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RESEARCH****Research Report****Gender differences in the mu rhythm during empathy for pain:
An electroencephalographic study**Chia-Yen Yang^a, Jean Decety^b, Shinyi Lee^c, Chenyi Chen^d, Yawei Cheng^{d,e,*}^aInstitute of Computer, Communication and System Engineering, Ching-Yun University, Chungli, Taiwan^bDepartment of Psychology and Psychiatry, and Center for Cognitive and Social Neuroscience, The University of Chicago, Chicago, IL, USA^cInstitute for Brain Sciences, National Yang-Ming University, Taipei, Taiwan^dInstitute of Neuroscience, National Yang-Ming University, Taipei, Taiwan^eDepartment of Physical Medicine and Rehabilitation, National Yang-Ming University Hospital, Yilan, Taiwan

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ABSTRACT

Our recent magnetoencephalography study demonstrated that the mu rhythm can reliably indicate sensorimotor resonance during the perception of pain in others (Cheng, Y., Yang, C. Y., Lin, C.P., Lee, P.L., Decety, J., 2008b). The perception of pain in others suppresses somatosensory oscillations: a magnetoencephalography study. *NeuroImage* 40, 1833–1840). The current study further investigated the neurophysiological mechanism underpinning empathy for pain in relation with gender through the measurements of the electroencephalographic mu suppression in healthy female ($N=16$) and male ($N=16$) adults during the observation of body parts in painful or no-painful situations. The results demonstrate that both genders exhibited sensorimotor activation related to pain empathy. However, females showed stronger mu suppressions than males when watching the painful as well as the non-painful situations. Further, the mu suppression for pain empathy was positively correlated with the scoring on the personal distress subscale of the interpersonal reactivity index only in the female participants. The present findings suggest the existence of a gender difference in pain empathy in relation with the sensorimotor cortex resonance. The mu rhythm can be a potential biomarker of empathic mimicry.

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1. Introduction

Empathy allows one to quickly and automatically relate to the emotional states of others, which is essential for the regulation of social interaction (de Waal and Thompson, 2005). It is believed that empathy has evolved in the context of parental care in the mammalian species. Females alerted and affected by their offspring's needs likely out-reproduced those who remained indifferent (MacLean, 1985). In humans, the issue of gender differences in empathy is quite controversial. With

regard to the social role theory, men are responsible to fulfill tasks that required speed, strength, and the ability to be away from home whereas women serve to facilitate interpersonal harmony within the family (Wood and Eagly, 2002). The female superiority in empathy may spring from the stereotype of females' social role. An amount of psychological researches found that females appear to perform better at reading others' facial and body actions while communicating, and score higher on tests of emotional recognition (Hall, 1984; Geary, 1998; McClure, 2000; Baron-Cohen et al., 2005). However,

* Corresponding author. Institute of Neuroscience, School of Life Science, National Yang-Ming University, Taipei, Taiwan.

E-mail address: ywcheng2@ym.edu.tw (Y. Cheng).

evidence for gender differences in empathy are high for self-report questionnaires of empathy in which it is obvious what was being indexed, but are smaller or nonexistent for other types of indexes that are less self-evident with regard to their purpose (Eisenberg and Fabes, 1990). Moreover, adults' self-reports of empathy have been associated with indexes of social desirability in some studies (Cialdini et al., 1987). It is therefore crucial to investigate the neurophysiological mechanism that underpins empathy in relation with gender differences. Such measures provide more objective assessments of potential gender differences in social cognition.

One crucial aspect of empathy relies on unconscious emotional mimicry that leads to affective sharing between self and other (Decety and Jackson, 2004; Decety and Lamm, 2006; Decety and Batson, 2007; Hatfield, in press). This sharing stems from the perception–action coupling (supported by the mirror-neuron system), which automatically activates, in the observer, sensorimotor representations and associated automatic responses (Preston and de Waal, 2002). On the basis of extensive knowledge about the neural mechanisms of the first-hand experience of pain, the perception of pain in others constitutes a valuable and ecologically valid paradigm to investigate the neural underpinning of human empathy (Decety, 2007). A number of functional neuroimaging studies demonstrated that attending to the pain of others activates the affective and motivational components involved in the first-hand experience of pain processing, including the anterior insula, anterior mid and dorsal anterior cingulate cortex, and periaqueductal gray (e.g., Singer et al., 2004; Jackson et al., 2005, 2006a,b; Cheng et al., 2007b; Gu and Han, 2007; Lamm et al., 2007a; Decety et al., 2008). As for the perception–action coupling component, recent electrophysiological studies pointed out a sensorimotor resonance during empathy for pain. For instance, motor-evoked potentials, elicited by transcranial magnetic stimulation was specifically reduced for the muscles that subjects observed being pricked (Avenanti et al., 2005). The observation of needle and Q-tip stimulations delivered to a model differentially modulated the amplitudes of the somatosensory-evoked potentials (P45) (Bufalari et al., 2007). Another study, using event-related potentials (ERPs) of pain empathy found an early automatic component at 140–180 ms and a late cognitive control process after 380 ms (Fan and Han, 2008). Also, our previous magnetoencephalography (MEG) study demonstrated subtle changes in the primary somatosensory cortex elicited by the perception of pain in others with the use of mu suppression (Cheng et al., 2008b).

Mu rhythm, also known as the central rolandic or sensorimotor rhythm, has been consistently observed over the primary sensorimotor cortex (Gastaut, 1952; Pfurtscheller and Andrew, 1999). Mu suppression and enhancement echo sensorimotor processing in frontoparietal networks. Mu rhythm recorded from electrodes at scalp location over sensorimotor cortex can be attenuated by self-initiated movements, imagined movements, as well as action observation (Gastaut and Bert, 1954; Pfurtscheller and Limesch, 1991; Pfurtscheller and Neuper, 1997). The mu suppression has also been reported to be closely linked to the mirror-neuron activity (Pineda, 2005; Oberman et al., 2005, 2008; Cheng et al.,

2006, 2008a). Accordingly, the mu suppression can be a reliably indicator of sensorimotor involvement, supported by the mirror-neuron system, when participants perceive other people in painful situations (Cheng et al., 2008b).

In addition, it has been demonstrated that gender influences the first-hand processing of pain. Females displayed lower pain threshold as well as a higher sensory and supramotor excitability to surface electrical stimulation than males (Garcia et al., 2007; Maffiuletti et al., 2008). Gender bias has also been documented in the pain matrix activity evoked by noxious stimuli (Henderson et al., 2008). Driven from gender differences in the first-hand experience of pain, it is thus reasonable to hypothesize that the perception of pain in others should differ between genders. Han et al. used ERPs to point out the gender differences in the processing of pain empathy (Han et al., 2008), and found that females differed from males in that the task demands modulated the long-latency empathic response to a stronger degree and that the subjective ratings of perceived pain and unpleasantness correlated with the ERP amplitudes at 140–180 ms.

The present study measured the differential electroencephalographic (EEG) mu suppressions, as a reliable indicator of the sensorimotor cortical resonance of empathy for pain, in male and female participants to explore if gender differences existed in the neural mechanisms underpinning the perception of pain in others. We anticipated that females should exhibit stronger sensorimotor resonance than males, as indicated by EEG mu suppression of empathy for pain. Moreover, the degree of sensorimotor resonances in relation to gender difference may be related to participant's self-report empathy disposition.

2. Results

2.1. Behavior performance

Table 1 lists the results from the dispositional measures. The between-group analysis revealed a significant gender difference for the scores from the personal distress subscale of the interpersonal reactivity index (IRI) ($Z = -2.065$, $P = 0.04$). The pain intensity ratings after EEG recordings indicated that participants rated the painful stimuli (Pain) significantly higher on the visual analogue scale (mean 6.9, $SD = 1.5$) than

Table 1 – Dispositional measures of the female and male subgroups

Variable	MALES (n = 16)		FEMALES (n = 16)		Mann–Whitney	
	Mean	SD	Mean	SD	Z value	P
Interpersonal reactivity index						
Fantasy	19.6	4.3	19.5	5.1	–0.038	0.985
Personal distress	11.8	4.1	14.7	3.0	–2.065	0.039
Perspective taking	16.8	5.2	19.5	4.6	–1.382	0.171
Empathic concern	20.4	3.8	20.4	3.7	0.000	1.000
Emotional Empathic	19.6	19.9	31.3	16.5	–1.849	0.067
Contagion Scale						
Empathizing Quotient	29.8	14.9	38.1	10.0	–1.640	0.102

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