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Perspective taking modulates event-related potentials to perceived pain

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ABSTRACT

Recent event-related brain potential (ERP) study disentangled an early automatic component and a late top-down controlled component of neural activities to perceived pain of others. This study assessed the hypothesis that perspective taking modulates the top-down controlled component but not the automatic component of empathy for pain by recording ERPs from 24 subjects who performed pain judgments of pictures of hands in painful or non-painful situations from either self-perspective or other-perspective. We found that, relative to non-painful stimuli, painful stimuli induced positive shifts of ERPs at frontal–central electrodes as early as 160 ms after sensory stimulation and this effect lasted until 700 ms. The amplitudes

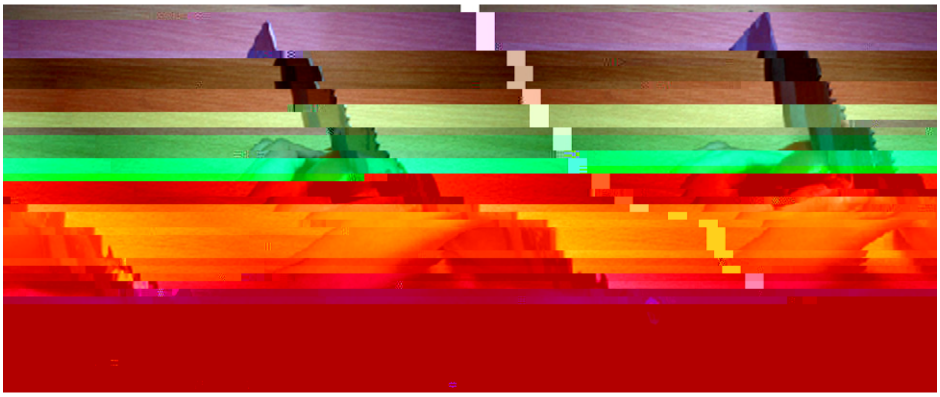

Fig. 1. Illustration of painful and non-painful stimuli used in this study.

participants to perform a pain judgment task from self-perspective or other-perspective. Neural responses to perceived pain were identified by examining the pain effect (i.e., ERPs differentiating painful and non-painful stimuli) and the influence of perspective taking on neural responses to perceived pain was assessed by comparing the pain effect when subjects imagined that hands in stimuli were their own or unfamiliar others'.

Twenty-four healthy adults (12 males and 12 females, mean age = 23.21 ± 2.65) participated in the study. All were right-handed (assessed using Edinburgh Inventory), had normal or corrected-to-normal vision, and were not color blind. Informed consent was obtained prior to the study.

Similar to the previous studies [7–9], visual stimuli consisted of 40 color pictures showing hands in painful situations and 40 color pictures of hands in non-painful situations (Fig. 1), which were repeatedly used in different blocks of trials. Painful pictures included situations such as a hand trapped in a door or cut by scissors. Each painful picture was matched with a non-painful picture. Each stimulus was presented in the center of a grey background of a 21-inch color monitor and subtended a visual angle of 2.58 × 3.43 (width × height) at a viewing distance of 100 cm.

On each trial a picture was presented for 200 ms, followed by a fixation cross with a duration varying randomly between 800 and 1600 ms. Painful and non-painful stimuli were presented in a random order. Subjects had to judge painful vs. non-painful pictures on each trial. The assignment of the left or right index finger to painful and non-painful stimuli and the order of perspectives were counterbalanced across subjects. Each subject participated in 8 blocks of 80 trials. Each block started with the presentation of instructions for 3 s that defined perspectives from which subjects performed the pain judgment task, i.e., self-perspective ("Imagine that hands shown in the picture are your own") in 4 blocks or the perspective of a specific but unfamiliar person ("Imagine that hands shown in the picture are unfamiliar others") in 4 blocks.

After the electroencephalography (EEG) recording session, subjects were asked to rate the intensity of perceived pain and the related self-unpleasantness from self- or other-perspectives when they observed each stimulus using the Face Pain Scale-Revised (FPS-R) adapted from the Faces Pain Scale [2] (an 11-point scale with 0 = no pain, 10 = very much painful, or 0 = not unpleasant, 10 = very much unpleasant). Individual differences in empathy ability were measured using the Interpersonal Reactivity Index (IRI) Scale [5] that contains four subscales related to empathic concern, perspective taking, fantasy scale and personal distress.

The EEG was recorded from 62 scalp electrodes that were mounted on an elastic cap in accordance to the extended 10–20 system and were referenced to the average of the left and right mastoid electrodes. The electrode impedance was kept less than 5 kΩ. Eye blinks and vertical eye movements were monitored with electrodes located above and below the left eye. The horizontal electro-oculogram was recorded from electrodes placed 1.5 cm lateral to the left and right external canthi. The EEG was amplified (band pass 0.1–100 Hz) and digitized at a sampling rate of 250 Hz. The ERPs in each condition were averaged separately off-line with an epoch beginning 200 ms before stimulus onset and continuing for 1000 ms. Trials contaminated by eye blinks, eye movements, or muscle potentials exceeding ±50 μV at any electrode were excluded from the average. The baseline for ERP measurements was the mean voltage of a 200 ms prestimulus interval and the latency was measured relative to the stimulus onset. Mean amplitudes of each ERP component were calculated at electrodes selected from the frontal (Fz, FCz, F3, F4, FC3, FC4), central (Cz, CPz, C3, C4, CP3, CP4), parietal (Pz, P3, P4), temporal (T7, T8, TP7, TP8, P7, P8), occipito-temporal (POz, Oz, PO3, PO4, PO7, PO8) regions.

Reaction times (RTs), response accuracies and subjective rating scores were subjected to a repeated measure analysis of variance (ANOVA) with pain (painful vs. non-painful stimuli) and perspective (self vs. other) as within-subjects independent variables. The mean ERP amplitudes were subjected to ANOVAs with the factors being pain, perspective, and hemisphere (electrodes over the left and right hemisphere) as within-subjects independent variables. Statistical data were reported at the electrode that showed the most conservative results (frontal electrodes: FC3–FC4; central electrodes: CP3–CP4; parietal electrodes: P3–P4).

The mean rating scores (standard deviation) of IRI questionnaire were perspective taking scale = 17.29(4.20), fantasy scale = 17.38(5.60), empathic concern scale = 19.00(4.26), and personal distress scale = 15.21(4.69). Table 1 shows mean RTs and response accuracies in each condition. ANOVAs of RTs showed a significant interaction of pain × perspective ($F(1, 23) = 7.409$, $p < 0.05$) because subjects responded faster to painful than non-painful stimuli in self-perspective condition ($t(23) = 3.058$, $p < 0.01$), but not in other-perspective condition ($t(23) = 0.401$, $p > 0.05$). ANOVAs of response accuracy also showed a significant interaction of pain × perspective reached significance ($F(1,23) = 9.10$, $p < 0.01$). Response accuracies were higher to non-painful than painful

Table 1
Mean RTs (ms) and response accuracy (%) (standard deviation) in each perspective condition.

	Self-perspective	Other-perspective
RTs		
Painful	687(87.0)	707(82.8)
Non-painful	714(99.6)	712(111)
Accuracies		
Painful	85.0(10.9)	80.8(15.7)
Non-painful	85.8(9.50)	87.5(8.94)

Table 2
Mean FPS-R scores (standard deviation) in each perspective condition.

	Self-perspective	Other-perspective
Painful stimuli		
Pain	5.95(2.04)	5.46(2.04)
Unpleasantness	5.94(1.89)	5.54(1.90)
Non-painful stimuli		
Pain	0.17(0.29)	0.14(0.36)
Unpleasantness	0.85(0.88)	0.44(0.56)

stimuli in other-perspective condition ($t(23) = 2.153$, $p < 0.05$), but did not differ between painful and non-painful stimuli in self-perspective condition ($t(23) = 0.358$, $p > 0.05$).

ANOVAs of rating scores of pain intensity showed significant main effects of Pain ($F(1,23) = 186.85$, $p < 0.001$) and perspective ($F(1,23) = 4.529$, $p < 0.05$, Table 2). Although the interaction of pain × perspective did not reach significance ($F(1,23) = 3.566$, $p > 0.05$), separate analysis suggested that the scores of pain intensity were significantly higher in the self-perspective than other-perspective conditions ($t(23) = 2.077$, $p < 0.05$), whereas there was no significant difference in the scores of self-unpleasantness between the conditions ($t(23) = 1.506$, $p > 0.05$). The scores of pain intensity positively correlated with those of self-unpleasantness in both the self- ($r = 0.846$, $p < 0.001$) and other-perspective conditions ($r = 0.792$, $p < 0.001$).

Fig. 2 illustrates grand-averaged ERPs to painful and non-painful stimuli and the voltage topographies of specific ERP components. Stimuli in all conditions evoked a negative component between 80 and 120 ms (N110) over the frontal area, which was followed by a positive deflection at 140–180 ms (P160) and a negative wave peaking at 220–270 ms (N240) over the frontal/central areas. There was a long-latency negativity at 310–350 ms (N320) over the frontal–central area and a positivity at 340–740 ms (P3) with the maximum amplitude over the central area.

ANOVAs of the mean ERP amplitudes showed a significant main effect of pain at 160–180 ms (parietal electrodes: $F(1,23) = 9.128$, $p < 0.01$), 230–250 ms (frontal electrodes: $F(1,23) = 14.024$, $p < 0.01$; central electrodes: $F(1,23) = 7.547$, $p < 0.05$), 290–360 ms (frontal electrodes: $F(1,23) = 7.902$, $p < 0.01$), 370–420 ms (frontal electrodes: $F(1,23) = 13.699$, $p < 0.01$; central electrodes: $F(1,23) = 13.308$, $p < 0.01$; parietal electrodes: $F(1,23) = 9.045$, $p < 0.01$), 420–500 ms (frontal electrodes: $F(1,23) = 13.709$, $p < 0.01$; central electrodes: $F(1,23) = 19.182$, $p < 0.001$; parietal electrodes: $F(1,23) = 15.154$, $p < 0.001$),es: < 0.p(ii.7968

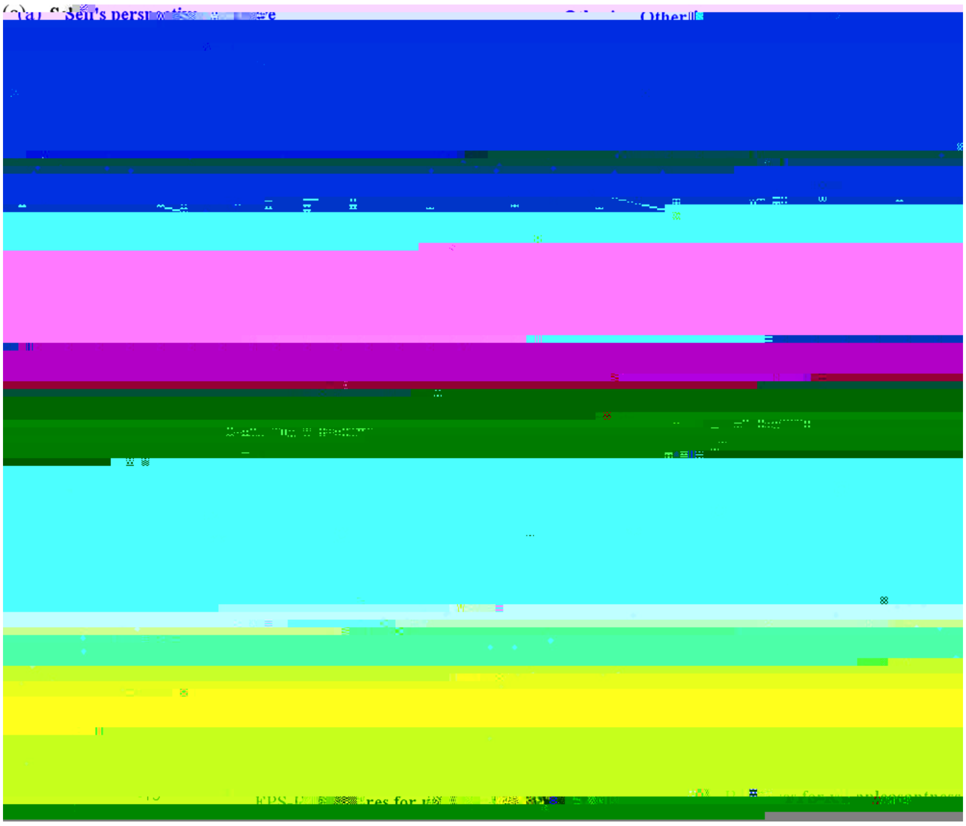

Fig. 3.

processing of empathy when subjects took both self-perspective