



New reflections on agency and body ownership: The moving rubber hand illusion in the mirror



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ABSTRACT

No previous study has simultaneously examined body ownership and agency in healthy subjects during mirror self-observation. We used a moving rubber hand illusion to examine how both body ownership and agency are affected by seeing (i) the body moving in a mirror, compared with (ii) directly viewing the moving hand, and (iii) seeing a visually identical hand rotated by 180°. We elicited ownership of the hand using direct visual feedback, finding this effect was further enhanced when looking at the hand in a mirror, whereas rotating the hand 180° abolished ownership. Agency was similarly elicited using direct visual feedback, and equally so in the mirror, but again reduced for the 180° hand. We conclude that the reflected body in a mirror is treated as 'special' in the mind, and distinct from other external objects. This enables bodies and actions viewed in a mirror to be directly related to the self.

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1. Introduction

What happens when we look in a mirror?¹ In a basic, physical sense, looking in a mirror provides a simple tool for observing one's outer appearance by reflecting light according to geometric rules (Prinz, 2013). Humans are one of only a few animals who can recognise themselves in a mirror, and as such mirror self-recognition is regarded as a litmus test of self-awareness (Amsterdam, 1972; Gallup, 1970; Plotnik, de Waal, & Reiss, 2006; Reiss & Marino, 2001). However, we do not use mirrors to just passively recognise ourselves; we regularly perform complex, mirror-guided actions such as shaving, applying make-up, and brushing our teeth. We are able to perform these intricate actions without consideration, or even awareness, of the many unique properties of mirror images (see Bertamini & Parks, 2005; Bianchi, Savardi, & Bertamini, 2008; Lawson & Bertamini, 2006) and thus the motor transformations required.

In cognitive neuroscience terms, the self that we experience when moving in front of a mirror comprises both a sense of body ownership (i.e. the sense that one's body belongs to oneself) and agency (i.e. the sense that one is the cause or author of one's actions). An abundance of research has sought to understand the functional and neuroanatomical mechanisms underlying these fundamental aspects of the self (e.g. Farrer et al., 2003; Jenkinson, Edelstyn, Preston, & Ellis, 2014; Jenkinson, Haggard, Ferreira, & Fotopoulou, 2013; Kalckert & Ehrsson, 2012; Newport & Preston, 2010; Tsakiris, Prabhu, & Haggard, 2006). However, only a handful of experimental studies have specifically sought to examine the effect of mirror

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¹ References to looking in the mirror and mirror reflections through this paper refer to the image produced by a frontally positioned mirror, which is distinct from other research looking at the effect of placing a mirror in the sagittal position.

self-observation on body ownership in healthy individuals (see Bertamini, Berselli, Bode, Lawson, & Wong, 2011; Jenkinson et al., 2013; Kontaris & Downing, 2011), and no study to date has examined the effect of mirror self-observation on agency.

Bertamini et al. (2011) conducted the now classic rubber hand illusion (RHI; Botvinick & Cohen, 1998), but with the rubber hand observed only in a mirror. They found that a mirror view of the rubber hand elicited strong embodiment, as measured using subjective ratings and perceived drift in location of the real hand towards the rubber hand (i.e. proprioceptive drift). Jenkinson et al. (2013) replicated and extended this effect, finding that the RHI was elicited (as measured using questionnaire ratings), irrespective of whether vision and attention were focused on a directly observed rubber hand, or the specular image of the rubber hand in the mirror. Importantly, in these studies ownership during the mirror RHI was equal to that induced by direct view (but see Kontaris & Downing, 2011), which contrasts with the finding that ownership is not elicited when the rubber hand is rotated by 180° and placed in the same location as the specular image (such that the visual properties are identical to that of the mirror condition; see Bertamini et al., 2011; Kontaris & Downing, 2011). These findings show how a strong sense of ownership is experienced when seeing our body in a mirror, and support the unique representation of mirror reflections in the mind.

However, the question of how *agency* is affected by looking in a mirror has never been specifically and directly examined. A case report of immediate, complete and permanent remission of chronic anosognosia for hemiplegia (i.e. unawareness of paralysis) following video-feedback provides striking evidence of the possible effect that viewing the body from a third-person perspective (similar to that produced from looking in a mirror) can have on (disturbed) agency (Fotopoulou, Rudd, Holmes, & Kopelman, 2009). However, the mechanism by which this dramatic effect was obtained is unclear, with the change in awareness potentially arising as a result of viewing the body ‘from the outside’, from observing motor performance ‘offline’ (i.e. when there was no intention to perform a movement), or from a combination of these two factors.

Importantly, both agency and perspective taking have been proposed as critical components of self-consciousness (Vogeley & Fink, 2003); however, there has been little attempt to investigate the interaction of these two factors in healthy individuals (see David et al., 2006, for an exception). The third-person/observer view of our body (such as that provided by mirror and video feedback) may be important for the sense of agency, given that the ability to discriminate between self and other actions allows us not only to recognise ourselves and guide our own actions, but also to interpret the actions of others (Preston & Newport, 2010). Alternatively, controlling the body in the mirror may be more similar to using a tool, and so distinct from feelings of agency over the actual body (i.e. external vs. body agency; see Kalckert & Ehrsson, 2012).

Owing to the absence of any existing experimental evidence, this study specifically set out to examine the effect of mirror self-observation on agency, whilst also attempting to replicate existing findings concerning body ownership. We used an existing method: the moving rubber hand illusion (mRHI; Kalckert & Ehrsson, 2012, 2014a, 2014b), during which participants observe movements of a model hand while their own hand is hidden from view. The model hand can be moved either actively (under the control of the participant) or passively (under the control of the experimenter), with the movements made by the model and real hand being either synchronous or asynchronous. Using this method, Kalckert and Ehrsson (2012) found that asynchronous movement or rotating the model hand by 180° abolished the illusion of ownership, and that ownership was higher during active compared with passive synchronous movements. Agency, on the other hand, was still experienced even for an anatomically impossible, rotated hand. Extending this method to the current experiment, healthy participants performed the mRHI whilst looking at a model hand either directly, rotated 180°, or via a mirror. We expected results of the directly viewed and rotated conditions to replicate those of Kalckert and Ehrsson (2012), as described above. We expected that, in the mirror, ownership and agency would be greater during synchronous as compared with asynchronous movement, and active as compared with passive movement overall. In addition, we predicted that synchronous movements observed in the mirror would produce body ownership equal to that of directly observed movements (see Bertamini et al., 2011; Jenkinson et al., 2013), whereas a 180° view would abolish ownership. For agency in the mirror, we expected only active and synchronous movement to elicit a sense of agency, and for all three views to produce the same effect (based on the previous finding that a 180° view does not abolish agency).

We measured the illusion using both subjective (embodiment questionnaire) and objective (proprioceptive drift) measures. In addition to drift in the perceived height of the real hand towards the model hand (Kalckert & Ehrsson, 2012, 2014a, 2014b; hereafter referred to as “height drift”) we also measured drift away from the body/towards the mirror (hereafter referred to as “forward drift”). Objects viewed in a mirror are treated as being located in peripersonal space, despite the image appearing in extrapersonal space (Maravita, Spence, Clarke, Husain, & Driver, 2000). Therefore, we predicted that despite the projected image being distant from the body (in extrapersonal space), the hand would still be perceived as located in peripersonal space. We therefore expected that the above predictions would be demonstrated via changes in height drift and subjective ratings, whereas the forward drift would show no difference across conditions, and was used as a control for demand characteristics and general susceptibility.

2. Method

2.1. Participants

Thirty-two healthy volunteers (11 male, 21 female; mean age = 23.50, SD = 4.36; range = 18–32 years) from the University of Hertfordshire participated in the experiment. All participants were right-hand dominant (Edinburgh

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