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THE COGNITIVE AND NEURAL TIME COURSE OF EMPATHY AND SYMPATHY: AN ELECTRICAL NEUROIMAGING STUDY ON SELF–OTHER INTERACTION

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Abstract—Although extensively investigated in socio-cognitive neuroscience, empathy is difficult to study. The first difficulty originates in its multifaceted nature. According to the multidimensional model, empathy combines emotional, automatic (simulation), cognitive (mentalizing) and regulatory (executive functions) processes. Substantial functional magnetic resonance imaging (fMRI) data demonstrated that co-activations in the mirror neuron system (MNS) and mentalizing network (MENT) sustain this co-recruitment of so-called first- and second-person-like processes. Because of the poor temporal resolution of fMRI techniques, we currently lack evidence about the precise timing of the MNS–MENT combination. An important challenge is, thus, to disentangle how MNS and MENT dynamically work together along time in empathy. Moreover, the role of the executive functions in the MNS–MENT combination time course is still unknown. Second, empathy – feeling *into* – is closely related to sympathy – feeling *with* – and both phenomena are often conflated in experimental studies on intersubjectivity. In this electrical neuroimaging (EEG) pilot-study, we tested whether the egocentered vs. heterocentered visuo-spatial mechanisms respectively associated with sympathy and empathy differentially modulate the dynamic combination of the MNS–MENT activations in their respective neural time course. For that, we employed our newly developed behavioral paradigm assessing the visuo-spatial – but not emotional – features of empathy and sympathy. Using a data-driven approach, we report that empathy and sympathy are underlied by sequential activations in the MNS from the insula to the inferior frontal gyrus (IFG) between 63 ms and 424 ms. However, at 333–424 ms, empathy triggered greater co-activations in the right IFG and dorsolateral prefrontal cortex (dlPFC) (executive functions). Linking together our present and prior (Thirioux et al., 2010) findings from the same dataset, we suggest that this greater recruitment of the right dlPFC monitors the shift from egocentered and first-person-like mechanisms in the MNS to heterocentered and second-person-like mechanisms in the left temporo-parietal junction within the MENT, i.e., reflecting the onset of perspective-change processes in the neural time course of empathy. Contrasting with sympathy, this recruitment of the executive functions could modulate the output end of the mirroring processing in the premotor and sensorimotor cortices.

Key words: empathy, sympathy, simulation, mentalizing, visuo-spatial mechanisms, cortical dynamics.

INTRODUCTION

Empathy is the capacity to share, react to, and understand the lived experience and associated mental state of others (Davis, 1994). Two major difficulties hinder the scientific study of empathy. The first one lies in its multifaceted nature (Davis, 1994; Preston and de Waal, 2002; Preston, 2007). As a complex socio-cognitive construct (Berthoz, 2004; Thakkar et al., 2009), empathy incorporates emotional, automatic, cognitive and regulatory processes, and relies upon the dynamic combination of cooperating and/or competing activations (Berthoz, 2004) in topographically distributed

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Abbreviations: AAHC, atomize and agglomerate hierarchical clustering; aSTS, anterior part of the superior temporal sulcus; CV, cross-validation; dlPFC, dorsolateral prefrontal cortex; dPMC, dorsal part of the premotor cortex; dmPFC, dorsomedial prefrontal cortex; EBA, extrastriate body area; EEG, electrical neuroimaging; EP, evoked potential; fMRI, functional magnetic resonance imaging; GEV, global explained variance; GFP, global field power; IFG, inferior frontal gyrus; IPL, inferior parietal lobule; KL, Krzanowski–Lai; LAURA, local auto-regressive average; MENT, mentalizing network; MIR-task, Mirroring task; MNI, Montreal Neurological Institute; MNS, mirror neuron system; MTG, middle temporal gyrus; OBT-task, Own-Body Transformation task; pMTG, posterior MTG; pSTG, posterior STG; pSTS, posterior part of the superior temporal sulcus; SPO-task, spontaneous task; SP, solution point; STG, superior temporal gyrus; ToM, Theory of Mind; TP, temporal poles; TPJ, temporo-parietal junction; vmPFC, ventromedial PFC; vPMC, ventral part of the PMC.

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and functionally distinct (e.g., bottom-up and top-down) brain networks (Decety and Jackson, 2004; Decety, 2007). A main challenge is, thus, to disentangle how different domain-specific components and neuro-functional mechanisms dynamically cooperate in empathy. The second difficulty is that empathy is closely related to sympathy. As these share basic processes (feelings and autonomic responses) and outcomes (moral development and prosocial behavior) (Decety and Michalska, 2009; Walter, 2012), empathy and sympathy are often conflated in the devoted literature, except in a few outstanding studies (Decety and Michalska, 2009; Thirioux et al., 2009, 2010; Hojat et al., 2011a,b; Malti et al., 2012). Hence, robust phenomenological and neuro-functional criteria dissociating empathy from sympathy are still missing (Decety, 2009; Thirioux, 2011).

To assess whether and how empathy and sympathy neuro-functionally distinguish, we here focused on elementary but key phenomenological features of the bodily self which are substantial in self-other interaction and differentiate empathy from sympathy (Berthoz, 2004; Berthoz and Thirioux, 2010; Thirioux and Berthoz, 2011): i.e., self-location (the experience of where I am in space; Blanke, 2012) and the egocentered visuo-spatial perspective (the experience from where I perceive the world; Blanke, 2012). Using electrical neuroimaging (EEG), we aimed to test whether different self-location and visuo-spatial mechanisms in empathy and sympathy modulate the dynamic combination of the automatic, cognitive, and regulatory processes and their underlying neural networks along time. To our knowledge, there is until now no study that has explored this question.

Phenomenological distinction between sympathy and empathy

Sympathy and empathy consist respectively in ‘‘feeling with’’ and ‘‘feeling into’’ someone else (from the Germane ‘‘mit [with] vs. ein [into] - fühlen [to feel]’’; Jorland and Thirioux, 2008; Gelhaus, 2011; Hojat et al., 2011b). This feeling refers to the mental experience of one’s physiological and bodily states and changes (Damasio and Carvalho, 2013) that are triggered by the perception of the others’ current experience. In accordance with the traditional phenomenological theories (Lipps, 1913; Vischer, 1927; Husserl, Hua XII–XV), we define this feeling as what enables to access the embodied mind of others, i.e., ‘‘in their bodily and behavioral expressions’’ (Zahavi, 2008) – irrespective of the content (emotions, sensations, actions etc.. . .) of the others’ lived experience. Accordingly, we do not reduce empathy and sympathy to the sole sphere of emotions – although emotions are the core of these social phenomena – but further extend them to the intentional, motor and somatosensory modalities (Berthoz, 2004; Berthoz and Thirioux, 2010; Thirioux, 2011; Thirioux and Berthoz, 2011).

When sympathizing – feeling with – individuals are feeling the same thing as others are feeling (the same kind of inner state; Gelhaus, 2011) and at the same time (Olinick, 1987), tending to merge identities (Wilmer, 1968). This self-other identification is prompted by the attribution of the other’s experience to oneself as if individuals were the other person (Gelhaus, 2011). We have lately proposed that self-attribution is based upon a body-related mental imagery and spatial transformation process in which individuals are mapping the others’ body into their own-body in a mirror-like linear manner [Other→Self] (Thirioux et al., 2009, 2010). Accordingly, sympathy is associated with embodied self-location (the normal experience that the self is located within one’s bodily borders at a specific position in space; Arzy et al., 2006) and egocentered visuo-spatial perspective (Fig. 1A), i.e., without perspective-change.

In contrast, the prerequisite for empathy – feeling into – is a sort of awareness of being outside the other person and having ‘‘to reach [her/him]’’ (Gelhaus, 2011). It enables to understand the other’s current experience as the experience of another one, maintaining self-other distinction (Decety and Jackson, 2004; Singer et al., 2004; Decety, 2007; Hein and Singer, 2008). Therefore, empathy requires perspective-change – contrasting with sympathy – and is based upon a mental transformation of one’s own-body in space in which individuals are mapping their body into the other’s body in a rotation-like manner [Self→Other] (Thirioux et al., 2009, 2010). Accordingly, empathy is associated with disembodied self-location (in which the imagined self-location does not match the position of one’s physical body in space; Blanke et al., 2005) and heterocentered (centered on the other’s body; Degos et al., 1997) visuo-spatial perspective (Fig. 1A).

The multidimensional model of empathy

The automatic and emotional components of empathy correspond to the internal reproduction of another person’s subjective experience and associated mental state, as if individuals were experiencing this given mental state themselves. These are very similar to the first-person-like processes involved in simulation (Goldman, 2006). Mirror neuron system (MNS) has been hypothesized to be the plausible neurobiological bases for simulation (Gallese et al., 1996; Gallese, 2001). Numerous neuroimaging studies have reported isomorphic activations between observation and action execution in the motor system (Iacoboni et al., 1999; Buccino et al., 2001; Grèzes et al., 2003; Binkofski and Buccino, 2006; Newman-Norlund et al., 2007) as well as in the anterior insula and amygdala (Wicker et al., 2003; Schnell et al., 2011) and secondary somatosensory cortex (Keysers et al., 2004) in the case of emotions and sensations, respectively. Specifically, an ‘‘extended motor MNS’’ – insula, middle temporal gyrus (MTG), posterior part of the superior temporal sulcus (pSTS), dorsal part of the premotor cortex (dPMC) and sensorimotor cortex (i.e., primary motor cortex and S1/S2) – has been put forward to critically transform the information essential for the motor simulation outcome that is sustained by the ‘‘core MNS’’ – inferior parietal lobule (IPL) and ventral part of the PMC (vPMC or inferior frontal gyrus [IFG]) (Pineda, 2008). Furthermore,