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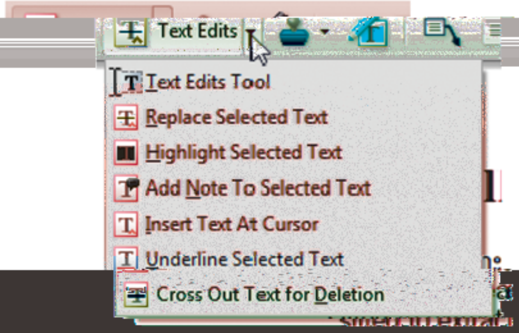

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Self-construal priming modulates pain perception: Event-related potential evidence

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We investigated whether and how temporary shifts in self-construals ~~modulates~~ neural correlates of pain perception. Event-related potentials (ERPs) to painful and non-painful electrical stimulations were recorded from adults after being primed with independent and interdependent self-construals. Electrical stimulations to the left hand elicited two negative components (N60 and N130) over the frontal /central regions and two positive components (P90 and P300) over the central/parietal regions with larger amplitudes over the right rather than the left hemispheres. Painful vs. non-painful stimulations enlarged P90, N130, and P300 amplitudes. Independent vs. interdependent self-construal priming induced larger N130 amplitudes to painful stimulations but did not affect the N130 amplitudes to non-painful stimulations. The self-construal priming effect on the P300 amplitudes to painful stimulation positively correlated with self-reported interdependence. Our ERP results suggest that temporary shifts in self-construals affect pain perception by modulating the neural activities engaged in early somatosensory and late evaluation processing of physical pain.

Keywords: Pain; Self-construal priming; ERP; N130; P300.

People hold different cultural views about the self that emphasize either autonomy and independence (an independent self-construal) in Western societies or connections between oneself and others and interdependence in Eastern Asian societies (an interdependent self-construal) (Markus & Kitayama, 1991). Recent brain imaging studies have shown that temporary shifts of self-construals can influence multiple neurocognitive processes in the human brain. An early functional magnet resonance imaging (fMRI) study showed that the right frontal activity engaged in self-face recognition was enhanced by self-construal priming that emphasize independent vs. interdependent self-construals in Chinese (Sui & Han, 2007). A following event-related potential (ERP) study showed that self-construal priming modulated the frontal activity underlying recognition of faces of oneself or a close other (Sui et al., ~~in press~~). Other fMRI research found that priming independent vs. interdependent self-construals AQ1 modulated the medial prefrontal activity involved in reflection of personality traits of a close other (Harada, Li, & Chiao, 2010). Self-construal priming also modulates perceptual or motor activity in the human brain. Lin, Lin, and Han (2008) found that priming independent vs. interdependent self-construals increased the occipital activity underlying perception of local properties of hierarchical visual stimuli. Recent transcranial magnetic stimulation (TMS) research reported that priming interdependent self-construal enhanced motor cortical output during an action observation task (Obhi,

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Hogeveen, & Pascual-Leone, 2011). These findings suggest that temporary shifts in self-construals modulate neural activities underlying perceptual, social cognitive, and motor processing in the human brain.

The current work further investigated whether and how self-construal priming modulates neural correlates of pain perception that involves somatosensory processing and negative affect. It is well known that a cortical circuit consisting of the primary (SI) and second (SII) somatosensory cortex, anterior cingulate (ACC), insula, and supplementary motor area (SMA) is engaged in physical pain (Peyron, Laurent, & García-Larrea, 2000). Specifically related to the current work, fMRI research revealed that painful electrical stimulations applied to body parts significantly activated the SI/SII, ACC, and insula (see Apkarian, Bushnell, Treede, & Zubieta, 2005 for review). The results of ERP studies that recorded electroencephalography (EEG) from electrodes over the scalp suggest that the early neural activities to painful stimulations (e.g., the N60 at 20–90ms and N130 at 100–160ms) arise from the contralateral SI/SII and are related to early somatosensory processing of physical pain, whereas the long-latency activity to painful stimulations might arise from the ACC (Bromm & Chen, 1995; Christmann, Koeppe, Braus, Ruf, & Flor, 2007; Tarkka & Treede, 1993) and is related to affective processing of physical pain. A study using intracortical recordings further identified that nociceptive laser stimuli applied to the dorsum of the hand produced evoked potentials that peaked between 120ms and 190ms over the SI and between 200ms and 330ms over the insula (Frot, AQ2 Magnin, Mauguière & García-Larrea, in press). Both the early somatosensory component (e.g., the N80 and N140, Eimer & Forster, 2003) and the long-latency component (e.g., the P300) that mediates cognitive evaluation of painful stimulations (Zaslansky, Sprecher, Tenke, Hemli, & Yarnitsky, 1996) are modulated by attention.

Because priming independent compared to interdependent self-construals may facilitate self-focused attention, according to Markus and Kitayama (1991), it is likely that independent vs. interdependent self-construal priming may enhance the neural activity to painful stimulations. Moreover, as chronic views of the self constrain the effect of self-construal priming on AQ1 neural activity underlying self-recognition (Sui et al., ~~in press~~), the effect of self-construal priming on neural correlates of physical pain may also vary as a function of subjects' chronic self-construals. We tested these hypotheses by recording EEG to painful and non-painful electrical stimulations from adults after they had been primed with independent and interdependent self-construals. ERPs that were characterized with high time resolution were then extracted so that we were able to examine whether the early somatosensory processing and the late evaluative processing of physical pain were similarly modulated by self-construal priming. We were particularly interested in whether self-construal priming modulates ERPs to painful and non-painful stimulations in a similar vein. Chronic self-construals were estimated using the self-construal scale (SCS, Singelis, 1994) so as to assess whether the effect of temporal shifts in self-construal varies across individuals with different chronic self-construals.

METHODS

Subjects

Twenty-eight healthy male college students participated in this study as paid volunteers. Four subjects were excluded from data analysis due to excessive eye blinks or head movements during EEG recording. The final sample for data analysis included 24 subjects aged between 19 and 30 years (Mean ± $SD = 22.7 \pm 3.0$). All subjects were right-handed and self-reported no chronic diseases and neurological history. This study was approved by a local ethics committee at the Department of Psychology, Peking University. Written informed consent was obtained prior to the study.

Priming materials

Four essays were printed on separate sheets for priming independence and interdependence, similar to Gardner, Gabriel, and Lee (1999). These essays described seashore or shopping tours. Two essays contained singular pronouns (e.g., "I", "me", "my") to prime independent self-construal and two essays contained plural pronouns (e.g., "we", "us", "our") to prime interdependent self-construal. Each essay contained 11–12 pronouns. During self-construal priming, participants were instructed to read each essay and circle all the pronouns in each essay.

Electrical stimulation

Electrical stimulation was a single 0.5ms pulse with a square waveform and was delivered to the dorsum of the left hand via a pair of foil electrodes (DS7A

Digitimer). Before EEG recording, sensory and pain tolerance thresholds were determined individually using the ascending limit method (Niddam et al., 2002; Wager et al., 2004). A stimulation of 0.8mA was applied first. Current intensity was then increased by 0.2mA each time while subjects reported their feelings. The sensory threshold was defined as the current intensity with which subjects for the first time answered “yes” to the question “can you feel this shock?” (0.80mA to 1.80mA, mean = 1.28mA). The pain tolerance threshold was defined as the current intensity with which subjects for the first time answered “no” to the question “Can you tolerate a stronger shock?” (2.40mA to 9.20mA, mean = 4.02mA). The current intensities of sensory and tolerance thresholds were used as “non-painful” and “painful” stimulation during EEG recording.

Procedure

Each participant underwent four sessions of electrical stimulations with simultaneous EEG recording. Before each session, participants were primed with either independent or interdependent self-construals by reading an essay in three minutes. The first two sessions were assigned to one priming condition and the last two sessions to another priming condition. The order of independent or interdependent self-construal priming was counterbalanced across subjects.

Each session consisted of 24 trials of electrical stimulations. Twelve painful and 12 non-painful stimulations were given in a pseudorandom order. Each trial started with the presentation of a square of 1500ms at the center of a monitor, which was followed by a 1500ms fixation. The square reminded subjects of upcoming stimulations in order to avoid surprise-induced head movements. Subjects were asked not to blink by looking at the fixation. A 0.5ms electrical stimulation was then delivered to the left hand. After 2000ms, subjects were asked to rate their painful feelings within 4000ms on a 10-point visual analogue scale (VAS) by scrolling a bar to indicate rating scores of painful feelings (0 = *no sensation*, 1= *feel something but not pain*, 4 = *slight pain*, 8 = *strong pain*, 10 = *worst imaginable pain*). The mean interval between two successive trials varied randomly between 1000ms and 3000ms.

To assess the extent of endorsement of self-construal cultural values, before the EEG session, subjects completed the SCS (Singelis, 1994) with a seven-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). Twelve items of the SCS estimate independence and 12 items estimate interdependence.

EEG recordings and data analysis

EEG was recorded from 62 Ag-AgCl electrodes mounted on an elastic cap in accordance with the extended 10–20 system. The linked left and right mastoids served as a reference for EEG recording. To monitor eye movement, both horizontal (HEOG) and vertical (VEOG) electro-oculograms were also recorded from electrodes placed 1.5cm lateral to the left and right external canthi and electrodes placed above and below the left eye. The impedance of all electrodes was kept less than 5 kΩ. The EEG data were sampled at 500Hz and filtered with a band pass of 0.05∼100Hz. Evoked potentials were extracted with an epoch 200ms before the onset of an electrical stimulation and lasting for 1000ms. To obtain grand average ERPs for each individual, we first removed the artifact at the stimulus onset caused by the electric stimulator, similar to Zaslansky et al. (1996), and improved the signal at 0∼20ms around the stimulation by cubic spline interpolation, similar to Christmann et al. (2007). We then excluded trials with potentials exceeding ±50μV over either HEOG or VEOG electrodes. This resulted in acceptance of 83.3% of trials. Finally, EEG was offline filtered with a band pass of 0.1∼40Hz and 24dB and detrended. The baseline of each epoch was corrected in reference to potentials prior to the onset of electrical stimulation before a grand average was conducted.

Electrodes were clustered into the frontal (AF4-AF3, F6-F5, F4-F3, FZ), frontal-central (FC4-FC3, FC2-FC1, FCZ), central (C6-C5, C4-C3, C2-C1, CZ), central-parietal (CP6-CP5, CP4-CP3, CP2-CP1, CPZ), and parietal (P4-P3, P2-P1, PZ) areas. We extracted the mean amplitude for the N60 (50–80ms) and the N130 (120–140ms) from each electrode over the frontal/central areas and for the P90 (80–100ms) and the P300 (240–320ms) from each electrode over the central/parietal areas. We conducted a repeated analysis of variance (ANOVA) of ERP amplitudes with Priming (independence vs. interdependence), Stimulus Intensity (painful vs. non-painful stimuli), and Hemisphere (electrodes over the left vs. right hemispheres) as independent within-subjects variables. P*ost-hoc* analyses were conducted to examine the priming effects on ERPs elicited by painful and non-painful stimulation, respectively.

RESULTS

Behavioral performance

The mean rating scores (± *SD*) of painful feelings were 7.69 ± .74 for painful stimulations and 1.44 ± .56 for non-painful stimulations in the independent self-construal priming condition and 7.77 ± .73 for painful stimulations and 1.41 ± .61 for non-painful stimulations in the interdependent self-construal priming condition. The rating scores of painful (or non-painful) stimulation did not differ significantly between the two priming conditions (*ps* > .1). The rating score of independence varied between 3.58 and 6.08 (Mean ± *SD* = 4.86 ± .72) and the rating score of interdependence varied between 3.67 and 6.58 (Mean ± *SD* = 5.13 ± .68) across the final sample of 24 participants.

Electrophysiological data

Figure 1a illustrates grand average ERPs elicited by electrical stimulations. These were characterized by two successive negative components, i.e., the N60 at 50–80ms and N130 at 120–140ms, over the lateral frontal/central electrodes. There was also a positive component at 80–100ms over the central/parietal electrodes (P90), followed by a long-latency positive component at 200–400ms with the maximum amplitude over the central region (P300).

Relative to non-painful stimulation, painful stimulation elicited significantly larger P90 amplitudes over the right centroparietal electrodes (*F*(1, 23) = 5.668–20.22, *p* < .05), larger N130 amplitudes over the bilateral frontocentral electrodes (*F*(1, 23) = 5.26–44.83, *p* < .05), and larger P300 over the centroparietal electrodes (*F*(1, 23) = 19.04-63.42, *p* < .001).

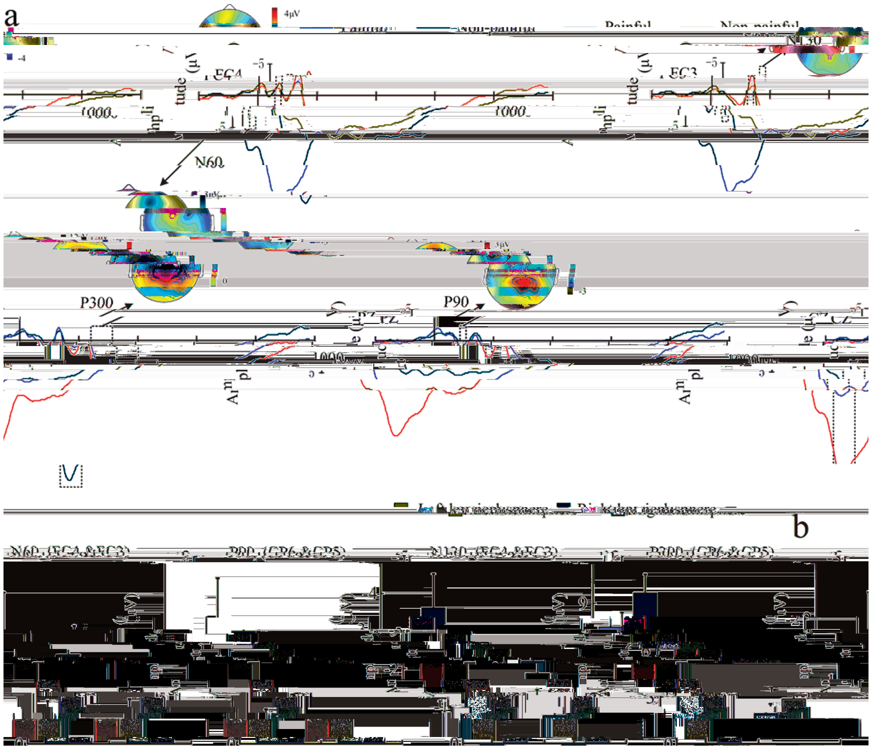

Figure 1. (a) Illustration of grand-average ERPs elicited by electrical painful and non-painful stimulations at electrodes FC4, FC3, PZ, and CZ, where each ERP component showed the maximum amplitude. (b) Illustration of the contralaterality of ERPs to painful stimulations at electrodes FC4 vs. FC3 and CP6 vs. CP5. The ERP amplitudes were larger over the right hemisphere contralateral to the left hand receiving painful stimulations.

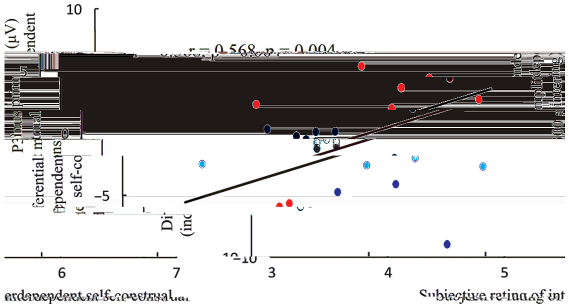

Figure 3. The correlation between subjective ratings of interdependent self-construals and the differential P300 amplitude elicited by painful stimulation after independent vs. interdependent self-construal priming at electrode CZ.

Because electrical stimulations were delivered to the left hand, we expected larger amplitudes of evoked potentials over the right rather than left hemispheres. This was confirmed by significant effects of Hemisphere on the amplitudes of the N60 ($F(1, 23) = 11.08$-39.40, $p < .005$) and N130 ~~over the frontocentral electrodes~~ ($F(1, 23) = 8.501$–15.78, $p < .01$), and of the P90 ($F(1, 23) = 6.226$–8.281, $p < .05$) and P300 ($F(1, 23) = 11.39$–17.17, $p < .005$) over the centroparietal electrodes (see Figure 1b).

Most interestingly, ANOVAs of the N130 amplitudes showed a significant interaction of Priming × Stimulus Intensity over the centroparietal electrodes ($F(1, 23) = 4.48$–9.58, *ps* $< .05$). Post-hoc analyses confirmed that independent vs. interdependent self-construal priming resulted in larger N130 amplitudes to painful stimulations over the centroparietal electrodes ($t = 2.37$–2.69, *ps* $< .05$), whereas the N130 amplitudes to non-painful stimulation did not differ significantly between the two priming conditions (*ps* $> .05$, see Figure 2).

ANOVAs of the P300 amplitudes did not show a significant effect of self-construal priming (*ps* $> .05$). Thus we further examined the priming effect on the P300 amplitudes by including self-reported interdependent self-construals as a covariant in order to control the influences by subjects' chronic self-construals. This analysis showed a significant effect of self-construal priming on the P300 amplitudes to painful stimulation over the centroparietal electrodes ($F(1,23) = 4.85$–15.68, $p < .05$). To further explore the relationship between individual differences in self-construals and the priming effect on the P300 amplitudes, we calculated differential P300 amplitudes by subtracting the P300 amplitudes to painful stimulation in the interdependent self-construal priming condition from that in the independent self-construal priming condition. We then conducted a regression analysis and found a significant positive correlation between the differential P300 amplitude and rating scores of interdependent self-construals over the centroparietal electrodes ($r = .406$–$.622$, *p* ~~=.001–~~.05~~0~~, see Figure 3). It appears that the independent relative to interdependent self-construal priming increased the P300 amplitude in those with high interdependence but decreased the P300 amplitude in those with low interdependence.

DISCUSSION

Similar to the previous studies that recorded somatosensory-evoked potentials (Bromm & Chen, 1995; Christmann et al., 2007; Tarkka & Treede, 1993), we found that electrical stimulations applied to subjects' left hands elicited an early N60-P90-N130 complex over the frontal/central/parietal electrodes. The activities showed greater amplitudes over the electrodes contralateral to the stimulated hand. Moreover, electrical painful compared to non-painful stimulations significantly increased the P90 amplitudes over the right centroparietal electrodes. The P90 possibly arose from the right SI given its peak latency and contralaterality of the amplitude. Electrical painful compared to non-painful stimulations also increased the N130 amplitudes over the bilateral frontocentral electrodes. Frot, Rambaud, Guénot, and Mauguière (1999) found that CO2-laser stimulation of the skin at the dorsum of one hand elicited a negative activity that peaked around 135ms post stimulation and was localized to the bilateral SII. Thus the N130 observed in our work possibly had sources in the bilateral SII.

Interestingly, we found that, while self-construal priming did not influence the P90 amplitudes to painful stimulations, independent compared to interdependent self-construal priming significantly increased the N130 amplitudes. The priming effect on the N130 amplitudes was specific to painful stimulations because the N130 amplitudes to nonpainful stimulations were not affected by self-construal priming. This result supports our hypothesis that independent compared to interdependent self-construal priming facilitates self-focus attention and thus enhances neural responses to painful stimulations applied to the self. The previous studies of self-construal priming have shown that priming independent or interdependent self-construals modulate perceptual processing in the occipital cortex (Lin et al., 2008), self-face recognition in the lateral frontal cortex (Sui & Han, 2007), reflection of personality traits in the medial prefrontal cortex (Harada et al., 2010), and motor resonance in the motor cortex (Obhi et al., 2011). Our findings complement the previous research by showing the first evidence that independent vs. interdependent self-construal priming enhances the somatosensory processing (possibly in the SII).

The effect of self-construal priming on the P300 amplitudes seemed to depend on subjects' chronic self-construals. We found a significant effect of self-construal priming on the P300 amplitudes to painful stimulation only when controlling subjects' chronic self-construals. The regression analysis further uncovered that independent self-construal priming produced opposite effects on P300 amplitudes in subjects of high ~~or~~ low interdependence in self-construals. The independent relative to interdependent self-construal priming increased the P300 amplitude in those with high interdependence but decreased the P300 amplitude in those with low interdependence. The P300 for the pain modality is related to cognitive evaluation of painful stimulations and is modulated when attention is focused on or distracted from pain stimulations (Crawford et al., 1997; Kanda et al., 1996; Zaslansky et al., 1996). Our results indicate that how independent self-construal priming modulates the cognitive process of physical pain is constrained by subjects' chronic cultural values of self-construals. Temporary shifts in self-construals against one's chronic self-construal (e.g., interdependence) enhanced late evaluation processes of painful stimulations. Our recent study that examined the effect of self-construal priming on neural responses to perceived pain in others found that reinforcing interdependent self-construal in Chinese decreased the neural activity to perceived pain in unknown others whereas priming independent self-construal produced little effect on empathic neural
AQ3 responses (Jiang, Varnum, Hou & Han, under review). Thus it is likely that priming independent and interdependent self-construals in Chinese may respectively influence neural activities in response to one's own pain and pain in others.

Together with previous brain imaging studies of self-construal priming, our work raised an interesting question, i.e., How does self-construal priming modulate brain activity involved in cognitive/emotional processing? Our recent fMRI study that investigated the effect of self-construal priming on the resting state brain activity found that self-construal priming changed the activity of default mode network in the resting-state, with more involvement of dorsal medial prefrontal cortex after interdependent self-construal priming (Wang et al., ~~in press~~). It is thus perhaps speculated that AQ4
self-construal priming may first change the resting state activity in the cortical midline structure, which may in turn modulate other brain regions engaged in multiple cognitive/emotional processing. This, however, should be tested in future research.

In sum, the results that self-construal priming modulates neural activities underlying multiple cognitive/emotional processing are consistent with other observations that cultural priming affects the medial prefrontal activity involved in reflection of one's own personality traits (Chiao et al., 2010; Ng, Han, Mao, & Lai, 2010). These findings extend our understanding of how the plastic nature of the human brain helps people to fit into specific sociocultural environments. Behavioral studies indicate that self-construal priming can make either independence or interdependence accessible and provide a situated cognition framework to make sense of the task at hand (Kühnen & Oyserman, 2002; Lin & Han, 2009; Oyserman, 2011). Brain imaging studies further uncover that both long-term sociocultural experiences (e.g., Ma
et al., in press; Zhu, Zhang, Fan, & Han, 2007~~;~~) and AQ5
temporary cultural priming shape dynamic functional organization of the human brain so that the brain may function efficiently in response to a variety of tasks in different sociocultural contexts (Han & Northoff, 2008; Han et al., 2013). Self-construal not only provides a framework to define the self and its relationship with others but also influences neural activities

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