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https://link.springer.com/referenceworkentry/10.1007/978-3-319-28099-8_863-1

Temporo-parietal junction

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Short Entry contribution for the *Encyclopedia of Personality and Individual Differences* (Eds. Virgil Zeigler-Hill and Todd Shackelford).

The authors have no conflict of interest to declare.

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Word count: 2,077 words (2,000 words max)
Reference count: 10 (10 references max)

Title of entry: Temporoparietal junction
Synonyms: temporo-parietal junction, tempo-parietal junction, tempoparietal junction, TPJ.

Definition

The temporoparietal junction (TPJ) is a heteromodal association cortex located, in each hemisphere, at the intersection of the parietal and the temporal lobe. Its functions are mainly associated with attention and social cognition. Its anterior and posterior parts have distinct connectivity and functional profiles, suggesting that they deal with different high-level processes contributing to monitoring for salient stimuli and reasoning about oneself and others, respectively.

Introduction

Due to its size and its bi-laterality, the TPJ is attributed numerous functions. Whether these functions are underpinned by one overarching mechanism is highly debated given that there is evidence in favour of both functional overlap (Carter & Huettel, 2013; Decety & Lamm, 2007; Geng & Vossel, 2013; Lamm, Bukowski, & Silani, 2016) and functional division (Igelstrom, Webb, & Graziano, 2015; Kubit & Jack, 2013). In light of this complexity, this entry puts an emphasis on the attentional and social cognitive aspects, the two most established sets of functions associated with the TPJ. To facilitate the understanding of the functional organization of the TPJ ,the entry is organized by first describing its anatomy, then its functions and their associated localizations within the TPJ, an illustration of putative functional specializations based on meta-analytic data (see Figure 1), and finally an outline of hypothesized overarching mechanisms.

Anatomy

The TPJ is consistently viewed as encompassing neural tissue bordering the boundary between the posterior temporal and inferior parietal lobes (Bzdok et al., 2013; Corbetta, Patel, & Shulman, 2008; Decety & Lamm, 2007). Since this lacks clear anatomical landmarks, one way to better grasp this boundary is to draw a straight line connecting the end of the Sylvian fissure to the rostrolateral edge of the occipital cortex. Above that line, there are anteriorly the supramarginal gyrus (SMG) and posteriorly the angular gyrus (AG). Below the line, there are the most posterior extents of the superior temporal gyrus (STG) and sulcus (STS). Some authors have decomposed this vast area in sub-regions based on their structural and functional connectivity (Geng & Vossel, 2013; Igelstrom et al., 2015), their cytoarchitecture, or their functional specializations (Bzdok et al., 2013; Cabeza, Ciaramelli, & Moscovitch, 2012; Carter & Huettel, 2013; Decety & Lamm, 2007; Kubit & Jack, 2013). A dual partition into anterior TPJ (aTPJ) and posterior TPJ (pTPJ) is most consistently reported across these studies. The aTPJ covers the posterior SMG and the most dorsal extent of the STG and is associated with attention through a mid-cingular – insular – ventral prefrontal network. The pTPJ covers the AG and the last segment of the STS and is associated with social cognition through a parietal – medial prefrontal network.

Functions

A variety of functions has been assigned to the TPJ, of which some of the most consistently discussed ones are:

<u>Reorienting attention</u> refers to detection of unattended but behaviourally salient stimuli towards which attention is shifted, or reflexively reoriented from a different focus of attention. These stimuli are salient because they were expected (e.g., searched for), unexpected, or associated with emotion or reward. This attentional mechanism is implemented via the ventral attention network , in which the aTPJ (with a right hemispheric dominance) plays a major role (Cabeza et al., 2012; Corbetta et al., 2008).

Conflict, or interference, resolution consists in selecting the appropriate response and inhibiting the inappropriate and interfering response following the detection of a stimulus signalling the need to update the internal model (e.g., planned action) of what is the appropriate response such as in during go/no-go, stroop, and stop signal tasks. Conflict resolution consistently recruits the right middle TPJ, in between the SMG and the AG (Seghier, 2012).

Episodic memory is the memory of personal events, whose time, place, and subjective experience can be explicitly recalled. Recalling personal events, or judging whether an event has been previously personally experienced recruits bilaterally the pTPJ, with a left hemispheric dominance that might stem from the higher prevalence of verbalization of the memories (Cabeza et al., 2012; Seghier, 2012)**.**

Autobiographical memory gathers the episodic memory but also involves the semantic memory regarding all the known facts and meanings about our personal identity. It typically recruits bilaterally the pTPJ, with a left hemispheric dominance (see also STS for details)(Seghier, 2012).

Resting state refers to a paradigm consisting in freely thinking about oneself (i.e., **self-referential thinking**) and others (i.e., mentalizing) and largely recruits the so-called default network, which includes the pTPJ (Seghier, 2012) (see also STS entry for details).

Semantic processing: The left pTPJ is particularly associated with concept retrieval, conceptual integration, and more generally with processing of words and sentences conveying meaning (Cabeza et al., 2012; Seghier, 2012).

Mentalizing refers to inferring the mental states of others. This process is the common denominator of all social cognitive tasks and typically recruits bilaterally the pTPJ with a right hemispheric dominance (Bzdok et al., 2013; Cabeza et al., 2012; Decety & Lamm, 2007; Seghier, 2012). These social cognitive tasks encompass **Theory of Mind** (ToM; i.e., attributing mental state to others, in particular in paradigms where the other person holds a false belief), **perspective taking** (i.e., de-centring from our egocentric perspective), **cognitive empathy** (i.e., when the other person's feelings need to be imagined or understood rather than perceived or felt), **economic games** (i.e., predicting others' strategies), **altruism** (i.e., prioritizing the other person's interest over our own), and **moral reasoning** (i.e., assess morality of hurtful actions). Because mentalizing relies on the combination of many cognitive processes, the TPJ itself may contribute to mentalizing across various, possibly complementary, functions presented in this entry, such as self-other distinction, perspective shifting, social context representation, detection of unexpected event, and updating the internal model. Congruently, **individual differences** in TPJ's anatomical and functional features have been related to anthropomorphism tendencies, altruism, loneliness, warmth-altruism personality traits, and social network size.

Self-body awareness consists in knowing where is and what constitutes our body, based on the multisensory integration of exteroceptive and interoceptive signals. The TPJ, with a right hemispheric dominance, integrates visual, somatosensory, and vestibular bodily information and is particularly active during multisensory conflicts altering our self-body awareness, such as the "out-of-body" experience (Decety & Lamm, 2007).

Agency refers to the feeling of being the cause of our own actions and mental states. Alterations of the sense of agency through mismatching multisensory perception recruits the right pTPJ (Decety & Lamm, 2007).

Self – other distinction refers to a set of processes whose common function is the distinction between our own body parts, actions, and mental states from those of other people. Without self – other distinction, we tend to, e.g., automatically imitate the other or feel like the other, or fail to recognize the non-shared qualities of the other person's mental life.

Emotion regulation through cognitive reappraisal consists in re-interpreting or changing the appraisal of an affective stimulus in order to regulate its emotional impact. This process consistently recruits bilaterally the middle TPJ.

Hypothetical overarching mechanisms

In light of this variety of functions, there have been some attempts to integrate them, such as into:

Social context representation: The TPJ is proposed to be a nexus integrating highly processed information from social perception (see STS), space and body perception, semantic processing, and memory retrieval. This integration allows representing social agents embedded in a rich social context that may include their location and orientation in space, their appearance, identity, feelings, intentions, beliefs, and personality. This social context then influences information processing, decision-making, and behavior (Carter & Huettel, 2013).

Global detection and re-orienting, that is the detecting and reorienting to salient stimuli, with each TPJ sub-region processing different sensory-cognitive domains (e.g., motor, visual, verbal, social or memory stimuli) based on their particular network connectivity profile (Cabeza et al., 2012).

Breach, or violation, of expectations, or detection of incongruences, in reorienting (invalid trials), Theory of Mind (false-belief trials), or multimodal body perception (visuo-proprioceptive conflicts) paradigms all consistently recruit the TPJ (Corbetta et al., 2008; Geng & Vossel, 2013).

Circuit breaking, network resetting, shifting: The ventral attention network activates once a salient stimulus has been detected; its activation facilitates the reconfiguration of the dorsal attentional network (e.g., search for a new stimulus, or stop searching) or the shifting to a new mode of thinking. This would enable shifting from externally-oriented processes, such as effortful controlled processing of the environmental stimuli to internally-oriented processes, such as retrieval of autobiographical memories or other self-referential processes (Corbetta et al., 2008). Applied to social cognition, **perspective shifting**, that is bidirectional shifting from another person's perspective to our egocentric perspective, could activate the whole TPJ as it requires reorienting attention to detect when such shifting is necessary but also multisensory body representations that needs to become aligned with social agents in the environment (Corbetta et al., 2008).

Generation, testing, and updating of the internal models is a combination of several aforementioned mechanisms, where the TPJ allows inferences richly representing and predicting the environmental social context, and continuously testing its predictions through comparison between the internal models (e.g., intended or predicted sequence of actions) and the external stimuli. According to this view, the right TPJ most strongly responds to needs of significant model updating, that is following the detection of stimuli that are unexpected or violating expectations. Concretely, this overarching mechanism would represent, test, and update the expected sensory experiences of our body actions, the intended actions and mental states of other people, or simply the location of a target (Decety & Lamm, 2007; Geng & Vossel, 2013; Seghier, 2012).

Conclusion

In terms of possible anatomical subdivisions, the anterior TPJ seems to be a key monitoring centre involved in the detection of potentially important stimuli. Their detection is then followed by changing the current thinking to accommodate the detection of this novel information. The posterior TPJ is associated with a large range of high-level functions that implies to reason about oneself and others, an activity we excel at that defines what we do at rest, spontaneously, and every single hour of our wakeful and dreaming lives.

In terms of whether there is an overarching function, no conclusion can be made at the moment. Alternately, the TPJ's putative functions are strongly interacting because we are continuously planning and predicting simultaneously our own and others' actions and outcomes while monitoring for behaviourally salient stimuli signalling the need to shift our current thinking or update our plans and predictions. In this context, such highly complementary functions are difficult to tease apart experimentally and whether these functions form one overarching mechanism could rather depend on the scientist's usefulness of viewing the TPJ as such.

Cross-references

Superior temporal sulcus, Medial Prefrontal Cortex (MedPFC), Theory of Mind, Empathy, Altruism, Agency, Emotion Regulation.

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Figure caption

Figure 1. Illustrations of most common topics of neuroimaging literature (indexed from studies' title and abstract) associated with twelve different TPJ sites equally spaced vertically. Size of the pie slice reflects the proportional z-score (i.e., statistical support) of the site–topic association. Data calculated from Neurosynth, an online platform allowing to perform meta-analyses on the results from currently (Jun 2016) about 11,000 fMRI studies (http://neurosynth.org/)