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Does the experience of ownership over a rubber hand change body size perception in anorexia nervosa patients?

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ABSTRACT

Anorexia nervosa (AN) patients show disturbances in body size experience. Here, malleability of body representation was assessed by inducing the Rubber Hand Illusion (RHI). Specifically the impact of the illusion on body size estimation was investigated.

Thirty AN patients and thirty healthy females participated. The RHI was induced synchronously (experimental condition) and asynchronously (control condition) Both before and after induction of the RHI participants were asked to estimate the size of their own and the rubber hand.

The results showed that AN patients had a stronger experience of ownership over the rubber hand than healthy females in the experimental, but not the control condition. AN patients and HC did not differ on proprioceptive drift. Before induction of the illusion AN patients overestimated hand width. After induction of the illusion (experimental as well as control condition) AN patients no longer overestimated the width of their hand. Healthy females correctly estimated hand size both before and after induction of the RHI.

In conclusion, stronger experience of ownership over the rubber hand in the AN group implies a more malleable body representation in AN patients compared to healthy females. Changed hand size estimation in the AN group appears to be unrelated to the RHI, as it occurred under both experimental and control conditions of the illusion. Alternative interpretations are discussed.

1. Introduction

One of the key-features of anorexia nervosa (AN) is a disturbed experience of body weight and shape (APA, 2000). This is traditionally referred to as a disturbance in body image. The literal "image" of the body, i.e. how AN patients visually perceive themselves, has been investigated extensively in previous research (see e.g. Cash & Deagle, 1997; Farrell, Lee, & Shafran, 2005; Skrzypek, Wehmeier, & Remschmidt, 2001; Smeets, Smit, Panhuysen, & Ingleby, 1997). Many studies have shown that AN patients visually overestimate their body size compared to healthy controls (e.g. Cash & Deagle, 1997; Skrzypek et al., 2001; Smeets et al., 1997), although other authors have failed to reach this conclusion (e.g. Cornelissen, Johns, & Tovee, 2013; Farrell et al., 2005).

In recent years an increasing number of researchers has taken an interest in understanding the disturbed experience of body size in AN from a neuro(psycho)logical viewpoint (e.g. Faris et al.,1992; Friederich et al.,2010; Grunwald et al., 2001, 2002; Guardia, Cottencin, Thomas, Dodin, & Luyat, 2012; Miyake et al., 2010; Mohr et al., 2010; Nico et al., 2010; Suchan et al., 2010; Wagner, Ruf, Braus, & Schmidt, 2003). Notably, recent studies have shown that the disturbed experience of body shape and size in AN is not limited to thinking about the body as bigger than it actually is, and visually perceiving it as such, but that it also extends to altered performance on tasks involving tactile perception (e.g. Keizer et al., 2011; Keizer, Smeets, Dijkerman, van Elburg, & Postma, 2012), haptic perception (e.g. Grunwald et al., 2001, 2002; Guardia, Cottencin, et al., 2012) as well as action-oriented tasks (e.g. Guardia, Cottencin, et al., 2012, 2010; Keizer et al., 2013; Nico et al., 2010). Thus it appears that body (size) representation disturbances can be identified in multiple modalities, which underlines its central role in AN pathology. What is yet unclear is whether this disturbed body representation can be experimentally manipulated. This is an important question as current treatment

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approaches focusing on the disturbed experience of body size in AN have not been very successful (e.g. Exterkate, Vriesendorp, & de Jong, 2009). These therapeutic interventions mainly focus on visual processing of bodily information. Perhaps a more multisensory approach offers new insights into body representations in AN that can be used in treatment. Previous studies with healthy participants suggest that multisensory *bodily illusions* are an excellent way of increasing our understanding of the plasticity of the representation of the body in the brain. Several studies have for example shown that multisensory bodily illusions can be used to modulate the experienced size of different body parts in healthy populations (see e.g. Kilteni, Normand, Sanchez-Vives, & Slater, 2012; Normand, Giannopoulos, Spanlang, & Slater, 2011; Preston & Newport, 2012; van der Hoort, Guterstam, & Ehrsson, 2011)

Eshkevari, Rieger, Longo, Haggard, and Treasure (2012) were among the first to investigate differences between AN patients and healthy females using a bodily illusion. They found that AN patients are more susceptible to the *Rubber Hand Illusion* (RHI) than healthy females. The RHI is an illusion in which participants experience ownership over a fake rubber hand once the rubber hand and (occluded) own hand receive synchronized tactile stimulation (see e.g. Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004; Kammers, de Vignemont, Verhagen, & Dijkerman, 2009). This experience of ownership arises as a result of visuotactile integration; as soon as there is a temporal match between visual input (seeing a rubber hand being stroked) and tactile input (at the same time feeling the own hand being stroked), the brain integrates the two events into a single event, which gives participants the illusionary experience that the felt touch occurs on the rubber hand, and that this hand belongs to their body (Botvinick & Cohen, 1998). The strength of the illusion is measured on a subjective self-report level with a questionnaire (see e.g. Longo, Schuur, Kammers, Tsakiris, & Haggard, 2008), but also on a perceptual level using proprioceptive drift. Proprioceptive drift refers to a shift in the reported location of the index finger after induction of the illusion, i.e. the felt position of the hand has "drifted" towards the rubber hand (Botvinick & Cohen, 1998). Note that the illusion only occurs when the rubber hand and actual hand are stimulated in synchrony, but not during asynchronous stimulation, which is often included as a control condition (e.g. Kammers et al., 2009).

Eshkevari et al. (2012) concluded that a stronger experience of the illusion in AN patients indicates increased plasticity of the bodily self. The authors (2012) related this to increased sensitivity for visual aspects of body perception in this group (e.g. viewing the body from an appearance-based perspective rather than a competence-based perspective), which in turn may result in enhanced visual capture. In other words, characteristics inherent to AN might facilitate a dominance of visual input over proprioceptive input during the RHI, resulting in a stronger experience of the rubber hand belonging to the own body. The authors further supported this conclusion with the finding that AN patients show a stronger effect on the RHI under both synchronous and asynchronous (control) conditions, implying AN patients' excessive focus on visual information.

Interestingly, just as other multisensory bodily illusions (see e.g. Kilteni et al., 2012; Normand et al., 2011; Preston & Newport, 2012; van der Hoort et al., 2011), the RHI can be used to manipulate body size experience. For example, Haggard and Jundi (2009) induced the RHI using a big and small rubber hand in a healthy population, and afterwards asked participants to estimate the weight of an object by placing it in the hand of the participants. They found that participants perceived objects to be heavier after induction of the RHI with a big hand compared to a small hand. They thus induced a *Size Weight Illusion* (SWI): Although the objects were identical in weight during the big and small rubber hand condition, participants perceived the object to be heavier in the big rubber hand condition, as the object was smaller relative to the big rubber hand (Haggard & Jundi, 2009). This suggests that during the RHI participants do not only experience ownership over the rubber hand, and perceive the location of their hand to have drifted towards the location of the rubber hand, but also that the size of the rubber hand is incorporated into the mental representation of the body. Although not directly assessed, these findings imply that after successful induction of the RHI participants regard their own hand as equal in size to the rubber hand (Haggard & Jundi, 2009). This is in accordance with reports of Longo et al. (2008) who found that participants experience the rubber hand not as an additional limb, but as a replacement of their own hand (see also Moseley et al., 2008). In addition Longo, Schuur, Kammers, Tsakiris, and Haggard (2009) argue that the subjective experience of the illusion results in greater perceived similarity between the own and rubber hand (Longo et al., 2009).

This is a particularly interesting line of reasoning in relation to AN, as AN patients experience their body size unrealistically. Would it be possible to change body size experience in an AN group using a bodily illusion such as the RHI? To answer this question we *directly* assessed the effect of the RHI on perceived hand-size by asking AN patients as well as healthy participants to estimate the size of the rubber hand and their own hand, both before and after induction of the RHI. Increased insight into whether the experience of body size can be changed in AN is crucial, as the disturbed experience of body size has been linked to the development and maintenance of AN (Stice, 2002; Stice & Shaw, 2002). In addition, the enlarged experience of body size in AN is very persistent, and not corrected by accurate visual input (e.g. in a mirror) or after otherwise successful treatment (Exterkate et al., 2009). In clinical settings AN patients for example report that treatment focused at improving body size experience using visual input (e.g. mirrors) can indeed result in visually perceiving their body more accurately, but that it does not eliminate the *experience* of being bigger altogether. From our clinical observations it may be inferred that patients learn to cope with feeling bigger than they are, but that the experience of such feelings still remains after treatment.

The aim of the present study was twofold. The first aim was to replicate Eshkevari et al. (2012) traditional RHI study. Based on their results we expected that AN patients would have a stronger experience of the RHI than healthy females (Eshkevari et al., 2012). Second we investigated the effect of the RHI on the experience of body (hand) size. AN patients show altered processing of information related to their own body (Guardia et al., 2012; Sachdev, Mondraty, Wen, & Gulliford, 2008; Wagner et al., 2003). The literature further indicates that although AN patients do not have a general deficit in estimating the size of objects or bodies of others, they overestimate their own body size (Guardia et al., 2012; Slade & Russell, 1973). After successful induction of the RHI the rubber hand is no longer an external object but experienced as part of the own body. This would allow for the hypothesis of AN patients showing an increase in size estimation of the rubber hand after induction of the RHI compared to before induction of the RHI, as it is no longer an external object, but part of the own body. However, would the change in ownership over the rubber hand (i.e. not mine vs. mine) also affect the experience of *actual*, own, body size? Assuming that AN patients will initially overestimate own hand size, size estimations made after induction of the RHI can change in two directions, either they become smaller (i.e. more accurate) or overestimation remains.

At first glance the hypothesis suggesting a decrease in size estimation of the own hand seems unlikely. Several studies using bodily illusions other than the RHI in healthy populations have