Empathy for Face Pain and Its Cognitive Neural Mechanism

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Article type: Review
Number of words: 3783
Number of figures: 2

Funding Statement

This work was supported by the Project Commissioned by the 13th Five-year Plan of Chongqing Education Science in 2019 [grant number: 2019-WT-28].

ABSTRACT: Empathy for pain was a hot topic in the field of empathy research due to its specific cognitive and neural mechanism. At present, researches on empathy for pain can be divided into two categories according to the body parts of pain depicted by experimental stimuli: Empathy for face pain and empathy for body pain, which conveys painful information by individuals' face or body parts respectively. Evidences revealed the differences of cognitive and neural mechanism between the two kinds of empathy for pain, but current studies tend to confuse their findings. This review summarized the differences between empathy for face pain and empathy for body pain, including the findings in behavioral reactions, brain activations, electrophysiological (EEG) signals, and the results of transcranial direct current stimulation (tDCS). That is probably because human's face contains more emotional information but less perceptual information than body parts. Thus, future studies may identify the differences between empathy for face and body pain, explore how others' facial information and observers' personality affect empathy for facial pain, as well as the empathy for face pain in autism spectrum disorders (ASD) individuals.
KEYWORDS: empathy; empathy for pain; face; cognitive and neural mechanism

1 Empathy for pain

Empathy is considered as the psychological process that individuals perceive or imagine others' emotion as well as partially experience the feelings of others [1]. Empathy for pain is one of the typical performances of empathy, it is defined as how individuals perceive, estimate and response to others' suffering [2]. Empathy for pain is commonly observed in daily life. It has evolution meanings for individuals to build prosocial behaviors and develop interpersonal relationships.

Due to its specific cognitive and neural mechanism, researches paid significant attention to empathy for pain and made it one of the most popular topics in the studies of empathy. According to one meta-analysis of the fMRI (functional magnetic resonance imaging) studies, the brain regions including the anterior cingulate cortex (ACC), anterior insula(AI), the amygdala and some other brain areas were activated while people observing others in painful scenes compared to non-painful scenes [3]. These brain regions, which were considered as the pain matrix, a nervous system related to processing of self-pain, were considered including emotional component and sensory component. The emotional component of empathy for pain means the unpleasant feelings caused by observing others' pain, and the sensory component means the location and the intensity to others' pain [4]. Based on the findings of event-related potentials (ERPs) studies, there are two basic neural processing stages of empathy for pain in time domain. The first one is the earlier automatic processing stage (before 380ms), which including the perception of others' pain and the sharing of others' feelings. The second one is the later cognitive evaluation stage(after 380ms), which including higher evaluations to others' stations and action preparations [5]. However, these studies neglected the pain areas according by the establishment of the painful scene, and empathy for pain to others' faces may have unique cognitive and neural mechanisms [6, 7].

2 Empathy for face and body pain

Most previous studies explored the cognitive and neural mechanisms of empathy for pain in the visual modality by introducing participants observing others' suffering in laboratory experimental conditions. There are mainly two kinds of empathy for pain, depending on the pictures showing others' pain used in previous experiments. (1) Empathy for face pain. Observers estimated pain information from others' faces. Shown as **Figure 1**, painful face pictures depicted the faces pining by a needle, while non-painful face pictures depicted the faces touching with a swab at the same location, e.g., [6]. (2) Empathy for body pain. Observers estimated pain information by the injures of others' body parts, e.g., accidental injuries to hands or feet in daily life [2]. As **Figure 2** shows, the painful body pictures depicted hands or feet accidentally hurting by a knife or pining by a needle, while the non-painful body pictures were with the same scene but without any information of pain.

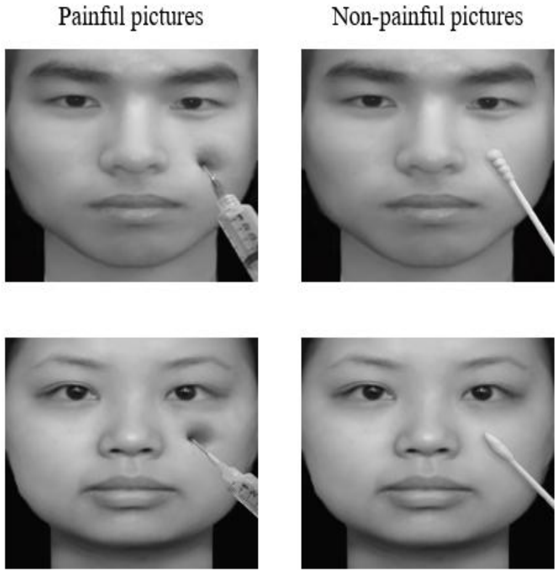

Figure 1 Pictures of empathy for face pain (left panel: painful face pictures, right panel: non-painful face pictures)[6]

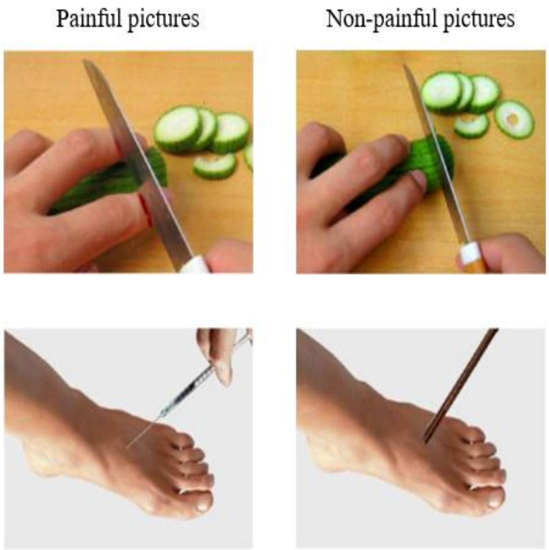

Figure 2 Pictures of empathy for body pain (left panel: painful body pictures, right panel: non-painful body pictures)[2]

However, individuals may exhibit different empathic behavioral and neural responses to others' faces and bodies. For instance, one research found that more activation were observed over the right ventral premotor area while watching others' facial movement compared to the finger movement [8].This result indicates that there may be discrepancies in the processing of others' faces and bodies. There are also evidences indicated that when participants observed pictures of painful faces and bodies, more activation over the rostral left inferior parietal lobule (IPL) were observed in response to painful bodies than faces, suggested that the processing of others' faces pain will activate specific coding of somatosensory information [9]. These evidences suggest that cognitive and neural mechanisms may differ between empathy for face and body pain.

However, most of previous researches of empathy for pain did not distinguish the cognitive and neural responses between empathy for face and body pain, which may confuse some researchers' findings [3, 10]. Therefore, it is necessary to distinguish the gaps between mechanisms of these two kinds of empathy for pain so as to understand the cognitive and neural mechanisms of empathy more clearly and deeply.

3 Differences between empathy for face and body pain

The differences between empathy for face and body pain are mainly reflected in the observers' behavioral responses, activation of the brain regions, electrophysiological (EEG) signals, and results of transcranial direct current stimulation (tDCS).

3.1 Behavioral responses

Empathy for face and body pain may differ in behavioral responses, and they were modulated by different factors. In the previous studies, participants were usually introduced to complete the pain judgement task, e.g., judging whether the person in the pictures or videos is painful or non-painful [2, 11]; or subjective feeling judgment task, e.g., rating their subjective emotional reactions in response to others' pain [12, 13].

In the study of empathy for body pain, it was found that participants were more accurate and faster in judging the painful body pictures compared to non-painful body pictures [7]. However, the result of a empathy for face pain study showed that the reaction times to painful face pictures was slower than that of non-painful face pictures [6].

In terms of subjective feeling judgment task, previous studies have found that higher pain intensity ratings and self-unpleasant levels of participants were observed in response to painful face pictures compared to non-painful face pictures, but such discrepancy will be modulated by the racial information transmitted by the face areas [14]. In the empathy for body pain studies, it was found that the skin color of the body would affect the participants' unpleasant ratings induced by painful body pictures, and dark-colored skin will cause a higher level of unpleasantness than fair-colored skin [15], but there was no discrepancy in pain rating scores for different skin bodies [16]. This indicates that the group information transmitted through the face and body may be different. And these evidence also suggested that there may be gaps between individuals' empathic behavioral responses to others' painful face and body pictures.

3.2 Activation of brain regions

Empathy for face and body pain is also related to the activation of different brain regions. The previous findings of fMRI studies suggested that there were still distinguishing areas of brain activation between empathy for face and body pain during individuals completing similar tasks, e.g., pain judgment task. In the study of empathy of body pain, it has found that judgment of others' body pain activate the anterior cingulate cortex, the paracingulate cortex, the right middle frontal gyrus and some other areas [17]. In the empathy for face pain study, others' painful face pictures induced more activation over the anterior cingulate cortex compared to non-painful face pictures [18].

Previous study had directly compared the activation of brain regions when individuals responded to others' painful body and face pictures, and found that body pictures activate more sensorimotor regions than face pictures, including the midline frontal, parietal cortices and the amygdale. In addition, others' painful body pictures caused stronger activation over the left inferior parietal lobule (IPL) area compared to the painful face pictures[9]. The differences in brain activation areas reflect that empathy for body pain may cause the brain to encode more soma-motor information, while empathy for face pain may cause more encoding of emotional information.

3.3 Electrophysiological signals

3.3.1 ERP components

ERP technique is widely used to explore the neural response of empathy for pain from the time domain because of its high time resolution. In previous empathy for body pain studies, the N1, P2 and N2 component over the frontal parietal lobe reflected early emotion sharing and pain perception, while P3 and LPC component over the parietal occipital lobe reflected late cognitive evaluation [7, 19]. These ERP components have proven to be a good indicator of empathy for body pain. The meta-analysis results of 40 ERP studies in this field suggested that centro-parietal P3 and LPC components are relatively stable components reflecting the late stage processing of others' pain, while the N1 and N2 component probably reflect the processing of early stage [10].

However, in addition to the above-mentioned ERP components in empathy for body pain, empathy for face pain may also induce N170, a specific component of facial processing [20]. N170 component over temporal occipital region reflected the processing of facial structure and recognition of facial spatial relationships [21]. In a recent study of empathy for face pain, the finding suggested that greater amplitudes of N170 was induced when participants were instructed to pay attention to facial cues than when they pay attention to the pain cues [6], indicated that empathy for face pain may be modulated by top-down attention to the pain cues. In another study, when primed with face of other people, it is found that others' painful body pictures induced larger early N1 and late P3 component compared to the non-painful body pictures [22], but smaller N1 and larger P3 component were observed while primed with the face of friends compared to strangers [23]. These evidences illustrated the relationship between the empathy for face and body pain neural processing.

3.3.2 Time-frequency analysis

Based on the results of time-frequency analysis, it is found that theta oscillations at 3 to 8 Hz and alpha oscillations at 9 to 14 Hz reflected the emotion sharing and cognitive control processing of empathy for pain respectively [24], and the individual’s perception of others’ body pain related to the primary somatosensory cortex. Studies have analyzed the ~10 Hz neural vibration of the primary somatosensory cortex, and the results found that greater suppression will be caused by others’ painful body pictures compared to non-painful body pictures [25].

In addition, mu suppression induced by pictures of body pain is modulated by emotional state [26], which suggests that there may be discrepancy between empathy for body and face pain over neural concussion. Many studies have analyzed mu suppression at 8-13 Hz within 2000ms after presentation of painful face pictures and painful body pictures, and found that others’ painful body pictures induced greater mu suppression than non-painful body pictures, but there is no difference between painful and non-painful face pictures [27]. So these evidences suggested the discrepancy over the neural concussion induced during the processing of empathy for face and body pain.

3.4 Results of Transcranial Direct Current Stimulation

According to the studies of transcranial direct current stimulation (tDCS) of empathy for pain, the dorsolateral prefrontal cortex (DLPFC) and the temporal-parietal junction (TPJ) were considered to be related to the cognitive control processing of empathy for pain [28, 29], but these regions may have distinguishing degrees of activation in empathy for face and body pain. Evidences of empathy for face pain studies found that compared to anodal or sham tDCS, when cathodal tDCS is applied over the right temporo-parietal junction (rTPJ), smaller amplitudes were induced by painful faces than non-painful faces. However, no such difference was found in the pictures of body pain [27], which indicates that cathodal tDCS over this area is mainly related to empathy for face pain.

In the empathy for body pain researches, when a anodal tDCS is applied over the DLPFC regions, participants’ pain intensity ratings of another person's body pain will increase, indicated that the application of tDCS over the DLPFC areas will influence the individual's perception of others’ body pain[30]. This indicates that the functional mechanism of tDCS on empathy for face and body pain may be different in the neural processing over these brain networks.

4 Reasons of differences in empathy for face and body pain

Due to the discrepancies in the presentation of pain stimuli in the pictures or videos, the neural mechanisms of empathy for face and body pain are different. The main reason may be the different information transmitted by the two categories of empathy. Painful face pictures contain more emotional information, while painful body pictures contain more perceptual information, which influence the observers' subjective empathy for pain processing. *Han and his colleagues* used video clips of emotional faces with pain (being pinned) or non-pain (touch with cotton swabs) as stimulation materials to explore the processing mechanism of empathy for face pain under different expressions (happy, neutral and painful). It was found that when individuals observed painful faces with happy and neutral expressions, the activation over ACC areas was weakened, but the activation over the secondary somatosensory cortex areas were enhanced [18]. These evidences showed that when emotional faces were used as a background to present painful stimuli, it can influence the emotional and perceptual responses associated with pain.

Other studies have found that the activation over the left dorsolateral prefrontal cortex associated with cognitive evaluation in the limbic system was enhanced when primed with the negative emotional faces [31], indicated that empathic processing of others' pain possibly influenced by emotional information transmitted by faces.

5. Conclusion and future study

In summary, empathy for pain is a research hotspot in the field of empathy studies. fMRI, ERPs, tDCS and other techniques were applied by previous researchers to explore the cognitive and neural mechanisms of empathy for pain. However, studies in this field were accustomed to treating empathy for face pain and body pain as the same, however, a great of evidences from previous studies had proved discrepancies between the two kinds of empathy among behavioral responses, activation of brain processing regions, EEG signals, and the results of tDCS. This may be for the fact that the human's face contain more emotional information while the body contain more perceptual information, which leads to differences in the processing of empathy for pain. Distinguishing the mechanism of empathy for face and body pain can help us better understanding the cognitive and neural mechanisms of empathy. Moreover, it is necessary to pay attention to the following aspects in future research.

Firstly, although some studies have begun to focus on the differences between the two kinds of empathy for pain, there is still insufficient evidence to explain it at the level of neural processing. Therefore, painful scenarios can be reasonably set up by future studies, so as to directly compare the discrepancies between the two kinds of empathy for pain from more aspects.

Secondly, face is an important part of human appearance, and it can also transmit other social information in addition to emotional information, such as trustworthiness [32], attractiveness [33], and plays an important role in social communication in our daily lives. Therefore, the impact of other facial features on empathy for pain can be explored in future researches, consequently help us to better understand the neural processing mechanism of empathy for face pain.

Furthermore, individuals with autism spectrum disorders (ASD) will show empathy deficit in their daily lives [34], and have abnormal face processing patterns [35]. In the study of the empathy for pain of autistic individuals, no discrepancies were found over the neural response of the empathy for body pain between the autistic individuals and the control group under different attention cues [7], but differences were found between the two groups in empathy for face pain [6]. These results suggested that autistic traits may have distinguishing impact on the two kinds of empathy, and future studies can further explore the mechanism of individual differences on empathy for face and body pain.

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