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Delusions of alien control in the normal brain

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Abstract

Delusions of alien control, or passivity experiences, are symptoms associated with schizophrenia in which patients misattribute self-generated actions to an external source. In this study hypnosis was used to induce a similar misattribution of self-generated movement in normal, healthy individuals. Positron Emission Tomography (PET) was employed to investigate the neural correlates of active movements correctly attributed to the self, compared with identical active movements misattributed to an external source. Active movements attributed to an external source resulted in significantly higher activations in the parietal cortex and cerebellum than identical active movements correctly attributed to the self. We suggest that, as a result of hypnotic suggestion, the functioning of this cerebellar-parietal network is altered so that self-produced actions are experienced as being external. These results have implications for the brain mechanisms underlying delusions of control, which may be associated with overactivation of the cerebellar–parietal network.

Keywords: Forward model; Schizophrenia; Passivity; Hypnotic suggestion; Prediction; Internal model

1. Introduction

Delusions of alien control are symptoms associated with schizophrenia in which patients misattribute self-generated actions to an external source [40]. The actions in question can be trivial, such as picking up a cup or combing one's hair. Patients describe their thoughts, speech and actions as having been influenced or replaced by those of external agents rather than being produced by themselves: "My fingers pick up the pen, but I don't control them. What they do is nothing to do with me" [29].

Normally, humans can readily detect whether a movement is self-generated or externally caused. It has been proposed that an internal predictor, or forward model, uses information about intentions to enable this distinction [31,47,49]. Forward models use an 'efference copy' of the motor command [24] to make a prediction of the consequences of the motor act. A *forward dynamic model* makes predictions about the next state of the system and compares this with the desired state. A *forward output model* makes predictions about the sensory consequences of the movement, and this prediction is compared with the actual sensory consequences of a movement (see Fig. 1). This comparison can be used to cancel the sensory effect of the motor act, attenuating it perceptually compared with identical stimulation that is externally produced [4,46]. This predictive system is useful because it filters incoming sensory signals, picking out sensory information caused externally, such as touch produced by an external object or agent, and distinguishes it from sensory stimulation that occurs as a necessary consequence of self-produced motion. An impairment in such a predictive system could cause a lack of attenuation of the sensory consequences of self-produced actions, which would therefore be indistinguishable from externally generated sensations [19,20]. This would result in the interpretation of one's own movements as being externally caused—a delusion of alien control.

How does the brain distinguish between self and externally produced sensory stimulation? The cerebellum is believed to be involved in predicting the sensory consequences of movement [30,48]. Forward models are proposed to be stored in the lateral cerebellar cortex [25]. The same region of the cerebellum is differentially activated according to the specific consequences of movement [2] and its activity increases as the actual feedback from movement deviates from the predicted sensory consequences [5]. There is accumulating evidence that the parietal cortex is also involved in the distinction between self-produced actions and actions generated by others. Activity in the parietal operculum (secondary

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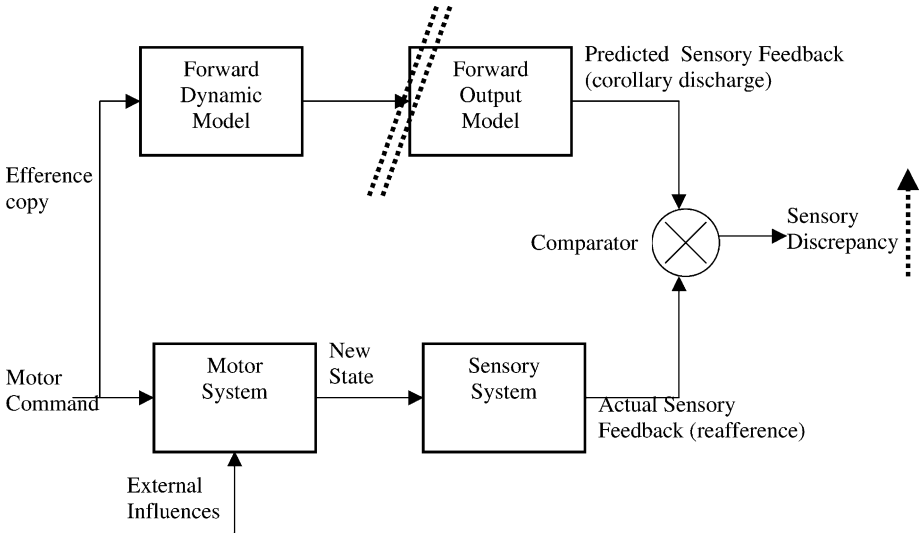

Fig. 1. The forward model of motor control, as proposed by Miall et al. [30]. A forward dynamic model predicts the consequences of motor commands and these are compared with the desired state. The forward output model makes a prediction of the sensory consequences of motor commands, which is compared with the actual consequences of movement (reafference). Discrepancies resulting from this comparison can be used to cancel reafferent inputs and to distinguish self-produced and externally produced signals. The dashed lines indicate the proposed underlying disorder leading to delusions of control, and a possible mechanism by which hypnotic suggestion can alter the experience of a self-produced movement. In both delusions of control and hypnotic suggestion the subject can formulate the action appropriate to his intention and the action is successfully performed. The forward output model is dysfunctional such that it cannot make an accurate prediction of the sensory consequences of the movement based on the efference copy. This might be because the efference copy signals do not reach the forward output model, or that the forward output model cannot make accurate predictions based on the efference copy it receives. This results in a high level of sensory discrepancy (indicated by the dashed arrow) and no cancellation of the reafference, so that the (self-produced) movement feels externally produced.

somatosensory cortex) is attenuated during self-initiated movements and self-produced sensory stimulation compared with passive movements and external sensory stimulation [2,45]. Patients with left parietal lesions tend to confuse the ownership of hand movements when they are shown someone else's hand making movements similar to those they are making themselves [43]. The right inferior parietal cortex is activated when subjects simulate actions from someone else's perspective but not from their own [40], and when subjects observe their own actions being imitated by someone else compared with when they imitate someone else's action [12,15]. Furthermore, overactivity of the parietal cortex appears to contribute to the feeling that active movements are externally controlled in delusions of alien control [44].

The current study was designed to test the hypothesis that the cerebellum and parietal cortex are involved in generating the feeling that a movement is externally produced. Hypnosis was used as a cognitive tool to create delusions of alien control in normal, healthy subjects. 'Ideomotor movement' is a frequently demonstrated hypnotic phenomenon in which self-produced actions are attributed to an external source [23,33,38]. A typical example involves suggesting to the hypnotised subject that their arm is being raised upwards passively by an external device, such as a helium balloon attached to their wrist. This suggestion causes highly hypnotisable subjects to produce an appropriate movement. Despite generating the movement themselves, such subjects describe the raising and lowering of their arm as being involuntary and typically claim that it was caused by the helium balloon. Here, Positron Emission Tomography (PET) was used to scan highly hypnotisable subjects during three movement conditions. In the Active Movement (AM) condition subjects were instructed to move their left arm up and down. In the Real Passive Movement (RP) condition, the left arm was moved up and down passively by a pulley system. In the Deluded Passive Movement (DP) condition, subjects were told that their left arm would be moved up and down by the pulley, but in fact the pulley did not move and resulting arm movements were self-generated. Movements in all conditions were performed while subjects were hypnotised. Thus, movements in the Active Movement and Deluded Passive Movement conditions were identical—subjects made the same self-generated arm movements in both conditions. The only difference between these two conditions was the source to which the movement was attributed.

Using this paradigm we were able to compare brain activation during active movements that are correctly attributed to the self (Active Movement condition) with identical active movements that are misattributed to an external source (Deluded Passive Movement condition) (see Section 2). Our results demonstrate that active movements attributed to an external source resulted in significantly higher activations in the parietal cortex and cerebellum than identical active movements correctly attributed to the self.