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Research Report

Neural activity during social signal perception correlates with self-reported empathy

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ABSTRACT

Empathy is an important component of human relationships, yet the neural mechanisms that facilitate empathy are unclear. The broad construct of empathy incorporates both cognitive and affective components. Cognitive empathy includes mentalizing skills such as perspective-taking. Affective empathy consists of the affect produced in response to someone else's emotional state, a process which is facilitated by simulation or "mirroring." Prior evidence shows that mentalizing tasks engage a neural network which includes the temporoparietal junction, superior temporal sulcus, and medial prefrontal cortex. On the other hand, simulation tasks engage the fronto-parietal mirror neuron system (MNS) which includes the inferior frontal gyrus (IFG) and the somotosensory related cortex (SRC). Here, we tested whether neural activity in these two neural networks was related to self-reports of cognitive and affective empathy in daily life. Participants viewed social scenes in which the shift of direction of attention of a character did or did not change the character's mental and emotional state. As expected, the task robustly activated both mentalizing and MNS networks. We found that when detecting the character's change in mental and emotional state, neural activity in both networks is strongly related to cognitive empathy. Specifically, neural activity in the IFG, SRC, and STS were related to cognitive empathy. Activity in the precentral gyrus was related to affective empathy. The findings suggest that both simulation and mentalizing networks contribute to multiple components of empathy.

1. Introduction

The capacity to empathize with others is crucial for building and maintaining successful interpersonal relationships (Batson and Shaw, 1991; Davis, 1996). Empathy requires understanding someone else's mental and emotional state and responding to them appropriately—a process which incorporates both affective and cognitive components (Davis, 1996; Leiberg and Anders, 2006; Singer, 2006). The affective component of empathy consists, primarily, of the affective state that is produced in response to another person's emotional experience. This affective response often results in sharing the same emotion that is observed, such as feeling sad about someone else's loss, and it is related to the understanding of

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the other person's emotional state. The cognitive component of empathy consists of understanding a situation from another person's point of view and taking into account that the other person acts and reacts to a situation based on beliefs, goals, and intentions that may be different from one's own. This process is referred to as *mentalizing* or *Theory of Mind*.

Evidence suggests that these two components of empathy rely on different psychological and neurological mechanisms (Shamay-Tsoory et al., 2009). Affective empathy is hypothesized to arise via the process of simulation which relies on imitation (or "mirroring" activity) to facilitate emotion understanding and produce affective sharing (Decety and Jackson, 2004; Preston and de Waal, 2002). This simulation theory of empathy is conceptually linked to action-perception models (Preston and de Waal, 2002) and suggests that the observation of an emotional expression automatically activates the motor and somatosensory representation of that emotional expression in the motor and somatosensory regions of the fronto-parietal "mirror neuron system" (MNS) (Gallese and Goldman, 1998; Gallese et al., 2004; Gallese, 2007) . The "mirroring" (i.e. the automatic and often subconscious imitation) of observed emotional expressions produces an embodied representation which can facilitate the decoding of the observed person's emotional state as well as induce that emotional state in the observer (Adolphs, 2002; Preston and de Waal, 2002). The ventrolateral premotor cortex and the inferior parietal cortex have been identified as key neural substrates involved in the "mirroring" of emotional expressions. This includes motor-related cortex, such as the precentral gyrus (BA 4, 6) and inferior frontal gyrus (IFG) (BA 44, 45) (Carr et al., 2003; Pfeifer et al., 2008) and somatosensory-related cortex (SRC) in the inferior parietal lobe, such as the postcentral gyrus (BA 3) and the supramarginal gyrus (BA 40) (Adolphs et al., 2000; Gazzola et al., 2006). Neuroimaging studies show that the IFG is active during the imitation of facial expressions (Carr et al., 2003), and among children, the amount of activity in this region during imitation is related to self-reported empathy (Pfeifer et al., 2008). Furthermore, a lesion in the IFG is associated with poor emotion recognition skills and low affective empathy (Adolphs et al., 2000; Shamay-Tsoory et al., 2009).

On the other hand, mentalizing is a more cognitively effortful process that develops later in life and involves a different set of neural mechanisms (Saxe et al., 2004). Neuroimaging studies which require participants to represent the belief state or intentional stance of another person reliably activates a set of brain regions, including the temporoparietal junction (TPJ), the superior temporal sulcus (STS), the medial prefrontal cortex (MPFC), and the temporal poles (Frith and Frith, 2006; Gallagher and Frith, 2003). Lesion studies support the idea of a devoted neural network for processes related to cognitive empathy. For example, neurological patients with left superior temporal lesions have deficits on theory of mind tasks, such as the false belief task (Samson et al., 2004), and ventral MPFC lesion patients have low self-reported cognitive empathy whereas their affective empathy is in normal range (Shamay-Tsoory and Aharon-Peretz, 2007; Shamay-Tsoory et al., 2009).

Despite this initial evidence that imitation and mentalizing support affective and cognitive components of empathy, it is still unclear the extent to which they rely on dissociable neural regions. More importantly, it is also unknown how neural activity in regions associated with the two systems (MNS and mentalizing) is related to the use of these empathic processes in daily life. Neuroimaging studies that have sought to show differences in the MNS versus mentalizing networks have used different stimuli for each condition (e.g. (Hynes et al., 2006; Nummenmaa et al., 2008; Shamay-Tsoory et al., 2005). These studies show that certain regions are more sensitive to specific stimulus features. For example, Saxe and Powell (2006) investigated neural response to stories describing another person's thoughts as compared to another person's bodily states. They found that the TPJ was active to descriptions of thoughts and beliefs whereas the SRC was active to descriptions of bodily states such as hunger, thirst, and exhaustion (Saxe and Powell, 2006). While this suggests that designated regions are relatively more sensitive to specific features, it does not reveal how neural activity in response to these stimulus features support the complex process of empathizing with another person.

Furthermore, most tasks that involve social and emotional processing, particularly those that attempt to mimic social interactions, will engage neural response from both the MNS, and the mentalizing systems (Hynes et al., 2006; Schulte-Ruther et al., 2007). This underscores the fact that it is difficult to separate emotions and beliefs because emotional response is usually based on a person's belief about a situation. Additionally, the observer's understanding of another person's emotional state is dependent of the observer's understanding of context. For example, the facial display of surprise may use the same facial motor action regardless of whether that surprise occurs in the context of a positive or negative event (Ekman and Friesen, 1978); however, it is only when the context is integrated with the expression does the observer really understand what that person is feeling and is able to respond appropriately (Barrett, 2006; Barrett et al., 2007; Kim et al., 2004).

Here, we address these issues with a task aimed at engaging activity related to both mentalizing and MNS and then identifying whether mentalizing and imitation-related regions are correlated with self-reports of cognitive and affective empathy, respectively. We created a series of complex social scenes in which each scene is a static snapshot of a different story scenario. In each scene, one character has full knowledge about what is happening in the scene (i.e. a "True Belief") and one character has only partial knowledge or a misunderstanding about what is happening (i.e. a "False Belief"). Both characters display emotional expressions based on their beliefs about the situation. During the task, participants view the scene and have time to comprehend the social scenario. Then one of the characters in the scene changes their direction of attention by shifting their head and body orientation. In the primary condition of interest, the Social Change condition, the shift in direction of attention results in a visible change in mental state. Due to the direction of attention shift, the character with only partial knowledge sees something in the scene which changes their belief about the situation as well as their emotional response based on that belief (see Supplemental Materials for a description of the scenarios). The expectation is that the observed biological action associated with the change in emotional state, as understood from body gestures and facial expressions, will activate MNS regions, such as the ventrolateral premotor cortex and the somatosensory related cortex (SRC). At the same time, the change in belief state, i.e. changing from a