, whereas it is very high if they experience high levels of empathy. These findings outrule the existence of an egoistic goal to reduce the own arousal when experiencing empathy.

On the other hand, empathy can also be used to damage others, for example, in order to hurt the other's feelings effectively in a fight or in competitive environments like sports (Lamm & Majdandžić, 2015; Singer & Lamm, 2009). Knowing the other's internal state, including thoughts and feelings, is obviously of use in these situations. Here, again, the definitions of empathy are of great importance (Lamm, Rütgen, & Wagner, 2017). The empathy-altruism hypothesis uses the term empathy referring to the concept of empathic concern, that is an other-oriented emotional response of sympathy and sorrow that differs from the target's state (Eisenberg et al., 1991). Here it is important to note that empathic concern should not be mixed up with the mere knowledge of another's internal state that can indeed be used to damage others (McCall & Singer, 2013). This is also evident when considering the counterpart of empathic concern, that is personal distress: A self-focused aversive response of unpleasantness similar to the target's state (e.g., Batson, Fultz, & Schoenrade, 1987). The main difference between personal distress and empathic concern lies in their orientation to the self and the other, respectively, leading to different motivational consequences: If observers experience more personal distress, they are eager to reduce their own unpleasantness, whereas if they experience more empathic concern, they should be motivated to reduce the target's suffering (e.g., Batson, O'Quin, Fultz, Vanderplas, & Isen, 1983; Decety, 2010; Goubert et al., 2005; Singer & Lamm, 2009). Indeed, various studies reported that empathic concern led to prosocial behavior (e.g., Batson & Ahmad, 2001; Batson & Moran, 1999). For example, Weng, Fox, Hessenthaler, Stodola, and Davidson

(2015) found that participants with greater empathic concern scores were more likely to help an unfair-treated other, whereas there was no relation to punishment behavior towards persons displaying the unfair behavior.

The relation between empathic concern and prosocial behavior is widely acknowledged. In order to answer the second question of Batson (2009), it is now important to investigate empathic concern and its counterpart personal distress in more detail and inquire when people experience which of the two emotional responses.

1.5 Evoking and measuring empathic concern and personal distress

As described in the previous paragraph, the experience of empathic concern and personal distress is an important determinant for the occurrence of helping behavior when witnessing another person in pain (e.g., Eisenberg, Shea, Carlo, & Knight, 1991). That is, empathic concern is related to an altruistic motivation to reduce the other's suffering, whereas personal distress is assumed to lead to an egoistic motivation in order to reduce one's own suffering (e.g., Batson et al., 1983; Decety, 2010). It is not yet clear, however, under which specific conditions these two emotional responses are occurring. Therefore, variables that influence their occurrence will be described in this section.

In this respect, one critical issue concerns the fact that the dispositions to experience empathic concern and personal distress differ between individuals. Furthermore, which phenomenon is present in a specific situation is not solely determined by the individual's empathic traits (Batson et al., 1987). It still remains an open question how, dispositional and situational empathic concern and personal distress are related, as will be discussed below. First, the measurements of dispositional traits and situational responses will be introduced. Dispositional empathic traits can be measured by the Interpersonal Reactivity Index (IRI, Davis, 1983b), a questionnaire with four scales of four items each: fantasy, perspective taking, personal distress and empathic concern. An item of the empathic concern scale is for example “I often have tender, concerned feelings for people less fortunate than me”. “I sometimes feel helpless when I am in the middle of a very emotional situation” is an item for personal distress. The Empathic Response Scale, on the other hand, measures situational empathic concern and personal distress by asking participants how much they experience certain affective states, like “compassionate”, “moved”, “worried”, “distressed” in a given situation (e.g., Batson et al., 1997; Batson, McDavis, Felix, Goering, & Goldman, 1976).

According to Decety and Lamm (2006), dispositional empathic traits, as well as the emotional background of the observer, but also situational factors like the context, the emotion and the level of arousal should influence the experience of the two empathic emotions. There are few studies that investigated the relationship between situational empathic concern and personal distress and these other variables. Davis (1983a) assessed dispositional traits with the IRI and situational empathic concern and personal distress with the Empathic Response Scale. He found only a small correlation between situational and dispositional measures (see also, Eisenberg et al., 1994; Light et al., 2015). In contrast, Eisenberg et al. (1994) found promising correlations between dispositional affect measured by the Positive and Negative Affect Schedule (PANAS, Watson, Clark, & Tellegen, 1988) and situational personal distress as measured with the Empathic Response Scale.

Decety and Lamm (2006) view self-other differentiation as the key feature in determining whether empathic concern or personal distress arises from empathy. Thus, too much self-other overlap results in personal distress. In this respect, an important factor seems to be the type of pain experienced by the target: Batson, Early, and Salvarani (1997) proposed that physical pain should evoke more personal distress than empathic concern in the observer, irrespective of the self-other differentiation. In contrast, for psychological pain, the focus on the own versus the other’s feelings plays an important role (e.g., Batson et al., 1997;

Decety & Lamm, 2006; Goubert et al., 2006; Wondra & Ellsworth, 2015). More specifically, if the observer is focusing on the own feelings, personal distress is evoked; if the focus lies on the target's situation, empathic concern is the result (Batson et al., 1997). Batson et al. (1997) found that when listening to a dramatic story of a girl who lost her parents, the perspective-taking instructions that direct the focus either toward the own or the other feelings determine whether more personal distress or empathic concern is evoked.

Eisenberg et al. (1996) assume that high levels of empathy are likely to lead to high levels of empathic concern if the observer is well-regulated (see also, Eisenberg et al., 1994). However, according to Eisenberg and Eggum (2009), if individuals experience intense emotions and have difficulties in self-regulation, they are prone to experience personal distress because of overarousal. Thus, self-regulation abilities are a key point in preventing high levels of arousal from resulting in personal distress (Decety & Jackson, 2004). In other words, there seems to exist a stronger link from arousal to personal distress than to empathic concern (for a review, see Eisenberg, Valiente, & Champion, 2004). Since arousal is known to speed up responses, it may be observable in RTs (Sanders, 1983).

There are few studies investigating the occurrence of empathic concern and personal distress, always using few trials and often not taking important variables like perspective and affect into account. This is the reason why Study 3 of this dissertation project aimed at manipulating their occurrence with the aid of pictures of persons in psychological and physical pain in a randomized controlled study and measure their relation to situational and dispositional factors.

1.6 Interim Summary

There is now substantial evidence for the assumption that specific brain regions are active during the experience of pain and the observation of pain in others. Importantly, however, the time course of empathic processing is not that well investigated. It is still not clear whether there is an early automatic empathic influence on information processing, whereas the results of the late controlled component of empathy seem to be quite stable. Other studies investigating empathic influences on motor processing did not agree on whether empathy leads to an inhibition or a facilitation of motor responses.

Another open issue concerns differences in empathic influences for racial in- and out-group targets on information processing. Regarding the two empathic emotions empathic concern and personal distress that follow the initial empathic response, it is an open question which factors influence situational empathy and how empathic concern and personal distress influence motor responses. The main goal of this doctoral thesis is to address these open questions as will be discussed in the following paragraphs.

Chapter 2

Aim of the present work

Given the different meanings of empathy (cf. Batson, 2009), it is important to clarify that in the present thesis, I will stick to the definition of empathy by de Vignemont and Singer (2006). According to these authors, empathy is an affective state isomorphic to and elicited by another person's affective state, with the knowledge about the source of the own state.

This doctoral thesis aimed at contributing answers to the following questions (Batson, 2009): How can we get to know another's internal state and when do we respond with care to another's suffering. In the review of previous studies (Chapter 1), I identified various research gaps that will be addressed in this work. Thus, the main aims can be defined as the following: On the one hand, the time course of the immediate automatic and controlled empathic response to another person in pain shall be investigated regarding early encoding, late categorization and motor processing stages. Then, influences of the target's racial background on empathic responses shall be determined, including their time point and automatic or controlled manner. On the other hand, I wanted to examine the occurrence of empathic concern and personal distress following the initial empathic reaction. The specific studies will be outlined in more detail in the following paragraphs.

2.1 Empathic influences on perceptual and motor processing

Currently it remains unclear at which stages of information processing empathic influences can be observed. Nevertheless, previous studies provide hints that early processing stages are influenced automatically, whereas later stages are influenced in a controlled manner. Moreover, it is unclear whether empathy-evoking stimuli inhibit or facilitate motor processing. Study 1 aimed at investigating automatic and controlled influences on empathic processing on the encoding, categorization and motor processing stages in a single experiment. Until now, at least to my knowledge, no study has comprehensively investigated empathic influences on the different stages of information processing in a single experiment. The empathic influences were investigated with the aid of ERPs and oscillatory EEG activity while participants were watching empathy-evoking and neutral stimuli: Early ERP components like P1, N1 and EPN reflect the early encoding stage, the late P3 component represents the later categorization stage and EEG power changes over the sensorimotor cortex reflect motor activation. In response to the critique of Zaki and Ochsner (2012) regarding the missing link between brain activity and behavior in previous studies, the first and second study assessed RT and response force in a pain judgment and a counting task as behavioral measurements.

2.1.1 Approach and hypotheses of Study 1

In Study 1, 124 pictures of body parts in neutral or painful daily-life situations (Meng, Hu et al., 2012) were presented on a computer screen. A painful picture was for example a hand that was accidently cut while slicing a cucumber. The neutral pendant showed the same arrangement of hands and objects without the painful element. Participants judged the pictures according to their painfulness (painful vs. neutral) or the amount of presented body parts (one vs. two or more), while RT, response force, and EEG were recorded. The aim of the different tasks was to direct the attention either toward or away from the pain dimension in order to determine controlled and automatic processes.

If automatic empathic influences on the early encoding stage exist, the early ERP components (P1, N1, EPN) should differ between painful and neutral stimuli in both tasks. Later controlled influences on the categorization stage, reflected by P3 amplitudes, should depend on the attention to pain. If empathic influences on the motor processing stages manifest themselves in motor inhibition, EEG oscillations over the sensorimotor cortex should synchronize. If empathy leads to motor facilitation, they should desynchronize.

2.2 The modulation of empathic processing by racial background

Study 2 was designed to measure whether these empathic influences on information processing change when the target's racial background is changed. Previous studies investigating mainly face stimuli of different racial backgrounds revealed contradictory results. Nevertheless, there are hints that empathic processing differs for other and own racial backgrounds in early but not later time intervals and that the motor facilitation or inhibition to painful stimuli is larger for targets with the same racial background (Avenanti et al., 2010; Riečanský et al., 2014; Sessa et al., 2014). Because of the potential limitations of face stimuli outlined above (Chapter 1.3.5), it seemed reasonable to examine empathic responses to outgroup targets with newly created and prerated, less complex hand stimuli.

2.2.1 Approach and hypotheses of Study 2

Pictures of dark- and fair-colored hands in neutral and painful daily-life-situations were generated. Caucasian participants judged the painfulness of the situation or the skin color of the presented hands, while RT, response force, and EEG were recorded. At the end of the experiment, participants completed the race IAT (Greenwald et al., 1998, 2003) in order to assess implicit ingroup preferences. After the EEG recording sessions in Study 1 and 2, participants also rated the painfulness they perceived on the painful pictures and their own self-unpleasantness during watching them, as well as their empathic dispositions.

In line with the literature, it was hypothesized that the automatic empathic influence on the early encoding stage should only be present for targets with the same skin color like the participant, whereas the influence on the late categorization stage should be present for both skin colors. Motor processing stages, again, should be subject to the racial bias in empathy.

2.3 Empathic concern and personal distress

Study 3 examined the empathic emotions that follow the initial empathic response investigated in the other two studies of this doctoral thesis. The aim was to determine how important dispositional empathic traits and situational variables are in evoking empathic concern and personal distress. Situational variables are for example affect experienced by the observer and the type of pain experienced by the target. Situational affect, empathic concern, and personal distress experienced by the participant as well as dispositional empathic traits were assessed. Based on the literature, a stronger relationship between the situational empathic responses and situational factors (type of pain, affect) was expected compared to dispositional empathic traits. It was further expected that observers experience more arousal with increasing levels of personal distress, leading to increasingly faster motor responses than if they experience empathic concern.

2.3.1 Approach and hypotheses of Study 3

Pretested pictures of persons in psychological pain (because of the death of the mother) or physical pain (because of a heart attack) or no pain in the control condition were presented on a computer screen, together with descriptions of situations that promoted an other-focused instead of a self-focused state (e.g., “Imagine yourself to be on a street facing a stranger who is obviously not feeling well. You ask him/her what has happened. He/she answers that he/she has just found out that his/her mother has died all of a sudden.”, “Imagine that you meet a new colleague at your office. All of a sudden, he/she complains about violent pain at the thoracic regions.”). After blocks of six pictures, participants rated their empathic responses on the adjusted version of the Empathic Response Scale (e.g., Batson et al., 1997; Batson et al., 1976). Participants performed an approach-avoidance task, moving a slider device either towards or away from their body depending on the pitch of a tone presented 1000 ms after picture onset. In order to direct the attention of the participants onto the pictures despite their irrelevance for the response, after each block, they were asked whether they remembered a specific person whose picture could have been presented in the preceding block. Dispositional empathic traits (IRI, Davis, 1983b) and positive as well as negative affect (PANAS, Watson et al., 1988) were assessed.

In line with the literature (Eisenberg et al., 1994), negative and positive affect before the experiment were assumed to predict personal distress and empathic concern, respectively, whereas dispositional empathy should not play an important role in predicting situational empathic concern and personal distress. Together with the other-focused state, physical pain should evoke personal distress and psychological pain should evoke empathic concern. Motor responses were expected to be faster for personal distress than empathic concern because of higher levels of arousal.

2.4 Interim summary

In sum, in order to understand empathy, it seemed helpful to investigate empathic influences on information processing, how these vary with racial group dependency of the target, and what determines the occurence of the resulting empathic emotions empathic concern and personal distress. In the following chapters the three studies, including their results, are presented. They are written as separately readable manuscripts. This results in overlapping contents to this introduction, the general discussion, and between the empirical chapters.

2.5 Declaration of contributions

Study 1: Fabi, S., & Leuthold, H. (2017). Empathy for Pain Influences Perceptual and Motor Processing: Evidence from Response Force, ERPs, and EEG Oscillations. *Social Neuroscience, 12*, 701-716.

Sarah Fabi

- idea & study conception
- collecting stimuli
- acquisition of data
- R analysis
- interpretation of results
- writing manuscript

Prof. Dr. Hartmut Leuthold

- idea & study conception
- interpretation of results
- writing manuscript

Dr. Ian G. Mackenzie

- programming the experiment
- writing custom Matlab routines for EEG and force key analysis
- R analysis

Study 2: Fabi, S., & Leuthold, H. (2018). Racial bias in empathy: Do we process dark- and fair-colored hands in pain differently? An EEG study. *Neuropsychologia, 114,* 143-157.

Sarah Fabi

- idea & study conception
- creating & pretesting stimuli
- acquisition of data
- R analysis
- interpretation of results
- writing manuscript

Prof. Dr. Hartmut Leuthold

- idea & study conception
- interpretation of results
- writing manuscript

Dr. Ian G. Mackenzie

- programming experiments
- writing custom Matlab routines for EEG and force key analysis
- R analysis & preparation of figures
- corrections to manuscript

Bachelor's students

- creating stimuli
- help with data collection

Study 3: Fabi, S., Weber, L.A., & Leuthold, H. (submitted). Empathic Concern and Personal Distress depend on situational but not dispositional factors. ***The Quarterly Journal of Experimental Psychology.***

Sarah Fabi

- idea & study conception
- collecting & pretesting stimuli
- supervising data acquisition
- R analysis
- interpretation of results
- writing the manuscript

Prof. Dr. Hartmut Leuthold

- idea & study conception
- interpreting results
- writing the manuscript

Dr. Ian G. Mackenzie

- programming experiment including creating novel dynamic 3-D display arrangement for the approach-avoidance task
- writing analysis software for the slider device
- R analysis
- corrections to manuscript (in particular method section)

Lydia Weber (Master's student)

- idea & study conception
- collecting & pretesting stimuli
- acquisition of data under supervision
- revising the manuscript

Chapter 3

Study 1: Empathy for pain influences perceptual and motor processing: Evidence from response force, ERPs, and EEG oscillations

Reprinted from *Social Neuroscience, 12,* Fabi & Leuthold, Empathy for Pain Influences Perceptual and Motor Processing: Evidence from Response Force, ERPs, and EEG Oscillations, 701-716, Copyright 2017, with permission from Routledge Taylor and Francis Group. The official citation that should be used in reference to this material is:

Fabi, S., & Leuthold, H. (2017). Empathy for Pain Influences Perceptual and Motor Processing: Evidence from Response Force, ERPs, and EEG Oscillations. *Social Neuroscience, 12*, 701-716.

Social Neuroscience is available online at:
http://www.tandfonline.com/toc/psns20/current

3.1 Abstract

The present study investigated the nature and chronometry of empathy for pain influences on perceptual and motor processes. Thus, event-related brain potentials (ERPs), response force (RF) and oscillatory electroencephalography (EEG) activity were measured while participants were presented with pictures of body parts in painful or neutral situations. Their task consisted in either judging the painfulness of the stimuli or counting the body parts displayed. ERP results supported the assumption of an early automatic component of empathy for pain, as reflected by the early posterior negativity (EPN), and of a late controlled component, as reflected by the late posterior positivity (P3). RF indicated that empathy-evoking stimuli facilitate motor responses if attention is directed towards the pain dimension, whereas EEG oscillations in the mu-and beta-band revealed, independent of the task, an enhanced activation of the sensorimotor cortex after the response to painful compared to neutral stimuli. In conclusion, present findings indicate that empathy-evoking stimuli produce automatic and controlled effects on both perceptual and motor processing.

3.2 Introduction

Observing another person suffering from physical or psychological pain changes our own feelings accordingly. This ability to share the feelings of another person, and at the same time knowing that the other is the source of ones own, is referred to as empathy (e.g., de Vignemont & Singer, 2006). It is evident that empathy plays a crucial role in our everyday social life. Therefore, it is not surprising that empathy, especially for pain, has been extensively studied recently. Specifically, functional magnetic resonance imaging (fMRI) studies revealed the neural substrates underlying empathy for pain, with brain regions forming the so-called pain matrix (anterior insula, anterior cingulate cortex) being activated while experiencing pain oneself, as well as while watching others experiencing pain (e.g., Decety & Meyer, 2008; Gu & Han 2007; Singer et al., 2004; for a review see Lamm, Decety, & Singer, 2011). Yet, it is still an unresolved issue which processes in the course of stimulus-response (S-R) processing are selectively influenced by empathy for pain, and whether empathy-related effects automatically modulate early perceptual as well as late motor processing stages. Therefore, it is the main objective of this study to investigate the time course of empathic influences on the various information processing stages by analyzing oscillatory electroencephalographic (EEG) activity, event-related brain potentials (ERPs), reaction time (RT), and response force (RF).

Different models have been proposed with regard to the time course and automaticity of empathic processes (e.g., de Vignemont & Singer, 2006), however, our understanding about these issues is still limited as will become clear later. For instance, de Vignemont and Singer (2006) suggested on the one hand a late appraisal model, according to which emotional cues automatically elicit empathy, while the emotional context is processed in parallel (see also, Preston & de Waal, 2002). Appraisal processes then modulate the automatically elicited empathic response. On the other hand, their early appraisal model understands the empathic response as a mere result of the appraisal processes elicited by the emotional cue and its context. That is, the outcome of the contextual appraisal process determines whether or not an empathic response is triggered. The critical difference between the two models is that in the late appraisal model, the empathic response happens automatically and is only modulated by the cognitive appraisal, whereas in the early appraisal model it is triggered in a controlled way dependent on the outcome of the appraisal process.

As concerns the automaticity assumption, fMRI studies have provided mixed results, for instance, showing activation of the neural pain matrix only in a task that required attention to pain (rating pain intensity), but not in a task in which pain was task-irrelevant (Gu & Han, 2007), whereas others found an activation pattern of pain matrix brain regions even if participants were informed that the hands in painful situations were anesthetized (e.g., Decety & Lamm, 2006; Lamm, Nusbaum, Meltzoff & Decety, 2007). Furthermore, because of the low temporal resolution of fMRI, it is difficult to draw definite conclusions concerning the time course of empathic processes on the basis of the above reviewed studies (cf. Zaki & Ochsner, 2012). Therefore, it has been recommended to use methods with high temporal resolution, such as EEG and ERPs, to investigate the mental chronometry of empathy-related automatic and controlled processing (e.g., de Vignemont & Singer, 2006; Zaki & Ochsner, 2012).

To guide such time course inferences, we propose to consider a model of information processing that consists of a sequence of distinct stages between stimulus input and response output, including stimulus encoding, categorization, response selection, and motor processing (cf. Sternberg, 2004; Sanders, 1990; cf. Figure 3.1). Since specific ERP components are known to sensitively reflect either the duration or extent of automatic and controlled mental processes, ERPs seem ideally suited to investigate the locus of empathic influences within information processing (for a review, see Olofsson, Nordin, Sequeira, & Polich, 2008). Thus, positively and negatively valenced stimuli (e.g., pictures, faces) have been shown to trigger larger visual ERP amplitudes than neutral stimuli between 100 and 300 ms after stimulus onset over occipito-temporal sites (P1, N1). The posterior P1 component is associated with early activity in the extrastriate cortex and known to be enhanced for attended than unattended stimuli (e.g., Hillyard & Anllo-Vento, 1998; Luck & Hillyard, 1994). The subsequent posterior negativity (N1) is elicited between 130 to 200 ms after the onset of visual stimuli, reflecting higher-order visual processes while also being sensitive to attention. It is worth noting that other researchers (e.g., Eimer & Holmes, 2002) found an earlier peaking anterior negativity (120 ms) to be smaller for attention-capturing, salient emotional than neutral stimuli that undergo automatic processing (e.g., Oehman, 2002). Also the early posterior negativity (EPN) between 200 and 300 ms after stimulus onset reflects such automatic emotion-related influences on information processing (e.g., Schupp, Junghöfer, Weike, & Hamm, 2004; Olofsson et al., 2008). In addition, emotional stimuli have also been found to elicit an augmented, centroparietally distributed late posterior positivity (P3) that is taken to reflect task-dependent stimulus classification processes (e.g., Donchin, 1981; Polich, 2007).

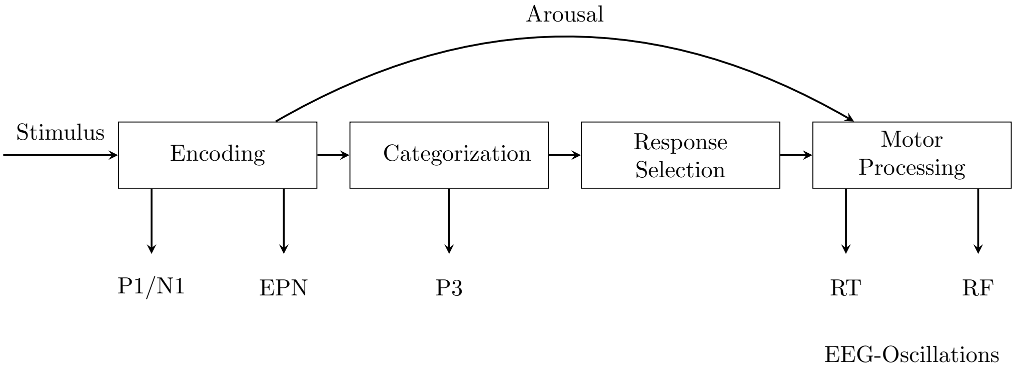


Fig. 3.1 Model of information processing including encoding, categorization, response selection, and motor processing stages as well as an energetic arousal pathway. See main text for further details.

A prominent ERP study addressing the time course of empathic processing was conducted by Fan and Han (2008). They presented pictures showing one or two hands in neutral or painful situations (e.g. cutting vegetables / cutting oneself). Participants were instructed to either judge the pictures as neutral versus painful or to count the number of hands displayed in the pictures. In the pain judgment task, they found more positive ERP amplitudes for painful than neutral stimuli in an early and a late time interval. More specifically, the ERP waveform between 140-200 ms (P180) and 200-280 ms (N240) over fronto-central regions reflected the task-independent, early pain effect. By contrast, the centroparietal P3 component (360-800 ms) indicated the task-dependent, late pain effect, that is, P3 amplitude was influenced by painful versus neutral stimuli only in the pain judgment but not the counting task. These findings indicate that distinct early-automatic and late-controlled processes contribute to empathy for pain, hence providing evidence for the late appraisal model of de Vignemont and Singer (2006). However, as will be outlined next, subsequent ERP-studies using similar stimulus materials and tasks revealed discrepant results.

For instance, using different stimuli and tasks, Meng, Hu et al. (2012) and Decety, Yang, and Cheng (2010) found early (N1, P2) and late (P3) ERP components to be influenced by empathy as in Fan and Han's (2008) study. However, other studies could only replicate the empathy for pain influence on the P3 component (Lyu, Meng, & Jackson, 2014; Sessa, Meconi, Castelli, & Dell'Acqua, 2014). Interestingly, using Fan and Han's (2008) stimuli and tasks, Mella, Studer, Gilet, and Labouvie-Vief (2012) found an early ERP effect only in adolescents but not adults, and it was opposite in direction to that reported by Fan and Han (2008).

Empathy-related influences on sensorimotor and late motor processes have been examined in studies analyzing either oscillatory EEG activity or motor evoked potentials (MEPs) triggered by transcranial magnetic stimulation (TMS). Thus, in a study of Valentini, Liang, Aglioti, and Iannetti (2012) participants watched video clips of hands while receiving simultaneous nociceptive stimulation. EEG time-frequency analysis showed for painful compared to neutral video clips reduced event-related desynchronizations (ERDs) in the beta-band (21.5-26.5 Hz) over central and frontal electrodes contralateral to the stimulated hand. The authors suggest that experiencing the pain of others reduces the sensorimotor cortex activity in the observer, triggered by nociceptive stimulation. Regarding late motor-related influences of empathy, Riečanský, Paul, Kölble, Stieger, and Lamm (2014) found that video clips depicting needle injections into hands compared to hands touched by a cotton swab triggered stronger ERDs of beta oscillations (13-30 Hz) over the sensorimotor cortex while watching the dynamic stimuli, and of mu oscillations (7-12 Hz) during the static phase at the end of the video. They interpreted these findings in terms of increased motor readiness. It is worth mentioning, however, that Avenanti and colleagues (Avenanti, Bueti, Galati, & Aglioti, 2005; Avenanti, Sirigu, & Aglioti, 2010) reported smaller MEP amplitudes when participants attended video clips presenting needle injections compared to touches with a cotton swab, suggesting motor inhibition in line with the beta-band ERD findings of Valentini et al. (2012). Crucially, Avenanti, Minio-Paluello, Sforza, and Aglioti (2009) found that corticospinal inhibition of motor activity was limited to the hand being penetrated, whereas corticospinal excitability was increased for the other hand, as indicated by larger MEPs when TMS-stimulation was applied to the motor cortex ipsilateral to the hand shown in the video.

Taken together, previous research concerned with the effects of empathy on information processing produced mixed results, for which it is difficult to come up with a straightforward explanation, because the reviewed studies differ with regard to tasks (e.g., behavioral RT task, pain judgment, pain intensity rating), stimuli (e.g., hands, faces, experience of own pain), ERP analysis approach and empathy measures used. With regard to the latter point, it is worth noting that some studies reported situational empathy, as measured via pain intensity and self-unpleasantness ratings, to underpin the relation of ERP effects to empathy (e.g., Decety et al., 2010; Fan & Han, 2008), whereas it is less clear whether dispositional empathy, as assessed with the aid of established questionnaires, shows a similar relation (e.g. Mella et al., 2012; Sessa et al., 2014). Also, some studies did not report behavioral effects (e.g., Decety et al., 2010; Riečanský et al., 2014) or did not test for the automaticity of the observed empathy-related effects (e.g., Meng, Hu et al. 2012; Lyu et al., 2014; Sessa et al., 2014), limiting the interpretation of EEG/ERP results. Additionally, at least to our knowledge, the studies reporting evidence in favor of automatic empathic processes, as indicated by the modulation of early anterior ERP waveforms, did not explicitly check for (pictorial) arousal effects on sensory processing (e.g., Decety et al., 2010; Fan & Han, 2008; Meng, Hu et al., 2012). Finally, the nature and time course of changes in the state of the motor system are not well understood, as well as whether these changes are elicited automatically in response to empathy-evoking stimuli.

3.2.1 Objectives of the current study

It was the main aim to extend previous studies by investigating in the same experiment the chronometry of automatic and controlled perceptual and motor processes underlying empathy for pain, as well as their relationship to dispositional empathy. To this end, we recorded the EEG while participants were watching pictures of hands or feet in painful or neutral situations. Like in the study of Fan and Han (2008), participants were either judging the pain (painful vs. neutral) or counting the body parts displayed in the pictures (one vs. two or more) in order to determine whether empathy for pain depends on attention to pain cues. Various studies (Toledo, Manzano, Barela, & Kohn, 2016; Peng, Hu, Zhang, & Hu, 2012; Sochurková, Brázdil, Jurák, & Rektor, 2006) implied an association between specific ERP components and event-related desynchronization or synchronization (ERD/ERS) in specific frequency bands. Yet, ERPs and ERD/ERS might reflect different neurophysiological phenomena. That is, ERPs are taken to mainly indicate the averaged postsynaptic potential activity that is strictly time-locked to a sensory, motor, or cognitive event, whereas ERD/ERS represents a decrease/increase in synchrony of the underlying electrophysiological activity (cf. Roach & Mathalon, 2008). Thus, ERD/ERS captures oscillatory brain activity that is not strictly phase-locked to a specific event, and hence eliminated by the averaging procedure involved in calculating ERPs (Gomarus, Althaus, Wijers, & Minderaa, 2006; Pfurtscheller & Lopes da Silva, 1999). Therefore, ERPs and ERD/ERS complement each other in measuring ongoing brain activity. Specifically, concerning the measurement of the empathy-related facilitative or inhibitory influences on the motor system, ERD/ERS is suitable because it can be interpreted as an electrophysiological correlate of activated cortical areas involved in the production of motor behavior (Pfurtscheller, 1992). We additionally assessed behavioral variables, namely RT and RF, to measure motor changes and their relation to brain activity. Finally, since the experience of situational empathy of persons appears to depend on their individual empathic dispositions (e.g., Eisenberg & Fabes, 1990), we obtained dispositional empathy measures in addition to situational ratings of perceived pain and self-unpleasantness for every picture.

In agreement with former studies, we expected differential ERP amplitudes in the painful than the neutral condition in early (before 300 ms; N1, P1, and EPN) and late (after 300 ms; P3) time intervals (cf. Figure 3.1). The early ERP effects should be independent of task demands if triggered by automatic empathic processes, whereas the late ERP effects should be present only in the pain judgment task if reflecting the controlled evaluation processes underlying empathy for pain. In addition, if painful situations inhibit the motor system (e.g., Avenanti et al., 2005; Valentini et al., 2012) contingent on the categorization of the situation, we would predict less forceful key presses and reduced ERDs in the mu- and beta-band to painful than neutral stimuli in the pain judgment task. Alternatively, if painful situations activate the motor system (e.g., Riečanský et al., 2014), this higher preparedness should lead to stronger RF and ERDs in the mu- and beta-band in comparison to neutral situations. Of course, it is conceivable that empathy-related activation of the motor system is produced by arousal, for instance, via a direct pathway from perceptual to motor processes (e.g., Miller, Franz, & Ulrich, 1999; cf. Figure 3.1). In this case, EEG and RF patterns should be present in both the pain judgment and the counting task. Finally, if situational and dispositional empathy are related to the way painful pictures are processed, we would expect early and late ERP amplitudes as well as EEG power changes triggered by painful stimuli to increase with the scores of perceived pain and self-unpleasantness, and with dispositional empathy scores.

3.3 Method

3.3.1 Participants

19 students from the University of Tübingen participated voluntarily for payment (8 Euros per hour) or course credits. Two participants were excluded because of technical problems

with the EEG recording; another did not appropriately operate the force-sensitive keys. The remaining 16 participants (seven females; 14 right-handed; mean age = 26.81 years) entered data analysis.

3.3.2 Materials and apparatus

Stimuli consisted of Meng, Hu et al.'s (2012) 124 digital color pictures, shot from first-person perspective. The pictures displayed body parts (hands, forearms or feet) in harmful or neutral (62 pictures each) daily life situations; otherwise the pictures were almost identical. Painful pictures included scenes like a hand being cut by a knife or a foot being pricked by a needle, whereas the non-painful pictures showed the same arrangement of body parts except for the harmful component. That is, there were 62 picture pairs consisting of a painful and its corresponding non-painful picture, matched for their luminance, contrast and color. 62 pictures displayed one and 62 pictures two or more body parts.

Participants were tested in an electrically shielded, low-noise booth with ambient light at low level. Instructions, stimuli, and feedback were presented on a 1100 MB Samsung SyncMaster screen with a resolution of 1280 x 960 pixels and a refresh rate of 60 Hz. A fixed chin rest guaranteed a constant viewing distance of 60 cm and helped to minimize head movements. Dimensions of the stimuli were 354 x 266 pixels. Stimulus presentation and response recording were controlled by a Mac Mini (Apple Inc.) running a MATLAB (The Math Works, Inc., Version R2014b) program using the Psychophysics Toolbox 3.0.12 (Brainard, 1997; Kleiner et al., 2007).

3.3.3 Procedure

Participants were informed about the experiment and the EEG procedure before giving their informed consent. In the pain judgment task, they were asked to decide whether the stimulus depicted a painful or a neutral scene and in the counting task whether one or more body parts were displayed. The experiment consisted of four blocks of 62 stimuli each. Half of the participants performed the pain judgment task in the first two blocks and the counting task in the last two blocks, whereas the other half received the reverse task order. Each stimulus was presented once per task in randomized order, with the constraint that pictures of the same picture pair were shown in different blocks. The mapping of left and right keys changed after every block and was balanced across participants. In order to get participants used to the task and the S-R mapping, every experimental block was preceded by 20 practice trials. Participants were free to take a short break after each block.

Each individual trial started with the presentation of a fixation cross for 800 ms, followed by the display of the pictorial stimulus for 200 ms. Participants were to respond to this stimulus within 1500 ms following its onset. After the response, and in the case of an incorrect, too fast (RT < 200 ms) or too slow (RT > 1500 ms) trial, feedback was shown at the center of the screen for 1000 ms. A blank screen of 1000 ms followed. If the response was correct, feedback was only shown in the practice trials; in the experimental blocks a blank inter-stimulus-interval of 2000 ms followed the correct response.

RT was recorded using force-sensitive keys, which allowed continuously measuring RF with a sampling rate of 512 Hz for the index fingers of both hands (for details, see Leuthold, Sommer & Ulrich, 1996). Participants pressed this key with the left or right index finger; the forearm rested comfortably on a supporting panel. RT was measured as the interval between the onset of the stimulus and the point in time when RF displayed a change of about 100 cN relative to the mean baseline activity within the preceding 100 ms.

After the EEG recording all painful stimuli were presented again. Participants were asked to rate on a 6-point scale (1 = very low, 6 = very high) the intensity of the pain supposedly experienced by the person in the picture and their own self-unpleasantness while watching the pictures. Then, as measures of dispositional empathy, participants completed a German version (de Haen, 2006) of the Empathy Quotient (EQ, Baron-Cohen & Wheelwright, 2004) and the German version of the Interpersonal Reactivity Index (IRI, Davis, 1983) that is called the Saarbrücker Persönlichkeitsfragebogen (SPF, Paulus, 2009).

3.3.4 Electrophysiological measures

EEG activity was recorded continuously with a sampling rate of 256 Hz from 72 Ag-AgCl electrodes using a BIOSEMI Active-Two amplifier system (for details, see Filik, Leuthold, Wallington & Page, 2014). Using a procedure similar to that described by Nolan, Whelan, and Reilly (2010), all EEG channels were recalculated off-line to an average reference, (ocular) artifacts were removed and EEG data were corrected and high-pass filtered (0.1 Hz, 36 dB/oct) (for details, see Filik et al., 2014). Following this procedure and after removing trials with incorrect response, there remained on average 51.14 trials (out of 62; range = 37-61, median = 49-56) per condition.

3.3.5 Data analysis

Peak force (PF) for the responding hand was determined in each correct trial at the time point where RF was maximal within a 200-1500 ms time interval after stimulus onset.

Separately for each experimental condition, ERPs were averaged for the analysis epoch that started 200 ms prior to stimulus onset and lasted for 1,400 ms. The averaged ERPs were low-pass filtered (40 Hz, 36 dB/oct) and aligned to a 200 ms pre-stimulus baseline. Mean ERP amplitudes were measured in ERP waveforms within time intervals during which specific ERP deflections were found to be most pronounced, similar to previous studies (e.g., Fan & Han, 2008): 90-130 ms (P1), 140-180 ms (N1), 200-300 ms (N240, EPN), and 300-500 ms (rising P3) and 500-800 ms (P3) relative to stimulus onset.

ERP amplitudes at midline and lateral electrode sites were separately analyzed. Lateral electrodes were pooled to form eight regions of interest (ROIs), divided along left-right, anterior-posterior, and dorsal-ventral dimensions. The four ROIs over the left hemisphere were defined as follows: left-anterior-ventral (AF7, F5, F7, FT7, FC5, C5, T7, F9), left-anterior-dorsal (AF3, F1, F3, FC1, FC3, C1, C3), left-posterior-ventral (TP7, CP5, P5, P7, PO9', PO7, O9'), left-posterior-dorsal (CP3, CP1, P1, P3, PO3, O1). Four analogous ROIs were defined for homolog electrodes located over the right hemisphere. Additionally, analyses were calculated for frontal (Fz, FCz, F3, F4, FC3, FC4) and central ROIs (Cz, CPz, C3, C4, CP3, CP4) as defined by Fan and Han (2008). EPN amplitudes were determined for two ROIs (left hemisphere: P5, P7, PO7, PO9', right hemisphere: homolog sites) (cf. Scott, O'Donnell, Leuthold & Sereno, 2009).

Oscillatory brain activity was analyzed to reveal decreases versus increases in the synchrony of oscillatory brain activity that is not strongly phase-locked to a specific sensory or motor event, and hence might not be reflected by averaged ERPs (cf. Tallon-Baudry & Bertrand, 1999; Roach & Mathalon, 2008). The analysis epoch started 500 ms prior to the stimulus and lasted until 1500 ms after stimulus onset. Power was analyzed from 4 to 30 Hz in 1-Hz frequency steps during the analysis epoch for successive 50-ms time steps. For the time-frequency decomposition, we used Morlet wavelets with a five-cycle width (e.g., Tallon-Baudry & Bertrand, 1999). The averaged power values in the analysis windows between 300 and 600 ms and between 700 and 1500 ms were subsequently converted to a percentage change scale relative to a pre-stimulus baseline from -200 to 0 ms within mu (7-12 Hz) and beta (13-18 Hz) frequency bands for left- and right-hemispheric ROIs over the somatosensory cortex (left hemisphere: C1, FC1, C3, CP1, right hemisphere: homolog sites) (cf. Riečanský et al., 2014).

Statistical analyses were performed by means of repeated measures analysis of variance (ANOVA). Bonferroni-adjusted planned comparisons were performed in order to decompose the interaction effect of condition and task. The specific ANOVA designs will be described in the respective result sections.

3.4 Results

3.4.1 Ratings and questionnaires

Across participants, ratings of perceived pain (M = 3.99) and self-unpleasantness (M = 3.58) correlated positively as indicated by the Kendall rank coefficient, τ = .73, p < .001. SPF scores ranged from 33 to 52 (M = 43.4) and EQ scores from 31 to 63 (M = 42.5). Internal consistency was good for the EQ (*Cronbach's* α = .86) and the different subscales of the SPF: *Cronbach's* α = .82 (Empathic Concern), .87 (Perspective Taking), .82 (Fantasy), .89 (Personal Distress).

3.4.2 Behavioral performance

For accuracy, RT, and PF, repeated measures ANOVAs with variables condition (neutral, painful) and task (pain judgment, counting) were conducted.

Accuracy

The ANOVA showed a main effect of condition, F (1, 15) = 5.55, MSE = 9.50, p < .05, and a significant Task x Condition interaction, F (1, 15) = 94.03, MSE = 4.20, p < .001. Response accuracy was higher for painful than neutral stimuli in the pain judgment task (89.11 vs. 85.99 %), F (1, 15) = 8.59, MSE = 9.10, p < .05, but lower in the counting task (79.64 vs. 86.39 %), F (1, 15) = 80.26, MSE = 4.50, p < .001 (cf. Figure 3.2).

Reaction time

Responses were faster in the counting than the pain judgment task (652 vs. 723 ms), F (1, 15) = 11.68, MSE = 6911.00, p < .01, and for painful than neutral stimuli (681 vs. 694 ms), F (1, 15) = 5.73, MSE = 454.60, p < .05. The Task x Condition interaction was significant, F (1, 15) = 46.39, MSE = 834.00, p < .001, indicating shorter RTs to painful than neutral

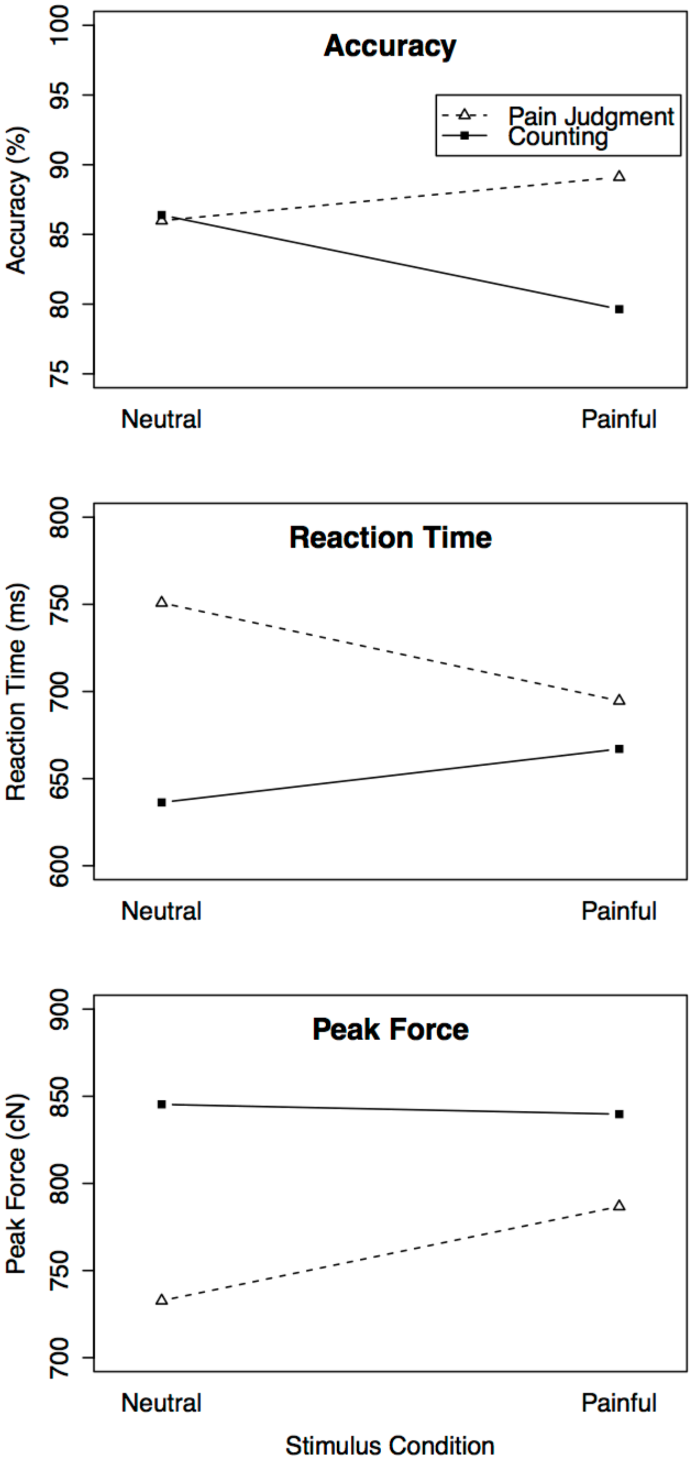


Fig. 3.2 Mean accuracy (upper panel), reaction time (middle panel), and peak force (lower panel) as a function of stimulus condition (painful vs. neutral) and task (pain judgment vs. counting).

stimuli in the pain judgment task (695 vs. 751 ms), *F* (1, 15) = 36.59, *MSE* = 691.00, *p* < .001, but longer RTs in the counting task (667 vs. 636 ms), *F* (1, 15) = 12.64, *MSE* = 597.00, *p* < .01 (cf. Figure 3.2).

Response force

The ANOVA of PF revealed a significant Condition x Task interaction, *F* (1, 15) = 6.78, *MSE* = 2102.00, *p* < .05. Further tests indicated higher PF in the painful than the neutral condition of the pain judgment task (787 vs. 733 cN), *F* (1, 15) = 7.91, *MSE* = 2954.00, *p* < .05, but not the counting task (840 vs. 845 cN), *F* (1, 15) = 0.09, *MSE* = 2915.60, *p* = .77 (cf. Figure 3.2).

3.4.3 Event-related potentials

As can be seen in Figure 3.3, the ERP waveform was characterized over posterior-ventral ROIs by a first positive deflection (P1), peaking at about 120 ms, followed by a negative deflection (N1) maximal at about 160 ms. After 200 ms a rising positivity appeared, leading to the P3, which was most pronounced over posterior midline sites between 300 and 700 ms and larger in the pain judgment task for painful stimuli in comparison to the three other conditions.

ERP amplitudes measured at midline electrode sites were subjected to an ANOVA with variables condition (neutral, painful), task (pain judgment, counting) and electrode (AFz, Fz, FCz, Cz, CPz, Pz, POz, Oz). ERP data from lateral electrodes were submitted to an ANOVA with variables condition (neutral, painful), task (pain judgment, counting), hemisphere (left, right), anterior-posterior (anterior, posterior), and laterality (ventral, dorsal). Additionally, like Fan and Han (2008), ERP amplitudes over frontal and central ROIs and in time intervals up to 300 ms were subjected to an ANOVA with variables condition (neutral, painful), task (pain judgment, counting), and ROI (frontal, central). For the EPN, an ANOVA with variables

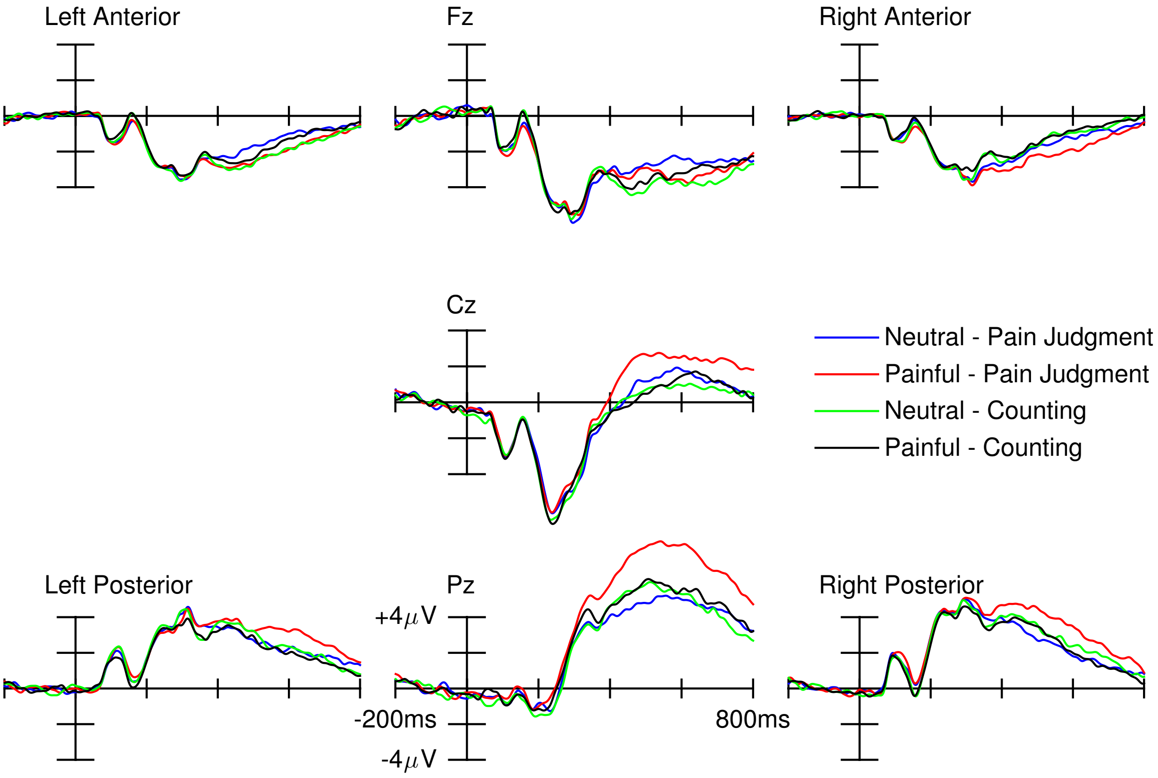


Fig. 3.3 Grand average ERP waveforms recorded over different ROIs (left anterior, Fz, right anterior, Cz, left posterior, Pz, right posterior) time-locked to the presentation of the stimuli as a function of stimulus condition (painful vs. neutral) and task (pain judgment vs. counting).

condition (neutral, painful), task (pain judgment, counting), and hemisphere (left, right) was conducted.

Time interval 90-130 ms (P1)

The lateral ROI analysis of this time window yielded a significant Condition x Hemisphere x Anterior-Posterior x Laterality interaction, F (1, 15) = 10.06, MSE = 0.05, $p < .01$. Separate tests for the different ROIs only revealed a significant Condition x Hemisphere x Anterior-Posterior interaction over ventral ROIs, F (1, 15) = 9.24, MSE = 0.11, $p < .01$, but further tests did not produce any significant main effect of condition, Condition x Hemisphere, or Condition x Anterior-Posterior interaction, all Fs $\leq$ 4.65, ps > .05.

The analysis including only frontal and central ROIs analogously to Fan and Han (2008) revealed no significant main effects or Condition x Task interaction, all Fs $\leq$ 1.63, ps > .22.

Time interval 140-180 ms (N1)

The lateral ROI analysis revealed a significant main effect of task, F (1, 15) = 9.54, MSE = 0.09, $p < .01$, and a reliable Task x Anterior-Posterior interaction, F (1, 15) = 6.51, MSE = 2.34, $p < .05$, indicating more positive ERP amplitudes for the pain judgment than the counting task over posterior ROIs (0.64 vs. 0.21 μV), F (1, 15) = 7.37, MSE = 1.57, $p <$ .05, but not over anterior ROIs (-0.57 vs. -0.30 μV), F (1, 15) = 5.23, MSE = 0.86, p = .04 (Bonferroni-corrected -level = .025). Additionally, the Task x Condition x Hemisphere interaction was significant, F (1, 15) = 5.5, MSE = 0.34, $p < .05$. Separate tests for the two tasks did not reveal any significant main effect or Condition x Hemisphere interaction, all Fs $\leq$ 3.53, ps > .08.

The Fan and Han (2008) analysis revealed a significant difference between the pain judgment and the counting task (-0.56 vs. -0.30 μV), F (1, 15) = 5.5, MSE = 0.42, $p < .05$, but no significant condition or interaction effects, all Fs $\leq$ 2.90, ps > .11.

Time interval 200-300 ms (N240, EPN)

The midline analysis of this time window did not produce significant main effects or a reliable Task x Condition interaction, all Fs ≤ 1.84, ps $> .20$. The lateral analysis yielded a significant Condition x Anterior-Posterior x Laterality interaction, F (1, 15) = 5.35, MSE = 0.10, $p < .05$, but subsequent tests revealed no significant condition effect, all Fs ≤ 5.11, ps $> .04$ (Bonferroni-corrected -level = .0125). Further analyses of the Task x Laterality interaction, F (1, 15) = 4.71, MSE = 1.74, $p < .05$, revealed no significant task effects over ventral and dorsal ROI, all Fs ≤ 5.11, ps $> .04$ (Bonferroni-corrected -level = .025). Likewise, follow-up analyses for the significant Task x Hemisphere x Anterior-Posterior interaction, F (1, 15) = 4.62, MSE = 0.28, $p < .05$, did not reveal any significant task effect, all Fs ≤ 1.16, ps $> .30$. The same held true for the Condition x Anterior-Posterior x Laterality interaction, F (1, 15) = 5.35, MSE = 0.10, $p < .05$, for which further tests did not reveal any significant condition effects, all Fs ≤ 5.11, ps $> .04$ (Bonferroni-corrected -level = .0125). In line, the analysis of frontal and central ROIs revealed no effect of condition or task, all Fs ≤ 2.16, ps $> .16$.

By contrast, the analysis of EPN amplitudes produced a significant main effect of condition, F (1, 15) = 9.02, $p < .01$, indicating more negative-going EPN amplitudes in the painful than the neutral condition over posterior ROIs for both tasks (6.2 vs. 6.6 μV), as can be seen in Figure 3.4.

Time interval 300-500 ms (Rising P3)

The analysis of ERP amplitudes in the rising P3 time range over midline electrodes revealed a significant main effect of condition, F (1, 15) = 7.02, MSE = 3.32, $p < .05$, due to larger ERP amplitudes in the painful than the neutral condition (0.94 vs. 0.51 μV). In addition, the Task x Condition interaction, F (1, 15) = 26.55, MSE = 1.16, $p < .001$, and the Task x Condition x Electrode interaction were significant, F (7, 105) = 3.22, MSE = 1.01, $p < .01$. Further analyses for the pain judgment task showed a significant main effect of condition, F (1, 15) =

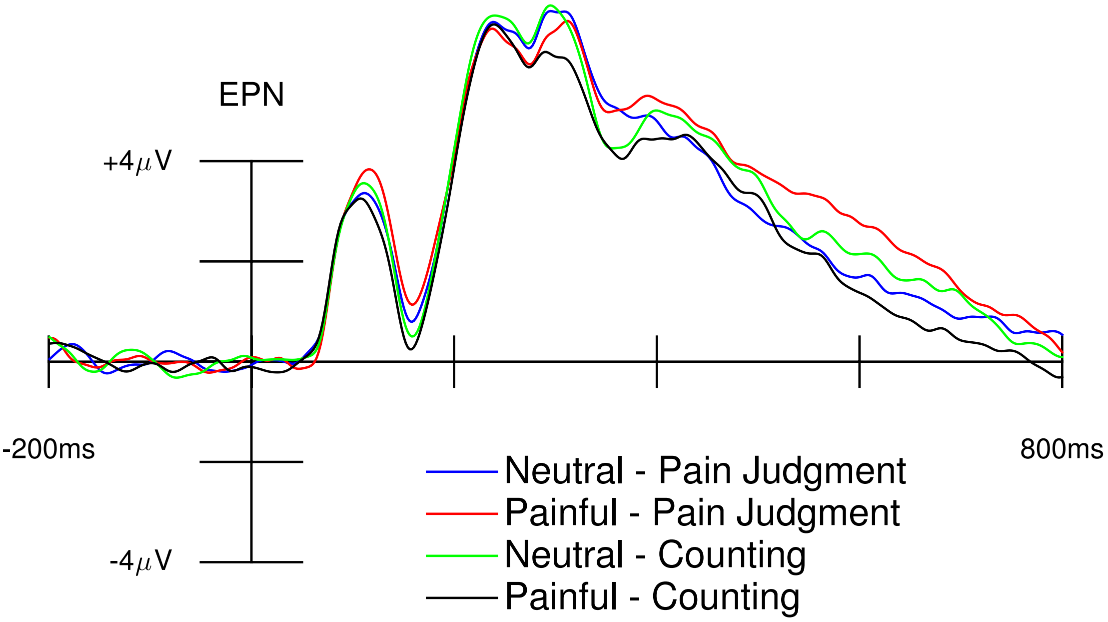


Fig. 3.4 Grand average ERP waveforms recorded over posterior-ventral electrode sites (EPN) time-locked to the presentation of the stimuli as a function of stimulus condition (painful vs. neutral) and task (pain judgment vs. counting), reflecting the early posterior negativity.

28.59, $MSE = 1.88$, $p < .001$, due to larger amplitudes of the rising P3 in the painful than the neutral condition (1.34 vs. 0.42 μV), and a Condition x Electrode interaction, F (7, 105) = 4.83, $MSE = 0.93$, $p < .001$, indicating this condition effect to be most pronounced over parietal electrodes. By contrast, analyses of the counting task did not reveal any significant main effect of condition (0.53 vs. 0.60 μV) or Condition x Electrode interaction, all Fs $\leq$ 0.57, ps > 0.78.

The lateral analysis corroborated the midline findings as indicated by the significant Task x Condition x Anterior-Posterior interaction, F (1, 15) = 7.97, $MSE = 1.72$, $p < .05$. Separate tests for the pain judgment task indicated larger amplitudes in the painful than the neutral condition over posterior ROIs (4.23 vs. 3.66 μV), F (1, 15) = 8.03, $MSE = 1.27$, $p < .05$, but no significant reverse effect over anterior ROIs (-2.86 vs. -2.53 μV), F (1, 15) = 7.30, $MSE = 0.49$, $p = .02$ (Bonferroni-corrected -level = .0125). No reliable condition effects were found in the counting task (0.57 vs. 0.57 μV), all Fs $\leq$ 1.65, ps > .22. In addition, there was a significant Task x Condition x Laterality interaction, F (1, 15) = 20.02, $MSE = 0.32$, $p < .001$, indicating in the pain judgment task a numerically more pronounced condition effect over dorsal ROIs (painful vs. neutral = 1.49 vs. 0.88 μV), F (1, 15) = 16.89, $MSE = 0.70$, $p < .001$, as compared to ventral ROIs (-0.12 vs. 0.25 μV), F (1, 15) = 16.46, $MSE = 0.28$, $p < .01$. The condition effect was not reliable in the counting task, all Fs $\leq$ 0.24, ps > .63.

Time interval 500-800 ms (P3)

The midline analysis in this time window yielded a significant main effect of condition, F (1, 15) = 7.62, $MSE = 3.66$, $p < .05$, due to larger ERP amplitudes in the painful than the neutral condition ($M = 1.09$ vs. 0.63 μV). Furthermore, the Task x Condition interaction was significant, F (1, 15) = 9.51, $MSE = 1.14$, $p < .01$. Separate tests for the tasks implied larger amplitudes in the painful than the neutral condition in the pain judgment task ($M = 1.56$ vs. 0.80 μV), F (1, 15) = 14.72, $MSE = 2.50$, $p < .01$, but not in the counting task ($M = 0.63$

vs. 0.45 μV), *F* (1, 15) = 0.86, *MSE* = 2.31, p = .37. The condition effect and the Task x Condition interaction were further qualified by electrode, *F* (7, 105) = 3.66, *MSE* = 1.79, p < .01 and *F* (7, 105) = 4.84, *MSE* =1.49, p < .001, respectively, indicating the previously reported effects to be maximal over Pz. The significant main effect of task, *F* (1, 15) = 5.53, *MSE* = 9.41, p < .05, indicated larger amplitudes for the pain judgment than for the counting task (*M* = 1.18 vs. 0.54 μV).

The lateral analysis corroborated the midline findings by revealing a significant Task x Condition interaction, *F* (1, 15) = 10.37, *MSE* = 0.19, p < .01, indicating for the pain judgment task larger ERP amplitudes in the painful than the neutral condition (*M* = 0.82 vs. 0.54 μV), *F* (1, 15) = 20.04, *MSE* = 0.24, p < .001, whereas there was no such difference in amplitudes in the counting task (*M* = 0.52 vs. 0.50 μV), *F* (1, 15) = 0.18, *MSE* = 0.18, p = .68. The Task x Condition interaction was further qualified by Anterior-Posterior, *F* (1, 15) = 10.49, *MSE* = 3.12, p < .01, and Laterality, *F* (1, 15) = 6.32, *MSE* = 0.45, p < .05.

Separate analyses revealed that over anterior ROIs, no condition effect was found, neither in the pain judgment, *F* (1, 15) = 8.02, *MSE* = 1.00, p = .013, nor in the counting task, *F* (1, 15) = 1.86, *MSE* = 1.18, p = .19, whereas over posterior ROIs, ERP amplitudes were more positive in the painful than the neutral condition for the pain judgment task (*M* = 3.10 vs. 2.06 μV), *F* (1, 15) = 14.62, *MSE* = 2.39, p < .01, but not for the counting task (*M* = 1.94 vs. 2.15 μV), *F* (1, 15) = 0.85, *MSE* = 1.77, p = .37. Over dorsal ROIs, ERP amplitudes were larger in the painful than the neutral condition for the pain judgment task (*M* = 1.95 vs. 1.16 μV), *F* (1, 15) = 22.57, *MSE* = 0.88, p < .001, but not for the counting task (*M* = 1.10 vs. 0.85 μV), *F* (1, 15) = 1.69, *MSE* = 2.71, p = .21, whereas there was no significant main effect or Task x Condition interaction over ventral ROIs, all *F*s $\leq$ 5.04, *p*s = .04 (Bonferroni-corrected α-level = .025).

The significant main effect of task, *F* (1, 15) = 10.93, *MSE* = 0.34, p < .01, was due to larger amplitudes in the pain judgment than the counting task (*M* = 0.68 vs. 0.51 μV).

Furthermore, there were significant interactions of Task x Anterior-Posterior, F (1, 15) = 4.55, MSE = 3.72, $p < .05$, Task x Laterality, F (1, 15) = 6.63, MSE = 3.39, $p < .05$, and Task x Anterior-Posterior x Laterality, F (1, 15) = 6.07, MSE = 0.48, $p < .05$. Further analyses revealed that there was no task effect over anterior ROIs (M = -1.21 vs. -1.02 μV), F (1, 15) = 1.52, MSE = 1.56, p = .24, but over posterior ROIs, amplitudes of the pain judgment task were larger than those of the counting task (M = 2.58 vs. 2.04 μV), F (1, 15) = 7.30, MSE = 2.51, $p < .05$. A significant main effect of task was further found over dorsal (M = 1.56 vs. 0.97 μV), F (1, 15) = 9.11, MSE = 2.45, $p < .01$, but not over ventral ROIs, F (1, 15) = 5.04, MSE = 0.61, p = .04 (Bonferroni-corrected α-level = .025).

Correlational analyses

We performed correlational analyses to test the relation between mean ERP amplitudes measured in different time intervals for the painful condition of the pain judgment task and scores of perceived pain, self-unpleasantness and the dispositional empathy scores of the EQ and the SPF. ERP amplitudes for ROIs where ERP components were found to be most pronounced in previous studies were entered into the correlational analyses: ventral-posterior ROIs for time intervals 90-130 ms and 140-180 ms, fronto-central (N240) and lateral-posterior ROIs (EPN) for the 200-300 ms interval, and centro-parietal ROIs for the P3 time ranges (300-500 ms and 500-800 ms). Similarly, correlational tests were calculated between EQ scores and mu- and beta-band power change values over the left and right somatosensory cortex of the painful condition. The same correlational tests were conducted for the neutral condition to reveal empathy-unspecific correlations. The significance level (alpha) was Bonferroni adjusted in order to control for the problem of multiple comparisons.

There were no significant correlations between scores of perceived pain or self-unpleasantness and ERP amplitudes of the painful condition, $-.39 < r < .23$, all ps $\geq .14$. The correlations between the SPF empathy score and ERP amplitudes of the painful condition were not significant either, $-.33 < r < .06$, all ps $\geq .21$.[1] Concerning EQ scores (cf. Figure 3.5), we found a negative correlation with P1 amplitudes at left posterior-ventral ROIs of the painful condition, $r = -.62$, $p < .05$, and of the neutral condition, $r = -.61$, $p < .05$. N1 amplitudes of painful and neutral conditions did not significantly correlate with EQ scores, $-.38 < r < -.11$, all ps $\geq .14$. ERP amplitudes at FCz between 200 and 300 ms (N240) correlated positively with EQ scores for the painful condition, $r = .57$, $p < .05$ (cf. Figure 3.5), but not for the neutral condition, $r = .50$, $p = .05$ (Bonferroni-corrected -level = .025), whereas there were no significant correlations for posterior ROIs (EPN), $-.49 < r < -.42$, all ps $\geq .05$. Additionally, amplitudes of the rising P3 at Pz between 300 and 500 ms did not significantly correlate with EQ scores neither in the painful condition, $r = -.55$, $p = .027$ (Bonferroni-corrected -level = .025), nor in the neutral condition, $r = -.53$, $p = .03$. Between 500 and 800 ms, there was a correlation between EQ scores and the P3 amplitudes of the painful condition, $r = -.59$, $p < .05$, as well as the neutral condition, $r = -.72$, $p < .01$ (cf. Figure 3.5).

3.4.4 Oscillatory EEG activity

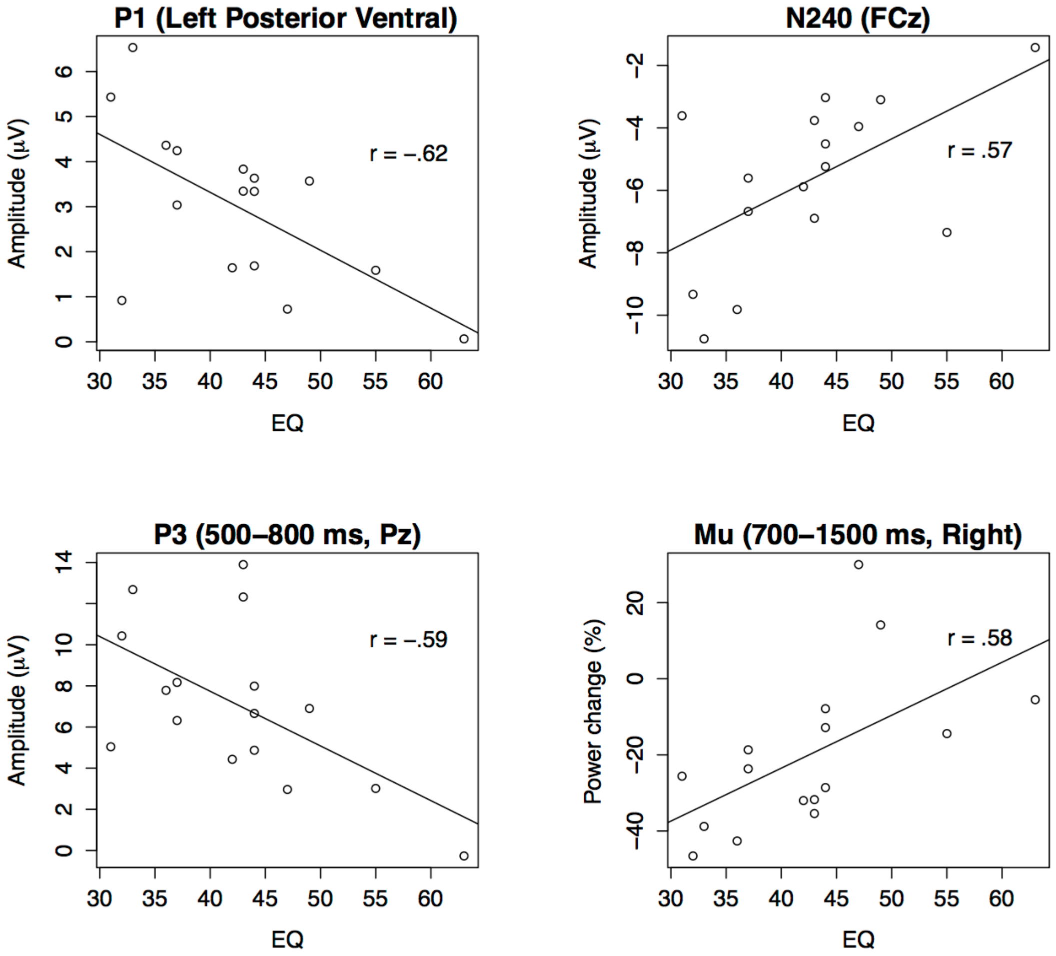
Percentage power change values were subjected to an ANOVA with variables condition (neutral, painful), task (pain judgment, counting), and hemisphere (left, right).

Time interval 300-600 ms

The analysis of mu-band (7-12 Hz) power in this time window revealed an ERD (-7.43 %) that was not significantly different from zero, $t\,(15) = -1.06$, $p = .31$, and did not produce any significant effects including the factors task or condition, all Fs ≤ 2.29, ps $> .15$. In contrast, the analysis of beta-band (13-18 Hz) power in the time interval from 300 to 600 ms after stimulus presentation revealed an ERD (-25.70 %) significantly different from zero, $t\,(15) =$

---

[1] Correlational analyses of ERP amplitudes of the painful condition and all subscales of the SPF only revealed one significant correlation between the subscale Personal Distress and ERP amplitudes over left posterior ventral ROIs from 90 to 130 ms, $r = .58$, $p = .017$.


P1 (Left Posterior Ventral)

N240 (FCz)

P3 (500–800 ms, Pz)

Mu (700–1500 ms, Right)

Fig. 3.5 Correlations between ERP amplitudes or power change values in the painful condition of the pain judgment task and EQ scores. Upper left panel: P1 amplitudes over left posterior-ventral ROIs. Upper right panel: N240 amplitudes at FCz. Lower left panel: P3 (500-800 ms) amplitudes at Pz. Lower right panel: Mu-ERD (700-1500 ms) over the right somatosensory cortex.

-7.77, $p < .001$, but did not reveal any significant main effect or Task x Condition interaction, all *F*s $\leq$ 1.57, *p*s > .23 (cf. Figure 3.6).

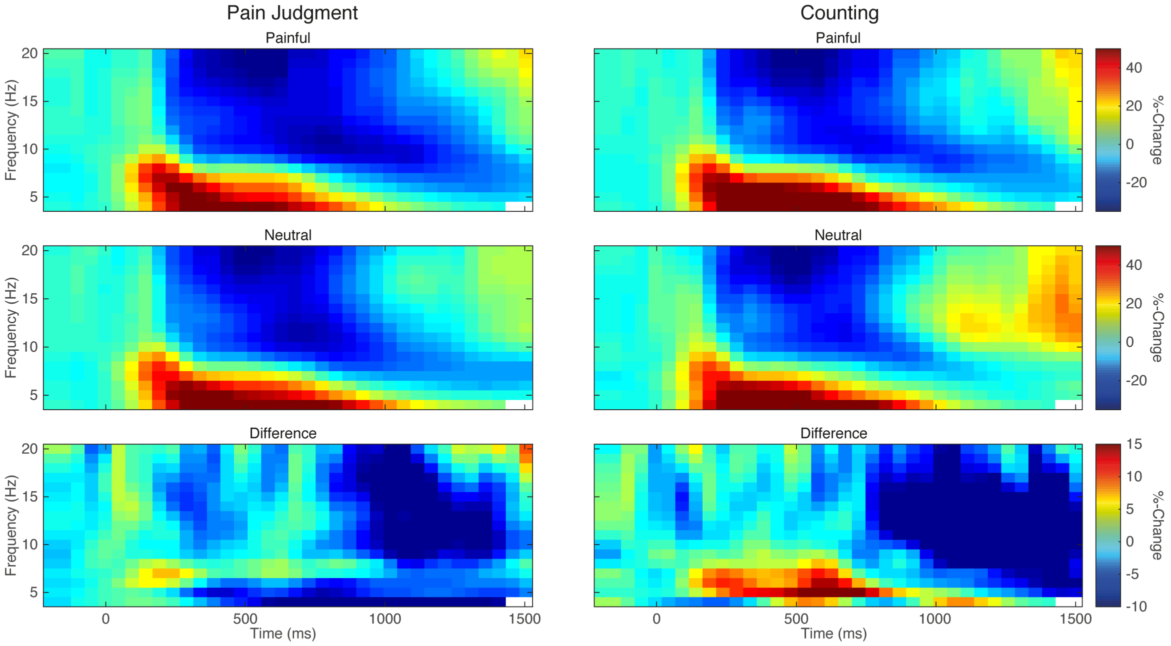


Fig. 3.6 Grand average percentage-change values relative to the baseline power over left and right sensorimotor cortex as a function of time and frequency. Upper panels: Painful condition. Middle panels: Neutral condition. Lower panels: Difference values for the painful minus the neutral condition; note the difference in scaling for this plot.

Time interval 700-1500 ms

The analysis of mu-band (7-12 Hz) power yielded an overall ERD (-10.15 %) significantly different from zero, t (15) = -2.15, $p < .05$, a main effect of condition, F (1, 15) = 11.15, *MSE* = 273.90, $p < .01$, due to larger ERDs in the painful than the neutral condition (-15.04 vs. -5.27 %) (Figure 3.6), and a main effect of task, F (1, 15) = 5.50, *MSE* = 550.70, $p < .05$, due to larger ERDs in the pain judgment than the counting task (-15.02 vs. -5.29 %).

The overall ERD (-1.61 %) of beta-band (13-18 Hz) power in this time interval did not significantly differ from zero, t (15) = -0.29, $p = .78$, but the analysis yielded a significant main effect of condition, F (1, 15) = 15.92, *MSE* = 180.80, $p < .01$, indicating a decrease in power in the painful compared to the neutral condition (-6.36 vs. 3.13 %) (Figure 3.6). The main effect of task, F (1, 15) = 6.37, MSE = 518.00, $p < .05$, indicated decreased power in the pain judgment compared to the counting task (-6.69 vs. 3.46 %). The reliable Condition x Task x Hemisphere interaction, F (1, 15) = 4.94, MSE = 32.71, $p < .05$, reflected a decrease in power in the painful compared to the neutral condition in the counting task (-2.57 vs. 9.50 %), F (1, 15) = 11.23, MSE = 207.40, $p < .01$, and a Condition x Hemisphere interaction in the pain judgment task, F (1, 15) = 6.88, MSE = 30.87, $p < .05$. Further tests for the pain judgment task revealed a numerically larger, but non-significant condition effect over the left hemisphere (-7.46 vs. 3.09 %), F (1, 15) = 5.88, MSE = 151.50, $p = .03$ (Bonferroni-corrected -level = .0125), compared to the right hemisphere (-12.83 vs. -9.56 %), F (1, 15) = 1.15, MSE = 73.91, $p = .30$.

Correlational analyses

There were no significant correlations between EQ or SPF scores and power change values in the mu- or beta-band for the 300-600 ms time interval, $-.15 < r < .48$, all ps $\geq .06$. However, for the mu-band we found a significant correlation between EQ scores and power change values between 700 and 1500 ms for the painful condition over the right, $r = .58$ $p < .05$, but not the left sensorimotor cortex, $r = .50$ $p = .05$ (Figure 3.5), whereas those for the neutral condition were not significant, $r = .40$, $p = .12$ and $r = .31$, $p = .25$. There were no significant correlations between SPF scores and power change values in the mu-band in this time interval, $.22 < r < .41$, all ps $\geq .11$.

The correlational analyses of beta-band oscillations over the left and right somatosensory cortex in the late time interval did not reveal any significant correlation between EQ scores and power change values of the two conditions, $.21 < r < .39$, all ps $\geq .13$. For the SPF score, there were no reliable correlations with power change values in the beta-band either, $.27 < r < .46$, all ps $\geq .07$.

3.5 Discussion

In this study, compared to similar others, we used a more comprehensive set of behavioral and brain-based measures to investigate the time course of empathy-related influences on information processing (cf. Figure 3.1). The main novel findings of this study concerned (a) the EPN, which indicated an early automatic component of empathy for pain, (b) empathy-related and task-dependent facilitation of the motor system by painful stimuli, and (c) that motor readiness was generally increased for both tasks after the response to painful stimuli. In the following, these and other findings will be discussed in more detail.

First, it is worth noting that the present experiment produced the expected behavioral effects. Thus, the relatively high scores in ratings of perceived pain and self-unpleasantness, as well as the positive correlation between the two measures, suggest that painful stimuli indeed influenced participants' affective state. In addition, response accuracy was generally high in both tasks and for all participants. More specifically, responses were more accurate for painful than neutral stimuli when pain judgments were required, most likely indicating that painful stimuli automatically capture attention in contrast to neutral stimuli. This assumption is also supported by the finding that for the counting task, responses to neutral stimuli were more accurate than to painful stimuli. Here, attention is attracted by task-irrelevant pain-related stimulus features, away from task-relevant ones, thereby obstructing processing of painful stimuli in the counting task. The latter conjecture is corroborated by faster responses to painful than neutral stimuli in the pain judgment task and a reverse RT effect in the counting task.

Second, and more importantly, present results provide novel insights regarding the time course of automatic and controlled processes of empathy for pain. In the following, we discuss key findings with regard to the information processing model depicted in Figure 3.1. Concerning early perceptual processes, it is instructive that painful compared to neutral stimuli did not differentially influence P1 and N1 amplitudes over lateral posterior regions, speaking against the possibility that pictorial (physical) differences influence information processing. Moreover, it is worth noting that, despite the fact that we used the same picture set, we could not replicate the early fronto-central empathy-related ERP effect of Meng, Hu and colleagues (2012) who reported more positive-going ERP amplitudes to painful than neutral stimuli like others (Decety et al., 2010; Fan & Han, 2008). However, the present absence of early empathy-related effects over fronto-central ROIs accords with similar zero effects reported previously (Lyu et al., 2014; Mella et al., 2012; Sessa et al., 2014). In the 200-300 ms time interval, again, we did not find any empathy-related ERP amplitude effects over fronto-central regions, in contrast to some previous reports (Fan & Han, 2008; Meng, Hu et al., 2012). Unfortunately, we do not have a straightforward explanation for these discrepancies, except that our study differed from others with regard to the sample (e.g., young Asian vs. slightly older German participants), task (e.g., pain intensity rating vs. pain judgment), and the EEG recording (e.g., right mastoid reference vs. average reference).[2] Future studies should test participants with different cultural background and age using the same stimulus, task, EEG recording and analysis procedures to reveal potential causes underlying the varied ERP amplitude findings across studies. Also, it should be examined whether possible attentional influences on early perceptual processing as indicated by early posterior ERP components are related to fronto-central empathy-related ERP effects. Furthermore, a final limitation of our study concerns the sample size, since we tested only 16 participants, which might limit the statistical power of the present study.

Crucially, in line with the assumption of an automatic empathic response within information processing, we found painful compared to neutral stimuli to trigger a more negative, task-independent EPN component. We take this finding to reflect the selective processing of affectively arousing stimuli (cf. Olofsson et al., 2008), following initial perceptual encoding as reflected by P1 and N1. Given the fact that the EPN is triggered by salient emotional stim-

---

[2] After re-referencing to the right mastoid as reference, we did not find any early fronto-central ERP condition effect either.

uli (cf. Olofsson et al, 2008), we assume that the influence of painful stimuli on information processing is of affective but empathy-unspecific nature.

In line with previous studies (e.g., Fan & Han, 2008; Mella et al., 2012), P3 amplitudes over posterior regions were larger for painful than neutral stimuli in the pain judgment task but not in the counting task. We take this P3 amplitude effect to reflect a late empathic influence on the categorization stage (Donchin, 1981; for a review, see Polich, 2007). More specifically, like Fan and Han (2008) we interpret the P3 effect in our study as reflecting the controlled, top-down empathic response on information processing. Together, present EPN and P3 amplitude findings provide converging evidence for the late appraisal model (de Vignemont & Singer, 2006), which assumes that empathic cues influence processing before their cognitive appraisal, the latter only modulating late empathic responses as indicated by the P3 component.

Importantly, the present study offers novel insights regarding empathic influences on late motor processing stages (cf. Figure 3.1). Thus, the analysis of RF showed that participants responded more forcefully to painful than neutral stimuli in the pain judgment but not the counting task. This finding supports the idea that motor responses are facilitated when watching others experiencing pain, contingent on the controlled categorization stage because of the task-dependence. The faster responses to painful than neutral stimuli when attending the pain dimension can also be explained by motor facilitation. Thus, in line with the RT results of Meng, Shen et al. (2012) and Grecucci, Koch and Rumiati (2011), we assume that the readiness of a reactive movement is increased by the task-relevant observation of another individual in pain, leading to both faster and more forceful reactions. Due to this task-specific empathic effect, we can also exclude the possibility that the influence of painful stimuli on the motor system were simply produced by arousal, for instance leading to larger PF amplitudes via a direct energetic pathway from perceptual to motor stages (cf. Miller et al., 1999).

Somewhat surprisingly, though, we did not find these motor system changes being reflected by mu- and beta-band power ERD in the time interval close to the response (300-600 ms). In this respect, our ERD results contrast with those of Riečanský et al. (2014), who found increased beta ERD when participants were watching videos of moving needles and increased mu ERD when participants were watching the static endpoint of the painful video. A possible explanation for the discrepant results is that participants watched dynamic painful vs. neutral stimuli in the study of Riečanský and colleagues, whereas in the current study participants performed a choice response task to static stimuli. Static stimuli may exert a weaker influence on the motor system than dynamic stimuli, as indicated by Riečanský et al.'s finding of smaller beta-band ERD effects during the static treatment-endpoint of the videos. Since overt responses are preceded by large beta-ERDs (e.g., Androulidakis et al., 2007; Neuper & Pfurtscheller, 2001), as observed here too, it is further conceivable that present strong choice response-related ERD effects masked the much smaller differential beta-ERDs induced by static painful versus neutral stimuli which become visible in a passive viewing task. Future studies should examine whether the nature of stimulation, response demands, or both factors play a role in producing the beta-ERD effects, and further test for condition-specific mu-ERD effects, which were absent in the present study. Also, since Avenanti et al. (2009) found that the muscle of the hand corresponding to the one penetrated in the stimuli was inhibited, whereas the corticospinal excitability of the muscles of the other hand was increased, future studies should separately measure RF of participants responding to painful and neutral stimuli that depict the corresponding finger versus a finger of the opposite hand.

In contrast to ERDs in the response-related analysis interval, we observed larger ERDs in the painful than the neutral condition in the mu- and beta-band in the late time interval preceding the presentation of the next stimulus (700-1500 ms). Since this ERD effect was found for both the pain judgment and the counting task, it appears to reflect an automatic activation of the motor system following the response to empathy-evoking stimuli, thereby increasing motor readiness to forthcoming events. Similarly, the larger ERD in the pain judgment than the counting task in the late time interval indicates an enhanced preparedness for processing the forthcoming stimulus. Since tasks changed between blocks, participants might be more attentive in processing the pain-related than the counting-related stimulus dimension. In line with this attentional account, N1 amplitudes were more positive in the pain judgment than the counting task, too.

Finally, concerning the relationship between individual empathic dispositions and brain-based measures of situational-empathic influences on information processing (e.g., Decety, Lewis & Cowell, 2015), we obtained some unexpected results. Before discussing these results in more detail, it is first worth noting that both SPF and EQ showed high internal consistency and were therefore considered as reliable measures of dispositional empathy. Whereas the SPF scores did not reliably correlate with ERP amplitudes or changes in the power of oscillatory brain activity, we found a negative correlation between EQ scores and P1 amplitudes over left posterior-ventral regions, as well as P3 amplitudes over Pz for painful stimuli in the pain judgment task, such that participants with increasing trait empathy showed increasingly smaller P1 and P3 amplitudes. Of course, it must also be mentioned that neutral stimuli produced similar correlations, suggesting a stimulus-unspecific effect. In line with Ikezawa, Corbera, and Wexler (2014), one possible account for the direction of the correlation is that persons with high trait empathy down-regulate the sensory and affective processing of incoming stimuli in order to avoid being overwhelmed by their empathic feelings in the case of painful stimuli. As a result of such emotion regulation, P3 amplitudes would decrease (see also Hajcak, MacNamara & Olvet, 2010). In line with this assumption, Decety et al. (2010) found smaller P3 amplitudes in physicians who have to regulate their empathic responses in their everyday working life. Additionally, there were positive correlations between EQ scores and N240 amplitudes over FCz in the painful but not the neutral condition. Crucially, the positive correlations between EQ scores and mu-band activity over the right somatosensory cortex in the post-response interval (700-1500 ms) were specific for painful stimuli, supporting the relation between late motor changes and empathy-evoking stimuli. Again, the direction of the correlation might indicate the down-regulation of the motor system with increasing dispositional empathy.

In conclusion, the present study extended our understanding of empathy for pain influences on perception, decision, and motor processing by the combined recording and analysis of RT, RF, ERPs, and oscillatory brain activity (ERD). Thus, the EPN component demonstrated the automatic and enhanced perceptual processing of empathy-evoking stimuli. In line with previous reports, the subsequent P3 component indicated top-down controlled empathic influences on stimulus categorization. RF and RT findings suggested that the observation of others in pain activates the motor system, an effect that was task-dependent and not mediated by arousal. Finally, empathy-evoking stimuli differentially influenced oscillatory EEG activity following response execution, indexing increased motor readiness. Taken together, while being generally in line with the late appraisal model of empathy (de Vignemont & Singer, 2006), our findings also indicate that empathy-provoking stimuli produce automatic and controlled effects within the motor system at different time points.

3.6 Acknowledgments

We wish to thank Jing Meng for providing the pictorial stimuli. Sarah Fabi was supported by a doctoral scholarship of the Federal State Baden-Württemberg (LGFG).

Chapter 4

Study 2: Racial bias in empathy: Do we process dark- and fair-colored hands in pain differently? An EEG study

Reprinted from *Neuropsychologia, 114*, Fabi & Leuthold, Racial bias in empathy: Do we process dark- and fair-colored hands in pain differently? An EEG study, 143-157, Copyright 2018, with permission from Elsevier. The official citation that should be used in reference to this material is:

Fabi, S., & Leuthold, H. (2018). Racial bias in empathy: Do we process dark- and fair-colored hands in pain differently? An EEG study. *Neuropsychologia, 114,* 143-157.

Neuropsychologia is available online at:
https://www.journals.elsevier.com/neuropsychologia

4.1 Abstract

The aim of this study was to identify racial bias influences on empathic processing from early stimulus encoding, over categorization until late motor processing stages by comparing brain responses (electroencephalogram) to pictures of fair- and dark-colored hands in painful or neutral daily-life situations. Participants performed a pain judgment task and a skin color judgment task. Event-related brain potentials (ERPs) substantiated former findings of automatic empathic influences on stimulus encoding, reflected by the early posterior negativity (EPN), and late controlled influences on the stimulus categorization, as reflected by the late posterior positivity (P3b). Concerning the racial bias in empathy (RBE) effect, more positive amplitudes in the 280-340 ms time window over frontocentral electrodes in the painful than the neutral condition for fair- but not dark-colored hands speak for an early influence of racial bias. This was further supported by correlations with empathic concern scores for fair- but not dark-colored stimuli. Additionally, P3b amplitude differences between fair- and dark-colored hands to painful stimuli increased with the implicit racial attitude of participants, suggesting that the categorization stage is not completely immune to racial bias. Regarding the motor processing stages, power change values in the upper beta-band (19-30 Hz) revealed for painful compared to neutral stimuli larger facilitation of sensorimotor activity before the response and larger inhibition after the response, independent of skin color. In conclusion, present findings speak for an influence of the RBE on early perceptual encoding but also on the late categorization stage that depends on the participant's implicit attitude towards racial outgroups.

4.2 Introduction

Empathy has been defined as the ability to share the feelings of another person, whilst knowing that the other person is the source of one's own affective state (de Vignemont & Singer, 2006). There is wide agreement that empathy matters in many aspects of human social life, for instance, influencing whether we identify with others or respond altruistically to others in need. In this respect, it is a key research finding that empathy, at least for pain, appears not to be universal but rather modulated by group membership (Cikara, Bruneau, &

Saxe, 2011, Eres & Molenberghs, 2013). Thus, diminished empathy towards racial outgroups might have adverse consequences for them in everyday social life. In order to alleviate such negative consequences, it is therefore crucial to better understand the boundary conditions and signatures of this racial bias in empathy (RBE) as well as its underlying processing mechanisms. Using an electrophysiological approach, the aim of the current study is to contribute to this goal by presenting empathy-evoking fair- versus dark-colored hands to white-Caucasian participants in order to determine the influence of racial bias on the different stages of empathic processing.

Functional magnetic resonance imaging (fMRI) studies have provided important insights regarding the brain areas that are functionally involved in empathy for pain processing and the RBE. For instance, using a pain judgment task, Xu, Zuo, Wang, and Han (2009) were first in showing an RBE effect in anterior cingulate cortex (ACC) activity. That is, when displaying video clips of Caucasian and Asian faces where the cheeks were penetrated by a needle or touched by a Q-tip, only painful compared to neutral Asian ingroup stimuli triggered larger ACC activity. Moreover, using static Caucasian and Asian faces displaying either a neutral versus painful expression, Sheng, Liu, Li, Fang, and Han (2014) (see also, Mathur, Harada, Lipke, & Chiao, 2012) found larger ACC and anterior insula (AI) activity to painful than neutral expression faces when participants judged race but not pain. Importantly, this empathy for pain effect was limited to racial ingroup stimuli (Asian faces), demonstrating an RBE in brain areas of the pain matrix (AI, ACC). More directly relevant for present purposes, Gu and Han (2007) showed that the activation of similar brain areas by empathy-evoking static hand stimuli was modulated by task. That is, ACC, insular, and frontal cortex activity was increased when making pain ratings of painful hand stimuli compared to counting the number of hands depicted, whereas brain activity did not differ when counting the number of hands in painful versus neutral pictures. Crucially, when Azevedo et al. (2013) asked white-Caucasians and black-Africans to attend to video clips displaying fair-, dark-, and violet-colored hands in painful (needle) versus neutral conditions (Q-tip), they observed AI activity to indicate enhanced empathic processing of pain only for racial ingroup but not outgroup stimuli. Moreover, the size of the RBE in left AI activity increased with individual racial bias scores as measured with the race version of the implicit association test (IAT; Greenwald, McGhee, & Schwartz, 1998; Greenwald, Nosek, & Banaji, 2003), suggesting that the brain's intergroup empathic processing of pain is modulated by implicit attitudes towards one's own versus other race.

Whereas it is evident from the above studies that the fMRI approach is perfectly suited to reveal RBE-related brain areas, this approach is subject to certain constraints when it comes to determining the chronometric locus of the RBE within information processing. Thus, Sessa, Meconi, Castelli, and Dell'Acqua (2015) argued that RBE effects demonstrated with the presentation of video clips (e.g., Azevedo et al., 2013; Xu et al., 2009), and hence long stimulus exposures, are likely to reflect top-down or controlled aspects of empathic processing in the brain. But even when static stimuli are used (e.g., Sheng et al, 2014; Gu & Han, 2007), given the limited temporal resolution of fMRI, it is difficult to determine whether the empathy for pain effect and the RBE are localized within early automatic versus later controlled processes. For this reason, Zaki and Ochsner (2012) proposed to use electroencephalographic (EEG) measures in order to investigate more precisely the time course of empathic processing.

The analysis of event-related brain potentials (ERPs) has been demonstrated to be particularly beneficial to investigate the cognitive architecture of information processing (see Coles, Smid, Scheffers, & Otten, 1995, for a review). Thus, it is traditonally assumed that information processing between stimulus input and motor output proceeds in a sequence of functionally distinct stages, such as stimulus encoding and categorization, response selection, and motor execution (Sanders, 1990; Sternberg, 1969; see also Figure 3.1). Crucially, irrespective of whether these functionally distinct stages temporally overlap or not, if different mental processes manifest themselves in distinct ERP components, it becomes possible to determine the specific locus or loci of experimental effects within information processing. Thus, visual-sensory ERP components such as the posterior P1 and N1 are taken to reflect early perceptual processing and its attentional modulation (e.g., Hillyard & Anllo-Vento, 1998; Luck & Hillyard, 1994). Moreover, an early posterior negativity (EPN) between 200 and 300 ms (e.g., Schupp, Junghöfer, Weike, & Hamm, 2004) has been found to be enhanced after the onset of emotionally arousing compared to neutral stimuli. These ERP components are suited to reveal automatic influences on perceptual processing as elicited by salient or motivationally relevant stimuli. Subsequently, a centroparietal positivity that peaks later than 300 ms after stimulus onset (P3b) provides an electrophysiological marker of the cognitive categorization of task-relevant stimuli (Donchin & Coles, 1988, increasing in amplitude with the significance of stimulus input (e.g., Johnson, 1988). Thus, the P3b component can be used as a marker of late controlled cognitive processing.

Previous ERP studies comparing electrophysiological responses to static pictures of body parts like hands in painful (e.g., hands being cut by a knife) and neutral situations revealed influences of empathy on early ERP components, irrespective of whether the task demanded the attentive processing of the pain dimension of the stimulus or of another pain-unrelated stimulus dimension (e.g., number of body parts depicted) (e.g., Fabi & Leuthold, 2017; Fan & Han, 2008). More specifically, an early automatic empathy for pain-related influence was suggested by a frontocentral N1 peaking at about 100-120 ms after stimulus onset (Fan & Han, 2008; Gonzalez-Liencres, Breidenstein, Wolf, & Brüne, 2016; Meng et al., 2012) and by the EPN between 200 and 300 ms (Fabi & Leuthold, 2017). Moreover, these studies showed that P3b amplitude was enlarged for painful than neutral stimuli only in the pain judgment task, that is, when attention was directed towards the pain dimension (e.g., Fabi & Leuthold, 2017; Fan & Han, 2008), indicating a late empathic influence on controlled information processing. Thus, these ERP findings suggest that distinct early-automatic and late-controlled processes contribute to empathy for pain, in accord with a more general two-component model of empathy (e.g., Preston & de Waal, 2002).

Crucially, there are now several ERP studies providing preliminary evidence for the assumption that racial bias influences early (automatic) but not late (controlled) processing stages. Thus, using a pain judgment task, Contreras-Huerta et al. (2014) found a larger amplitude of the frontocentral N1 (80-140 ms) to painful (needle) versus neutral (Q-tip) pictures of own-race (Caucasian) but not other-race (Asian) faces, whereas the P3b component was larger for painful than neutral pictures irrespective of race. However, demanding pain judgments to similar white and black face stimuli, Sessa et al. (2014) found for their white-Caucasian participants the RBE to be reflected by a later (280-340 ms) frontocentral positive shift for painful than neutral white face stimuli only, which was found to originate in the left inferior frontal gyrus (left IFG). Whereas P3b amplitudes were larger to both own- and other-race painful versus neutral stimuli (static faces) as in Contreras-Huerta et al. (2014), the neural sources underlying these empathy for pain effects differed. That is, a P3b source was found in the left middle frontal gyrus for ingroup face stimuli but in the left temporo-parietal junction for outgroup face stimuli. In line with a differential RBE in P3b amplitude, the P3b pain effect increased at electrode position P3 with the implicit racial bias score as measured with the race IAT, but only for own-race but not other-race targets (see Meconi, Vaes, & Sessa, 2015, for a discussion of the link between ERP empathic responses and individual ingroup preferences). Finally, studies presenting a set of facial expression stimuli found for own- compared to other-race faces a larger enhancement of the frontocentral P2 amplitude (128-188 ms) to painful than neutral expressions in a race judgment task (Sheng et al., 2013; Sheng & Han, 2012), in a pain judgment task (Li et al., 2015; but see Sheng & Han, 2012), and when only filler items were judged for their orientation (Sheng, Du, & Han, 2017). In addition, Li et al. (2015) found RBE-related P3b amplitude differences if mortality salience was primed and participants judged the facial expression as painful versus neutral.

It is apparent that the different types of face stimuli used in the studies described above pattern with the early RBE effects on frontocentral N1 versus P2 amplitudes, respectively. Thus, it is possible that neutral expression faces penetrated by a needle as compared to a Q-tip provide low-level perceptual cues that rapidly elicit the process of emotional sharing, whereas this process might be triggered later due to the more time-consuming decoding of painful facial expressions (e.g., Contreras-Huerta et al., 2014). Yet, the interpretation of the RBE effect for face stimuli might also be complicated by the potential impact of other than empathy for pain-related influences. For instance, it is conceivable that own- versus other-race faces might be differentially categorized according to other face-related variables such as trustworthiness (e.g., Stanley, Sokol-Hessner, Banaji, & Phelps, 2011; Todorov, Said, & Verosky, 2011), making it more difficult to draw straightforward inferences with regard to a direct influence of racial group on empathic processing. That first impressions of faces modulate brain responses to empathy-evoking stimuli was shown in the study of Sessa and Meconi (2015) where the empathic P3b difference was strongly reduced when faces were categorized as untrustworthy.

Given these issues, ERP-based inferences regarding the influence of racial group on empathic processing would be much strengthened if other, less complex stimuli than faces would give rise to similar RBE effects. One promising alternative way to examine the locus of the RBE effect within information processing is the presentation of hands. The practicality of this approach is illustrated by the fact that when showing video clips of own-race and other-race hands in painful and neutral situations, differences in cross-racial empathic responses have been demonstrated using fMRI (Azevedo et al., 2013), motor-related EEG oscillations (Riečanský et al., 2014), and motor evoked potentials (MEPs, Avenanti, Sirigu, and Aglioti, 2010). Of course, due to the long duration of the video clips and also the specific dependent measures employed, these studies do not allow a localization of the RBE effect at early automatic versus late controlled stages of empathic processing. To investigate the potential impact of racial bias on the different stages involved in empathic processing, it appears most promising to present static hand stimuli and hence to build on the results of empathy for pain ERP-research described above (e.g., Fabi & Leuthold, 2017; Fan & Han, 2008; Meng et al., 2012).

Moreover, Fabi and Leuthold (2017) also investigated mu- and beta-band EEG oscillations and revealed a larger post-response activation of the sensorimotor cortex to painful than neutral stimuli This led them to assume that motor readiness is increased following the response to an empathy-evoking pain stimulus, independent of the task. Yet, their analysis of response force (RF), defined as the force with which participants pressed response keys, indicated motor facilitation to painful stimuli only when attending to the pain dimension, thereby arguing against an automatic impact of empathy or one of arousal by a direct pathway from the perceptual to the motor stage (e.g., Miller, Franz, & Ulrich, 1999; cf. Figure 3.1). However, an automatic empathy effect on the motor system should not be excluded too early. Thus, when presenting video clips of Asian face stimuli, Han et al. (2017) found that participants applied larger response force (RF) to painful than neutral stimuli when asked to press a button from the start of the video clip until 1s after its end. Interestingly, in their fMRI experiment, empathy-related brain activity (middle cingulate cortex, supplementary motor cortex, bilateral second somatosensory and inferior frontal cortex) was reduced in this button press condition compared to a passive viewing condition, which led Han and colleagues to propose that there is a motivational link between empathy for pain and motor actions.

In this respect, it is also noteworthy that Riečanský et al. (2014) found an RBE effect on oscillatory sensorimotor activity in the brain. In this study, video clips of hands with dark and fair skin colors in painful and neutral situations (needle versus Q-tip) were presented. For own-race hand stimuli, event-related desynchronization (ERD) of the beta-band (13-30 Hz) over the sensorimotor cortex was stronger from 300-1500 ms after the onset of painful than neutral video clips, whereas there was no difference for other-race hand stimuli. Since decreases in beta-band power are generally viewed as representing motor cortex excitability, whereas increases are interpreted as motor inhibition (e.g., Fonken et al., 2016; Takemi, Masakado, Liu, & Ushiba, 2013), Riečanský and colleagues took their results to indicate greater sensorimotor activation only when watching an ingroup target in pain compared to a neutral situation. However, it must be mentioned that Avenanti et al. (2010) found smaller motor evoked potentials for own-race hands in painful than neutral situations, suggesting an inhibitory effect on motor activation, whereas there was no difference for other-race hands. Noteworthy, the RBE in MEP difference amplitudes between in- and outgroup's pain increased with a bias towards ingroup targets as measured with the race IAT. Whereas the different methodologies make it difficult to reconcile the discrepant findings of Avenanti et al. (2010) and Riečanský et al. (2014), it is conceivable that ERD reflects the facilitation of larger muscle groups rather than only that of an isolated finger muscle. Another possibility is that ERD and MEP effects mirror the differential time course of initial motor resonance when watching others in pain and the later inhibition of this effect.

In summary, previous studies investigated influences of the RBE only on single (e.g., motoric) or some (perceptual and cognitive) stages potentially involved in empathic processing. Moreover, these studies differed with regard to the stimuli used (dynamic versus static face stimuli), producing sometimes mixed results concerning the time course and the task-dependency of the RBE (e.g., Contreras-Huerta et al. 2014; Sessa et al, 2014; Sheng and Han, 2012). Crucially, the case for an RBE effect on early automatic processing would be much strengthened if demonstrated for empathy-evoking, static hand instead of face stimuli.

4.2.1 The current study

It is the main objective of the current study to address this issue by examining empathy for pain and racial bias influences on information processing using a combined behavioral and electrophysiological approach. As outlined earlier, to investigate the cognitive architecture of information processing, it is beneficial to map ERP components and EEG oscillations of interest to specific stages within information processing (cf. Figure 3.1). Thus, we recorded EEG and RF while Caucasian participants were watching pictures of dark- or fair-colored hands in painful or neutral situations. In order to manipulate attention to the pain dimension, participants either judged the painfulness of the situation or the skin color of the hands. ERP amplitudes were analyzed in order to assess the locus of the RBE within information processing (cf. Figure 3.1), that is on early (automatic) encoding and perceptual stages (posterior P1 and N1, EPN) versus late (controlled) categorization processing stages (P3b). Furthermore, we analyzed specific ERP components that were sensitively indicating an RBE in previous studies. To investigate the influence of the RBE on motor processing, EEG oscillations, RF amplitudes and the time from force onset to force peak (time-to-peak, TTP) were analyzed.

In line with studies investigating racial group influences (e.g., Contreras-Huerta et al., 2014; Sheng et al., 2017) and the study of Fabi and Leuthold (2017), we expected early ERP components reflecting automatic empathic processing (e.g., posterior P1 and N1, EPN) to differ in amplitude irrespective of the task for painful than neutral racial ingroup but not outgroup stimuli. In contrast, we predicted the P3b component as a marker of the task-relevant categorization process to be enlarged in amplitude by painful than neutral stimuli in the pain judgment but not the skin color judgment task. Crucially, based on previous findings (e.g., Contreras-Huerta et al., 2014; Sessa et al., 2014; Sheng et al., 2017), we expected this P3b amplitude effect to be independent of racial group. As regards motor processing, like Riečanský et al. (2014), the analysis of EEG oscillatory activity was predicted to reveal, independent of the task, larger ERDs in the beta-band in response to painful than neutral own-race but not other-race hand stimuli. Similar to Fabi and Leuthold (2017), we expected to find such an empathic influence not only before but also after response execution. Moreover, following the RF findings of Fabi and Leuthold (2017), we predicted RF amplitudes to be larger and TTPs and RTs to be shorter in the painful than the neutral condition for fair- but not dark-colored hands in the pain judgment task only.

To assess the potential functional relationship between specific ERP components and empathic processing as well as the RBE, we also assessed the subjective perception of stimuli (perceived pain and self-unpleasantness) and participants' dispositional empathy. Thus, after the main experimental blocks, like in previous studies (e.g., Fan & Han, 2008; Li & Han, 2010; Mella, Studer, Gilet, & Labouvie-Vief, 2012), each participant rated perceived pain and self-unpleasantness for each picture. Moreover, dispositional empathy was assessed by standard questionnaires. Like Fan and Han (2008; see also Fabi & Leuthold, 2017; Han, Fan, & Mao, 2008; Li & Han, 2010; Mella et al., 2012), we correlated ERP amplitudes and EEG power change values in the painful condition of the pain judgment task with ratings of perceived pain and self-unpleasantness and furthermore, with dispositional questionnaire scores. In line with previous ERP studies, we expected a correlation between the early ERP components and the subjective ratings for fair-colored hand stimuli (Fan & Han, 2008; Li & Han, 2010; Mella et al., 2012; Sessa et al., 2014) but not for dark-colored hand stimuli (Sessa et al., 2014). Based on Fabi and Leuthold (2017), we also predicted negative correlations between empathic dispositions and P1 as well as P3b amplitudes, and a positive correlation with mu oscillations over the sensorimotor cortex in a late time interval after the motor response. Finally, participants completed the race version of the IAT (Greenwald et al., 1998, 2003) in order to measure their implicit attitude towards racial outgroups and to reveal potential relations to the RBE as in previous studies (Sessa et al., 2014; see also Azevedo et al., 2013). Thus, in line with the procedure of Avenanti et al. (2010), we assessed whether the difference in amplitudes toward fair- and dark-colored hands was related to participants' implicit ingroup preference.

4.3 Method

4.3.1 Participants

Sample size was determined based on the study of Fabi and Leuthold (2017) and studies reporting RBE effects on the ERP waveform (*M* = 24.17). All 24 participants voluntarily taking part in the experiment for payment (8 Euros per hour) or course credits were white-Caucasian students of the University of Tübingen. One participant was excluded because of too noisy EEG data. Of the remaining 23 participants 14 were female, 21 right-handed and the average age was 23.09 years (SD = 2.00).

4.3.2 Materials and apparatus

We used 120 digital color pictures (cf. Figure 4.1) that displayed hands with dark or fair skin color in painful or neutral situations (30 pictures per condition) with painful stimuli depicting, for instance, hands that are hurt by a household tool like a hammer or scissors. Neutral pictures depicted the same arrangement of hands but without the painful component. We matched the luminance of the background in the pictures, however, because fair- and dark-colored hands differ naturally regarding luminance, color and contrast, it was not possible to control for all low-level physical features. Stimuli were selected based on the results of a pilot study, in which 68 Caucasian participants performed a discrimination task between painful and neutral stimuli and rated pain intensity and self-unpleasantness of the painful pictures of 33 situations; none of these participants took part in the present EEG experiment. Two situations were excluded because pain intensity differences between fair- and dark-colored pain stimuli exceeded two standard deviations from zero; a third one because of obvious differences in the spatial arrangement of hands. The remaining 30 situations did not significantly differ between dark- and fair-colored hands with regard to the pain intensity rating (*M* = 3.75 vs. 3.72), *t*(58) = 0.17, *p* = .87, or the self-unpleasantness rating (*M* = 3.38

vs. 3.31), *t*(58) = 0.39, *p* = .70, and also not regarding reaction times (*M* = 876 vs. 887 ms), *t*(58) = 0.59, *p* = .56, and accuracy of the discrimination task (*M* = 81.99 vs. 81.13 %), *t*(58) = 0.32, *p* = .75.

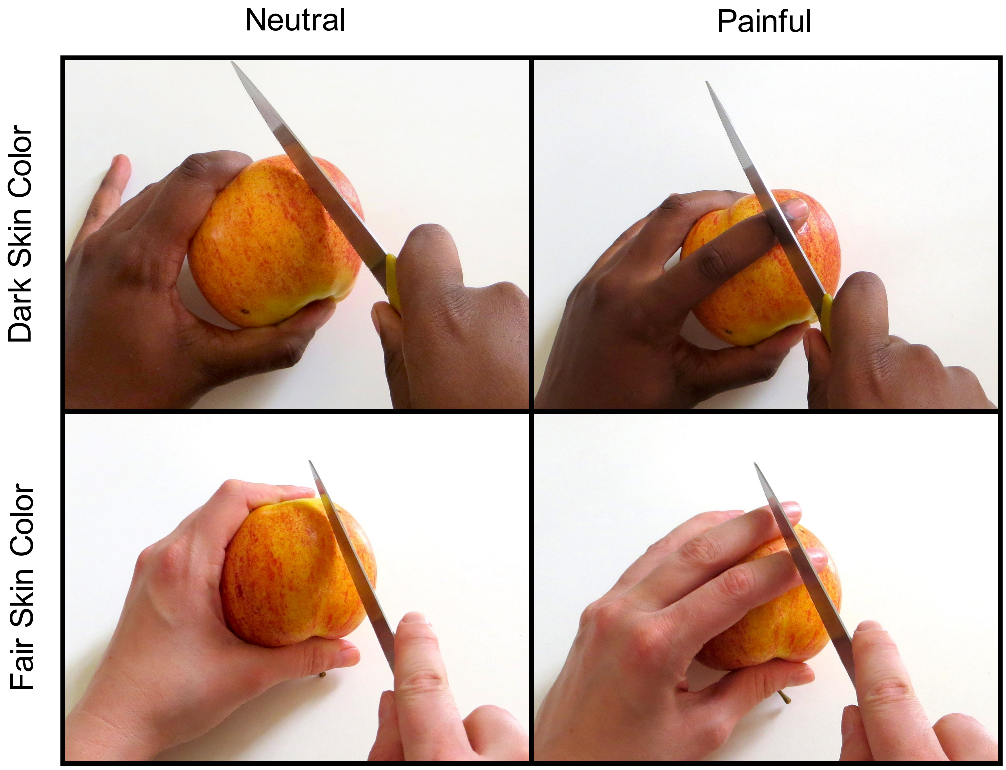


Fig. 4.1 Stimuli of dark- and fair-colored hands in painful and neutral daily-life situations.

Participants were tested in an electrically shielded, low-noise booth with ambient light at low level. They sat in front of a 1100 MB Samsung SyncMaster screen with a resolution of 1280 x 960 pixels and a refresh rate of 60 Hz, on which all materials were presented on black background. A constant viewing distance of 60 cm was guaranteed by a chin rest. Dimensions of the stimuli were 18.5 x 14 cm. A Mac Mini (Apple Inc.) controlled stimulus presentation and response recording running a MATLAB (The Math Works, Inc., Version R2015b) program using the Psychophysics Toolbox 3.0.12 (Brainard, 1997; Kleiner et al., 2007) together with custom MATLAB routines. In order to judge the stimuli, participants pressed force-sensitive keys with their left or right index finger in order to measure peak force

(PF) amplitudes and latencies (sampling rate = 512 Hz, for details, see Leuthold, Sommer, & Ulrich, 1996).

4.3.3 Procedure

After being informed about the procedure and giving informed consent, participants were asked to judge pictures of dark- or fair-colored hands in painful or neutral situations regarding their painfulness or the skin color of the hands, while EEG was recorded simultaneously. Tasks changed after every two blocks, consisting of 60 stimuli each, with task order being balanced across participants. In the first four blocks, each stimulus was presented once per task in randomized order, with the constraint that pictures of the same painful-neutral picture pair were shown in different blocks. The first four blocks were repeated. Every task change was preceded by 9 practice trials. The mapping of painful/neutral and fair/dark judgments to left and right keys was balanced across participants.

Individual trials consisted of a fixation cross (800 ms), followed by the stimulus presented for 400 ms and the participants' response. In case of an incorrect, too fast (RT < 200 ms) or too slow (RT > 1500 ms) response, feedback was provided (1000 ms), followed by a blank screen (1000 ms). Except for practice trials, feedback was not shown if the response was correct. On average, trials with correct responses lasted for a duration of 2866 ms. After the choice-response experiment, participants rated for all stimuli the intensity of the pain felt by the person in the picture and their own self-unpleasantness on a 6-point scale (1 = very low, 6 = very high). Then, participants completed two questionnaires of dispositional empathy: the German version (de Haen, 2006) of the Empathy Quotient (EQ, Baron-Cohen & Wheelwright, 2004) and the German version of the Interpersonal Reactivity Index (IRI, Davis, 1983), the Saarbrücker Persönlichkeitsfragebogen (SPF, Paulus, 2009). Finally, participants performed the race IAT in order to measure their implicit attitudes toward racial in- versus outgroup members.

4.3.4 Implicit Association Test (IAT)

We applied the standard race IAT following the procedures of Greenwald et al. (2003, cf. Table 1). As depicted in Table 1, the race IAT consisted of 7 blocks, with only the fourth and the seventh block being test blocks. The remaining blocks were practice blocks, in which participants practiced the different stimulus-key mappings. In the first block, participants learned the mapping between response keys and pictures of fair-/dark-colored faces. In the next block, participants learned the mapping between the same keys and positive/negative words. The third block consisted of pictures and words. Then, a test block followed, in which RTs to pictures and words were measured. In the next block, only pictures were presented and participants practiced the new (reversed) mapping of fair-/dark-colored faces to response keys. In the sixth block, pictures and words were presented, and in the seventh block RTs to pictures and words were measured. The IATd score was determined by subtracting the RTs of the fourth from the seventh block and dividing this result by the total standard deviation. Positive scores then represent a preference towards fair-colored faces and negative scores towards dark-colored faces.

4.3.5 Electrophysiological measures

Using a BIOSEMI Active-Two amplifier system, EEG activity was recorded continuously with a sampling rate of 256 Hz from 72 Ag-AgCl electrodes (for details, see Dudschig, Mackenzie, Strozyk, Kaup, & Leuthold, 2016). All EEG/ERP analyses were performed using available MATLAB toolboxes (FieldTrip: Oostenveld, Fries, Maris, & Schoffelen, 2011) and custom MATLAB scripts. EEG data preprocessing followed a procedure similar to Nolan, Whelan, and Reilly (2010). As described in detail by Dudschig et al. (2016), after recalculating EEG channels to an average reference and high-pass filtering (0.1 Hz, 12 dB/oct), a spatial independent components analysis (ICA) based on the infomax algorithm (Bell & Sejnowski, 1995) was performed. Ocular artifacts (blinks and horizontal eye movements) were eliminated by removing from the EEG data set those ICA components that reflected ocular activity. This was followed by a correction of noisy EEG channels. After this procedure and excluding incorrect trials, 87.87 % of all trials entered analysis. For each condition and participant, minimally 53 to 68 % and maximally 98 to 100 % of the trials entered analyses. The mean number of trials remaining (M = 50 out of 45 to 60; range = 28-59, median = 52) per condition was not reliably different across the different combinations of conditions, p = .77.

4.3.6 Data analysis

At the time point where RF was maximal within a 200-1500 ms time interval after stimulus onset, PF was determined in correct trials. When RF exceeded a threshold of 30 centinewton (cN) relative to the mean baseline activity within the preceding 200 ms, RT was recorded. The time between force onset and force peak defined TTP.

Within an analysis window of 200 ms before stimulus presentation until 1200 ms after stimulus onset, ERPs were averaged separately for each experimental condition using the corrected, average-reference EEG data set. The averaged ERPs were low-pass filtered (30 Hz, 36 dB/oct) and aligned to a 200 ms pre-stimulus baseline. Time intervals for analyzing the early ERP amplitudes were selected based on the empathy effects of Fabi and Leuthold (2017): 90-130 ms (P1), 140-180 ms (N1), and 200-300 ms (EPN) relative to stimulus onset. P1, N1, and EPN amplitudes were analyzed over posterior ventral electrodes (left hemisphere: P5, P7, PO7, PO9', right hemisphere: homolog sites), where they are typically maximal (Fabi & Leuthold, 2017, Schupp et al., 2004). The time interval and the electrodes for the P3b analyses were selected in accordance with the most commonly used intervals and electrodes of former RBE studies (e.g., Sessa et al., 2014, Sheng et al., 2017): 400 to 700 ms after stimulus onset at Pz, P3, and P4 electrodes. In addition, we further analyzed mean ERP amplitudes for those time intervals and electrodes for which former studies reported an RBE

(Contreras-Huerta et al., 2014; Li et al., 2015; Sessa et al., 2014, Sheng et al., 2017; Sheng et al., 2013; Sheng and Han, 2012), as will be outlined in more detail in the respective results section.

The analysis epoch for the oscillatory brain activity started 500 ms prior to the stimulus and lasted for 2000 ms. Power was analyzed from 4 to 30 Hz in 1-Hz frequency steps during the analysis epoch for successive 50-ms time steps. Morlet wavelets with a five-cycle width were applied for the time-frequency decomposition (e.g., Tallon-Baudry & Bertrand, 1999). We selected mu- (7-12 Hz), lower beta- (13-18 Hz) and upper beta-frequency bands (19-30 Hz) for left- and right-hemispheric ROIs over the somatosensory cortex (left hemisphere: C1, FC1, C3, CP1, right hemisphere: homolog sites). As in the previous study (Fabi & Leuthold, 2017), power values in the analysis windows between 300 and 600 ms and between 700 and 1500 ms were averaged and subsequently converted to a percentage change scale relative to a pre-stimulus baseline of 200 ms. Since participants executed their response on average 595 ms after stimulus onset, the early and late time interval are interpreted as before and after motor responses, respectively.

We analyzed data with repeated measures analyses of variance (ANOVAs), which are specified in the following corresponding sections, combined with Bonferroni-adjusted comparisons.

4.4 Results

4.4.1 Ratings and questionnaires

For the ratings, we performed ANOVAs with factors condition (painful, neutral) and skin color (dark, fair). The ANOVA of perceived pain revealed larger scores in the painful than the neutral condition ($M = 3.81$ vs. 1.06), $F(1, 22) = 636.20$, $MSE = 0.27$, $p < .001$, and a marginally significant Condition x Skin Color interaction, $F(1, 22) = 3.52$, $MSE = 0.02$, p

= .07. Further tests did not reveal any significant skin color difference in the painful or the neutral condition, all Fs ≤ 3.15, ps $\geq .09$. For self-unpleasantness, we found larger scores in the painful than the neutral condition as well (M = 3.36 vs. 1.26), $F(1, 22) = 195.00$, MSE = 0.52, $p < .001$, and a significant Condition x Skin Color interaction, $F(1, 22) = 6.80$, MSE = 0.01, $p < .05$. Post-hoc tests revealed that dark- compared to fair-colored hands in the painful condition were rated as marginally more self-unpleasant (M = 3.41 vs. 3.31), $F(1, 22) = 4.35$, MSE = 0.03, $p = .05$ (Bonferroni-corrected α-level = .025), whereas there was no difference in the neutral condition (M = 1.24 vs. 1.27), $F(1, 22) = 1.39$, MSE = 0.01, $p = .25$. Because rating scores for the neutral pictures showed little variability for perceived pain (range = 1 to 1.1) and self-unpleasantness (range = 1 to 1.5), they were excluded from further correlation analysis. The correlation between the ratings of perceived pain and self-unpleasantness were only marginally significant for both fair- and dark-colored hands, $r = .36$, $p = .09$ and $r = .38$, $p = .08$, respectively.

Concerning the questionnaires of dispositional empathy, SPF empathy scores ranged from 31 to 56 (M = 42.87) and EQ scores from 19 to 64 (M = 45.96). Two participants showed EQ scores smaller than 30, the cut-off value for autism spectrum disorders[1] (Baron-Cohen & Wheelwright, 2004). Internal consistency was good for the EQ (*Cronbach's* α = .82) and good or even excellent for the different subscales of the SPF: *Cronbach's* α = .88 (Empathic Concern), .93 (Perspective Taking), .88 (Fantasy), .90 (Personal Distress).

IATd scores ranged from -0.69 to 1.16, with negative scores revealing an implicit preference of the racial outgroup and positive scores indicating a preference for the racial ingroup. Across all participants, the mean IATd score was 0.20, which was significantly different form zero, $t(22) = 2.24$, $p < .05$.

---

[1] Exclusion of the two participants with EQ scores smaller than 30 did not change the key findings.

4.4.2 Behavioral performance

For accuracy, RT, TTP, and PF, repeated measures ANOVAs with variables condition (neutral, painful), skin color (dark, fair), and task (pain judgment, skin color judgment) were conducted.

Accuracy

The ANOVA for accuracy showed a main effect of task, $F(1, 22) = 24.9$, $MSE < 0.01$, $p < .001$, which was due to lower accuracy in the pain judgment than the skin color judgment task ($M = 92.4$ % vs. 97.2 %).

Reaction time

Responses were faster for the skin color judgment than the pain judgment task ($M = 507$ vs. 684 ms), $F(1, 22) = 280.40$, $MSE = 5098.00$, $p < .001$. There were significant interactions of Task x Condition, $F(1, 22) = 9.85$, $MSE = 737.00$, $p < .01$, and of Task x Skin Color, $F(1, 22) = 17.22$, $MSE = 427.00$, $p < .001$. Post-hoc tests revealed that in the pain judgment task, RTs were shorter for painful than neutral stimuli ($M = 673$ vs. 695 ms), $F(1, 22) = 9.08$, $MSE = 1216.00$, $p = .006$, and for dark- than fair-colored hands ($M = 674$ vs. 693 ms), $F(1, 22) = 23.90$, $MSE = 332.00$, $p < .001$, whereas there were no differences in the skin color judgment task, all Fs < 1.31, all ps > .26 (cf. Figure 4.2). The Task x Condition x Skin Color interaction was significant, $F(1, 22) = 7.24$, $MSE = 551.00$, $p < .05$, but further tests of dark- and fair-colored hands in both tasks did not reveal significant differences between the painful and the neutral condition, all Fs < 4.81, all ps > .04 (Bonferroni-corrected α-level = .0125).

Time-to-peak latency

The analysis of the time between force onset and PF did not reveal any significant main or interaction effect, all Fs < 1.93, all ps > .18 (cf. Figure 4.3).

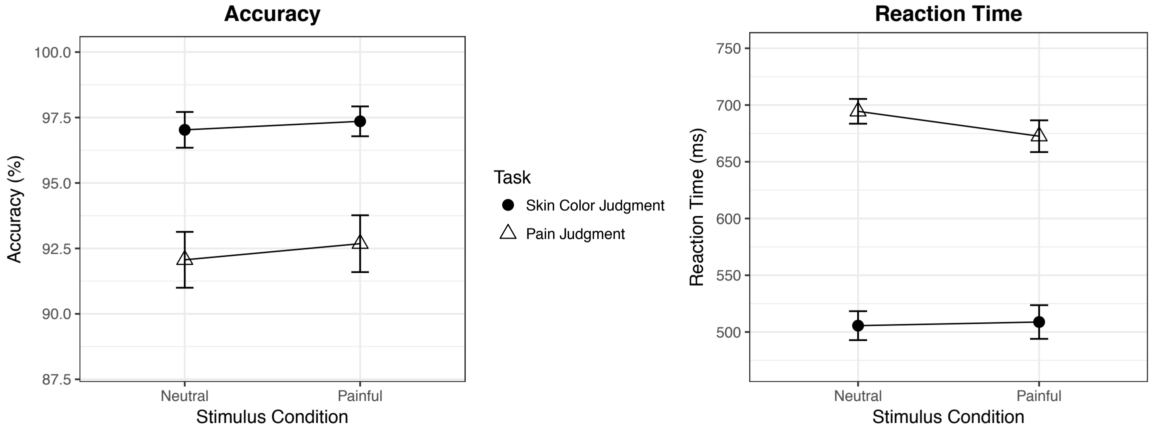


Fig. 4.2 Mean accuracy and reaction time as a function of stimulus condition (painful vs. neutral) and task (pain judgment vs. skin color judgment).

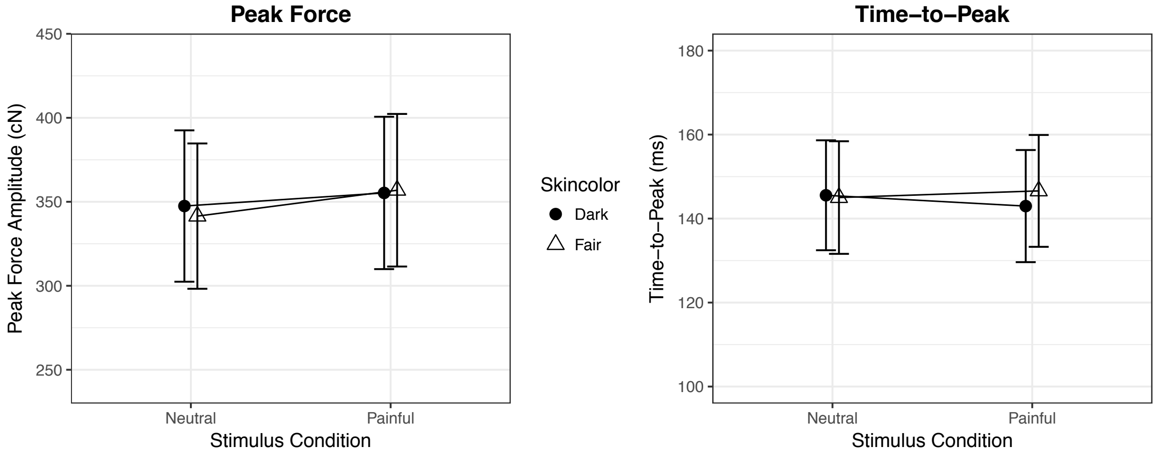


Fig. 4.3 Mean peak force amplitude and time-to-peak latency as a function of stimulus condition (painful vs. neutral) and skin color (dark vs. fair).

Peak force amplitude

The ANOVA of PF revealed a significant main effect of task, $F(1, 22) = 5.43$, $MSE = 10661.00$, $p < .05$, which was due to higher PF amplitudes in the pain judgment task than the skin color judgment task ($M = 368$ vs. 333 cN). No other effects were significant, all Fs ≤ 1.61, ps $\geq .22$.

4.4.3 Event-related brain potentials

ERP waveforms over posterior-ventral ROIs were composed of a first positive deflection (P1), maximal at about 120 ms, a negative deflection (N1), peaking at about 160 ms, and a posterior positivity peaking at about 230 ms. Subsequently, there was a late positivity (P3b), which was maximal over posterior midline electrodes between 400 and 550 ms for the skin color judgment task and between 450 and 650 ms for the pain judgment task (cf. Figure 4.4).

For mean P1, N1, and EPN amplitudes, we calculated ANOVAs with variables hemisphere (left, right), condition (neutral, painful), skin color (dark, fair), and task (pain judgment, skin color judgment). Mean P3b amplitudes were analyzed by an ANOVA with variables condition (neutral, painful), skin color (dark, fair), and task (pain judgment, skin color judgment).

P1 (90-130 ms)

The ANOVA for P1 amplitudes revealed a main effect of skin color, $F(1, 22) = 9.03$, $MSE = 1.08$, $p < .01$, which was due to larger P1 amplitudes for fair than dark-colored hands ($M = 3.41$ vs. $3.08\ \mu$V). We found a significant Condition x Skin Color x Hemisphere interaction, $F(1, 22) = 5.33$, $MSE = 0.30$, $p < .05$. Separate tests for the left and right hemisphere did not reveal any significant Condition x Skin Color interaction, all Fs < 2.94, ps $> .10$.

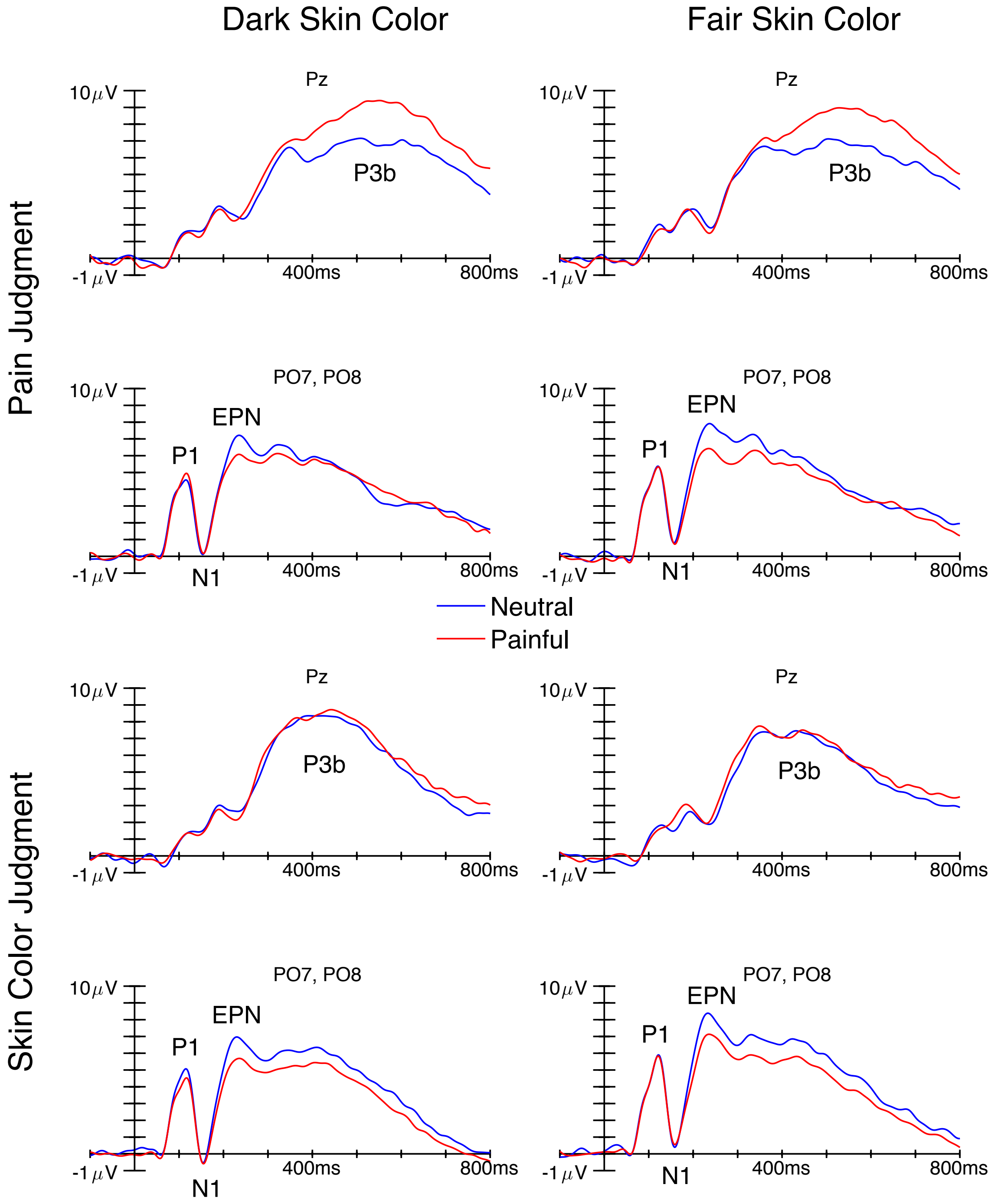


Fig. 4.4 Grand average ERP amplitudes (in μV) recorded over Pz and PO7/PO8 as a function of stimulus condition (painful vs. neutral), skin color (dark vs. fair) and task (pain judgment vs. skin color judgment).

N1 (140-180 ms)

The N1 ANOVA revealed a significant main effect of skin color, $F(1, 22) = 14.86$, $MSE = 1.57$, $p < .001$, indicating more positive amplitudes for fair- than dark-colored hands (0.77 vs. 0.27 μV). The main effect of task, $F(1, 22) = 7.63$, $MSE = 1.32$, $p < .05$, was due to more positive N1 amplitudes for the pain than the skin color judgment task ($M = 0.69$ vs. 0.36 μV).

EPN (200-300 ms)

The analysis of EPN amplitudes (cf. Figure 4.5) produced a significant main effect of condition, $F(1, 22) = 38.94$, $MSE = 1.78$, $p < .001$, indicating more negative-going amplitudes in the painful than the neutral condition ($M = 4.00$ vs. 4.86 μV). Furthermore, EPN amplitudes were more negative-going for dark than fair hands ($M = 4.11$ vs. 4.75 μV), $F(1, 22) = 35.82$, $MSE = 1.03$, $p < .001$, but this effect was modulated by task as indicated by the significant Task x Skin Color interaction, $F(1, 22) = 9.54$, $MSE = 0.65$, $p < .01$. The skin color effect on EPN amplitude was larger in the skin color judgment task ($M = 3.93$ vs. 4.82 μV), $F(1, 22) = 33.21$, $MSE = 1.10$, $p < .001$, than in the pain judgment task ($M = 4.30$ vs. 4.67 μV), $F(1, 22) = 11.21$, $MSE = 0.57$, $p = .003$.

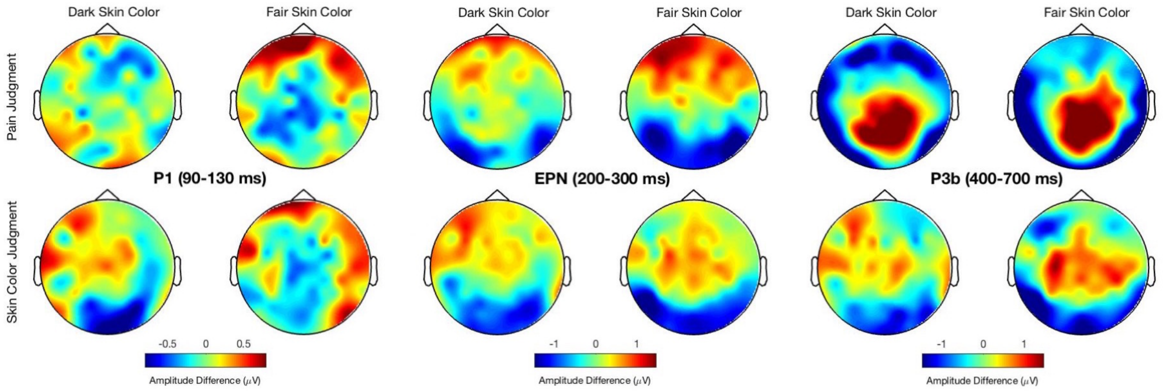


Fig. 4.5 Topoplots of P1, EPN and P3b amplitude differences for the painful minus the neutral condition in the pain judgment and the skin color judgment task, for dark- and fair-colored hands. Note the changed scaling for the P1.

P3b (400-700 ms)

The analysis of mean P3b amplitude in the 400-700 ms time window revealed main effects of condition, $F(1, 22) = 15.92$, $MSE = 2.12$, $p < .001$, and task, $F(1, 22) = 9.06$, $MSE = 6.83$, $p < .01$, due to larger P3b amplitudes in the painful than the neutral condition ($M = 6.29$ vs. 5.43 μV), and for the pain judgment than the skin color judgment task ($M = 6.44$ vs. 5.28 μV). The Task x Condition interaction was significant, $F(1, 22) = 17.44$, $MSE = 1.08$, $p < .001$, indicating significantly larger P3b amplitudes for the painful than neutral condition in the pain judgment task ($M = 7.19$ vs. 5.69 μV), $F(1, 22) = 21.48$, $MSE = 2.40$, $p < .001$, but not in the skin color judgment task ($M = 5.39$ vs. 5.17 μV), $F(1, 22) = 1.34$, $MSE = 0.80$, $p = .26$.

Correlation analyses

Correlations between mean ERP amplitudes for dark- and fair-colored hands measured in different time intervals for the painful condition of the pain judgment task and scores of perceived pain and self-unpleasantness for painful pictures, and the dispositional empathy scores of the EQ and the SPF, were tested for significance.[2] The same correlation tests were conducted for ERP amplitudes of the neutral condition in order to reveal empathy-unspecific correlations. However, this was possible only for correlations with the EQ and SPF, whereas the restricted variability of perceived pain and self-unpleasantness scores for neutral pictures mentioned above did not permit such correlation tests for the neutral condition. Besides, correlations between IATd scores and difference scores for amplitudes for fair- minus dark-colored hands in the painful and the neutral condition of the pain judgment task were tested. The significance level (alpha) was Bonferroni-adjusted.

---

[2] Some other authors investigating correlations between empathy questionnaires, ratings, and ERP amplitudes used the amplitude difference between painful and neutral conditions. In a likewise analysis for the early ERP components (P1, N1, EPN), we did not find any significant correlations, -.31 < rs < .41, all *p*s >.05. After Bonferroni correction, the correlations between P3b difference amplitudes and rating or questionnaire scores were not significant, -.22 < rs < .47, all *p*s >.03.

Scores of perceived pain correlated positively with amplitudes for both dark- and fair-colored hands in the painful condition in both P1, $r = .71$, $p < .001$ and $r = .67$, $p < .001$, N1, $r = .51$, $p = .01$ and $r = .48$, $p < .05$, and EPN time intervals, $r = .68$, $p < .001$ and $r = .65$, $p < .001$. P3b amplitudes did not show any significant correlations with perceived pain, self-unpleasantness, or dispositional empathy, $.14 < r < .33$, all ps $\geq .12$. Crucially, IATd scores correlated positively with P3b amplitude differences (fair minus dark) for painful stimuli, $r = .52$, $p = .01$, but not with amplitude differences for neutral stimuli, $r = -.01$, $p = .97$ (cf. Figure 4.6).

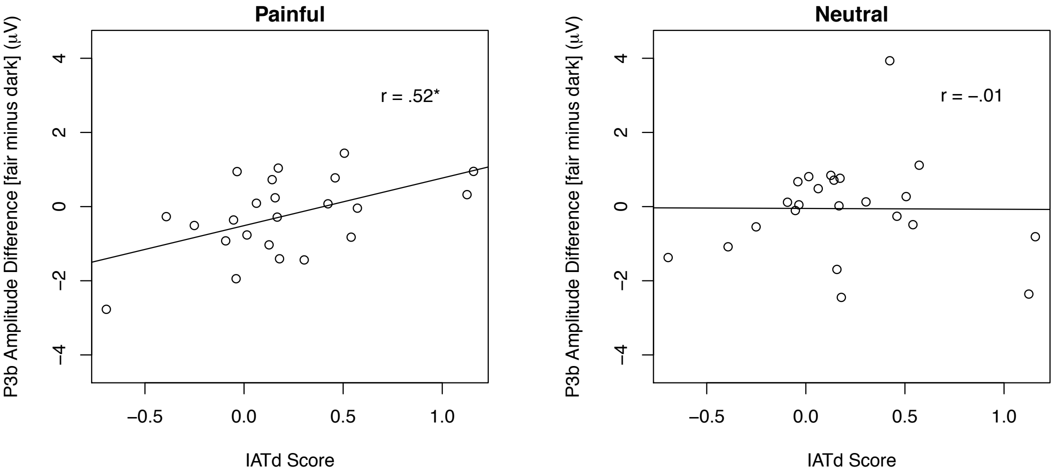


Fig. 4.6 Correlations between IATd scores and difference scores of P3b amplitudes for fair-minus dark-colored hands in the painful and the neutral condition.

Analyses according to previous RBE studies

In an ERP analysis of average reference data identical to Contreras-Huerta et al. (2014), there was a significant Condition x Skin Color interaction for mean ERP amplitudes between 80-140 ms at frontal electrodes (Fz, and FCz), $F(1, 22) = 5.18$, $MSE = 0.37$, $p < .05$. This interaction was due to a trend for a larger negativity for painful than neutral fair-colored hand stimuli, $F(1, 22) = 3.23$, $p = .086$, but not for dark-colored hand stimuli, $F < 1$, $p = .53$. Since most ERP studies investigating the RBE found an RBE in mean amplitudes over frontal-central electrodes with EEG signals referenced to mastoids (Li et al., 2015; Sheng et al., 2017; Sheng et al., 2013; Sheng & Han, 2012; Sessa et al., 2014), we also analyzed the present ERP data in an analogous manner. In ERP amplitude analyses adopting the specific procedures of Li et al. (2015), Sheng et al. (2013, 2017), and Sheng and Han (2012), there were no significant Condition x Skin Color interactions, all Fs(1, 22) < 2.95, *p*s > .10. Finally, in an analysis identical to those of Sessa et al. (2014), mean ERP amplitudes (280-340 ms) over frontal electrodes (AF3/AF4, AF7/AF8, Fz, FCz, F1/F2, F3/F4, F5/F6, F7/F8, FC1/FC2, FC3/FC4, FC5/FC6, FT7/FT8) produced a trend for the Condition x Skin Color interaction $F(1, 22) = 3.00$, $MSE = 5.13$, $p = .098$. For fair-colored hands, ERP amplitudes were less negative for painful than neutral stimuli ($M = -0.47$ vs. -1.78 μV), $F(1, 22) = 8.51$, $MSE = 4.63$, $p < .01$, but not for dark-colored hands ($M = 0.24$ vs. 0.08 μV), $F(1,22) < 1$, $p = .73$. The Condition x Skin Color interaction was significant over central electrodes (Cz, C1/C2, C3/C4, and C5/C6), $F(1, 22) = 4.38$, $MSE = 3.99$, $p < .05$, due to larger ERP amplitudes for painful than neutral fair-colored hand stimuli ($M = 2.67$ vs. 1.23 μV), $F(1, 22) = 9.70$, $MSE = 4.86$, $p < .01$, but not dark-colored hand stimuli ($M = 3.31$ vs. 311 μV), $F(1, 22) < 1$, $p = .61$ (cf. Figure 4.7). Similar to those of Sessa et al., the correlational analyses revealed significant correlations between the IRI subscale “empathic concern” and the mean ERP amplitude difference (pain minus neutral; 280-340 ms) at the F3 and FC5 electrodes to fair-colored, $r = .47$ and $r = .49$, *p*s = .02, but not to dark-colored hands, $-.06 < r < .12$, all *p*s $\geq .57$ (Figure 4.8).

4.4.4 Oscillatory EEG activity

Percentage power change values were subjected to an ANOVA with variables condition (neutral, painful), skin color (dark, fair), task (pain judgment, skin color judgment) and hemisphere (left, right).

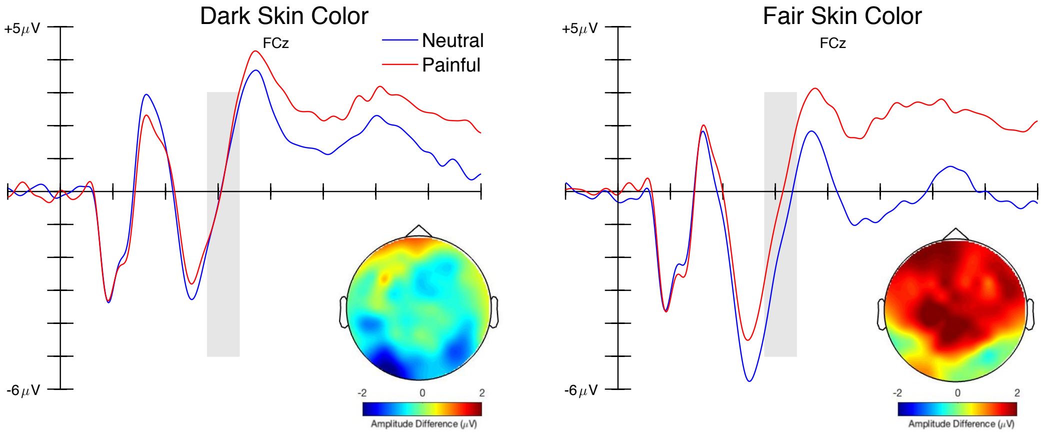


Fig. 4.7 Amplitudes (in μV) at FCz, rereferenced to the mastoid electrodes, as a function of stimulus condition (painful vs. neutral) and skin color (dark vs. fair) with the analysis window of Sessa et al. (2014) and associated topoplots of the amplitude difference for the painful minus the neutral condition.

Time interval 300-600 ms

The analysis of mu-band (7-12 Hz) power in this time window revealed an ERD (-13.75 %) that was significantly different from zero, $t(22) = -2.30$, $p < .05$. The main effect of task was significant, $F(1, 22) = 7.94$, $MSE = 356.70$, $p < .05$, due to larger ERDs in the pain judgment than the skin color judgment task ($M = -16.53$ % vs. -10.98 %).

The analysis of lower beta-band (13-18 Hz) power in this time interval also revealed an ERD ($M = -27.51$ %) significantly different from zero, $t(22) = -7.94$, $p < .001$, and a main effect of task, $F(1, 22) = 12.96$, $MSE = 256.00$, $p < .01$, due to larger ERDs in the pain judgment than the skin color judgment task ($M = -30.51$ % vs. -24.50 %).

Upper beta-band (19-30 Hz) power analysis revealed a significant ERD as well ($M =$ -25.42 %), $t(22) = -10.44$, $p < .001$. Furthermore, the Condition x Task interaction was significant, $F(1, 22) = 17.65$, $MSE = 21.30$, $p < .001$, which was due to larger ERDs in the painful than the neutral condition in the pain judgment task ($M = -27.21$ % vs. -24.98 %), $F(1, 22) = 7.12$, $MSE = 32.34$, $p = .01$, and smaller ERDs in the painful than the neutral condition in the skin color judgment task ($M = -23.85$ % vs. -25.66 %), $F(1, 22) = 6.10$, MSE

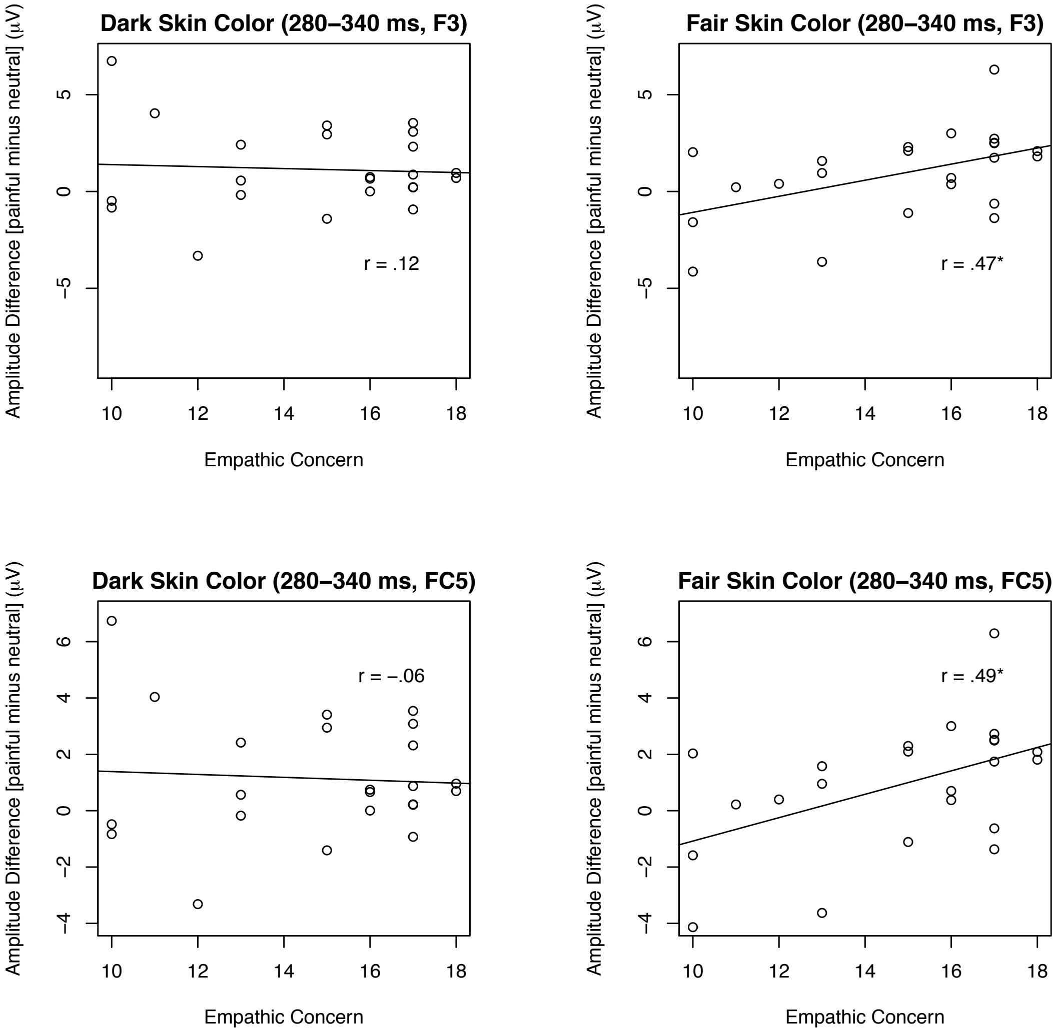


Fig. 4.8 Correlations between empathic concern and difference scores of ERP amplitudes (280-340 ms) for painful minus neutral conditions (over electrodes F3 and FC5), separately for both skin colors.

= 24.71, *p* = .02. Post-hoc tests of the Condition x Skin Color x Hemisphere interaction, *F*(1, 22) = 5.61, *MSE* = 12.52, $p < .05$, did not reveal any significant effect, all *F*s $\leq$ 2.34, *p*s $\geq$ .14 (cf. Figure 4.9).

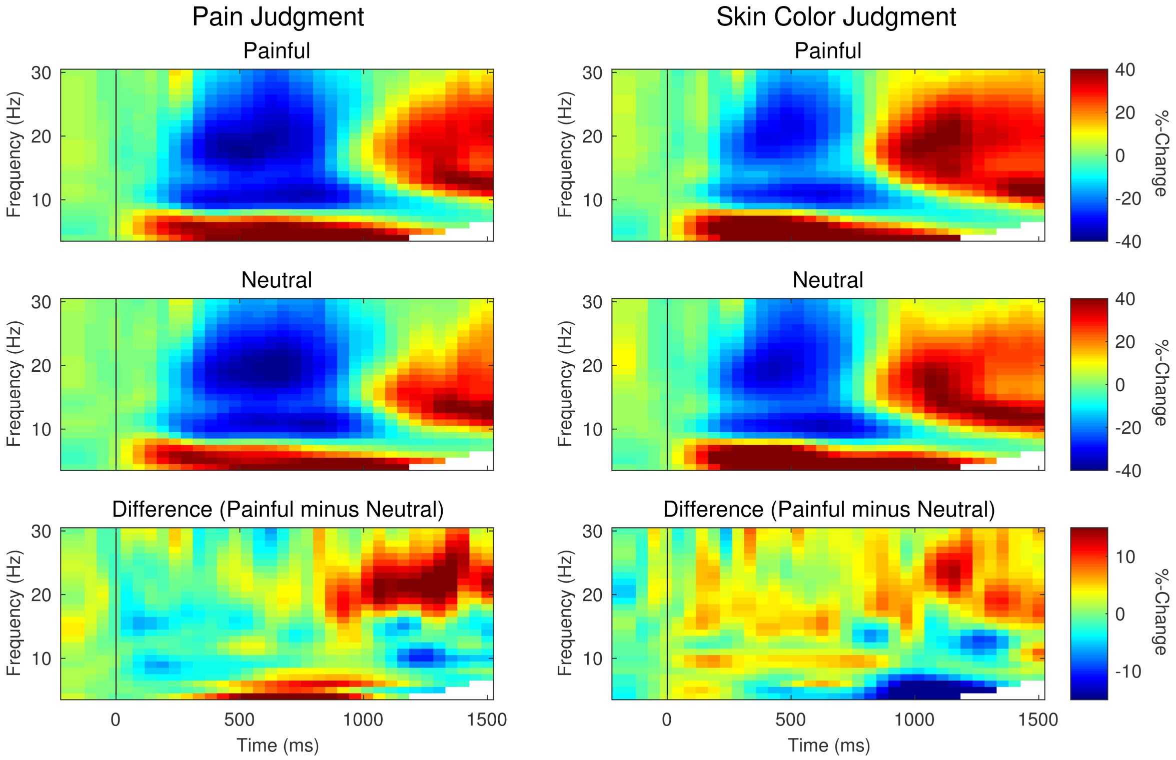


Fig. 4.9 Grand average percentage-change values over lateral sensorimotor cortex (averaged across left and right electrodes: FC1, FC2, C1, C2, C3, C4, CP1, CP2) relative to a 200 ms pre-stimulus baseline as a function of time and frequency. Power changes are displayed for the pain judgment and the skin color judgment task, and the painful, the neutral and the difference between the painful minus neutral conditions. Note the difference in scaling in the lower panels.

Time interval 700-1500 ms

The analysis of mu-band (7-12 Hz) power yielded an overall ERD (*M* = -2.24 %) that was not significantly different from zero, *t*(22) = -0.48, *p* = .64. The main effect of task was significant, *F*(1, 22) = 6.67, *MSE* = 700.00, $p < .05$, indicating a decrease in power in the pain judgment compared to the skin color judgment task (*M* = -5.81 % vs. 1.32 %).

The overall lower beta-band (13-18 Hz) power change (M = 15.35 %) in this time interval was significantly different from zero, $t(22) = 2.97$, $p < .01$. Again, we found a significant main effect of task, $F(1, 22) = 29.94$, $MSE = 486.00$, $p < .001$, due to smaller increases in power in the pain judgment compared to the skin color judgment task (M = 9.06 % vs. 21.64 %).

In this late time interval, the overall numerical increase in upper beta-band (19-30 Hz) power (M = 6.65 %) was not significantly different from zero, $t(22) = 1.41$, $p = .17$. However, there was a larger upper beta-band power increase for painful than neutral stimuli (M = 8.98 % vs. 4.31 %), $F(1, 22) = 13.12$, $MSE = 152.90$, $p < .01$, and for the skin color judgment task compared to the pain judgment task (M = 13.66 % vs. -0.36 %), $F(1, 22) = 29.54$, $MSE = 612.00$, $p < .001$.

Correlation analyses

Correlation analyses between scores of perceived pain, self-unpleasantness, EQ or SPF, and power change values for both skin colors in the painful condition of the pain judgment task and between IATd scores and difference scores of power change values for dark- and fair-colored hands were calculated. In order to control for unspecific effects, the same analyses were calculated for the neutral condition, except for perceived pain and self-unpleasantness as mentioned earlier.

There were no significant correlations between the various rating scores and the power change values for the mu-band (7-12 Hz) as well as the upper beta-band (19-30 Hz) in the painful condition or between the IATd scores and the difference amplitudes, $-.42 < r < .24$, all ps $\geq .05$. However, self-unpleasantness scores correlated significantly with power change values in the lower beta-band (13-18 Hz) for the 300-600 ms time interval in the painful condition for fair-colored hands, $r = -.57$, $p < .01$ (Bonferroni-corrected α-level = .025), and marginally for dark-colored hands, *r* = -.45, *p* = .03 (Figure 4.10), whereas there were no significant correlations for the 700-1500 ms time interval, -.40 < *r* < .17, all *p*s ≥ .05.

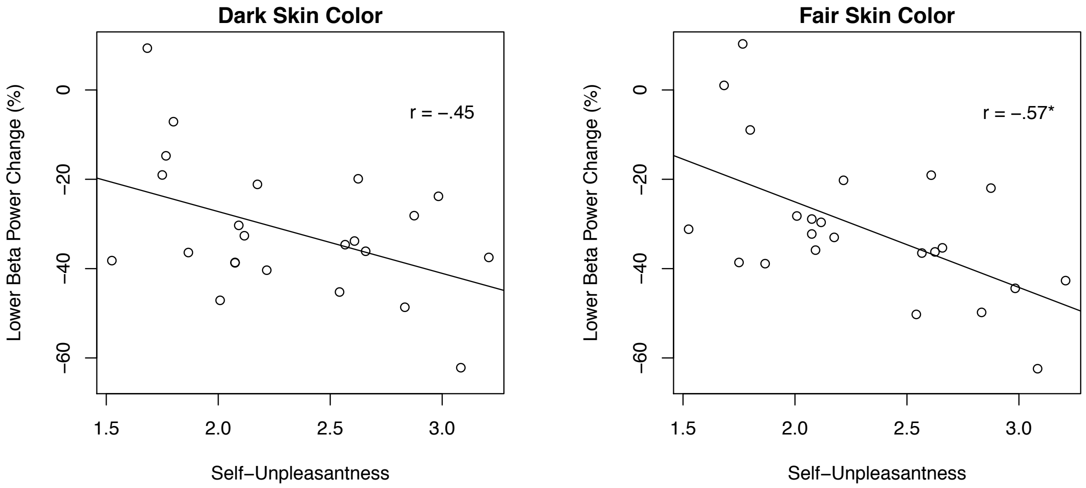


Fig. 4.10 Correlations between self-unpleasantness and lower beta power change values (13-18 Hz, 300-600 ms), separately for both skin colors.

4.5 Discussion

The main aim of this study was to investigate differences in empathic responses for racial in- and outgroup targets analyzing ERPs, EEG oscillations, RT and RF in response to simple pictures of fair- and dark-colored hands in painful and neutral situations. The key findings will be discussed with regard to early perceptual encoding, late cognitive categorization, and motor-related processing stages. Following initial perceptual encoding as reflected by posterior P1 and N1 components, we found a task- and skin color-independent EPN difference (200-300 ms) between empathy-evoking and neutral stimuli which we take to indicate the selective processing of affectively arousing stimuli (cf. Olofsson, Nordin, Sequeira, & Polich, 2008). Whereas no reliable RBE was obtained in the early ERP waveform (< 280 ms), like in Sessa et al. (2014), there was an RBE over frontocentral electrodes in the 280-340 ms time window. Moreover, the analysis of P3b amplitude showed that the cognitive categorization stage was influenced by empathy-evoking stimuli if attention was directed towards the pain dimension and that this influence depended on participants' implicit ingroup preference. Finally, motor-related EEG oscillations suggested an empathic influence before (larger facilitation) and after response execution (larger inhibition), but no RBE.

4.5.1 Empathy-unrelated task and skin color effects

Concerning the speeded choice-response task, participants showed accurate performance in both judgment tasks. The higher accuracy and shorter reaction times for the skin color than the pain judgment task indicate that the skin color judgment was slightly easier to accomplish, presumably because only one prominent visual characteristic (color) had to be discriminated. By contrast, in order to appropriately perform the pain judgment task, participants had to capture and evaluate the whole situation. This conjecture appears to be supported by the finding that N1 amplitudes revealed task-related effects on early visual processing. Furthermore, larger P3b amplitudes in the pain judgment than the skin color judgment task further indicate that the former task received more cognitive processing resources (Kok, 2001; Polich, 2007). Together, behavioral and ERP findings are consistent with the view that skin color judgments included the processing of a single prominent visual stimulus feature, whereas pain judgments required the attentionally more demanding processing of the whole scene.

Regarding motor processing, we found in the time interval before response onset, larger ERDs for the pain judgment than the skin color judgment task in the mu- and lower beta-band and in the time interval after response onset additionally in the upper beta-band, suggesting larger sensorimotor activation in the pain judgment than the skin color judgment task. This effect on sensorimotor activation is corroborated by the larger PF amplitudes in the pain judgement than the skin color judgment task.

Regarding skin color-related effects, responses were faster to dark than fair stimuli in the pain judgment but not the skin color judgment task, possibly because the visual discriminability was higher for dark than fair-colored hands. The more positive P1 amplitude for fair- than dark-colored hands over posterior ROIs, an amplitude effect that propagated to the N1 and EPN time interval, might be attributed to the fact that dark- and fair-colored hand stimuli differed in low-level perceptual features like their luminance and color. These ERP findings contrast with those of studies investigating facial skin color effects on ERPs (Ito & Urland, 2003; Kubota & Ito, 2007; for a review, see Ito & Bartholow, (2009)). These studies found larger amplitudes in the early N1 component (at Cz) for outgroup than ingroup targets, which was ascribed to the attention-capturing nature of racial outgroup targets. We can only speculate regarding the potential reasons for the divergent ERP results compared to our study. Thus, it is conceivable that the use of black and white yearbook stimuli as compared to hand stimuli together with the different cultural background of participants (e.g., higher relevance of race issues for US citizens) differentially influenced ERPs. Moreover, since the stimuli were presented on black background, it is possible that fair-colored hands captured attention more easily than dark-colored hands.

4.5.2 Empathy-related effects

Higher ratings of perceived pain and self-unpleasantness for painful than neutral stimuli indicate that pictures of painful situations successfully elicited empathic responses in the observer.

Early perceptual processing

Like in the study of Fabi and Leuthold (2017), P1 and N1 amplitudes did not differ for painful versus neutral stimuli, whereas EPN amplitudes were more negative-going in the painful than the neutral condition, and this empathy effect was independent of the task. We take this particular finding to indicate that painful stimuli automatically capture attention and undergo further selective processing following their initial encoding. Crucially, the empathy-related EPN amplitude difference was neither modulated by task nor by skin color, indicating an automatic influence during selective perceptual processing. Whereas some previous studies reported such a task-independent (automatic) empathy effect to occur even earlier during information processing, as indicated by frontocentral N1 amplitudes (e.g., Fan & Han, 2008; Han, Luo, & Han, 2016; Meng et al., 2012), other studies failed to replicate this N1 effect (e.g., Fabi & Leuthold, 2017; Mella et al., 2012; Sessa et al., 2014). With regard to the mixed results, it is noteworthy that Cui, Zhu, Luo (2017) found that the empathy-related difference in frontocentral N1 amplitude (110-160 ms) was only present in a threatening but not a friendly social context as induced by a facial prime stimulus, whereas the later P3 effect was only present in the friendly context. Thus, future ERP studies might benefit from controlling the social context within which the experiment is conducted.

Still, ERP components earlier than the EPN might be related to empathy effects as indicated by the present results of the correlational analyses. Thus, mean P1 amplitude in the painful condition increased with the intensity of the subjective pain rating for both fair- and dark-colored hand stimuli, and this correlational effect propagated to the N1 and EPN time range. It therefore appears that early perceptual processes are influenced at the inter-individual level by the pain an observer subjectively perceives, potentially reflecting the attention-capturing effect of personally salient stimuli.

Late cognitive categorization

Importantly, concerning empathic influences on the duration of information processing, RTs were shorter to painful than neutral stimuli in the pain judgment task, whereas there was no such RT difference in the skin color judgment task. This finding might suggest that a task-dependent processing stage following task-independent perceptual encoding is generally shortened in its duration by empathy-evoking stimuli. In agreement with previous studies (e.g., Fabi & Leuthold, 2017; Fan & Han, 2008), we found larger P3b amplitudes for painful than neutral stimuli in the pain judgment but not the skin color judgment task. Therefore, we assume that painful compared to neutral stimuli receive more processing resources at the late categorization stage, thereby being processed faster as indicated by RT results.

Motor processing

Concerning the analysis of oscillatory brain activity, ERDs in the mu-, lower beta- and upper beta-band before response onset indicate sensorimotor activation prior to the motor response as in previous studies (e.g., Pfurtscheller, 1989). Crucially, however, upper beta-band-ERD was larger in the painful than the neutral condition for the pain judgment and smaller for the skin color judgment task, irrespective of skin color. This particular finding suggests that sensorimotor activation is enhanced for painful targets if attention is directed towards the pain dimension, also potentially shortening the duration of motor processing before response onset.

After response onset, the finding of a power increase (ERS) in the lower beta-band indicated an inhibition of sensorimotor reactivity (cf. Pfurtscheller, Zalaudek, & Neuper, 1998), as often observed after the onset of speeded responses (e.g., Pfurtscheller, Stancak, & Neuper, 1996). In contrast to the results of Fabi and Leuthold (2017), we found no lower beta-band evidence for larger facilitation of sensorimotor activity after the response for painful than neutral stimuli. Rather, there was a larger increase of upper beta-band power to painful than neutral stimuli irrespective of task and skin color, implying a larger and task-independent inhibition of motor reactions for empathy-evoking stimuli. It is worth noting that a similar increase of beta-band power to painful stimuli was reported in a study of Valentini, Liang, Aglioti and Iannetti (2012; see also MEP amplitude findings of Avenanti, Bueti, Galati, & Aglioti, 2005), in which participants performed no motor response but merely attended to video clips showing fair-colored hands in painful and neutral situations. Together, present findings accord with the view that empathy for pain is motivationally linked to motor actions (see also Han et al., 2017), as indicated by the stronger facilitating influence of empathy-evoking stimuli during the early pre-response phase, which might subsequently lead to a stronger motor inhibition during the post-response phase.

4.5.3 Racial bias of empathy

Fair- and dark-colored hands did not differ in participants' perceived pain, but unlike the results from the pilot rating study, dark-colored hands in pain were judged as more self-unpleasant than fair-colored hands.

RBE and early perceptual processing

The analyses of the posterior P1, N1, and EPN amplitudes did not reveal any RBE effect. However, similar to Contreras-Huerta et al. (2014), frontocentral N1 amplitudes (80-140 ms) were more negative-going for painful than neutral ingroup but not outgroup hand stimuli, but this RBE effect remained a statistical trend. Moreover, replicating the results of Sessa et al. (2014) with hand instead of face stimuli, there was a positive shift of frontal and central ERP amplitudes in the 280-340 ms time window in the painful than the neutral condition for fair-colored but not for dark-colored hands. Thus, early perceptual processing before stimulus categorization does indeed seem to be influenced by the RBE. Extending previous studies that used either pain or race judgment tasks (Contreras-Huerta et al. 2014; Li et al., 2015; Sessa et al. 2014; Sheng & Han, 2012; Sheng et al., 2013), our results are first in demonstrating such an early RBE effect independent of the judgment task (pain versus skin-colour). In line with the view of bottom-up emotional sharing, this result suggests that the racial background influences early perceptual processing in an automatic manner. Similar to the correlational results of Sessa et al. (2014) and also in line with an early RBE effect, we found a significant positive correlation of the ERP amplitude difference for fair-colored hands with the IRI subscale “empathic concern”, whereas the correlation with amplitude differences for dark-colored hands were not significant. In line with the findings of Sessa et al., we speculate that the present RBE effect might originate in the left IFG (see also Vachon-Presseau et al., 2012, reflecting the automatic component of empathic sharing.

RBE and late cognitive categorization

Importantly, in line with previous studies investigating the RBE with face stimuli (e.g., Contreras-Huerta et al., 2014; Sheng et al., 2017; Sheng et al., 2013), the P3b empathy effect was not modulated by skin color. Thus, we cautiously infer from this zero effect at the group level that the racial background of the target, at least on average, has no impact on controlled stimulus categorization. Because of different studies revealing the importance of individual implicit ingroup preferences, we also applied the race IAT. Azevedo et al. (2013), for example, found that the higher a person’s implicit ingroup preferences was, the larger was the difference in the empathy effect between in- and outgroup targets represented by the differential left AI activity between painful and neutral stimuli. Thus, they assumed that IATd scores were able to predict affective-motivational neural responses to racial in- and outgroup targets’ pain. Most interestingly, we found a positive correlation between IATd scores and P3b differences between fair- and dark-colored hands for painful but not neutral stimuli. This result is in line with Sessa et al. (2014), who reported a positive correlation between IATd scores and the P3b amplitude difference (400-750 ms) for fair- but not dark-colored faces. Our finding suggests that the categorization of empathy-evoking stimuli of dark- and fair-colored hands is not immune to racial biases but differentially influenced by the individual’s implicit preferences towards own-race stimuli. That is, the larger the own-race preference was, the larger was the difference in evaluating empathy-evoking stimuli for dark- and fair-colored hands, whereas the difference in evaluating neutral stimuli was independent of implicit preferences. In contrast, it has been previously assumed in this research domain that the empathic influence on the categorization stage, as indicated by the late P3b, is insensitive to racial biases (e.g., Contreras-Huerta et al., 2014; Sheng & Han, 2012). However, these ERP studies did not differentiate between persons with low and high implicit racial bias. Certainly, there is a need to further examine the boundary conditions under which the stimulus categorization stage, as indicated by the P3b component, is subject to influences of racial bias (see also Li et al., 2015).

RBE influences on motor processing

Our oscillatory results that did not show any influence of skin color on empathy-related motor processing stand in contrast to those of Riečanský et al. (2014) who found stronger activation of sensorimotor activity for ingroup than outgroup targets in pain. Given the procedural differences across studies, it is difficult to come up with a straightforward explanation for these mixed results concerning an RBE effect on late motor processing. Thus, our participants performed speeded choice-responses to static stimuli, whereas those of Riečanský et al. (2014) passively watched video clips.

Like for perceptual and cognitive ERP components, also motor-related EEG signatures might be sensitive to RBE influences as indicated by correlational analyses. The more self-unpleasant a participant rated a stimulus, the larger was the mean lower beta-band-ERD to fair-colored painful stimuli, whereas this correlation was only marginally significant for dark-colored ones. Thus, one might speculate that motor behavior is facilitated more strongly in participants with high sensitivity for self-unpleasantness when confronted with others' pain. This relation seems to be larger for ingroup than outgroup targets, an effect that should be replicated in future studies before taking it seriously.

4.5.4 Conclusion

In summary, this study reveals to our knowledge for the first time an influence of racial bias on an early (automatic) perceptual processing stage for static hand stimuli. Moreover, there was a further RBE influence on the late (controlled) stimulus categorization stage that depended on participants' individual ingroup preference. In contrast, late motor processing stages were hardly influenced by racial bias, despite the fact that empathic responses were evident in a way that sensorimotor activity was more strongly facilitated before and more strongly inhibited after the motor response. Together, the present study should be viewed as an important first step in demonstrating the practicality of approaching the mechanisms underlying the RBE by presenting static hand stimuli rather than the commonly employed, more complex racial face stimuli. As highlighted by Decety and Cowell (2014), such knowledge would seem important to promote moral progress by overcoming RBE effects and expanding empathy from close persons to humanity in general.

4.6 Acknowledgments

We thank Ian G. Mackenzie for programming the experiment, writing the custom MATLAB routines for the EEG and forcekey analysis, and help with the R analysis and the preparation of the figures.

Sarah Fabi was supported by a postgraduate fellowship of the state Baden-Württemberg. All authors report no financial interests or potential conflicts of interest.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Chapter 5

Study 3: Empathic Concern and Personal Distress depend on situational but not dispositional factors

This is the pre-peer reviewed manuscript of the following study submitted to *The Quarterly Journal of Experimental Psychology*: Fabi, S., Weber, L.A., & Leuthold, H. (submitted). Empathic Concern and Personal Distress depend on situational but not dispositional factors.

The Quarterly Journal of Experimental Psychology is available online at:
https://www.tandfonline.com/toc/pqje20/current

5.1 Abstract

Empathic concern and personal distress are empathic emotions that result from the initial empathic response when observing someone in pain. Even though these empathic responses have received lots of attention in past research, it is still unclear which conditions contribute to their respective experience. Hence, the main goal of this study was to examine if dispositional empathic traits or rather situational variables are more likely to evoke empathic concern and personal distress and how the two empathic emotions influence motor responses. We presented pictures of persons in psychological, physical, or no pain and matching descriptions of situations that promoted an other-focused perspective. Participants responded to a subsequent tone. Regression analysis revealed that situational factors, like the type of pain and the affect experienced by the participants before the experiment, but not dispositional empathic traits predicted the two empathic emotions. In addition, personal distress led to faster motor responses compared to empathic concern, presumably reflecting an effect of arousal. In conclusion, this study extends previous research by revealing that when participants adopted an other-focused perspective, psychological and physical pain stimuli lead to empathic concern and personal distress, respectively, whereas dispositional empathic traits do not systematically contribute to these situational empathic responses.

5.2 Introduction

Empathy is often defined as the similarity between the emotional states of the observer and a target person, with the observer knowing that the target is the source of her or his own feelings (Decety & Jackson, 2004; Eisenberg & Eggum, 2009). The experience of empathy can result in at least two qualitatively distinct emotional responses, namely empathic concern and personal distress (cf. Batson, Early, & Salvarani, 1997; Batson, Fultz, & Schoenrade, 1987). Empathic concern, often also called sympathy, is taken to reflect an emotional response of sorrow or concern that results from the comprehension of the target's emotional state but differs from it (Eisenberg, Shea, Carlo, & Knight, 1991). Personal distress is viewed as a self-focused aversive response that results from the apprehension of another's distress and is similar to the target's state (e.g., Batson et al., 1987). Importantly, the observer's experience of such a specific emotional response is assumed to have certain motivational consequences on behaviour. For instance, it is assumed that empathic concern leads to an altruistic motivation and helping behaviour in order to reduce the other's suffering, whereas personal distress leads to an egoistic motivation to reduce the own unpleasant feelings (e.g., Batson, O'Quin, Fultz, Vanderplas, & Isen, 1983; Decety, 2010). Still, there is much to learn about how these two empathic responses are differentially influenced by dispositional empathy and situational factors like type of pain of the target person and the affect experienced by the observer when encountering a person in pain, and also in which way the resulting altruistic and egoistic motivations influence motor behaviour. It is the aim of the present study to investigate these issues.

In order to measure situational emotional responses, researchers have frequently used rating scales including various adjectives that are either typically associated with empathic concern (warm, tender, moved, compassionate, sympathetic, soft-hearted) or personal distress (alarmed, upset, worried, disturbed, distressed, troubled, perturbed, grieved) (e.g., Batson et al., 1997; Batson, McDavis, Felix, Goering, & Goldman, 1976). In the following, we refer to these rating scales as Empathic Response Scale. Individual differences in trait empathy, namely the general disposition to feel empathic concern or personal distress for persons in pain, are typically measured by questionnaires like the Interpersonal Reactivity Index (IRI) of Davis (1983a).

Of course, as already highlighted by Batson et al. (1987), which specific empathic emotion is experienced by an observer in a given situation (situational empathy) is not necessarily strongly related to his or her general tendency to empathise with others in a specific way (dispositional empathy). More recently, Decety and Lamm (2009) proposed that individual factors such as empathic traits, but also abilities of emotion regulation, the emotional background of the observer (i.e. depressive mood) in interaction with situational factors, like the context, the emotion and the level of arousal induced by the situation, determine whether the observation of another in need leads to empathic concern or personal distress. The few studies that have investigated the relationship between dispositional and situational empathic responses indicated only modest correlations. Thus, Davis (1983b) assessed dispositional empathic concern with the aid of the IRI and situational empathic concern with the aid of the Empathic Response Scale in response to the Katie Banks vignette, a story about a girl who had lost her parents and was responsible for her younger siblings (e.g., Coke, Batson & McDavis, 1978). The correlation between dispositional and situational measures was moderate (r = .28). Eisenberg et al. (1994) applied the same instruments and a single videotape about deprived children to induce empathy. Again, their results revealed no strong correlations between situational and dispositional measures (empathic concern: $r = .35$, personal distress: $r = .11$). Finally, using seven sad excerpts of a TV show that participants rated with regard to their empathic concern, Light et al. (2015) found a similarly moderate correlation between dispositional and situational empathic concern (r = .26).

Whereas the above reported results suggest that individual differences in dispositional empathy relate somewhat to situational empathic responses, it is also clear that other factors contribute to situational emotional responses as well. According to many authors, self-other overlap is a key factor that determines the type of situational empathic response (e.g., Decety & Lamm, 2009; Wondra & Ellsworth, 2015). Thus, the cognitive projection of oneself into the situation (self-focus) has been proposed to lead to higher personal distress and that of focusing onto the target's reaction (other-focus) to higher levels of empathic concern (e.g., Batson, Early & Salvarani, 1997; Lamm, Nusbaum, Meltzoff & Decety, 2007; López-Pérez, Carrera, Ambrona & Oceja, 2014). In support of this former assumption, studies that induced psychological pain by presenting participants short stories like that about Katie Banks found higher situational personal distress scores under the instruction to maintain a self-focused state and increased situational empathic concern scores under the instruction to imagine the perspective of the other (e.g., Jackson, Brunet, Meltzoff & Decety, 2006; Lamm, Nusbaum, Meltzoff & Decety, 2007). It is worth mentioning, however, that Batson et al. (1997) assumed that this perspective-dependent, empathic response pattern holds only for psychological pain, whereas physical pain should evoke personal distress in the observer irrespective of his or her perspective (see Figure 5.1).

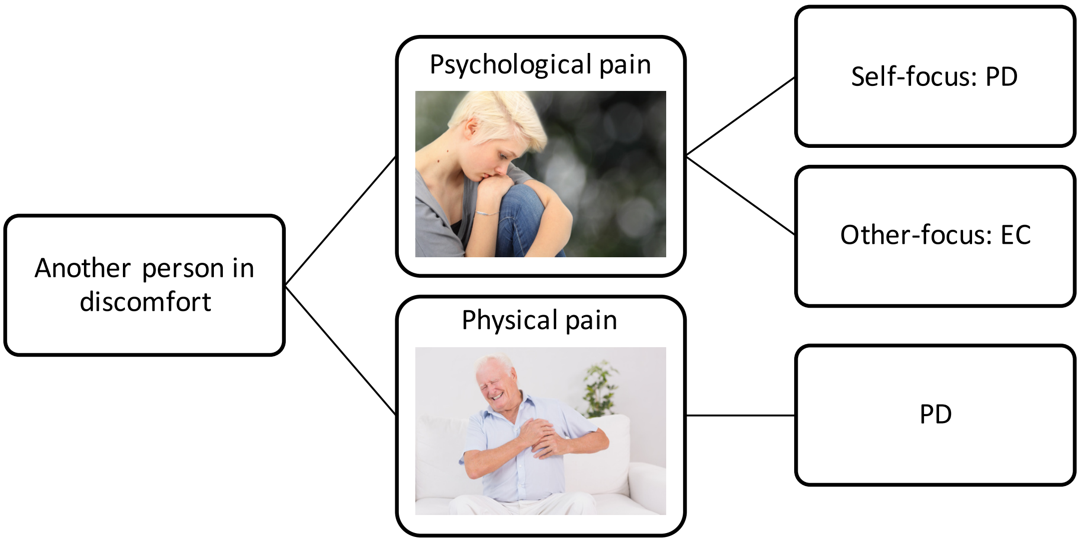


Fig. 5.1 Empathic concern (EC) and personal distress (PD) as a result of physical and psychological pain combined with the focus of the observer (upper picture: © K.- P. Adler/fotolia.com, lower picture: © WavebreakmediaMicro/fotolia.com).

In the light of these observations, it is worthwhile to consider potential reasons for the moderate correlations between situational and dispositional empathy reported previously. Thus, the above reported studies that investigated the relation between dispositional and situational empathic responses (Davis, 1983b; Eisenberg et al., 1994; Light et al., 2015) did not explicitly control for the perspective participants adopted during the experiment. Consequently, it cannot be excluded that the perspective adopted by participants varied, thereby influencing measures of situational empathic concern and personal distress. Moreover, to our knowledge, only Eisenberg et al. (1994) assessed the general tendency for positive and negative affect with the Positive and Negative Affective Schedule (PANAS, Watson, Clark & Tellegen, 1988), even though according to Decety and Lamm (2009), emotions and the arousal induced by a given situation play an important role in triggering empathic responses. For instance, Eisenberg et al. (1994) found that participants' personal distress score during the experiment increased with their general tendency to experience negative affect. The tendency to experience positive affect, on the other hand, correlated negatively with personal distress. Moreover, most studies relied on the spontaneous occurrence of situational empathic concern and personal distress in individuals following the presentation of only a single vignette or video (Davis, 1983b; Eisenberg et al., 1994) or just a few video excerpts (Light et al., 2015). Given that situational empathy was assessed on so few occasions, it is also possible that the observed correlations are bound by potentially low reliability of the situational empathy score. Relatedly, it remains unclear whether the observed results would generalise to other scenarios that are presented to participants in the form of static pictorial stimuli. Together, it appears that the relationship between situational empathic responses and dispositional empathy is in need of further investigation, specifically by manipulating situational empathic responses more systematically, by obtaining more reliable situational empathy scores, and by using a wide range of pictorial stimuli.

By employing a larger number of empathy-evoking pictures, it will also become possible to investigate if situational empathic responses influence motor behaviour. According to Eisenberg et al. (1996), personal distress is accompanied by higher levels of physiological arousal than empathic concern. Since arousal is a variable known to influence response speed, these two empathic responses might influence RT differentially. Previous studies concerned with the general impact of empathy on information processing found shorter reaction times (RTs) for empathy-inducing than control stimuli (e.g., Fabi & Leuthold, 2017, 2018; Hu, Fan, & He, 2015; Mella, Studer, Gilet, & Labouvie-Vief, 2012; but see Sheng & Han, 2012). Moreover, as outlined earlier, empathic concern might lead to an altruistic motivation to reduce the target's suffering, whereas personal distress might result in an egoistic motivation to reduce one's own suffering by withdrawing from the situation (Batson et al., 1983; Decety, 2010). We assume that these motivations manifest themselves in motor predispositions for approach or avoidance movements, respectively. In accord with this assumption, Morrison, Poliakoff, Gordon, and Downing (2007) found faster withdrawal (key release) and slower approach movements (key press) to a visual go-/nogo-signal after observing another person in pain, which presumably induced personal distress. Until now, at least to our knowledge, there is no study that investigated whether and how empathic concern and personal distress influence approach-avoidance motor behaviour.

5.2.1 Current Study

To address the above-mentioned limitations of previous research, in the current study, we controlled perspective and more systematically manipulated situational empathic concern and personal distress. To control for possible effects of perspective taking in the present experiment, participants received a description of the situation (heart attack vs. death of the mother) that promoted an other-focused state before watching a block of empathy-inducing pictures. Since Batson et al. (1997) claimed that psychological pain leads to empathic concern if the observer is in an other-focused state, whereas physical pain leads to personal distress independent of the focus, we presented pictures of persons apparently suffering from physical and psychological pain. In a rating study, we affirmed that in combination with the respective description of the situation, the stimuli of persons in physical emergencies (heart attack) provoked more personal distress in the observer, whereas persons in psychological pain (death of the mother) provoked more empathic concern.

A primary aim of the study was to advance our understanding of the variables that influence the situational empathic responses, like dispositional empathic traits or situational affect, which is why we applied the IRI (Davis, 1983a) and the PANAS (Watson, Clark & Tellegen, 1988), respectively. More specifically, we tested to what extent the general ability to experience empathic concern or personal distress influences the actual experience of empathic concern or personal distress in a specific situation, respectively. Additionally, we hypothesised that positive affect before the experiment would predict empathic concern, whereas negative affect would be related to personal distress, as implied by the results of Eisenberg et al. (1994).

In addition, it was a second aim to investigate empathy-related influences on motor performance. To this end, we combined the processing of the empathy-evoking stimuli with a variant of the approach-avoidance task (AAT). This task has been shown to sensitively reveal the relationship between positively or negatively valenced items and specific approach vs. avoidance responses (cf. Krieglmeyer, De Houwer & Deutsch, 2013). Using this task, previous studies have shown that emotional stimuli automatically activate valence-dependent approach versus avoidance tendencies (e.g., Krieglmeyer, Deutsch, De Houwer & De Raedt, 2010). We hypothesised that the altruistic approach motivation ascribed to empathic concern and the egoistic avoidance motivation related to personal distress (Batson et al., 1983; Decety, 2010) biases the motor system in an automatic manner. Hence, RTs should be faster for physical than psychological pain in general. Moreover, approach movements to the tone should be faster in the psychological than the physical pain condition, whereas RTs for avoidance movements should be faster in the physical than the psychological pain condition.

5.3 Method

5.3.1 Participants

58 students from the University of Tübingen (*M*(age) = 24.47 years; 44 females and 49 right-handed participants) voluntarily participated for payment (8 Euros per hour) or course credits.

5.3.2 Apparatus

Stimulus presentation and response recording were controlled by a Mac Mini (Apple Inc.) running a MATLAB (The Math Works, Inc., Version R2015a) program using the Psychophysics Toolbox 3.0.12 (Brainard, 1997; Kleiner, Brainard, Pelli, Ingling, Murray & Broussard, 2007) together with custom MATLAB routines. Participants sat in an electrically shielded, low-noise booth with ambient light at low level. A chin rest guaranteed a constant distance to the 1100 MB Samsung SyncMaster screen, on which materials were presented, with a resolution of 1280 x 960 pixels and a refresh rate of 60 Hz. Dimensions of the stimuli were 318 x 424 pixels at the beginning of each trial, but changed with movement. The response device consisted of a self-constructed metal box ("slider device") measuring approximately 10 cm in height, 25 cm in width and 50 cm in length. The internals of the slider device consisted of rails along which a handle could be pushed/pulled (lengthwise with a total movement distance of 38 cm). A potentiometer was attached to the internal rails in such a way that the voltage output varied according to handle position. A software-based calibration routine converted the output voltage to cm and was calibrated such that 0 cm was the middle position, with values ranging from -18 to +18 cm. The internals of the device also contained an electromagnet that could be controlled online via software to prevent the handle from being moved. A force of approximately 150 cN was required to initiate the movement of the handle when the magnet was not active.

5.3.3 Materials

Auditory stimuli were sine waves of 400 and 800 Hz with a volume of 60 dB that were presented via headphones (Sennheiser, PX-100-II). Pictorial stimuli consisted of 117 pictures depicting persons in either emotionally neutral situations, and in situations in which they seemed to grieve or appeared to be haunted by strong pain in the chest (39 pictures for each type of pain: no pain, psychological pain, physical pain). Additionally, written descriptions of the situation were provided, which promoted an other-focus perspective followed by a statement that another person is sad because of the death of his or her mother or that the person experiences a strong pain in the chest (e.g., "Imagine yourself to be on a street facing a stranger who is obviously not feeling well. You ask him/her what has happened. He/she answers that he/she has just found out that his/her mother has died all of a sudden.", "Imagine that you meet a new colleague at your office. All of a sudden, he/she complains about violent pain at the thoracic regions."). Pictures with physical pain and some of them with psychological pain were purchased from Fotolia (https://de.fotolia.com), a commercial picture platform. Further stimuli of sad persons were selected from the picture set used by Morelli and Lieberman (2013). The remaining pictures were selected from the International Affective Picture System (Lang, Bradley & Cuthbert, 1999). The picture set will be provided upon request by the authors.

We performed a web-based rating study of the stimuli, with 275 members of the University of Tübingen participating. The picture items and their corresponding descriptions were presented together and were arranged in six stimulus lists. Each of the four 19-20 item lists consisted of three blocks of six pictures, with each list being rated by about 45 participants. Participants rated the following dimensions for each picture:

- Experienced empathic concern as the mean rating of six items of Batson et al. (1997): 1 (not at all) to 8 (very much)
- Experienced personal distress as the mean rating of eight items of Batson et al. (1997): 1 (not at all) to 8 (very much)
- Arousal while watching the picture: 1 (not at all) to 8 (very much)
- State of the person depicted in the picture: 1 (fine) to 8 (extremely bad)
- Realism of the picture: 1 (absolutely unrealistic) to 8 (absolutely realistic)
- Fit between description of the situation and picture: 1 (not at all) to 5 (very good)
- Facilitation of imagining the situation by the description: 1 (not at all) to 5 (very good)

Mean rating scores are provided in Table 5.1. Analyses of variance (ANOVAs) were calculated across all pictures with the three-level factor type of pain (no pain, psychological pain, physical pain). ANOVAs of all dependent variables revealed significant main effects, all Fs > 4.15, all ps < .02. To investigate the direction of the significant main effects, we performed post hoc Tukey tests that are reported next.

Table 5.1. Results of the Rating Study

	Psychological pain	**Physical pain**	**No pain**
State of observer			
empathic concern	4.71	3.75	2.24
personal distress	3.02	4.01	1.63
arousal	4.75	5.16	2.81
Pictorial stimuli			
state of depicted person	6.50	6.23	3.10
realism	6.12	5.72	5.58
Description of situation			
fit of description	3.80	3.57	3.06
facilitation of perspective taking by description	3.89	3.62	3.35

Note. Mean rating scores on different dimensions for the three types of pain.

Concerning the state of the participant, less empathic concern was provoked by the no-pain compared to the physical pain condition, $p < .001$, and by these two conditions compared to the psychological pain condition, *p*s < .001. Personal distress revealed lower values for the no-pain than the psychological pain condition, $p < .001$, and for these two conditions compared to the physical pain condition, *p*s < .001. Significantly lower arousal values were reported for the no-pain than the psychological pain condition, $p < .001$, which both differed from the physical pain condition, *p*s < .05, for which the arousal value was highest.

Regarding picture-related factors, the state of the depicted persons was rated as more positive in the no-pain than the psychological pain condition, $p < .001$, and the physical pain condition, $p < .001$, whereas scores in the psychological and the physical pain conditions did not differ, $p = .37$. Post-hoc tests of realism of the pictures showed that pictures of persons without pain were rated as less realistic than those of persons with psychological pain, $p < .05$, whereas there was no difference between the psychological and the physical pain conditions, $p = .11$.

Concerning the description of the situation, the match between description and situation was rated worst in the no-pain condition, *p*s < .001, whereas pictures depicting persons suffering from psychological and physical pain did not differ in terms of fit of the description of the situation, $p = .19$. The facilitation of perspective taking with the aid of the description was larger in the psychological pain than the physical pain condition, $p < .05$, and both conditions showed larger values than the no-pain condition, *p*s < .05.

In conclusion, pictures were suited to provoke empathic concern and personal distress differentially. Physical pain pictures were given the highest arousal ratings in line with the assumption of Eisenberg et al. (1996) who claimed that personal distress goes along with more arousal than empathic concern. Ratings of the state of the person displayed and the realism of the pictures were satisfactory, because they did not differ between the psychological and the physical pain condition but only with the no-pain condition. We therefore decided to use all picture stimuli, except for three pictures that were outliers on some dimensions and therefore selected to become filler items for the memory task. Descriptions of the situation did not differ in their fit to the pictures of the physical and the psychological pain condition.

5.3.4 Procedure

Before giving their informed consent, participants were informed about the experiment. After two practice blocks of six trials, the experimental picture stimuli were presented in 18 blocks, each block consisting of a description of a situation and six pictures of the same category. In the current AAT version, participants produced approach-avoidance movements to an affect-neutral auditory stimulus by pushing or pulling a lever depending on the tone's pitch. A novel dynamic display arrangement was employed. Here, visual stimulus size was determined by the extent of the participant's movement parameter. That is, when participants were to perform a pushing movement away from their body, the perceived depth position of the picture within a 3-D graphics scene moved away from the participant. Alternatively, when a pulling movement was required, the picture within the same scene appeared to move towards the participant. In contrast to static paradigms, this experimental setup allows one to disambiguate between the action and the outcome of this action. Specifically, within static paradigms, a movement away from one's body can be internalized as either a push-away or a reach-to type of action.

The sequence of events within a single block is depicted in Figure 5.2. At the beginning of each block, participants were given a description of the situation, in which they were either meeting someone who was experiencing strong pain in the chest, who was grieving because of the death of the mother, or who was in an emotionally neutral situation. This was followed by the presentation of the six experimental picture trials. After each block, participants were asked to rate their empathic responses on an adjusted version of the Empathic Response Scale (Batson et al., 1997). This translated German version contained the following adjectives: “mitfühlend” (compassionate), “bewegt” (moved), “berührt” (tender) for empathic concern and “beunruhigt” (worried), “alarmiert” (alarmed), “ängstlich” (distressed) for personal distress. Average values of the ratings were separately calculated for empathic concern and personal distress. Afterwards, they were shown a familiar or unfamiliar picture and asked if it was part of the preceding block in order to direct their attention during the block onto the pictures.

Participants determined the start of each trial by bringing the slider into its start position. This position corresponded to +/-1cm from the middle position as visually indicated on the stimulus display; once the slider was inside this region, the brake was applied. 1000 ms after bringing the slider to this position, a trial started with the presentation of a fixation cross for 1500 ms, followed by the display of the pictorial stimulus, thereby releasing the brake. After 1000 ms the tone was presented for 200 ms. Participants were to respond to the tone within 2000 ms following its onset. 500 ms after movement offset the picture disappeared and feedback was shown for correct, incorrect, too fast (movement onset < 200 ms) or too slow (movement onset > 2000 ms) responses at the centre of the screen for 1000 ms. A blank screen of 1000 ms followed. RT was defined as the time interval from picture onset to the time point when the slider reached a position 0.2 cm away from the actual starting point.

The order of physical pain, psychological pain, and no-pain conditions was randomised across participants with the constraint that for each picture approach and avoidance movements occurred equally often and that two consecutive blocks were always of the same type of pain. The mapping of tone pitch to movement direction (push/pull) was balanced across participants. In half of the blocks, the memory task consisted of a picture of the previous block, in the other half a new picture was presented.

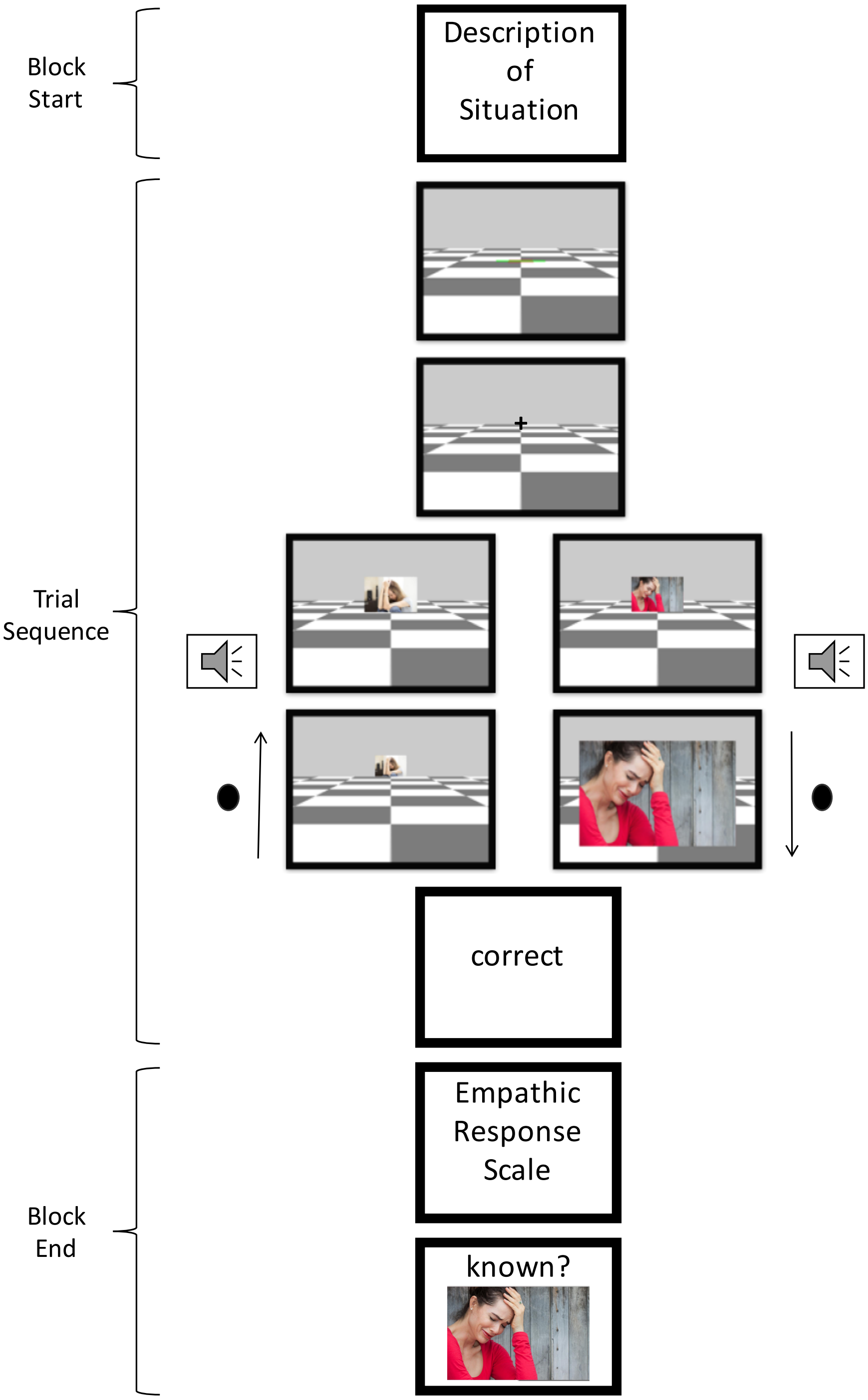


Fig. 5.2 Schema of the procedure of one block: Presentation of the description of a situation, followed by six trials consisting of the start screen (1000 ms), fixation cross (1500 ms), presentation of picture, tone presentation 1000 ms after picture onset, approach vs. avoidance movement (up to 2000 ms) leading to an increase or decrease of the picture and 500 ms after movement offset, feedback presentation (1000 ms). At the end of the block, participants completed the Empathic Response Scale and the memory task (left picture: © Boggy/fotolia.com, right picture: © Johan Larson/fotolia.com).

At the beginning and at the end of the experiment, we asked participants to complete a German version (Krohne, Egloff & Kohlmann, 1996) of the PANAS (Watson, Clark & Tellegen, 1988). At the end of the experiment, participants were additionally asked if they had ever experienced a loss of a close relative or a heart attack of a close person. Furthermore, they completed the German version of the IRI (Davis, 1983a), the Saarbrücker Persönlichkeitsfragebogen (SPF, Paulus, 2009), as a measure of dispositional empathy.

5.3.5 Data analysis

We analysed the influence of the different variables on empathic concern and personal distress scores using linear mixed-effects modelling (Baayen, Davidson & Bates, 2008) with the aid of R and the lme4 package (Bates, Maechler, Bolker & Walker, 2014). As random effects, we entered random intercepts for subjects and items and a by-subject random slope for type of pain. For empathic concern, we included in the full model as fixed effects dispositional empathic concern, type of pain, and positive affect before the experiment and excluded them in a stepwise manner. For personal distress, the full model included as fixed effects dispositional personal distress, type of pain, and negative affect before the experiment, excluding them in a stepwise manner. After every step, models were compared in order to determine the best-fitting model. In order to further determine the influence of type of pain on the two empathic responses, repeated-measures ANOVAs including the factor type of pain with levels no pain, psychological, and physical pain were conducted.

For RT, the factors movement direction (push vs. pull) and type of pain (psychological vs. physical) were included in a repeated-measures ANOVA.

The significance level was set to alpha = .05 and post-hoc tests were conducted with Bonferroni correction for factors with two levels and sphericity correction for factors with three levels.

5.4 Results

5.4.1 Response Behavior and Reaction Time

Response accuracy to the tone trials was high, since 98.12 % of the 6264 trials were answered correctly. For RT data analyses, we excluded all incorrect response trials, trials with movement onset times shorter than 200 ms or movement offsets longer than 2000 ms (1.88 %), as well as all partial error trials, in which slider movements started in the wrong direction but ended at the correct end point (3.77 %). Participants also followed the instructions to process the pictures as indicated by the high accuracy in the memory task (94.44 %).

The ANOVA of RT revealed shorter RTs in the physical than the psychological pain condition (522 vs. 534 ms, 95 % CIs [503, 541], [514, 555]), F (1, 57) = 4.0, $p < .05$, $\eta^2 = .07$. The main effect of response direction and the Movement Direction x Type of Pain interaction were not significant, all Fs < 0.03, all ps >.85.

5.4.2 Positive and Negative Affect

As compared to the start of the experiment, values on the positive affect scale decreased after the experiment (27.74 vs. 25.18), t (57) = 4.27, $p < .001$, and increased on the negative affect scale (11.90 vs. 13.36), t (57) = -4.98, $p < .001$.

5.4.3 Dispositional Empathy

Dispositional empathy, as measured by the SPF, ranged from 32 to 58 ($M = 43.58$), with a mean dispositional empathic concern value of 15.03 and a personal distress score of 11.74.

5.4.4 Situational empathic Responses

Measurements of situational empathic responses via an adjusted version of the Empathic Response Scales (Batson et al., 1987) showed excellent internal consistencies (empathic concern: *Cronbach's* α = .98, personal distress: *Cronbach's* α = .92). Values for both situational empathic concern (M = 3.28) and personal distress (M = 2.63) ranged between 1 and 8. The two empathic responses were highly correlated, $r = .78$, $p < .001$.

In the following, the results of the linear mixed-effects analysis are outlined. For empathic concern, the best-fitting model with type of pain and positive affect as fixed effects is presented in Table 5.2. Excluding dispositional empathic concern from the full model did not deteriorate the model fit, χ^2 (1) = 0.96, $p = .33$. In contrast, further exclusion of type of pain or positive affect reduced the model fit significantly, χ^2 (2) = 73.60, $p < .001$ and χ^2 (1) = 6.88, $p < .01$, respectively. For personal distress, the best-fitting model with type of pain and negative effect as fixed effects is presented in Table 5.3. The fit of this model was equivalent to that of the full model, χ^2 (1) = 0.52, $p = .47$. Further exclusion of type of pain and negative affect deteriorated model fit, χ^2 (2) = 61.30, $p < .001$ and χ^2 (1) = 9.27, $p < .01$, respectively.

5.4.5 Type of Pain

The ANOVA of situational empathic concern (Figure 5.3) revealed a significant influence of type of pain, F (2, 114) = 108.3, $p < .001$, $\eta^2 = .66$, with the psychological pain condition provoking the highest values of empathic concern, followed by the physical pain condition, F (1, 57) = 29.2, $p < .001$, which in turn provoked higher empathic concern than the no-pain condition, F (1, 57) = 105.9, $p < .001$ (4.34 vs. 3.61 vs. 1.87, 95 % CIs [3.88, 4.80], [3.19, 4.03], [1.63, 2.12]). Also, the ANOVA for situational personal distress revealed a main effect of type of pain, F (2, 114) = 79.8, $p < .001$, $\eta^2 = .58$. The psychological pain condition provoked less personal distress than the physical pain condition, F (1, 57) = 53.5, $p < .001$, but more than the no-pain condition, F (1, 57) = 56.4, $p < .001$ (2.51 vs. 3.88 vs. 1.48, 95 % CIs [2.18, 2.83], [3.40, 4.36], [1.31, 1.66]).

Table 5.2. Best-fitting Model for Empathic Concern

Empathic Concern ~ Type of Pain + Positive Affect + (1 + Type of Pain|Subject) + (1|Item)

Fixed effects	**Estimate**	**(Std. Error)**
Intercept	0.28	(0.56)
Psychological pain	2.47 ***	(0.21)
Physical pain	1.74 ***	(0.17)
Positive affect	0.06 **	(0.02)

Random effects	**Explained variance**	**(Std. Dev.)**
Items	0.02	(0.13)
Subjects	0.79	(0.89)
Psychological pain	2.40	(1.55)
Physical pain	1.61	(1.27)

Note. Linear mixed-effects model with type of pain and positive affect before the experiment as fixed effects and random intercepts for subjects and items as well as by-subject random slope for type of pain as random effects.

Table 5.3. Best-fitting Model for Personal Distress

Personal Distress ~ Type of Pain + Negative Affect + (1 + Type of Pain|Subject) + (1|Item)

Fixed effects	**Estimate**	**(Std. Error)**
Intercept	0.07	(0.45)
Psychological pain	1.02 ***	(0.14)
Physical pain	2.39 ***	(0.23)
Negative affect	0.12 **	(0.04)

Random effects	**Explained variance**	**(Std. Dev.)**
Items	0.01	(0.11)
Subjects	0.38	(0.61)
Psychological pain	1.03	(1.02)
Physical pain	3.10	(1.76)

Note. Linear mixed-effects model with type of pain and negative affect before the experiment as fixed effects and random intercepts for subjects and items as well as by-subject random slope for type of pain as random effects.

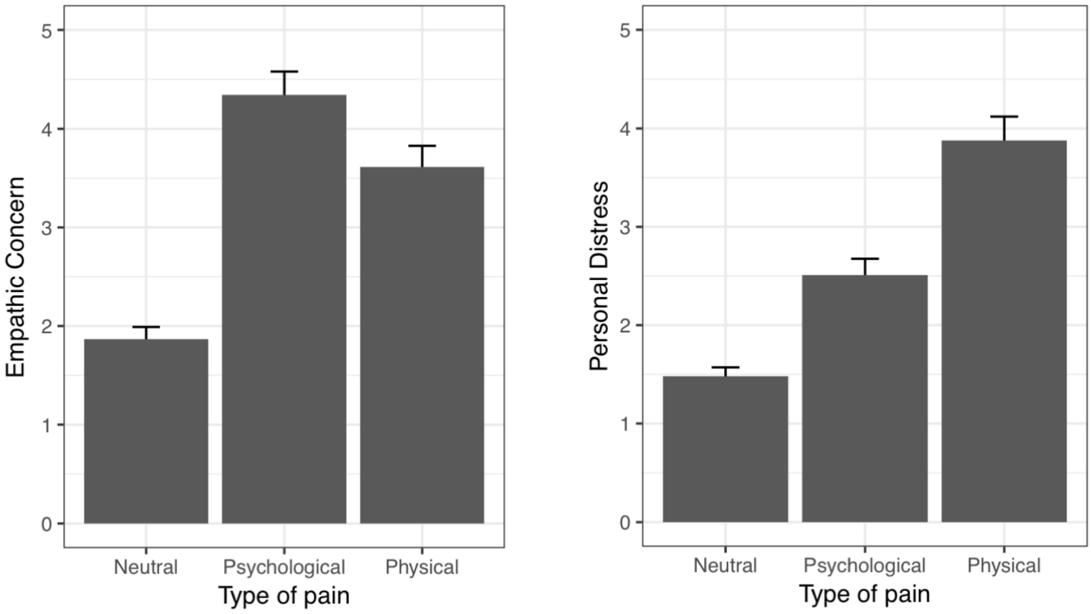


Fig. 5.3 Situational empathic concern and personal distress scores as a function of type of pain.

5.4.6 Prior Experience

45 of the participants had already experienced a loss of a close relative, whereas only 13 had experienced a heart attack of a close person. Those who had already experienced a loss reported less situational personal distress during the experiment than those who had not (2.49 vs. 3.08), t (25.91) = -2.09, $p < .05$, $\eta^2 = .07$, 95 % CIs [2.16, 2.82], [2.59, 3.59].

5.5 Discussion

The aim of this study was to examine whether situational variables like type of pain (psychological/physical) and affect influence empathic concern and personal distress, as well as how strongly these empathic responses are related to dispositional empathic traits. Furthermore, the motivational consequences of the two empathic responses and their implications on motor responses were investigated.

Most importantly, the present experiment succeeded in systematically manipulating the occurrence of the two situational empathic responses by varying the type of pain. As predicted, our results show that persons in psychological pain, because of the death of a close person, provoked significantly greater situational empathic concern than persons with physical chest pain, like during a heart attack. On the other hand, the physical pain condition provoked higher personal distress than the psychological or the no-pain condition. These results are in line with the assumption of Batson et al. (1997) that physical pain evokes personal distress in the observer, whereas psychological pain in combination with an other-focused state provokes empathic concern.

It is further important to note that the acceptable internal consistency for the shortened and translated version of the Empathic Response Scale (Batson et al., 1987) suggests that this scale is a reliable instrument to measure situational empathic concern and personal distress. Furthermore, the individual values on both scales ranged between the lowest and highest possible value, implying that the current experiment was able to provoke variable empathic responses across participants. In general, participants experienced less personal distress than empathic concern. Moreover, like Eisenberg et al. (1994), we found that the two responses were not independent but highly correlated. It therefore appears that the stronger people experience one situational empathic emotion, the stronger they experience the other as well.

A second key finding concerns the affect-related influence of the empathic responses, with affect being measured before and after the experiment. That is, there was a positive influence of positive affect on empathic concern and of negative affect on personal distress. Accordingly, even though these effects were not as pronounced as for type of pain, positive affect indeed predicted empathic concern, as suggested by Eisenberg et al. (1994). Negative affect before the experiment promoted personal distress, corroborating the assumption of Eisenberg et al. that persons with negative affect experience more personal distress.

A third major finding relates to the fact that dispositional empathic concern and personal distress did not reliably contribute to the explanation of the experience of situational empathic concern and personal distress, respectively. This outcome by and large accords with previous studies demonstrating no reliable or only moderate correlations between dispositional and situational empathy measures. We therefore assume that aspects of the situation like the type of pain and the person's mood are far more relevant to predict the occurrence of empathic concern and personal distress than individual differences in empathic traits. This particular insight has important implications regarding the examination of empathic responses more generally. For instance, recent studies concerned with the behavioural and neural correlates of empathic responses mainly focused on individual differences in dispositional empathic concern and personal distress (e.g., Cheetham, Pedroni, Angus, Slater & Jäncke, 2009; FeldmanHall, Dalgleish, Evans & Mobbs, 2015; Hu, Fan & He, 2015). However, they did not assess whether the empathy-evoking stimuli triggered individually different situational empathic responses, presumably because it is often implicitly assumed that dispositional empathy traits and situational empathic responses are strongly related to each other. At least in the light of the present data, this assumption is questionable and hence the above studies might provide a biased picture with regard to the neural correlates associated with empathic responses. Thus, future research should be concerned about this problem and measure situational empathic emotions instead of dispositional empathic traits when investigating neural and behavioural correlates of situational empathy.

A further relevant finding concerns prior experience of participants. The general assumption is that empathy should be influenced by the observer's experience (cf. Eklund, Andersson-Straberg & Hansen, 2009; Melloni, Lopez & Ibanez, 2014; Preston & Hofelich, 2012). Our results show that participants, who had already experienced the loss of a close relative, felt less situational personal distress during the experiment than participants who had not. This could be due to the knowledge that coping with difficult situations is possible.

Having established that physical pain leads to higher situational personal distress and psychological pain to higher empathic concern, we investigated whether the two emotions differentially influence motor processing. The finding of faster responses in the physical compared to the psychological pain condition corroborates the assumption of Eisenberg et al. (1996) that personal distress leads to higher levels of arousal than empathic concern. It is also consistent with the evaluation of the arousal value of the pictures in our rating study. We did not find any differential influence of picture type on RT for approach (pull) versus avoidance (push) movements. The fact that the empathy-evoking stimuli were task-irrelevant, that is, movement direction depended on the pitch of a tone, might have produced an attenuated effect on motor processing as compared to a situation where such stimuli were task-relevant (cf. Krieglmeyer, De Houwer, & Deutsch, 2013). Furthermore, it must be noted that the tone was presented 1000 ms after the onset of the picture. Hence, it is possible that motor activations triggered by the empathy-evoking but response-irrelevant pictures might have already decayed at the time of tone onset. In this case, the present procedure would not have allowed to sensitively assess immediate automatic effects of the pictures on motor behaviour. Thus, future studies should use shorter time intervals between picture and tone onset when determining the automatic motor consequences of the two empathic responses.

To conclude, this study shows that pictures of persons in physical versus psychological pain together with written descriptions of the situation were well-suited to elicit personal distress and empathic concern from an other-focused perspective. Crucially, at least under these conditions, personal distress and empathic concern are mainly driven by situational factors like affect and type of pain rather than by dispositional empathic traits. In addition, it appears that situations of personal distress are more arousing compared to those of empathic concern, thereby facilitating information processing. Together, the present study advances our understanding of the commonalities and differences between empathic concern and personal distress.

5.6 Acknowledgments

We thank Ian G. Mackenzie for programming the experiment, especially for creating the novel dynamic display arrangement for the approach-avoidance task, and also for writing the analysis software for the slider device.

Chapter 6

General Discussion

This doctoral thesis was concerned with the following two questions regarding empathy for pain (Batson, 2009): How do we get to know the other's internal state and when do we respond with care to other's suffering. In order to investigate these issues, it was first important to examine general empathic responses to another person in pain with regard to their locus within information processing. A serial model of information processing was adopted, which identifies early stimulus encoding stages, later categorization stages and motor processing stages. Which processing stages are influenced by empathy was not clear from previous literature, even though various ERP studies suggested an early automatic and a late controlled empathic influence (e.g., Fan & Han, 2008). Moreover, research results regarding influences on the motor processing stage do not provide a consistent picture: Motor processing seems to be influenced by empathy, but it is not clear whether via inhibition or facilitation (Avenanti et al., 2010 vs. Riečanský et al., 2014). Another related issue concerns modulating influences on empathic responding. Specifically, this dissertation thesis aimed at determining the differences between empathic responding to racial in- and outgroup targets. Previous studies determined a racial bias in empathy suggesting that empathy is diminished if the target in pain belongs to the racial outgroup (e.g., Sessa et al., 2014; Sheng et al, 2017). How the different stages of the model of information processing are exactly influenced by the racial bias in empathy remains unclear, but former studies suggested that the early automatic empathic influence depends on the racial bias, whereas the controlled influence is independent of the target's racial background (e.g., Sessa et al., 2014). The motor processing stage seems to be influenced by the racial bias in empathy, even though the literature does not agree in which direction. The third study of this dissertation thesis was concerned with Batson's second research question: What leads us to respond with care to the other's distress? Empathic concern is assumed to result in an altruistic motivation to reduce the other's suffering, whereas personal distress should lead to an egoistic motivation to reduce the own suffering. Until now, it is not yet clear under which conditions empathic concern and personal distress arise. The few studies investigating these types of empathic emotions suggest that situational empathic concern and personal distress are not strongly related to dispositional empathic traits but more to situational factors like the affect of the observer or the type of pain combined with the focus of the observer.

Together, the aim of this dissertation thesis was to determine empathic influences on information processing, to find out how these influences change when the target is no longer part of the racial ingroup, and to identify under which conditions empathic concern and personal distress arise. In the following paragraphs, the findings regarding the initial empathic responses to others in pain and the empathic emotions empathic concern and personal distress will be summarized and integrated into the existing literature.

6.1 Empathic responses to pain

6.1.1 Findings of Study 1

The main goal of the first study was to determine the empathic influences on the different processing stages of the model of information processing. Pictures of body parts in painful or neutral situations were presented and EEG, RT, and response force were recorded. Participants' task was to either judge the painfulness of the situation or to count the body parts in order to determine which empathic influences are dependent on attention to the pain dimension.

The two tasks were successful in directing the attention towards or away from the pain dimension as observable in the accuracy and RT results: In the pain judgment task, accuracy was higher and RTs were shorter in the painful than the neutral condition because of the higher saliency of painful stimuli. If participants were asked to direct their attention away from the pain dimension by the counting task, accuracies were lower and RTs longer in the painful compared to the neutral condition. In general, the counting task was easier to accomplish, indicated by shorter RTs compared to the pain judgment task.

Regarding empathic influences on information processing, Study 1 revealed influences on the selective perceptual processing of affectively arousing stimuli (Olofsson et al., 2008) following initial perceptual encoding, as reflected by larger EPN amplitudes in the painful than the neutral condition, independent of the task. This new finding extends the results of former studies that have not investigated EPN amplitudes. In contrast to what one would expect from these prior studies (e.g., Decety et al., 2010; Fan & Han, 2008; Meng, Hu et al., 2012), P1 and N1 amplitudes did not differ between the two conditions (cf. Lyu et al., 2014; Mella et al., 2012; Sessa et al., 2014). These early zero-effects will be discussed in more detail below. Another interesting finding concerned the P3 amplitudes, which were larger for the painful than the neutral stimuli only in the pain judgment task (cf. Fan & Han, 2008; Mella et al., 2012). Thus, this late controlled categorization stage was influenced by empathy-evoking stimuli if attention was directed towards the pain dimension.

With respect to the motor processing stage, response force results showed that participants pressed the keys more forcefully in the painful than the neutral condition, but only in the pain judgment task, speaking for an attention-dependent sensorimotor activation during the response. The faster responses to painful than neutral stimuli are in line with the assumption of sensorimotor facilitation. Since these behavioral differences between the painful and neutral condition were only present in the pain judgment task, this cannot simply be explained by a direct arousal-driven path from stimulus input to motor processing that would be independent of task requirements (cf. Figure 3.1). In contrast to the response force results, EEG power change values did not differ for the two conditions or tasks in the time interval before the response (300-600 ms). In the time interval from 700 to 1500 ms, ERDs in the mu (7-12 Hz) and lower beta band (13-18 Hz) over the sensorimotor cortex were larger in the painful than the neutral condition and in the pain judgment than the counting task. This was interpreted as larger sensorimotor activation to painful than neutral stimuli and in the pain judgment compared to the counting task, possibly in order to enhance preparedness for processing forthcoming events. The results regarding empathic influences on motor activity differed across Study 1 and 2 and also in comparison with previous findings, as will be discussed below.

In summary, Study 1 assessed empathic influences on perceptual and motor processing in a single experiment. Painful compared to neutral pictures elicited more negative EPN amplitudes that reflect early automatic empathic influences on information processing and more positive P3 amplitudes that is interpreted as the late controlled influence. Furthermore, painful compared to neutral stimuli elicited faster and more forceful key presses if attention was directed towards the pain dimension and in the post-response time interval, sensorimotor activity was facilitated for empathy-evoking stimuli, independent of the task. So, empathy-evoking stimuli have automatic and controlled effects at different time points during information processing, that is, they influence separate stages from encoding over categorization to motor processing stages.

6.1.2 Findings of Study 2

The second study was designed to additionally investigate how these empathic influences change if the target has another skin color than the observer. It was based on Study 1, applying pictures of fair- and dark-colored hands in painful and neutral situations. EEG, RT, and response force were recorded while white Caucasian participants performed a pain judgment or skin color judgment task.

Results of the second study revealed faster responses to painful than neutral stimuli in the pain judgment task, but not the skin color judgment task. Thus, cognitive processes that require attention seem to be influenced by empathy-evoking stimuli, thereby again speaking against the view that painful stimuli trigger an arousal response mediated by a direct pathway from stimulus encoding to motor response (cf. Figure 3.1).

Concerning early automatic effects of empathy for pain, EPN-results of the first study could be replicated for both skin colors: EPN amplitudes were larger in the painful than the neutral condition, independent of the task. Interestingly, the ERP analysis according to Sessa et al. (2014) revealed larger amplitudes between 280 and 340 ms after stimulus onset over frontocentral electrodes in the painful than the neutral condition, but only for fair-colored hand stimuli. Furthermore, these frontocentral ERP amplitudes were positively correlated with the empathic concern scores of the IRI questionnaires. Hence, this early, task-independent influence on information processing seems to depend on the skin color of the target. In line with the results of Study 1, P3 amplitudes were larger in the painful than the neutral condition of the pain judgment task, but not the skin color judgment task, reflecting empathic influences on the late categorization processes that require attention. Neither the RT- nor the P3-differences between the painful and neutral condition were modulated by skin color, thereby suggesting that the late categorization stage was not influenced by the racial background of the target in pain consistent with previous studies (cf. Table 1.1; Contreras-Huerta et al., 2014; Sheng et al., 2017; Sheng et al., 2013). However, there was also a significant positive correlation between participants' implicit ingroup preference as measured by the IAT and the difference between P3 amplitudes to fair- and dark-colored hands in pain, whereas the correlation was not significant for hands in neutral situations. Hence, whether the late categorization stage of empathic processing is modulated by skin color seems to depend on the implicit ingroup preference: The larger the ingroup preference was, the larger was the difference in P3 amplitudes between skin colors for painful but not neutral stimuli.

Concerning the motor processing stage, participants pressed the keys more forcefully in the pain judgment than the skin color judgment task, whereas the painful and neutral condition did not differ in applied force. Regarding the oscillatory analyses, the results differed from those of Study 1. The two tasks seemed to be more potent in evoking differing sensorimotor activation because the ERDs in the mu (7-12 Hz) and beta band (13-18 Hz, 19-30 Hz) over the sensorimotor cortex were larger in the pain judgment than the skin color judgment task in the early and late time interval. This speaks for larger sensorimotor activation, if the attention was directed towards the pain dimension. Differences in power change values were only found in the upper beta band (19-30 Hz): Before the response, ERDs were larger in the painful than the neutral condition but only in the pain judgment task, speaking for an attention-dependent sensorimotor facilitation before the response. After the response, ERSs were larger to painful than neutral pictures, independent of the task, speaking for larger sensorimotor inhibition for empathy-evoking stimuli. Possible explanations for these differing results will be discoursed below.

To sum up, Study 2 addressed the modulation of empathic influences on information processing by the target's racial background with simple hand stimuli. The early automatic influence on ERP amplitudes (280-340 ms) was present for fair- but not dark-colored hands, speaking for an early influence of racial background on the encoding stage. The automatic EPN effect from Study 1 and the late controlled categorization difference, represented by P3 amplitudes, could be replicated for both skin colors, but the late categorization stage seemed to be modulated by skin color for individuals with high implicit ingroup preferences. This latter finding extends former studies that did not find any racial bias influence on the P3 (e.g., Contreras-Huerta et al., 2014; Sheng & Han, 2012, see Table 1.1). The motor processing stage was not influenced by skin color, but revealed a larger facilitation before and a larger inhibition after the response.

In short, Study 1 provided new insights into the temporal dynamics of automatic and controlled processes underlying empathy for pain by investigating perceptual, cognitive and motor processing in a single study. Study 2, on the other hand, extended previous research findings by investigating the empathic response to targets of the racial outgroup within the model of information processing as well, thereby applying new hand stimuli that have several advantages over the previously applied complex face stimuli. In the following paragraphs, the significance of these results are discussed in the light of the current state of empathy research.

6.1.3 Locus of empathy-related influences on information processing

Since the shared network hypothesis focused only on the affective component of empathy, and the theory-theory only on the cognitive part, various authors suggested to combine the bottom-up and top-down processes into one model and examine their interplay (e.g., de Vignemont & Singer, 2006). Building on an established model of human information processing in combination with the analysis of electrophysiological markers of mental processes, it was possible to investigate bottom-up and top-down empathic processing, as well as empathic influences on motor processes. The results of Study 1 and 2 speak for an early automatic influence and a later controlled cognitive influence of empathy on information processing, thereby providing evidence for the late appraisal model of de Vignemont and Singer (2006). This model assumes that an empathic response is elicited automatically by an empathy-evoking stimuli and later on diminished or enhanced by the cognitive appraisal of the context. At first sight, the EPN and P3 findings of Study 1 and 2 are in line with former studies, but the early empathic influence differs concerning the exact time interval and the topography, ranging from early N1 (e.g., Decety et al., 2010; Fan & Han, 2008; Meng, Hu et al., 2012), P180, and N240 (e.g., Fan & Han, 2008; Han et al., 2008) time intervals over frontocentral electrodes in previous studies (cf. Table 1.1) to the somewhat later interval between 280 and 340 ms over frontocentral electordes (Sessa et al., 2014) and the EPN intervals (200-300 ms) over posterior electrodes in present studies. Possible reasons for the inconsistent findings are the differences in the study design: In Study 1 and 2 of this dissertation thesis, participants were German, whereas in most other studies, they were Asians and slightly younger (20 vs. 23 vs. 26 years) than the German samples. The tasks as well as the EEG recording and the analyses procedures were different across studies, making it difficult to come up with a straightforward explanation for the different results across studies. Nevertheless, one could speculate that there exist two encoding pathways: One reflected by early frontocentral ERP activity and one by early posterior ERP activity (EPN). Until now, there does not exist a model for two different early encoding pathways, but further research should definitely have a closer look at these components. In sum, the studies provided evidence for the assumption of an early automatic empathic sharing that is later on modulated by top-down processes as suggested by Goubert and Craig (2009) and de Vignemont and Singer (2006) in their late appraisal model.

Regarding motor behavior, Study 1 revealed stronger responses to painful than neutral stimuli in the pain judgment task, whereas EEG oscillations did not reveal a corresponding facilitation of sensorimotor activation before the response. Study 2, on the other hand, revealed no difference in response force but found that before the response, sensorimotor activation was more strongly facilitated by painful than neutral stimuli if attention was directed towards the pain dimension, in line with shorter RTs in this condition. An interesting conclusion that can be drawn from these results is that empathic influences on motor processing do not seem to solely reflect simple motor resonance as suggested by Avenanti et al. (2005), because they depended on the task and were not automatically elicited via a direct arousal pathway from stimulus input to motor processing (see Figure 3.1).

The results concerning the sensorimotor activation after the response are somewhat inconsistent: Study 1 implied a facilitation of sensorimotor activation after the response by empathy-evoking stimuli, independent of the attention to pain. The results of Study 2, in contrast, indicated a stronger inhibition in the painful than the neutral condition, independent of task. Moreover, the results of Study 2 stand in contrast to those of Riečanský et al. (2014), who found sensorimotor facilitation when participants watched empathy-evoking videos. These studies differed in two important ways: Whereas Riečanský et al. applied dynamic stimuli and no task, in Study 1 and 2 static pictorial stimuli were used and participants were asked to perform a motor task what could have led to stronger response-related power changes that mask the smaller difference induced by the pictures (cf. Androulidakis et al., 2007; Neuper & Pfurtscheller, 2001). It can only be speculated about possible reasons for the discrepant results between the two studies of this doctoral thesis. The new stimuli, the larger sample size, the different tasks, or that stimuli were presented for 400 instead of 200 ms in the second study could be responsible for the different result patterns. What can be concluded from the results of Study 1 and 2 is that these empathic influences on motor processing stages after the actual motor response seem to be less stable than those on the pre-response and cognitive processing stages and need to be clarified in future studies. However, Study 1 and 2 were the first in investigating empathic influences on the different stages from stimulus input to response output in one study. They provide strong evidence for the late appraisal model combining early bottom-up and later top-down processes and therefore filling the gap between the shared network hypothesis, that disregarded top-down processing and the theory-theory that neglected bottom-up processes. One factor strongly modulating the empathic response is the racial background and thus the group dependence of the target in pain, as will be discussed in the next section.

6.1.4 The influence of group affiliation

People tend to care about others and experience empathy for them as long as they belong to their social or racial ingroup but do not experience the same empathic response for persons of the outgroup (Cikara et al., 2011; Lamm & Majdandžić, 2015). Thus, it is an important question how the empathic influences change when the target is no longer part of the racial ingroup. Concerning the cognitive processing stages, results of Study 2 revealed an influence of the target's racial background between 280 and 340 ms over frontocentral electrodes, where amplitudes were larger for painful compared to neutral stimuli for fair- but not dark-colored hands. This finding accords with those of Sessa et al. (2014) and is similar to other previous studies that investigated face stimuli and found an influence of racial background, but on earlier time intervals (80-140 ms, Contreras-Huerta et al., 2014; 128-188 ms, Li et al., 2015; Sheng et al., 2017; Sheng & Han, 2012). Even though there was no interaction between skin color and condition for the P3 amplitudes, a positive correlation between the implicit ingroup-preference and P3 amplitudes in the painful but not the neutral condition indicated that the late categorization stage may be influenced by skin color for persons with a dominant ingroup-preference. Study 2 did not find an influence of the racial background of the target on the motor processing stage contrasting the results of Riečanský et al. (2014). Possible reasons have already been outlined above. In sum, the skin color and thus the group affiliation of the target influences the empathic response of the observer on a very early stage in that way that the early automatic response is only present for ingroup targets.

It is hard to come up with a straightforward explanation for the fact that the time interval between 280 and 340 ms over frontocentral electrodes was influenced by the racial bias in empathy whereas the EPN was not, showing an empathy effect for both skin colors.

Nevertheless, this again speaks for two separate automatic early encoding pathways. The one reflected by early frontocentral ERP amplitudes was influenced by the target's background, whereas the one reflected by early posterior ERP amplitudes remained uninfluenced. Furthermore, at first sight, P3 results are in line with former studies (e.g., Contreras-Huerta et al., 2014, Sheng & Han, 2012), because in Study 2, there was no direct influence of racial background on the controlled categorization stage. But the results suggest that the higher the observer's implicit ingroup over outgroup preference was, the larger was the P3 amplitude difference between the two skin colors in the painful but not the neutral situations. This implies that for individuals with dominant implicit ingroup preference, the racial bias in empathy might indeed influence the controlled categorization stage. The correlation findings extend previous findings of a positive correlation between IATd scores and the P3 amplitude difference (painful minus neutral) for racial in- but not outgroup targets provided by Sessa et al. (2014). In the second study, the empathic influence on the motor processing stage was independent of skin color what contrasts with the the results of Study 1 and Riečanský et al. (2014). Therefore, it should be investigated more specifically in future research.

6.2 Empathic concern and personal distress

6.2.1 Findings of Study 3

In the next step of my dissertation project, I addressed the question when we respond with care to another's suffering by investigating the occurrence of empathic concern and personal distress. To this end, Study 3 assessed dispositional empathic traits, positive and negative affect before the experiment and personal distress and empathic concern after watching pictures of persons in psychological or physical pain together with a description of the situation that promoted an other-focused view.

Results showed that the psychological pain condition evoked highest levels of situational empathic concern, followed by the physical pain and then the no-pain condition. On the other hand, in the physical pain condition the personal distress scores were largest, followed by the psychological and then the no-pain condition. The type of pain together with positive affect before the experiment predicted situational empathic concern, with dispositional empathic concern not revealing any further information. A similar pattern was found for situational personal distress, which was explained by type of pain and negative affect before the experiment. Dispositional personal distress did not further improve the prediction of situational personal distress. These results show that situational variables are far more important than dispositional empathic traits in provoking situational empathic emotions. Motor responses were faster in the physical than the psychological pain condition, what is probably due to higher levels of arousal coming along with personal distress compared to empathic concern, as found in a rating study preceding the actual experiment.

In sum, in Study 3 the experience of empathic concern and personal distress was manipulated by applying different types of pain and the influence of further variables like affect and dispositional empathy were investigated. Results revealed that dispositional empathic traits are not significantly related to the actual empathic emotion in a specific situation, but that together with an other-focused state, psychological pain evokes higher levels of empathic concern and physical pain higher levels of personal distress. In line with the literature, positive affect before the experiment is predictive for empathic concern and negative affect for personal distress (cf. Eisenberg et al., 1994). In addition, motor responses were faster in the physical pain condition probably because personal distress was accompanied by higher levels of arousal.

In the following section, the results of the third study will be discussed in detail and embedded into the existing literature.

6.2.2 Situational and dispositional influences

An important issue regarding the question whether empathy leads to prosocial behavior is the differentiation between empathic concern and personal distress, because they are assumed to be related to altruistic and egoistic motivations, respectively (e.g., Batson et al., 1987). Still, it remains an open issue under which conditions the two empathic emotions arise and how they can be manipulated. Study 3 revealed that when participants adopted an other-focus, psychological pain led to higher levels of empathic concern as measured by the Empathic Response Scale, whereas physical pain led to higher levels of personal distress, thereby supporting the assumption of Batson et al. (1997). Furthermore, positive and negative affect also predicted empathic concern and personal distress, respectively, whereas dispositional empathic traits were not able to further explain the occurrence of the two empathic emotions. Thus, in a specific situation, it is not important whether participants generally feel more empathic concern or personal distress, but whether they experience positive or negative affect at the moment and whether the pain is of psychological or physical nature. Moreover, RTs to an empathy-unspecific tone were faster in the condition that evoked more personal distress than empathic concern, a finding that could be explained by higher levels of arousal accompanying personal distress. This is in line with the hypothesis that persons with low self-regulation face problems in regulating empathic overarousal, leading to higher levels of personal distress (Decety & Jackson, 2004). One may speculate that the contradictory RT results of the studies presented in Table 1.1 and 1.2 could be explained by the different levels of arousal coming along with empathic concern and personal distress, thereby influencing response speed. Thus, future studies investigating behavioral correlates of empathy like RT should take other arousal-sensitive measures, like response force, electrodermal activity, and ERPs, into account.

Empathic concern is considered to lead to helping behavior, whereas personal distress leads to an egoistic motivation to reduce the own suffering, possibly resulting in withdrawal behavior (cf. Batson et al., 1983; Decety, 2010; Goubert et al., 2005; Singer & Lamm, 2009). Therefore, the new results regarding their occurrence might be relevant regarding public discussions about emergency situations, in which people do not necessarily help the victims. That is, this (missing) helping behavior seems to be more closely related to the characteristics of the situation than to traits of the observer. It is also of great relevance for the research because until now, numerous studies investigated the relation between brain responses and empathic emotions with dispositional measures (e.g., Cheetham et al., 2009; FeldmanHall et al., 2015; Hu, Strang, & Weber, 2015) that are not significantly related to the situational response as has been shown in this study.

6.3 Perspectives

To sum up, this dissertation thesis reveals important insights into the empathic influences on information processing, how they vary with the racial background of the target, and the occurrence of empathic concern and personal distress. In the following paragraphs, I will discuss the limitations of the three studies individually and suggest further research in order to support the findings, followed by general perspectives and limitations of all studies combined.

The first important findings revealed early automatic and late controlled empathic influences on information processing. The motor processing stage was also influenced by empathy-evoking stimuli. These findings are especially interesting because they indicate that it is possible to investigate empathic influences on different processing stages within one single experiment by applying an established model of information processing. Thus, it is not only clear that this model can be applied in future research investigating empathic processing but that with the aid of EEG, it is possible to distinguish between automatic and controlled processes. This extends previous fMRI studies that failed to distinguish bottom-up and top-down processes (e.g., Jackson et al., 2005; Singer et al., 2004). The current studies revealed new findings of the EPN, a component that has not been investigated in earlier empathy research and should be taken into account in future studies, especially regarding the assumption that EPN amplitudes might represent another encoding pathway than the early frontocentral ERP amplitudes.

This dissertation project aimed at addressing another limitation mentioned by Zaki and Ochsner (2012), namely the missing link between brain responses and behavior. Therefore, the response force of the participants was measured, indicating more forceful key presses to painful than neutral stimuli, only when attention was directed towards the pain dimension. These results were not stable across studies, which is why future studies should measure response force to empathy-evoking and neutral stimuli as well. Additionally, since the results regarding motor behavior differed across the methodology used in this dissertation project and former studies (e.g., Avenanti et al., 2005; Riečanský et al., 2014), it would be helpful to measure response force, EEG oscillations over the sensorimotor cortex, and MEPs triggered by transcranial magnetic stimulation in the same experiment. Some of the variance between the findings of oscillations and MEPs could possibly be explained by the fact that one cannot distinguish between specific muscle activations from oscillations over the sensorimotor cortex, whereas MEPs are measured specifically at the corresponding muscles. In the present study, the signal to left and right presented hands was collapsed across hemispheres in order to achieve a reasonable signal-to-noise ratio, but it would be a further important step to measure the activity over the contralateral hemisphere to the presented hand in pain.

Further important findings of this dissertation thesis concerned the racial bias in empathy. Results showed that the empathic response is different for outgroup targets at an early processing stage and for persons with high implicit racial bias possibly also at a late processing stage, whereas the late motor processing stage was not influenced by the target's racial background. Especially important in this regard is that empathic responses were measured to hand instead of complex face stimuli, as done in previous studies (e.g., Contreras-Huerta et al., 2014; Sessa et al., 2014). Additionally, the study design was very similar to the first study making results comparable and allowing them to be integrated into the established model of information processing. In order to draw more confident conclusions, the late P3 results should be reinvestigated with a group of participants displaying high levels of implicit ingroup preference.

Previous research that most of the time tested Asian participants (cf. Table 1.2) was extended by fair-colored Caucasian participants. Nevertheless, studies with cross over designs, testing two groups of different racial background, would be necessary in order to generalize the results and to rule out effects that were solely driven by this specific experimental procedure, including stimuli and tasks.

More generally, the difference of empathy towards in- and outgroup targets is a key issue that should not be ignored when trying to enhance empathy. The current findings give important insights into the relationship between empathy and morality. Further research can build on this knowledge and look for possibilities to diminish this racial bias in empathy instead of looking for initiatives to enhance general empathy, since this would only enhance empathy toward the social ingroup and thereby enlarge the gap between different groups (Cikara et al., 2011; Lamm & Majdandžić, 2015).

Moreover, regarding the third main topic of this dissertation project, it can be concluded that whether empathic concern or personal distress are experienced in a situation is not related to dispositional empathic traits. The type of pain of the target, combined with an other-focused view, and the affect experienced by the observer when witnessing someone in pain seem to be more relevant in this regard. Future investigations should build on the possibility to manipulate the occurrence of empathic concern and personal distress.

A further step would be to test the assumed relation between personal distress or empathic concern and egoistic or altruistic motivations and thus the occurrence of prosocial behavior. Experiments in naturalistic settings like the one of Bethlehem et al. (2017), who investigated the relation of empathic dispositions to helping behavior in a cycling accident should be conducted more frequently in future research. Since dispositional traits do not automatically lead to the corresponding situational empathic emotion, the relation between situational empathic concern and prosocial behavior should be investigated. Of course, it is a challenge to measure prosocial behavior authentically, but instead of offering participants the possibility to donate different amounts of money, as done in previous studies (e.g., Happ, Melzer, & Steffgen, 2015), the participants could be given the possibility to work voluntarily for different amounts of time.

In the following paragraphs, I will present limitations and perspectives that concern all three studies and their results. They were conducted in the lab with participants sitting in front of computer screens presenting pictures of hands or persons in pain. Of course, these settings differ enormously from real-life encounters of others in pain, which is why the generalization of the results is questionable. Additionally, participants were asked to perform judgment tasks, making the situation even more artificial. Additionally, it cannot be ruled out that the tasks led the focus away from an empathic response towards the accuracy of the performance. In the future, empathy for pain should be investigated with more natural and realistic stimuli. After having determined the empathic responses to basic stimuli in this dissertation project, in a next step, it should be examined how these empathic responses change when the observer is presented with images or videos of more realistic settings. Then, in a further step, new technology like virtual reality goggles should be applied. Participants could experience an empathy-evoking situation in virtual reality, having the sensation of being part of the presented situation.

Furthermore, it remains unclear from the current empathy research, how empathy develops during lifespan, whether it is based on genetic disposition or acquired by experience (e.g., Lamm et al., 2017). Since there are some hints for differences in empathy between different age groups (e.g., Mella et al., 2012), it would be very interesting to execute a longitudinal developmental study investigating children's empathic responses during their development.

Even though the social neuroscience of empathy is a quite young research field, it is necessary that the focus is broadened towards other emotions than pain. Empathy can differ a lot across different situations but until now, almost all we know about empathy is deduced from empathy for pain research. More studies like the one of Morelli et al. (2012) who investigated empathy for happiness should follow.

All in all, this dissertation thesis marks an important step towards a better understanding of empathy. This is especially true for the understanding of automatic and controlled empathic influences on information processing, the differences of processing empathy-evoking stimuli of in- and outgroup targets, and the relationship between situational variables, dispositional empathic traits, and the two empathic emotions empathic concern and personal distress.

References

Androulidakis, A. G., Doyle, L. F., Yarrow, K., Litvak, V., Gilbertson, T. P., & Brown, P. (2007). Anticipatory changes in beta synchrony in the human corticospinal system and associated improvements in task performance. *European Journal of Neuroscience*, *25*, 3758–3765.

Avenanti, A., Bueti, D., Galati, G., & Aglioti, S. M. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nature Neuroscience*, *8*, 955–960.

Avenanti, A., Minio-Paluello, I., Sforza, A., & Aglioti, S. M. (2009). Freezing or escaping? Opposite modulations of empathic reactivity to the pain of others. *Cortex*, *45*, 1072–1077.

Avenanti, A., Sirigu, A., & Aglioti, S. M. (2010). Racial bias reduces empathic sensorimotor resonance with other-race pain. *Current Biology*, *20*, 1018–1022.

Azevedo, R. T., Macaluso, E., Avenanti, A., Santangelo, V., Cazzato, V., & Aglioti, S. M. (2013). Their pain is not our pain: brain and autonomic correlates of empathic resonance with the pain of same and different race individuals. *Human Brain Mapping*, *34*, 3168–3181.

Baayen, R. H., Davidson, D. J., & Bates, D. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*, 390–412.

Bargh, J. (1994). The four horsemen of automaticity: Awareness, efficiency, intention, and control in social cognition. In R.S.Wyer & T.K.Srull (Eds.), *Handbook of Social Cognition (2nd ed.)* (pp. 1–40). Hillsdale, NJ: Erlbaum.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"?. *Cognition*, *21*, 37–46.

Baron-Cohen, S. & Wheelwright, S. (2004). The empathy quotient: an investigation of adults with asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, *34*, 163–175.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). Lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-5.

Batson, C. (2009). These things called empathy: Eight related but distinct phenomena. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 3–15). Cambridge, MA: MIT Press.

Batson, C. D. (1987). Prosocial motivation: Is it ever truly altruistic? In L. Berkowitz (Ed.), *Advances in Experimental Social Psychology* (pp. 65 – 122). Academic Press.

Batson, C. D. & Ahmad, N. (2001). Empathy-induced altruism in a prisoner's dilemma II: what if the target of empathy has defected?. *European Journal of Social Psychology*, *31*, 25–36.

Batson, C. D., Batson, J. G., Slingsby, J. K., Harrell, K. L., Peekna, H. M., & Todd, R. M. (1991). Empathic joy and the empathy-altruism hypothesis. *Journal of Personality and Social Psychology*, *61*, 413 – 426.

Batson, C. D., Duncan, B. D., Ackerman, P., Buckley, T., & Birch, K. (1981). Is empathic emotion a source of altruistic motivation?. *Journal of personality and Social Psychology*, *40*, 290–302.

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

Batson, C. D., Eklund, J. H., Chermok, V. L., Hoyt, J. L., & Ortiz, B. G. (2007). An additional antecedent of empathic concern: valuing the welfare of the person in need. *Journal of personality and social psychology*, *93*, 65–74.

Batson, C. D., Fultz, J., & Schoenrade, P. A. (1987). Distress and empathy: Two qualitatively distinct vicarious emotions with different motivational consequences. *Journal of Personality*, *55*, 19–39.

Batson, C. D., McDavis, K., Felix, R., Goering, B., & Goldman, R. (1976). Effects of false feedback of arousal on perceived emotional state and helping. *Unpublished manuscript, University of Kansas*.

Batson, C. D. & Moran, T. (1999). Empathy-induced altruism in a prisoner's dilemma. *European Journal of Social Psychology*, *29*, 909–924.

Batson, C. D., O'Quin, K., Fultz, J., Vanderplas, M., & Isen, A. M. (1983). Influence of self-reported distress and empathy on egoistic versus altruistic motivation to help. *Journal of Personality and Social Psychology*, *45*, 706–718.

Bernhardt, B. C. & Singer, T. (2012). The neural basis of empathy. *Annual Review of Neuroscience*, *35*, 1–23.

Bethlehem, R. A., Allison, C., van Andel, E. M., Coles, A. I., Neil, K., & Baron-Cohen, S. (2017). Does empathy predict altruism in the wild?. *Social Neuroscience*, *12*, 743–750.

Bisiach, E. & Luzzatti, C. (1978). Unilateral neglect of representational space. *Cortex*, *14*, 129–133.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*, 433–436.

Broadbent, D. E. & Gregory, M. (1965). On the interaction of S-R compatibility with other variables affecting reaction time. *British Journal of Psychology*, *56*, 61–67.

Brothers, L. & Ring, B. (1992). A neuroethological framework for the representation of minds. *Journal of Cognitive Neuroscience*, *4*, 107–118.

Bushnell, M. C., Duncan, G. H., Hofbauer, R. K., Ha, B., Chen, J.-I., & Carrier, B. (1999). Pain perception: Is there a role for primary somatosensory cortex? *Proceedings of the National Academy of Sciences*, *96*, 7705–7709.

Cheetham, M., Pedroni, A. F., Angus, A., Slater, M., & Jäncke, L. (2009). Virtual milgram: Empathic concern or personal distress? Evidence from functional mri and dispositional measures. *Frontiers In Human Neuroscience*, *3*, 29.

Cheng, Y., Chen, C., & Decety, J. (2014). An EEG/ERP investigation of the development of empathy in early and middle childhood. *Developmental cognitive neuroscience*, *10*, 160–169.

Chiao, J. & Mathur, V. (2010). Intergroup empathy: How does race affect empathic neural responses? *Current Biology*, *20*, R478–R480.

Cikara, M., Bruneau, E. G., & Saxe, R. R. (2011). Us and them: Intergroup failures of empathy. *Current Directions in Psychological Science*, *20*, 149–153.

Clark, A. (1997). *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT press.

Coke, J. S., Batson, C. D., & McDavis, K. (1978). Empathic mediation of helping: A two-stage model. *Journal of Personality and Social Psychology*, *36*, 752.

Coles, M., Smid, H., Scheffers, M., & Otten, L. (1995). Mental chronometry and the study of human information processing. In M. Rugg & M. Coles (Eds.), *Electrophysiology of mind: Event-related brain potentials and cognition* (pp. 86–131). Oxford: Oxford University Press.

Contreras-Huerta, L. S., Hielscher, E., Sherwell, C. S., Rens, N., & Cunnington, R. (2014). Intergroup relationships do not reduce racial bias in empathic neural responses to pain. *Neuropsychologia*, *64*, 263–270.

Cui, F., Zhu, X., & Luo, Y. (2017). Social contexts modulate neural responses in the processing of others' pain: An event-related potential study. *Cognitive, Affective, & Behavioral Neuroscience*, *17*, 850–857.

Davis, M. H. (1983a). The effects of dispositional empathy on emotional reactions and helping: A multidimensional approach. *Journal of Personality*, *51*, 167–184.

Davis, M. H. (1983b). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*, 113–126.

de Haen, J. (2006). Deutsche Version der Cambridge Behaviour Scale. [German Version of the Cambridge Behaviour Scale.]. *Bochum: AUTISMO Praxis Autismus Therapie*.

de Vignemont, F. & Singer, T. (2006). The empathic brain: How, when and why?. *Trends in Cognitive Sciences*, *10*, 435–441.

Decety, J. (2010). The neurodevelopment of empathy in humans. *Developmental Neuroscience*, *32*, 257–267.

Decety, J. & Jackson, P. L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews*, *3*, 71–100.

Decety, J., Jeannerod, M., & Prablanc, C. (1989). The timing of mentally represented actions. *Behavioural brain research*, *34*, 35–42.

Decety, J. & Lamm, C. (2006). Human empathy through the lens of social neuroscience. *ScientificWorld Journal*, *6*, 1146–1163.

Decety, J., Lewis, K. L., & Cowell, J. M. (2015). Specific electrophysiological components disentangle affective sharing and empathic concern in psychopathy. *Journal of Neurophysiology*, *114*, 493–504.

Decety, J. & Meyer, M. (2008). From emotion resonance to empathic understanding: A social developmental neuroscience account. *Development and Psychopathology*, *20*, 1053–1080.

Decety, J., Yang, C. Y., & Cheng, Y. (2010). Physicians down-regulate their pain empathy response: an event-related brain potential study. *Neuroimage*, *50*, 1676–1682.

Donchin, E. (1981). Surprise . . . surprise?. *Psychophysiology*, *18*, 493–513.

Donchin, E. & Coles, M. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences*, *11*, 355–425.

Dudschig, C., Mackenzie, I., Strozyk, J., Kaup, B., & Leuthold, H. (2016). The sounds of sentences: Differentiating the influence of physical sound, sound imagery, and linguistically implied sounds on physical sound processing. *Cognitive, Affective, & Behavioral Neuroscience*, *16*, 940–961.

Eimer, M. & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Neuroreport*, *13*, 427–431.

Eisenberg, N. & Eggum, N. D. (2009). Empathic responding: sympathy and personal distress. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 71–83). Cambridge, MA: MIT Press.

Eisenberg, N. & Fabes, R. A. (1990). Empathy: Conceptualization, measurement, and relation to prosocial behavior. *Motivation and Emotion*, *14*, 131–149.

Eisenberg, N., Fabes, R. A., Murphy, B., Karbon, M., Maszk, P., Smith, M., O'Boyle, C., & Suh, K. (1994). The relations of emotionality and regulation to dispositional and situational empathy-related responding. *Journal of Personality and Social Psychology*, *66*, 776–797.

Eisenberg, N., Fabes, R. A., Murphy, B., Karbon, M., Smith, M., & Maszk, P. (1996). The relations of children's dispositional empathy-related responding to their emotionality, regulation, and social functioning. *Developmental psychology*, *32*, 195–209.

Eisenberg, N., Shea, C. L., Carlo, G., & Knight, G. P. (1991). Empathy-related responding and cognition: A "chicken and the egg" dilemma. *Handbook of Moral Behavior and Development: Research*, *2*, 63–88.

Eisenberg, N., V. C. . C. C. (2004). Empathy-related responding: Moral, social, and socialization correlates. In A. G. Miller (Ed.), *The social psychology of good and evil* (pp. 386–415). New York, NY: Guilford Press.

Eklund, J., Andersson-Straberg, T., & Hansen, E. M. (2009). "I've also experienced loss and fear": Effects of prior similar experience on empathy. *Scandinavian Journal of Psychology*, *50*, 65–69.

Eres, R. & Molenberghs, P. (2013). The influence of group membership on the neural correlates involved in empathy. *Frontiers in Human Neuroscience*, *7*, 176.

Eriksen, C. W. & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception & Psychophysics*, *25*, 249–263.

Fabi, S. & Leuthold, H. (2017). Empathy for pain influences perceptual and motor processing: Evidence from response force, ERPs, and EEG oscillations. *Social Neuroscience*, *12*, 701–716.

Fabi, S. & Leuthold, H. (2018). Racial bias in empathy: Do we process dark- and fair-colored hands in pain differently? An EEG study. *Neuropsychologia*, *114*, 143–157.

Fabiani, M., Gratton, G., & Coles, M. (2007). Event-related brain potentials: methods, theory, and applications. In J. T. Cacioppo, L. G. Tassinary, & G. Berntson (Eds.), *Handbook of Psychophysiology* (pp. 85–119). Cambridge, England: Cambridge University Press.

Fan, Y. & Han, S. (2008). Temporal dynamic of neural mechanisms involved in empathy for pain: An event-related brain potential study. *Neuropsychologia*, *46*, 160–173.

FeldmanHall, O., Dalgleish, T., Evans, D., & Mobbs, D. (2015). Empathic concern drives costly altruism. *Neuroimage*, *105*, 347–356.

Filik, R., Leuthold, H., Wallington, K., & Page, J. (2014). Testing theories of irony processing using eye-tracking and ERPs. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*, 811–828.

Fonken, Y. M., Rieger, J. W., Tzvi, E., Crone, N. E., Chang, E., Parvizi, J., & ... Krämer, U. M. (2016). Frontal and motor cortex contributions to response inhibition: evidence from electrocorticography. *Journal of Neurophysiology*, *115*, 2224–2236.

Frith, C. D. & Singer, T. (2008). The role of social cognition in decision making. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*, 3875–3886.

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

Gastaut, H. J. & Bert, J. (1954). EEG changes during cinematographic presentation (Moving picture activation of the EEG). *Clinical Neurophysiology*, *6*, 433–444.

Gomarus, H. K., Althaus, M., Wijers, A. A., & Minderaa, R. B. (2006). The effects of memory load and stimulus relevance on the EEG during a visual selective memory search task: An ERP and ERD/ERS study. *Clinical Neurophysiology*, *117*, 871–884.

Gonzalez-Liencres, C., Breidenstein, A., Wolf, O. T., & Brüne, M. (2016). Sex-dependent effects of stress on brain correlates to empathy for pain. *International Journal of Psychophysiology*, *105*, 47–56.

Goubert, L. & Craig, K.D., B. A. (2009). Perceiving others in pain: Experimental and clinical evidence on the role of empathy. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 153–166). Cambridge, MA: MIT Press.

Goubert, L., Craig, K. D., Vervoort, T., Morley, S., Sullivan, M. J. L., Williams, A. C. d., Cano, A., & Crombez, G. (2005). Facing others in pain: the effects of empathy. *Pain*, *118*, 285–288.

Grecucci, A., Koch, I., & Rumiati, R. I. (2011). The role of emotional context in facilitating imitative actions. *Acta Psychologica*, *138*, 311–315.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. K. (1998). Measuring individual differences in implicit cognition: the Implicit Association Test. *Journal of Personality and Social Psychology*, *74*, 1464–1480.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the Implicit Association Test: I. *An improved scoring algorithm. Journal of Personality and Social Psychology*, *85*, 197–216.

Gu, X. & Han, S. (2007). Attention and reality constraints on the neural processes of empathy for pain. *Neuroimage*, *36*, 256–267.

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-related potentials, emotion, and emotion regulation: an integrative review. *Developmental neuropsychology*, *35*, 129–155.

Han, S., Fan, Y., & Mao, L. (2008). Gender difference in empathy for pain: an electrophysiological investigation. *Brain Research*, *1196*, 85–93.

Han, X., He, K., Wu, B., Shi, Z., Liu, Y., Luo, S., Wei, K., Wu, X., & Han, S. (2017). Empathy for pain motivates actions without altruistic effects: evidence of motor dynamics and brain activity. *Social, Cognitive, and Affective Neuroscience*, *12*, 893–901.

Han, X., Luo, S., & Han, S. (2016). Embodied neural responses to others' suffering. *Cognitive Neuroscience*, *7*, 114–127.

Happ, C., Melzer, A., & Steffgen, G. (2015). Like the good or bad guy—empathy in antisocial and prosocial games. *Psychology of Popular Media Culture*, *4*, 80–96.

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

Hatfield, E., Rapson, R. L., & Le, Y. L. (2009). Emotional contagion and empathy. In J. Decety & W. Ickes (Eds.), *The social neuroscience of empathy* (pp. 19–30). Cambridge, MA: MIT Press.

Hesslow, G. (2002). Conscious thought as simulation of behaviour and perception. *Trends in Cognitive Sciences*, *6*, 242 – 247.

Hillyard, S. A. & Anllo-Vento, L. (1998). Event-related brain potentials in the study of visual selective attention. *Proceedings of the National Academy of Sciences*, *95*, 781–787.

Hoffman, M. L. (1987). *Empathy and its development.* New York, NY: Cambridge University Press.

Hoffman, M. L. (2001). *Empathy and moral development: Implications for caring and justice.* New York, NY: Cambridge University Press.

Hu, K., Fan, Z., & He, S. (2015). Uncovering the interaction between empathetic pain and cognition. *Psychological Research*, *79*, 1054–1063.

Ikezawa, S., Corbera, S., & Wexler, B. E. (2014). Emotion self-regulation and empathy depend upon longer stimulus exposure. *Social cognitive and affective neuroscience*, *9*, 1561–1568.

Ito, T. A. & Bartholow, B. D. (2009). The neural correlates of race. *Trends in Cognitive Sciences*, *13*, 524–531.

Ito, T. A. & Urland, G. R. (2003). Race and gender on the brain: electrocortical measures of attention to the race and gender of multiply categorizable individuals. *Journal of Personality and Social Psychology*, *85*, 616–626.

Jackson, P. L., Brunet, E., Meltzoff, A. N., & Decety, J. (2006). Empathy examined through the neural mechanisms involved in imagining how I feel versus how you feel pain. *Neuropsychologia*, *44*, 752–761.

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

Jackson, P. L., Rainville, P., & Decety, J. (2006). To what extent do we share the pain of others? Insight from the neural bases of pain empathy. *Pain*, *125*, 5–9.

Johnson, R. (1988). The amplitude of the P300 component of the event-related potential: review and synthesis. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in Psychophysiology*, volume 3 (pp. 69–138). Greenwich: JAI Press.

Johnson, S. C. (2003). Detecting agents. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*, 549–559.

Kanske, P., Böckler, A., Trautwein, F. M., Parianen Lesemann, F. H., & Singer, T. (2016). Are strong empathizers better mentalizers? Evidence for independence and interaction between the routes of social cognition. *Social Cognitive and Affective Neuroscience*, *11*, 1383–1392.

Keysers, C. & Gazzola, V. (2009). Expanding the mirror: vicarious activity for actions, emotions, and sensations. *Current Opinion in Neurobiology*, *19*, 666–671.

Keysers, C., Thioux, M., & Gazzola, V. (2013). Mirror neuron system and social cognition. In S. Baron-Cohen, H. Tager-Flusberg, & M. Lombardo (Eds.), *Understanding other minds: Perspectives from developmental social neuroscience* (pp. 233–263). Oxford, UK: Oxford University Press.

Kleiner, M., Brainard, D., Pelli, D., Ingling, A., Murray, R., & Broussard, C. (2007). What's new in psychtoolbox-3. *Perception*, *36*, 1.

Klimecki, O. M., Leiberg, S., Ricard, M., & Singer, T. (2014). Differential pattern of functional brain plasticity after compassion and empathy training. *Social Cognitive and Affective Neuroscience*, *9*, 873–879.

Kok, A. (2001). On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology*, *38*, 557–577.

Krieglmeyer, R., De Houwer, J., & Deutsch, R. (2013). On the nature of automatically triggered approach–avoidance behavior. *Emotion Review*, *5*, 280–284.

Krieglmeyer, R., Deutsch, R., De Houwer, J., & De Raedt, R. (2010). Being moved valence activates approach-avoidance behavior independently of evaluation and approach-avoidance intentions. *Psychological Science*, *21*, 607–613.

Krohne, H. W., Egloff, B., & Kohlmann, C.-W. Tausch, A. (1996). Untersuchung mit einer deutschen Form der Positive and Negative Affect Schedule (PANAS). *[Investigation of a German Version of the Positive and Negative Affect Schedule (PANAS).]. Diagnostica*, *42*, 139–156.

Kubota, J. T. & Ito, T. A. (2007). Multiple cues in social perception: The time course of processing race and facial expression. *Journal of Experimental Social Psychology*, *43*, 738–752.

Lamm, C., Decety, J., & Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. *Neuroimage*, *54*, 2492–2502.

Lamm, C. & Majdandžić, J. (2015). The role of shared neural activations, mirror neurons, and morality in empathy: a critical comment. *Neuroscience Research*, *90*, 15–24.

Lamm, C., Nusbaum, H. C., Meltzoff, A. N., & Decety, J. (2007). What are you feeling? using functional magnetic resonance imaging to assess the modulation of sensory and affective responses during empathy for pain. *PLOS ONE*, *2*, 1–16.

Lamm, C., Rütgen, M., & Wagner, I. C. (2017). Imaging empathy and prosocial emotions. *Neuroscience Letters*, 1–5.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). International affective picture system (IAPS): Technical manual and affective ratings. *Gainesville, FL: The Center for Research in Psychophysiology, University of Florida*, *2*.

Leng, Y. & Zhou, X. (2010). Modulation of the brain activity in outcome evaluation by interpersonal relationship: an ERP study. *Neuropsychologia*, *48*, 448–455.

Leuthold, H. (1994). *Analysis of spatial stimulus response compatibility and the Simon effect by means of overt behavioral and electrophysiological measures: covert response activation as a common basis?* Hartung-Gorre.

Leuthold, H., Sommer, W., & Ulrich, R. (1996). Partial advance information and response preparation: Inferences from the lateralized readiness potential. *Journal of Experimental Psychology: General*, *125*, 307–323.

Li, W. & Han, S. (2010). Perspective taking modulates event-related potentials to perceived pain. *Neuroscience Letters*, *469*, 328–332.

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

Light, S. N., Moran, Z. D., Swander, L., Le, V., Cage, B., Burghy, C., & ... Davidson, R. J. (2015). Electromyographically assessed empathic concern and empathic happiness predict increased prosocial behavior in adults. *Biological Psychology*, *104*, 116–129.

Luck, S. J. (2014). *An introduction to the event-related potential technique* (2 ed.). Cambridge, MA: MIT press.

Luck, S. J. & Hillyard, S. A. (1994). Electrophysiological correlates of feature analysis during visual search. *Psychophysiology*, *31*, 291–308.

Luck, S. J., Woodman, G. F., & Vogel, E. K. (2000). Event-related potential studies of attention. *Trends in cognitive sciences*, *4*, 432–440.

Lyu, Z., Meng, J., & Jackson, T. (2014). Effects of cause of pain on the processing of pain in others: An ERP study. *Experimental Brain Research*, *232*, 2731–2739.

López-Pérez, B., Carrera, P., Ambrona, T., & Oceja, L. (2014). Testing the qualitative differences between empathy and personal distress: Measuring core affect and self-orientation. *The Social Science Journal*, *51*, 676–680.

McCall, C. & Singer, T. (2013). Empathy and the brain. In S. Baron-Cohen, H. Tager-Flusberg, & M. Lombardo (Eds.), *Understanding other minds: Perspectives from developmental social neuroscience* (pp. 195–213). Oxford, UK: Oxford University Press.

McClelland, J. L. (1979). On the time relations of mental processes: an examination of systems of processes in cascade. *Psychological Review*, *86*, 287–330.

Meconi, F., Vaes, J., & Sessa, P. (2015). On the neglected role of stereotypes in empathy toward other-race pain. *Social Neuroscience*, *10*, 1–6.

Mella, N., Studer, J., Gilet, A.-L., & Labouvie-Vief, G. (2012). Empathy for pain from adolescence through adulthood: An event-related brain potential study. *Frontiers in Psychology*, *3*, 501.

Melloni, M., Lopez, V., & Ibanez, A. (2014). Empathy and contextual social cognition. *Cognitive, Affective, & Behavioral Neuroscience*, *14*, 407–425.

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

Meng, J., Shen, L., Lv, Z., Yang, Z., Chen, H., & Jackson, T. (2012). Pain representations in the self and others: A behavioral study of the congruency effect. *Acta Psychologica Sinica*, *44*, 1515–1522.

Meyer, D. E., Osman, A. M., Irwin, D. E., & Yantis, S. (1988). Modern mental chronometry. *Biological Psychology*, *26*, 3 – 67.

Meyza, K. Z., Bartal, I., Monfils, M. H., Panksepp, J. B., & Knapska, E. (2017). The roots of empathy: through the lens of rodent models. *Neuroscience and Biobehavioral Reviews*, *76*, 216–234.

Miller, J., Franz, V., & Ulrich, R. (1999). Effects of auditory stimulus intensity on response force in simple, go/no-go, and choice RT tasks. *Perception & Psychophysics*, *61*, 107–119.

Morelli, S. A., Rameson, L. T., & Lieberman, M. D. (2012). The neural components of empathy: predicting daily prosocial behavior. *Social Cognitive and Affective Neuroscience*, *9*, 39–47.

Morrison, I., Poliakoff, E., Gordon, L., & Downing, P. (2007). Response-specific effects of pain observation on motor behavior. *Cognition*, *104*, 407–416.

Mukamel, R., Ekstrom, A. D., Kaplan, J., Iacoboni, M., & Fried, I. (2010). Single-neuron responses in humans during execution and observation of actions. *Current Biology*, *20*, 750–756.

Neuper, C. & Pfurtscheller, G. (2001). Event-related dynamics of cortical rhythms: Frequency-specific features and functional correlates. *International Journal of Psychophysiology*, *43*, 41–58.

Nolan, H., Whelan, R., & Reilly, R. B. (2010). FASTER: Fully automated statistical thresholding for EEG artifact rejection. *Journal of Neuroscience Methods*, *192*, 152–162.

Oehman, A. (2002). Automaticity and the amygdala: Nonconscious responses to emotional faces. *Current Directions in Psychological Science*, *11*, 62–66.

Olofsson, J. K., Nordin, S., Sequeira, H., & Polich, J. (2008). Affective picture processing: An integrative review of ERP findings. *Biological Psychology*, *77*, 247–265.

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J. M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience*, *2011*, 156–869.

Paulus, C. (2009). Der Saarbrücker Persönlichkeitsfragebogen SPF (IRI) zur Messung von Empathie: Psychometrische Evaluation der deutschen Version des Interpersonal Reactivity Index. *[The Saarbrueck Personality Questionnaire on Empathy: Psychometric evaluation of the German version of the Interpersonal Reactivity Index]. Retrieved from http://psydok.sulb.uni-saarland.de/volltexte/2009/2363/.*

Peng, W., Hu, L., Zhang, Z., & Hu, Y. (2012). Causality in the association between P300 and alpha event-related desynchronization. *PLoS One*, *7*, 1–11.

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

Perry, A. & Shamay-Tsoory, S. (2013). Understanding emotional and cognitive empathy: A neuropsychological perspective. In S. Baron-Cohen, H. Tager-Flusberg, & M. Lombardo (Eds.), *Understanding other minds: Perspectives from developmental social neuroscience* (pp. 178–194). Oxford, UK: Oxford University Press.

Peyron, R., García-Larrea, L., Grégoire, M.-C., Costes, N., Convers, P., Lavenne, F., Mauguière, F., Michel, D., & Laurent, B. (1999). Haemodynamic brain responses to acute pain in humans' sensory and attentional networks. *Brain*, *122*, 1765–1780.

Pfurtscheller, G. (1989). Functional topography during sensorimotor activation studied with event-related desynchronization mapping. *Journal of Clinical Neurophysiology*, *6*, 75–84.

Pfurtscheller, G. (1992). Event-related synchronization (ERS): An electrophysiological correlate of cortical areas at rest. *Electroencephalography and Clinical Neurophysiology*, *83*, 62–69.

Pfurtscheller, G. & Da Silva, F. L. (1999). Event-related EEG/MEG synchronization and desynchronization: Basic principles. *Clinical Neurophysiology*, *110*, 1842–1857.

Pfurtscheller, G., Stancak, A., & Neuper, C. (1996). Post-movement beta synchronization. *A correlate of an idling motor area? Electroencephalography and Clinical Neurophysiology*, *98*, 281–293.

Pfurtscheller, G., Zalaudek, K., & Neuper, C. (1998). Event-related beta synchronization after wrist, finger and thumb movement. *Electroencephalography and Clinical Neurophysiology*, *109*, 154–160.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*, 2128–2148.

Preston, S. D. & de Waal, F. M. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences*, *25*, 1–20.

Preston, S. D. & Hofelich, A. J. (2012). The many faces of empathy: Parsing empathic phenomena through a proximate, dynamic-systems view of representing the other in the self. *Emotion Review*, *4*, 24–33.

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*, 893–901.

Roach, B. J. & Mathalon, D. H. (2008). Event-related EEG time-frequency analysis: An overview of measures and an analysis of early gamma band phase locking in schizophrenia. *Schizophrenia Bulletin*, *34*, 907–926.

Samson, D. & Michel, C. (2013). Theory of mind: Insights from patients with acquired brain damage. In S. Baron-Cohen, H. Tager-Flusberg, & M. Lombardo (Eds.), *Understanding other minds: Perspectives from developmental social neuroscience* (pp. 164–177). Oxford, UK: Oxford University Press.

Sanders, A. (1983). Towards a model of stress and human performance. *Acta Psychologica*, *53*, 61–97.

Sanders, A. F. (1990). Issues and trends in the debate on discrete vs. continuous processing of information. *Acta Psychologica*, *74*, 123–167.

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, *41*, 441–449.

Scott, G. G., O'Donnell, P. J., Leuthold, H., & Sereno, S. C. (2009). Early emotion word processing: Evidence from event-related potentials. *Biological Psychology*, *80*, 95–104.

Sessa, P. & Meconi, F. (2015). Perceived trustworthiness shapes neural empathic responses toward others' pain. *Neuropsychologia*, *79*, 97–105.

Sessa, P., Meconi, F., Castelli, L., & Dell'Acqua, R. (2014). Taking one's time in feeling other-race pain: An event-related potential investigation on the time-course of cross-racial empathy. *Social Cognitive and Affective Neuroscience*, *9*, 454–463.

Shamay-Tsoory, S. G., Aharon-Peretz, J., & Perry, D. (2009). Two systems for empathy: a double dissociation between emotional and cognitive empathy in inferior frontal gyrus versus ventromedial prefrontal lesions. *Brain*, *132*, 617–627.

Sheng, F., Du, N., & Han, S. (2017). Degraded perceptual and affective processing of racial out-groups: An electrophysiological approach. *Social Neuroscience*, *12*, 479–487.

Sheng, F. & Han, S. (2012). Manipulations of cognitive strategies and intergroup relationships reduce the racial bias in empathic neural responses. *NeuroImage*, *61*, 786–797.

Sheng, F., Liu, Q., Li, H., Fang, F., & Han, S. (2014). Task modulations of racial bias in neural responses to others' suffering. *NeuroImage*, *88*, 263–270.

Sheng, F., Liu, Y., Zhou, B., Zhou, W., & Han, S. (2013). Oxytocin modulates the racial bias in neural responses to others' suffering. *Biological Psychology*, *92*, 380–386.

Singer, T. & Lamm, C. (2009). The social neuroscience of empathy. *Annals of the New York Academy of Sciences*, *1156*, 81–96.

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

Sochurková, D., Brázdil, M., Jurák, P., & Rektor, I. (2006). P3 and ERD/ERS in a visual oddball paradigm: A depth EEG study from the mesial temporal structures. *Journal of Psychophysiology*, *20*, 32–39.

Stanley, D. A., Sokol-Hessner, P., Banaji, M. R., & Phelps, E. A. (2011). Implicit race attitudes predict trustworthiness judgments and economic trust decisions. *PNAS Proceedings of the National Academy of Sciences of the United States of America*, *108*, 7710–7775.

Sternberg, S. (2004). Memory-scanning: Mental processes revealed by reaction-time experiments. In D. A. Balota, E. J. Marsh, D. A. Balota, & E. J. Marsh (Eds.), *Cognitive psychology: Key readings* (pp. 48–74). New York, NY: Psychology Press.

Takemi, M., Masakado, Y., Liu, M., & Ushiba, J. (2013). Event-related desynchronization reflects downregulation of intracortical inhibition in human primary motor cortex. *Journal of Neurophysiology*, *110*, 1158–1166.

Tallon-Baudry, C. & Bertrand, O. (1999). Oscillatory gamma activity in humans and its role in object representation. *Trends in Cognitive Sciences*, *3*, 151–162.

Todorov, A. T., Said, C. C., & Verosky, S. C. (2011). Personality impressions from facial appearance. In J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford Handbook of Face Perception* (pp. 631–651). Oxford, NY: Oxford University Press.

Toi, M. & Batson, C. D. (1982). More evidence that empathy is a source of altruistic motivation. *Journal of personality and social psychology*, *43*, 281–292.

Toledo, D. R., Manzano, G. M., Barela, J. A., & Kohn, A. F. (2016). Cortical correlates of response time slowing in older adults: ERP and ERD/ERS analyses during passive ankle movement. *Clinical Neurophysiology*, *127*, 655–663.

Vachon-Presseau, E., Roy, M., Martel, M. O., Albouy, G., Chen, J., Budell, L., & ... Rainville, P. (2012). Neural processing of sensory and emotional-communicative information associated with the perception of vicarious pain. *Neuroimage*, *63*, 54–62.

Valentini, E., Liang, M., Aglioti, S. M., & Iannetti, G. D. (2012). Seeing touch and pain in a stranger modulates the cortical responses elicited by somatosensory but not auditory stimulation. *Human Brain Mapping*, *33*, 2873–2884.

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge, MA: MIT press.

Verleger, R., Jaskowski, P., & Wauschkuhn, B. (1994). Suspense and surprise: On the relationship between expectancies and P3. *Psychophysiology*, *31*, 359–369.

Wang, C., Wu, B., Liu, Y., Wu, X., & Han, S. (2015). Challenging emotional prejudice by changing self-concept: priming independent self-construal reduces racial in-group bias in neural responses to other's pain. *Social Cognitive and Affective Neuroscience*, *10*, 1195–1201.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*, 1063–1070.

Weng, H. Y., Fox, A. S., Hessenthaler, H. C., Stodola, D. E., & Davidson, R. J. (2015). The role of compassion in altruistic helping and punishment behavior. *PLOS ONE*, *10*, 1–20.

Whitmarsh, S., Nieuwenhuis, I., Barendregt, H., & Jensen, O. (2011). Sensorimotor alpha activity is modulated in response to the observation of pain in others. *Frontiers in Human Neuroscience*, *5*, 1–9.

Wimmer, H. & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*, 103–128.

Xu, X., Zuo, X., Wang, X., & Han, S. (2009). Do you feel my pain? Racial group membership modulates empathic neural responses. *Journal of Neuroscience*, *29*, 8525–8529.

Zahn-Waxler, C., Radke-Yarrow, M., & King, R. A. (1979). Child rearing and children's prosocial initiations toward victims of distress. *Child Development*, *50*, 319–330.

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

Zaki, J. & Ochsner, K. (2013). Neural sources of empathy: An evolving story. In S. Baron-Cohen, H. Tager-Flusberg, & M. Lombardo (Eds.), *Understanding other minds: Perspectives from developmental social neuroscience* (pp. 214–232). Oxford, UK: Oxford University Press.

Zaki, J. & Ochsner, K. N. (2012). The neuroscience of empathy: Progress, pitfalls and promise. *Nature Neuroscience*, *15*, 675–680.