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Reality monitoring in anosognosia for hemiplegia

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ABSTRACT

Anosognosia for hemiplegia (AHP) is a lack of awareness about paralysis following stroke. Recent explanations use a 'forward model' of movement to suggest that AHP patients fail to register discrepancies between internally- and externally-generated sensory information. We predicted that this failure would impair the ability to recall from memory whether information is internally- or externally-generated (i.e., reality monitor). Two experiments examined this prediction. Experiment 1 demonstrated that AHP patients exhibit a reality monitoring deficit for non-motor information (i.e., perceived vs. imagined drawings), whilst hemiplegic controls without anosognosia (nonAHP) perform like age-matched healthy volunteers (HVs). Experiment 2 explored if this deficit occurs when AHP patients discriminate performed, imagined, or observed movement. Results showed impaired reality monitoring for movements in AHP and nonAHP patients relative to HVs. Findings suggest that reality monitoring processes not directly related to movement, together with a failure to reality monitor movements, contribute to the pathogenesis of AHP.

1. Introduction

The seemingly effortless way that awareness of moving (or not moving) normally occurs might understandably lead to the conclusion that our self-awareness of action is a simple, unambiguous process. However, patients with anosognosia for hemiplegia (AHP) challenge this conclusion, because AHP patients are not aware of being unable to move. More precisely, AHP usually refers to a lack of awareness regarding motor impairment in patients suffering a right hemisphere stroke (Ellis & Small, 1993, 1997). In practice, a variety of clinical presentations are considered characteristic of AHP. Some AHP patients fail to recognise, appreciate the severity, or acknowledge the consequences of paralysis (Orfei et al., 2007). Other patients deny outright any motor impairment, whilst some acknowledge the presence of a motor deficit, but explain it away (Bisiach & Geminiani, 1991). In some cases AHP co-occurs with unilateral neglect (i.e., a failure to respond to stimuli on the contralesional side), whilst in others neglect is absent (Berti et al., 2005; Jehkonen, Laihosalo, & Kettunen, 2006). Furthermore, AHP can occur independently at verbal and non-verbal (i.e., behavioural) levels (Jehkonen et al., 2006). That is, some AHP patients refuse to acknowledge their paralysis, but are usually content to remain in bed, whereas other AHP patients may verbally acknowledge their paralysis, but attempt to get out of bed, stand, walk or perform other physical tasks that are clearly impossible (Bisiach & Geminiani, 1991). When asked to make self-evaluations, these patients are often unaware of their inability to execute bilateral tasks requiring use of the hemiplegic limb(s) (e.g., clap hands) (Berti, Làdavas, & Della Corte, 1996; Berti, Làdavas, Stracciari, Giannarelli, & Ossola, 1998; Marcel, Tegnér, & Nimmo-Smith, 2004; Nimmo-Smith, Marcel, & Tegnér, 2005).

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Despite several decades of AHP research, we are still without an adequate explanation, capable of accounting for the diverse clinical, emotional, cognitive and neuroanatomical presentation of AHP (see Adair et al., 1997; Berti et al., 1996; Gold, Adair, Jacobs, & Heilman, 1994; Hildebrandt & Zieger, 1995; Small & Ellis, 1996). The heterogeneous presentation of AHP is one factor that has impeded understanding of the disorder. A lack of consensus on how best to characterise and assess AHP means it is difficult to identify patterns in results across studies. Given the dissociation between verbal and behavioural awareness, AHP should be considered present if a patient displays either type of unawareness (Marcel et al., 2004; Nimmo-Smith et al., 2005). Berti et al. (1996) have developed a rigorous instrument for assessing AHP, which encompasses measures of both verbal awareness and awareness of the behavioural consequences of illness. Employing this type of robust diagnostic method allows more consistent and thorough characterisation of AHP, which can facilitate comparisons across studies and the development of a better understanding of the disorder.

Another major weakness of most AHP studies is a failure to frame their explanations within a robust theoretical model, instead using the disorder itself as a starting point for investigation and constructing an explanation. In contrast, a recent cognitive neuropsychological account of AHP provides a theory-driven, experimentally testable explanation of the disorder (Berti & Pia, 2006). Berti and Pia utilise a 'forward' model (Fig. 1) of normal motor control and awareness (Wolpert, 1997; Wolpert, Ghahramani, & Jordan, 1995), the utility of which has been established by numerous studies in normal, healthy individuals (Blakemore, 2003; Blakemore, Frith, & Wolpert, 1999; Blakemore, Frith, & Wolpert, 2001; Blakemore, Goodbody, & Wolpert, 1998; Blakemore, Rees, & Frith, 1998; Blakemore, Wolpert, & Frith, 1998) patients with schizophrenia (Blakemore, Smith, Steel, Johnstone, & Frith, 2000; Frith, 2005; Frith, Blakemore, & Wolpert, 2000) and recent studies of AHP (Fotopoulou et al., 2008; Jenkinson, Edelstyn, & Ellis, in press), and anosognosia for dyskinesias (i.e., involuntary movements) in Parkinson's disease (Jenkinson, Edelstyn, Stephens, & Ellis, submitted).

The forward model is so called because it proposes that the causal (or forward) relationship between intended/planned actions and their sensory consequences are predicted using an efference copy of motor commands. These predicted actions are believed to form the basis of motor awareness (Blakemore & Frith, 2003). Supporting evidence comes from studies showing remarkably limited knowledge of actual sensory feedback in healthy individuals (Fourneret & Jeannerod, 1998; Slachevsky et al., 2003), and a key role of sensory predictions in several aspects of normal motor awareness, such as correctly attributing actions to the self (i.e., internally produced) or an external source (Blakemore, Rees, et al., 1998; Blakemore, Wolpert, et al., 1998; Blakemore et al., 1999). A comparator monitors the congruence between these sensory predictions and the actual consequences of the movement arising from sensory feedback. When predicted and actual movement match no discrepancy signal is generated by the comparator; however, a failure to execute movement as intended results in the comparator signalling a mismatch, which comes into consciousness and produces subjective awareness of an error in performing the action. This is especially noticeable in situations where there is a mismatch between motor intentions, proprioception and/or visual feedback (Fink et al., 1999).

Berti and Pia (2006) propose that pathological awareness in AHP might occur if the ability to predict the expected sensory consequences of movement were preserved, but patients fail to detect when these predictions are not congruent with actual sensory feedback. Under these circumstances motor awareness in AHP becomes based entirely on sensory predictions, which erroneously indicate successful execution of the intended movement. This explanation predicts that patients with AHP retain the ability to form predictions about the consequences of movements, whilst the ability to monitor discrepancies is defective. In contrast, hemiplegic patients without anosognosia (i.e., nonAHP) possess preserved awareness of their motor impairment, because they are able to detect when the predicted and actual sensory consequences of their movement do not match.

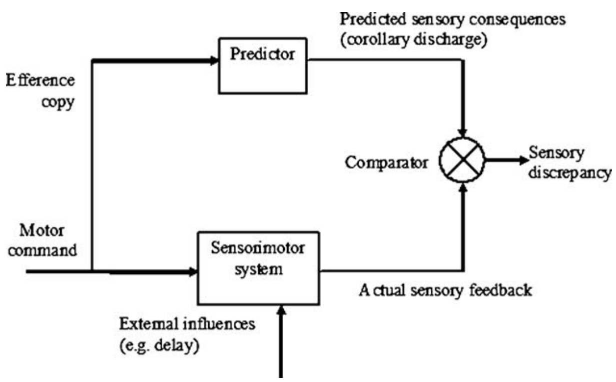

Fig. 1. A simple forward model of the normal motor system (from Blakemore et al., 2001). Predictions of sensory feedback are made by a movement predictor, using an efference copy of the motor command. These predictions are compared to the actual sensory feedback. In hemiplegic patients without anosognosia damage is located in the production of movement; therefore, comparison of actual and predicted sensory feedback produces a discrepancy and normal awareness of the motor deficit. Hemiplegic patients with anosognosia fail to execute this comparison successfully and register a discrepancy. Consequently, knowledge of the motor system is constructed from sensory predictions, resulting in a false belief of being able to move.