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Research report

The functional anatomy and connectivity of thought insertion and alien control of movement

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ABSTRACT

Alien control phenomena are symptoms reported by patients with schizophrenia whereby feelings of control and ownership of thoughts and movements are lost. Comparable alien control experiences occur in culturally influenced dissociative states. We used fMRI and suggestions for automatic writing in highly hypnotically suggestible individuals to investigate the neural underpinnings of alien control. Targeted suggestions selectively reduced subjective ratings of control and ownership for both thought and movement. Thought insertion (TI) was associated with reduced activation of networks supporting language, movement, and self-related processing. In contrast, alien control of writing movement was associated with increased activity of a left-lateralised cerebellar-parietal network and decreased activity in brain regions involved in voluntary movement, including sensory-motor hand areas and the thalamus. Both experiences involved a reduction in activity of left supplementary motor area (SMA) and were associated with altered functional connectivity (FC) between SMA and brain regions involved in language processing and movement implementation. Collectively these results indicate the SMA plays a central role in alien control phenomena as a high level executive system involved in the sense that we control and own our thoughts and movements.

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1. Introduction

As humans we can readily detect whether our bodily movements are self-generated or externally caused, and typically experience a sense of control and ownership of our thoughts. These fundamental features of experience are disrupted in psychiatric symptoms of alien control, where patients describe their thoughts and/or their movements as under the control of an external agent (Frith, 2005). For example, during the experience of thought insertion (TI), the patient "believes that thoughts that are not his own have been inserted into his mind" (Mullins & Spence, 2003). Mellor's classic example (Mellor, 1970) cites a patient's experience: 'I look out of the window and I think the garden looks nice and the grass looks cool, but the thoughts of Eamonn Andrews [TV presenter] come into my mind. There are no other thoughts there, only his … He treats my mind like a screen and flashes his thoughts onto it like you flash a picture.' Similarly, experiences of alien control of movement (ACM) involve the experience that movement is under the control of some force or entity outside the self, as in patient reports such as, "they inserted a computer in my brain. It makes me turn to the left or right"; or "my fingers pick up the pen but I don't control them" (Mellor, 1970).

Previous studies of the cognitive and neural bases of alien control phenomena have tended to focus on mechanisms underlying alien control of movement (Frith, 2005). We know of no published studies using functional imaging to investigate brain activity during TI. Nevertheless, neurocognitive models of both thought insertion and alien control of movement have been proposed in which both phenomena are the result of aberrant self-monitoring (Haggard, Cartledge, Dafydd, & Oakley, 2004; Szechtman, Woody, Bowers, & Nahmias, 1998). At a neural level, problems with self-monitoring have been linked to a 'forward model' where processing of movement-related sensory feedback involving a parietal-cerebellar network is subject to feedforward inhibition during voluntary movements (Synofzik, Vosgerau, & Newen, 2008). In this model, alien control of movement results from failure of feedforward inhibition, so that self-generated movements are experienced as though they are externally caused (Frith, 2005). A previous study investigated the neural correlates of alien control of movement by employing hypnotic suggestion and Positron Emission Tomography (PET) in healthy participants (Blakemore, Oakley, & Frith, 2003). Experimental conditions included misattributions of self-generated movement while participants produced repetitive vertical movements with their left arm. These 'deluded passive movements' were associated with significantly greater activations in bilateral cerebellum and parietal cortex relative to normal self-generated voluntary movements. Failure to attenuate sensory processing for what in reality were self-generated movements was proposed to underlie the observed increases in cerebellar-parietal activity during deluded passive movements (Blakemore et al., 2003).

Deeley, Walsh, et al. (2013) offered an alternative account of the experience of alien control of movement. This 'executive control' model proposes that alien control phenomena may be mediated by altered activity in motor planning regions, in particular the supplementary motor area (SMA) (Deeley, Walsh, et al. 2013). Reduced connectivity between SMA and motor implementation regions, including M1, during suggested involuntary compared to voluntary joystick movements was observed in our prior study. This finding is consistent with the proposed role of the SMA in the control and ownership of movements (Fried, Mukamel, & Kreiman, 2011; Grafton, Mazziotta, Woods, & Phelps, 1992; Haggard, 2008; Haggard & Magno, 1999; Nachev, Kennard, & Husain, 2008; Penfield & Welch, 1951). While cognitive neuroscience research to date has focused on alien control of movement, thought insertion symptoms remain twice as prevalent in patients with schizophrenia (Grafton, Mazziotta, Presty, et al., 1992; Mellor, 1970). Both thought insertion and alien control of movement also occur in other psychiatric disorders (Mullins & Spence, 2003) and have been observed in the general population (Wiles et al., 2006). Non-pathological instances of thought insertion and alien control of movement include culturally influenced dissociative phenomena linked to practices such as mediumship and automatic writing, which have been widely reported across different cultures and periods of history (Crapanzano & Garrison, 1977; Deeley, 2013; Ellenberger, 1970; Vitebsky, 2001).

By analogy with the forward model account of alien control of movement, it has been suggested that the experience of thought insertion may result from impaired monitoring of self-generated thought (Feinberg, 1978; Frith, 2005). This proposal has been criticised on the grounds that thoughts, unlike movements, do not have well defined sensorimotor characteristics that could inform feedforward inhibition of self-monitoring systems (Synofzik et al., 2008). The alternative 'executive control' model – assuming an analogy with the proposed role of the SMA in alien control of movement – would argue that a disruption of SMA function during generation of thoughts produces a loss of perceived control and ownership. However, a method for the experimental study of the neural basis of thought insertion does not exist. Experimental investigation of these unresolved questions about thought insertion, and its relation to alien control of movement, is especially challenging as thought is a covert process (Mullins & Spence, 2003). Also, the effects observed in our prior study involving simple joystick movements may not generalise to complex movements such as handwriting.

To investigate the neural bases of thought insertion and alien control of complex movements we extended the approach described in previous studies (Deeley, Walsh, et al., 2013; Walsh et al., 2014) by combining fMRI and suggestions for automatic writing in highly hypnotically suggestible individuals, employing a sentence completion task where thought and movement occur sequentially and discretely (see Fig. 1a). Writing involves expressing thoughts in words and then using hand movements to write the words down (Beeson, 2004). Cognitive and clinical models suggest that both thought and movement components of writing, though clearly linked, are nevertheless separable (Magrassi, Bongetta, Bianchini, Berardesca, & Arienta, 2010; Scarone et al., 2009). Furthermore, subjective reports of automatic writing suggest that the thought content and motor act of writing can be independently experienced as externally caused (Britton, 1997). Thus, a handwriting task provides a model system to investigate both types of alien control where targeted

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