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Illusion of sense of self-agency: discrepancy between the predicted and actual sensory consequences of actions modulates the sense of self-agency, but not the sense of self-ownership

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Abstract

It is proposed that knowledge of motor commands is used to distinguish self-generated sensation from externally generated sensation. In this paper, we show that the sense of self-agency, that is the sense that I am the one who is generating an action, largely depends on the degree of discrepancy resulting from comparison between the predicted and actual sensory feedback. In Experiment 1, the sense of self-agency was reduced when the presentation of the tone was unpredictable in terms of timing and its frequency, although in fact the tone was self-produced. In Experiment 2, the opposite case was found to occur. That is, participants experienced illusionary sense of self-agency when the externally generated sensations happened to match the prediction made by forward model. In Experiment 3, the sense of self-agency was reduced when there was a discrepancy between the predicted and actual sensory consequences, regardless of presence or absence of a discrepancy between the intended and actual consequences of actions. In all the experiments, a discrepancy between the predicted and actual feedback had no effects on sense of self-ownership, that is the sense that I am the one who is undergoing an experience. These results may suggest that both senses of self are mutually independent.

Keywords: Forward model; Motor awareness; Sense of agency; Sense of ownership; Self-recognition

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1. Introduction

When we act, we normally feel ourselves causing our own actions. It appears too self-evident to require further investigation. If I say "I think it is a beautiful day today", I could be wrong about the weather. But it seems that I could not be wrong about the "I". I could not misidentify myself when I state that it is I who am thinking (Wittgenstein, 1958). Such use of the first-person pronoun is thought to be immune to error through misidentification (Shoemaker, 1984). However, certain schizophrenic experiences including auditory hallucination, thought insertion and delusions of control could be counterexamples to the immunity principle. Auditory hallucinations typically consist of hearing spoken voices, which were misattributed to external force by patients although in fact they themselves spoke. The essence of delusions of control is that patient experiences his or her will as replaced by that of some other agency or force. In other terms the patient feels that he or she is not at the origin of his or her own acts. A schizophrenic patient who suffers from thought insertion might claim that he or she is not the one who is thinking a particular thought, when in fact he or she is the one who is thinking the thought. These symptoms are in common characterized by an inability to distinguish self- and externally produced actions.

Based on a established model of motor learning and control (Wolpert, 1997), Frith proposed that abnormalities in forward model might underlie these symptoms (Frith, 1992; Frith, Blakemore, & Wolpert, 2000). To optimize motor control and learning, the central nervous system has been thought to require containing internal models, which represent aspects of one's own body and its interaction with the external world. There are two types of internal model: inverse model and forward model (Wolpert, Ghahramani, & Jordan, 1995). The inverse model provides the motor commands necessary to achieve a certain goal based on the desired state. By contrast, the forward model makes predictions about the behavior of the motor system and its sensory consequences. Predictions can be used in several ways. First, prediction of the actual outcome of motor command can be compared with the desired outcome. This comparison enables rapid error correction before sensory feedback is available (Greenwald, 1970). Second, when a movement is made, an efference copy of the motor command is used to make a prediction of the sensory consequences of the movement. This sensory prediction can then be compared with the actual sensory feedback from the movement. This prediction can be used to anticipate and cancel the sensory effects of movement, as in the case during eye movements (Helmholtz, 1867). More importantly, this prediction can be also used to attenuate the sensory effect of self-generated movement and thereby enables differentiating self-produced sensation from externally generated sensations. Self-produced sensations can be correctly predicted from motor commands. As a result, there will be little or no sensory discrepancy resulting from the comparison between the predicted and actual sensory feedback. This accurate prediction can be used to attenuate the sensory effects of self-produced movement. In contrast, externally generated sensations are not associated with any efference copy and cannot be predicted by the forward model. As a result this comparison will produce a higher level of sensory discrepancy. As the discrepancy between the predicted and actual sensations increases, so does the likelihood that the sensation is externally produced.