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Review article

The junction between self and other? Temporo-parietal dysfunction in neuropsychiatry

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ABSTRACT

The temporo-parietal junction (TPJ) is implicated in a variety of processes including multisensory integration, social cognition, sense of agency and stimulus-driven attention functions. Furthermore, manipulation of cortical excitation in this region can influence a diverse range of personal and interpersonal perceptions, from those involved in moral decision making to judgments about the location of the self in space. Synthesis of existing studies places the TPJ at the neural interface between mind and matter, where information about both mental and physical states is processed and integrated, contributing to self-other differentiation. After first summarising the functions of the TPJ according to existing literature, this narrative review aims to offer insight into the potential role of TPJ dysfunction in neuropsychiatric disorders, with a focus on the involvement of the right TPJ in controlling representations relating to the self and other. Problems with self-other distinctions may reflect or pose a vulnerability to the symptoms associated with Tourette syndrome, Schizophrenia, Autistic Spectrum Disorder and Obsessive Compulsive Disorder. Further study of this most fascinating neural region will therefore make a substantial contribution to our understanding of neuropsychiatric symptomatology and highlight significant opportunities for therapeutic impact.

Contents

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1. Functions of the temporo-parietal junction

The temporoparietal junction (TPJ, Fig. 1) is a functionally defined region encompassing an area of cortex around the inferior parietal lobe, lateral occipital cortex, and posterior superior temporal sulcus (Mars et al., 2012). Anatomically, the TPJ has structural connections to areas including prefrontal cortex (Mesulam and Geschwind, 1978), cingulate gyrus (Chafee and Goldman-Rakic, 2000), premotor cortex (Rushworth et al., 2006) putamen and thalamus (Kucyi et al., 2012). The arcuate fasciculus and subcomponent III of the superior longitudinal fasciculus connect the TPJ and inferior frontal gyrus (Schmahmann et al., 2007; Umarova et al., 2010). TPJ connections to lateral and medial temporal areas include hippocampus and parahippocampus (Clower et al., 2001; Rockland and Van Hoesen, 1999; Seltzer and Pandya, 1984). Furthermore, some of these pathways may demonstrate hemispheric asymmetry, such as tracts along the extreme capsule which connect the TPJ to the insula (Kucyi et al., 2012).

The wealth of literature on TPJ function spans sensory, cognitive, emotional, social and motor domains, reflecting involvement in processes that contribute to our experience of both the external material world, derived through automatic awareness of sensory feedback; and the internal mental world, defined by transient emotional states and motivations. In sum, TPJ functions appear to underpin both mental and physical aspects of the self. TPJ dysfunction could therefore have a range of detrimental effects on conscious human experience and impact mental health. The focus of this narrative review reflects the emerging interest in the contribution of the right TPJ to the control of representations that differentiate between self and other. A brief introduction first highlights areas of research linked to the TPJ which may contribute to self-other judgments: multisensory processing, action imitation, sense of agency, attention and Theory of Mind (ToM): reasoning about mental states such as beliefs, intentions and emotions. Literature relating to TPJ subdivisions and lateralisation is then summarised. Discussion thereafter centres on application of theory and experimental observations involving self-other distinction to the understanding of symptoms in neuropsychiatric disorders, with a view to promoting discussion around the role of the TPJ in health and disease, and providing timely and novel hypotheses to stimulate further research. Studying conditions thought to involve TPJ dysfunction could highlight novel links between brain structure and function, as well as offer insight into the ontogenetic and neurodevelopmental aspects of this region, and the wider influence of TPJ involvement in healthy cortical networks.

1.1. Multisensory integration

The TPJ is an area of convergence for somatosensory, auditory and visual evoked responses (Matsuhashi et al., 2004) and involved in sensorimotor integration (Blanke and Mohr, 2005). Studies of multisensory integration frequently refer to the concepts of bodily self-consciousness and physical embodiment (see Blanke et al., 2015; Longo et al., 2008). Multisensory information is combined to give the feeling of bodily self-consciousness, and being a unified entity (Ionta et al., 2011a) localised at a certain position in space (Ionta et al., 2011b). If this process breaks down, or the mental and physical aspects of the self are poorly integrated, this may result in out of body experiences (e.g. Blanke and Arzy, 2005).

Blanke et al. (2005) showed that transcranial magnetic stimulation (TMS) of the TPJ region can selectively impair the ability to imagine relocation of the self. Participants completed a task which involved making decisions about whether a glove was on the left or right hand of a figure, versus the left or right side of a computer screen. Comparisons with a task which involved rotating letters indicated that TPJ stimulation specifically affected own body reorienting. More recently, Limanowski and Blankenburg (2015) showed increased activity in the TPJ was associated with decreased sense of body part ownership. Furthermore, TMS to the right TPJ can eliminate the effect of competing sensory information implying a role in the detection of inter-sensory conflict (Papeo et al., 2010). In sum, the TPJ underpins processes necessary for the perception of being mentally and physically in a single spatial location. These perceptions influence judgments relating to embodiment (Arzy et al., 2006) and self-other distinctions (van der Meer et al., 2011; Vogeley et al., 2001).

1.2. Control of imitation

Non-verbal imitation of conspecifics appears innate and automatic (Chartrand and Bargh, 1999) and is a context within which the distinction between self and other may become blurred. This ability may involve mirror neurons, which respond to both observation of another person performing a particular action and self-execution of that same action (Rizzolatti and Craighero, 2004). While the human mirror neuron system is thought to include premotor, posterior parietal and inferior frontal cortices (e.g. Plata Bello et al., 2015; Cerri et al., 2015), right TPJ is frequently active during imitation tasks that likely recruit mirror neurons. For example, one study found increased activity of right superior temporal sulcus extending to TPJ during trials in which the spatial mapping between observed and executed hand movements complicated the participants' task (Mengotti et al., 2012).

Shared representations, which contribute to behaviours such as imitation, may be the 'default-state' of the sensorimotor system (Brass et al., 2009). Spengler et al. (2010) found that TPJ lesions can impair the ability to suppress non-adaptive imitation. Furthermore, the ability to inhibit imitative responses was correlated with self-reported cognitive perspective taking (i.e. the tendency to put oneself in the position of another person). In addition, Santiesteban et al. (2015a) found that electrical stimulation over left or right TPJ can modulate participants' performance on both imitation inhibition and perspective taking tasks. Imitation inhibition involves exerting control over a shared representational system which may be similarly activated for the same actions and perhaps mental states (e.g. physical viewpoints) in both the self and others. This system could help us appreciate the goals of observed actions, and therefore actor intentions, perhaps in addition to more basic physical expressions of emotion (see Sperduti et al., 2014a; Keysers and Gazzola, 2014).

1.3. Sense of agency

Perceiving a coherent self which can be separated from others will impact sense of agency (SoA), i.e. perceptions about whether the self is the cause of experienced actions and sensory effects. A physically coherent self will at least partly rely on multi-sensory and sensorimotor integration, while a mentally coherent self may involve integration of mental states with physical self. SoA may be subdivided into automatic identification of actions as our own, and more conscious judgments of agency (Jeannerod, 2009). The automatic level allows for online action control. The forward model of motor control (Wolpert et al., 1995) holds that judgments about whether an action is as planned are based on whether the incoming sensorimotor information matches the original predicted state. The movement is perceived as self-generated only if re-afferent signals match the expectation of the internal model (Jeannerod, 2009). When visual feedback is involved, agency judgments for actions may rely on perception-action coupling within the TPJ (Ro et al., 1998). The conscious level of agency judgment provides information about the actor's goals or mental