

Comment

Matches, mismatches, and the experience of supernumerary body parts

Comment on “Left and right temporal-parietal junctions (TPJs) as “match/mismatch” hedonic machines: A unifying account of TPJ function”, by Doricchi et al.

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The temporal-parietal junction (TPJ) has been implicated in a bewildering array of cognitive abilities, from attention to theory of mind, from memory to humour. This apparent diversity of function might seem to preclude any general theory of the TPJ. In this light, the paper by Doricchi and colleagues [1] makes an ambitious attempt to provide such a theory. They propose that the right TPJ codes matches between expected and actual events, whereas the left TPJ has separate neural populations coding for matches and mismatches. This deceptively simple interpretation allows them to provide elegant interpretations of the TPJ’s role in several domains, including theory of mind, humour, and bodily awareness. This is an impressive achievement, which provides insight not only into TPJ function, but also into deep mechanistic similarities in superficially different cognitive domains. Here, we will focus on the role of the TPJ in bodily awareness, focussing on one form of abnormal experience of the body not discussed by Doricchi and colleagues, namely the experience of supernumerary body parts.

To maintain a coherent sense of the embodied self, Doricchi and colleagues argue that the right TPJ stores a template of the body against which to compare new stimuli, as a long-term updating belief system about our bodies. They discuss the involvement of the TPJ in several abnormal conditions involving altered bodily awareness, including out-of-body experiences, denial of hemiplegia (anosognosia), and claims that one’s own limb belongs to another person (somatoparaphrenia). Damage to mismatch detection mechanisms in the right TPJ could contribute to these conditions. For example, anosognosia would reflect the failure to recognise mismatches between motor commands instructing the arm to move and sensory feedback indicating that it has not moved, while somatoparaphrenia would reflect the failure to recognise mismatch between one’s own body and that of another person.

Patients with supernumerary phantom limbs feel like they have an extra limb, which is often described as a duplication of one of their arms, hands or legs [2–5]. The extra limb can be perceived to move and perform mundane actions, such as opening doors, leading to frustration when the door is not actually opened as intended. One patient claimed to

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be able to scratch an itch with her supernumerary arm, and reported an actual sensation of relief [6]. Supernumerary phantoms are often linked to disruption of proprioception, and may reflect a discrepancy between motor command and proprioception. For example, patient E.P. experienced an extra left arm that felt like it was in the location her actual *left* arm had been in several seconds previously [3]. In contrast, however, the third arm seemed to move when she moved her *right* arm. The supernumerary limb in this case appears to reflect the correct detection of mismatch between signals which shouldn't have been compared in the first place. The TPJ detects information signalling that the left hand is at two different locations simultaneously, which is then interpreted erroneously as reflecting the existence of two distinct left arms. This provides an interesting contrast to the interpretation of anosognosia and somatoparaphrenia in terms of failure to detect mismatch.

The proposal that supernumerary phantom limbs reflect the normal operation of mismatch mechanisms in the TPJ in the face of distorted sensori-motor signals is also consistent with evidence showing that similar experiences can be induced in healthy participants by experimentally altering sensory signals. For example, the experience of supernumerary sixth fingers can be induced using a mirror box to create the illusion that felt touches are caused by the movement of an object in empty space [7,8]. This creates the subjective feeling of an invisible sixth finger, which can differ from the actual fingers in terms of properties such as length [9] and shape [10]. This suggests that the features of the extra finger are based on immediate sensory signals and not only on a stored body template, which would duplicate the representation of an existing finger. In this sense, supernumerary bodily illusions are useful to investigate in what ways the induced mismatches are resolved into the most plausible bodily experience.

Delusions and misperceptions of the body have been widely investigated in neurology for more than a century. Advances in modern cognitive neuroscience are leading to these conditions being increasingly well understood, as is reflected in the paper of Doricchi and colleagues. The brain's ability to detect and resolve sensorimotor mismatches is central to these developments. Understanding the mechanisms underlying this process will lead to novel approaches to understanding – and correcting – such misperceptions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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