

The multisensory hypothesis of body ownership

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How do we come to feel that we own our body? What is the relationship between our body and our sense of self? Questions like these have been discussed in philosophy and psychology for centuries, but what advances have been made in understanding how the brain actually distinguishes between parts of one's own body and objects in the external world? In this lecture we will address this issue from the perspective of cognitive neuroscience, paying particular attention to multisensory integration.

We will investigate the hypothesis that parts of one's own body are distinguished from objects in the external world by the specific patterns of correlated signals from the different sensory modalities they produce. In this model ownership corresponds to the perceptual fusion of visual, tactile and proprioceptive information into a coherent object that is a body-part. This multisensory integration process is obeying precise temporal and spatial congruency principles, is limited to the space near the body, and is operating in body-part-centered reference frames. It is hypothesized that the integration is implemented by populations of neurons in the premotor cortex, intraparietal cortex and inferior parietal cortex, areas which in non-human primates contain cells with the capacity to integrate visual, tactile and proprioceptive signals.

We will present data from a combination of functional magnetic resonance imaging and human behavioral experiments that have tested these predictions. For the behavioral experiments we have used perceptual illusions where people experience dramatic changes in ownership of their body. For example, healthy volunteers will perceive another individual's body as their own (1), rubber hands as being part of their own body (2), or 'out-of-body' illusions (3), where ownership is projected outside the real body. These illusions are triggered by specific patterns of multisensory stimuli, and the identification of these patterns informs us about the principles governing the elicitation of ownership. Specifically our behavioral results demonstrate that ownership of limbs and entire bodies depend on the temporal and spatial congruency of visual, tactile and proprioceptive signals in body-centered reference frames, and that the visual information from first person perspective plays a crucial role (1-3).

Importantly, we can use these illusions as experimental tools in conjunction with neuroimaging techniques to test the specific neuronal hypotheses outlined above. Our imaging data show that neuronal populations in the premotor and intraparietal cortex are active when humans sense they own limbs (2,4), which supports the hypothesis that the integration of multisensory information in body-centered coordinates is crucial for ownership (1-4).

In summary, we will review multisensory hypothesis of body ownership. A large body of behavioral and neuroimaging data supports the hypothesis that self-attribution of limbs and other body parts depends on the integration of multisensory signals

operating in body part-centered coordinate systems. The strength of tackling this problem from a multisensory perspective is that it provides a parsimonious explanation of body ownership than does not require the inclusion of higher cognitive functions, which are often hard to define and even harder to relate to neuronal mechanisms. The perceptual distinction between one's own body and the environment could create the necessary foundation for higher cognitive functions related to self-consciousness to emerge, such as reflective self-awareness and the autobiographical self.

References:

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