



Research report

Exploring potential social influences on brain potentials during anticipation of tactile stimulation

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ABSTRACT

This study explored interpersonal influences on electrophysiological responses during the anticipation of tactile stimulation. It is well-known that broad, negative-going potentials are present in the event-related potential (ERP) between a forewarning cue and a tactile stimulus. It has also been shown that the alpha-range mu rhythm shows a lateralized desynchronization over central electrode sites during anticipation of tactile stimulation of the hand. The current study used a tactile discrimination task in which a visual cue signaled that an upcoming stimulus would either be delivered 1500 ms later to the participant's hand, to a task partner's hand, or to neither person. For the condition in which participants anticipated the tactile stimulation to their own hand, a negative potential (contingent negative variation, CNV) was observed in the ERP at central sites in the 1000 ms prior to the tactile stimulus. Significant mu rhythm desynchronization was also present in the same time window. The magnitudes of the ERPs and of the mu desynchronization were greater in the contralateral than in the ipsilateral hemisphere prior to right hand stimulation. Similar ERP and EEG changes were not present when the visual cue indicated that stimulation would be delivered to the task partner or to neither person. The absence of social influences during anticipation of tactile stimulation, and the relationship between the two brain signatures of anticipatory attention (CNV and mu rhythm) are discussed.

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1. Introduction

Increasing efforts are being dedicated to studying the role of somatosensory processes in social perception (see [Keyzers et al., 2010](#); [Zaki et al., 2016](#), for review), including the question of whether brain networks involved in somatosensory processing are active in response to observing tactile stimulation of others. Shared activations in primary (SI) and secondary somatosensory cortex (SII) during direct somatosensory stimulation and during observation of another person being touched have been reported in a number of studies employing functional magnetic resonance imaging (fMRI; [Blakemore et al., 2005](#); [Ebisch et al., 2008](#); [Keyzers et al., 2004](#); [Kuehn et al., 2014](#); [Schaefer et al., 2009](#)), with additional activation in anterior cingulate cortex (ACC) and anterior insular (AI) when experiencing or witnessing painful stimulation ([Costantini et al., 2008](#); [Jackson et al., 2006](#); [Lamm et al., 2009](#)). In addition to these fMRI findings, there is a growing literature examining related questions using electroencephalographic (EEG) and magnetoencephalographic (MEG) techniques. Much of

this work has focused on the mu rhythm, which occurs in the alpha frequency range at central electrode sites overlying sensorimotor cortices. Mu rhythm suppression has been documented during the experience of touch ([Cheyne et al., 2003](#); [Gaetz and Cheyne, 2006](#)), and during the observation of social touch ([Peled-Avron et al., 2016](#)) and pain ([Cheng et al., 2008](#); [Perry et al., 2010](#); [Riečanský et al., 2015](#); [Whitmarsh et al., 2011](#)). Furthermore, viewing painful stimulation elicits stronger mu desynchronization than watching non-painful tactile stimulation ([Höfle et al., 2013](#); [Perry et al., 2010](#); [Whitmarsh et al., 2011](#); [Yang et al., 2009](#)).

These findings of neural activation during observation of touch have been used to support the broader notion that we relate to others' experiences in part through mapping the sensations (e.g., tactile sensations) experienced by other people onto our own sensory representations ([Keyzers et al., 2010](#)). However, despite much interest in this idea, the necessary conditions under which such shared activations might occur remain poorly understood, and the specific role of activation of somatosensory cortex in understanding others' somatic states is not clear ([Chan and Baker, 2015](#); [Lamm et al., 2015](#)). One limitation of prior work in this area is that most studies have examined changes in brain activity at a relatively coarse temporal resolution. Different stages

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of a “touching” event (either seen or felt), such as the anticipation of stimulation, the motion of an object or a hand approaching the stimulation location, and the contact itself, might be associated with the activation of different neural circuitries. To explore the specifics of shared somatosensory activations, it may be useful to isolate and examine these various stages. In this respect, the high level of temporal resolution provided by EEG methods can be helpful in unraveling the complexities of the similarities and differences in cortical activity between somatosensory stimulation to oneself and stimulation of others.

In the current study we take a novel approach by applying EEG techniques to examine the anticipatory processes that occur following a cue signaling the impending presentation of a tactile stimulus to self or other. Although prior studies of shared somatosensory activations have generally not considered anticipatory responses, there is a growing literature on the dynamics of EEG responses during anticipation of sensory stimulation (Arnal and Giraud, 2012). Another novel aspect of the current study comes from the fact that prior work in this area has often employed short video stimuli depicting another person being touched. Here we focus on anticipation of tactile stimulation using a protocol in which touch was not observed, but instead was signaled through a visual cue that indicated the impending delivery of a tactile stimulus to oneself or to another person. Very few studies have employed this kind of protocol. An fMRI study on empathy for pain (Singer et al., 2004) employed a visual cue to signal that an impending painful or non-painful electrical stimulus would be delivered a few seconds later to the hand of either oneself or one's partner. Responses to the painful stimulation being delivered to the partner were noted in the anterior cingulate cortex (ACC) and anterior insula (AI), areas associated with empathy, arousal, and anxiety (Lamm and Singer, 2010). However, due to a lack of temporal resolution of fMRI data, the specific anticipatory aspects of these responses were not clear. It also remains an open question whether there are commonalities in neural responses over somatosensory areas during anticipation of tactile stimulation being delivered to oneself or another person. In the present study we examine this question by tracing changes in EEG alpha band power and changes in slow potentials in the event-related potential (ERP) during anticipation of an impending tactile stimulus.

There is increasing interest in the role of the alpha rhythm (8–14 Hz in adults) in anticipatory neural processes (Arnal and Giraud, 2012; Anderson and Ding, 2011; Haegens et al., 2012; Jones et al., 2010; van Dijk et al., 2008). Much of the work in this area has involved the anticipation of visual targets in spatial attention tasks, in which a cue signals the impending appearance of the target and further indicates the location (e.g., the left vs. right side of the monitor screen) at which the target can be expected to appear. During the epoch between the cue and the target, an event-related desynchronization (ERD) in alpha power is typically seen over occipital scalp sites contralateral to the cued location (Kelly et al., 2006; Sauseng et al., 2005; Thut et al., 2006; Worden et al., 2000), with some studies also reporting an ipsilateral event-related synchronization (ERS) of the posterior alpha rhythm (Rihs et al., 2009). With regard to anticipation of tactile stimuli, a similar desynchronization following a cue has been reported for the alpha-range mu rhythm over central electrode sites. For instance, if a cue signals impending stimulation of the left hand, an anticipatory desynchronization is seen in the alpha frequency range over the contralateral (right) central electrode site. The extent of anticipatory mu desynchronization is correlated with tactile discrimination and detection accuracy (Anderson and Ding, 2011; Jones et al., 2010; Linkenkaer-Hansen, 2004; Schubert et al., 2009), as well as with the expected intensity of tactile stimulation (Höfle et al., 2013). Across both visual and somatosensory modalities, the anticipatory desynchronization of alpha-range rhythms (over posterior and central sites

respectively) has been proposed to indicate an attentional mechanism involving an increase in local sensory cortex excitability, which increases the perceptual salience of incoming tactile stimuli (Foxe and Snyder, 2011).

In addition to the alpha rhythm, another anticipatory component in the EEG signal is a slow negative potential that is commonly known as the contingent negative variation (CNV; Brunia et al., 2012; Tecce, 1972; Van Boxtel and Bocker, 2004; Walter et al., 1964). The CNV is a slow buildup of a negative-going EEG potential during the interval between a warning/cue stimulus (S1) and a target stimulus (S2), which has been interpreted as reflecting the deployment of attention (Babiloni et al., 2003; Bickel et al., 2012; Hamano et al., 1997; Tecce, 1972), timing processes (e.g. gauging expected duration of cue-target interval; Jang et al., 2016; Macar and Vidal, 2009; Mento, 2013; van Rijn et al., 2011) or changes in alertness (Pauletti et al., 2014; Posner, 2008). The CNV is commonly observed over frontal-central regions prior to the delivery of auditory or tactile stimuli (Chennu et al., 2013; Kononowicz and Penney, 2016; Pauletti et al., 2014), and has a strong parietal-occipital distribution preceding visual targets (Gómez et al., 2007). The amplitude of the CNV is modulated by several factors, including whether the target stimulus (S2) requires a motor response, which elicits larger CNV amplitudes than non-motor responses (Bareš et al., 2007). Other studies have reported that the complexity of tasks is associated with CNV amplitude (Kranczoch et al., 2010; Cui et al., 2000). CNV amplitude is also reduced by insertion of distractors (Tecce and Scheff, 1969), but not attenuated by stimuli repetitions (Pauletti et al., 2014).

Studying mu ERD and the CNV has yielded useful insights into the neural processes that are active during the anticipation and subsequent perception of somatosensory stimulation. However, whether similar electrophysiological responses can also be observed during the anticipation of other peoples' somatosensory experiences has not yet been investigated. Vicarious activations elicited in somatosensory cortex during direct observation of tactile stimulations to others suggested an important role of somatosensory cortex in social perception and empathy (Keyers & Gazzola, 2009; Schaefer et al., 2009). However, the necessary conditions for such vicarious activation, as well as the time course of such activation, remain unknown. It is possible that social perception also influences anticipatory neural activities prior to the onset of actual tactile events, which would suggest a role for attention networks and thalamo-cortical circuitries. In the present study, EEG was recorded from undergraduate participants while they completed a simple tactile-discrimination task with an experimenter. Prior to each tactile stimulus, cues were presented on a screen signaling whether tactile stimulation would be presented to the participant, their partner, or neither. Analyses focused on changes in the mu rhythm and the amplitude of the anticipatory CNV between the onset of the visual cue and the tactile target stimulus. If vicarious activation in response to others' somatosensory states occurs during the anticipation of a tactile stimulus delivered to another person, mu rhythm ERD and a CNV potential would not only be observed when participants are expecting tactile stimulation to themselves, but would also be measurable during anticipation of stimulation of their task partner.

The insights gleaned from this study can add to our understanding of social influences on anticipatory neural processes, and can expand current understanding on vicarious activation and social empathy. A supplementary goal of the current analyses was also to examine the relations between mu rhythm ERD and the anticipatory negativities. Despite the fact that these two anticipatory measures are usually elicited in similar experimental paradigms and occur over similar time frames, the relation between them is not clear (Green and McDonald, 2010; Grent-T-Jong et al., 2011).

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