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Down the rabbit hole: Assessing the influence of schizotypy on the experience of the Barbie Doll Illusion

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Abstract

INTRODUCTION: 'Body swapping' illusions have been used to explore factors contributing to the experience of 'owning' an artificial body. Preliminary research indicated that those people diagnosed with schizophrenia experience more vivid illusions of this kind than do 'normal' individuals.

OBJECTIVES: Here, we explored whether participants who rated themselves 'high' on the cognitive-perceptual factor of the Schizotypal Personality Questionnaire (SPQ) experienced a more compelling sense of immersion in a variation of the body swapping illusion: The Barbie Doll Illusion. We also hypothesised that these individuals would experience a change in size perception when immersed in the illusion.

METHOD: Forty-four participants wore a pair of Head-Mounted Display goggles connected to a video-camera, and thus a doll's body replaced their own body in their visual field. In two conditions, touch was either applied synchronously or asynchronously to the doll's and each participant's leg. After each condition, participants filled out a questionnaire relating to their experience in the illusion. When both conditions were completed, they filled out the SPQ.

RESULTS: Our first hypothesis was confirmed, which suggested that people with higher cognitive-perceptual SPQ scores do indeed experience a more compelling Barbie Doll Illusion; however, our second hypothesis was not supported.

CONCLUSION: Our study demonstrated, for the first time, that proneness to the positive and interpersonal factors of schizotypy in a normal population is sufficient to produce a compelling sense of swapping bodies.

Introduction

Several researchers (e.g., Blanke et al., 2004; Bunning & Blanke, 2005; Ehrsson, 2007; Guterstam & Ehrsson, 2012; Petkova, Khoshnevis, & Ehrsson, 2011) have created the conditions for an experience where an individual feels as though they inhabit a different body, known as a body swapping illusion. Research exploring the boundary conditions of the body swapping illusion have manipulated the perceived size of one's body (see Kilteni, Normand, Sanchez-Vives, & Slater, 2012; van der Hoort, Guterstam, & Ehrsson, 2011). For example, Normand, Giannopoulos, Spanlang, and Slater (2011) found that synchronous visual and tactile information led participants to feel as though their stomach was growing, up to three times its actual size. A study by Kilteni et al. (2012) modified the classic Rubber Hand Illusion (RHI; e.g., the feeling that a rubber hand is one's own hand created by stroking the 'seen' rubber hand and the 'hidden' real hand in synchrony) in an attempt to see if participants would

claim ownership over a rubber hand when that hand was larger than their actual hand. Kilteni and colleagues found that participants were willing to claim ownership over the larger rubber hand, but there was a limit (i.e., four times actual size).

Interestingly, van der Hoort et al. (2011) discovered that participants could be convinced that they owned the body of a small doll (i.e., the Barbie Doll Illusion). The illusion is created by altering the participant's first-person perspective, through a Head Mounted Display, such that they view the lower extremities of a small doll. The 'hidden' leg of the participant and the 'seen' leg of the doll are touched at the same time, and in the same location (synchronous touch condition). In order to determine whether the person experiences the doll's body as theirs, the experimenter asks participants to (1) respond to several statements (e.g., I felt as if the doll's body was my body), and (2) estimate the size of a cube presented at the doll's feet after both synchronous and asynchronous touch conditions. Participants should, and do, over-estimate the size of the cube after the synchronous touch condition (i.e., when they experience the doll's body as their body).

The idea that body size influences the perceived size of objects in the external environment seems related to research conducted on the Alice in Wonderland Syndrome (AIWS). The AIWS is a neurological disorder characterised by hallucinations and perceptual distortions resulting in a perceived reduction or enlargement in one's body size (Ilik & Ilik, 2014). It appears that individuals with AIWS experience the size of their body changing, and this change is accompanied by a perceived change in the size of objects in their external environment (van der Hoort et al., 2011).

Another disorder of apparent relevance is schizophrenia. Individuals with schizophrenia experience aberrations in body image. For example, Priebe and Rohricht (2001) explored body image with a sample of individuals diagnosed with paranoid-type schizophrenia and schizoaffective disorder. They found that individuals with schizophrenia experienced significant aberrations in the perception of the size of their legs, which may be a consequence of spatial neglect (i.e., a syndrome where the individual suffers from attentional deficits in the perception of their body) (Cumming, 1988; He et al., 2007; Priebe & Rohricht, 2001).

These findings are relevant to the present study. Here, the Barbie Doll Illusion is used to induce ownership of the lower extremities of a doll. Although we are not assessing a clinical sample, we are interested in a normal population who rate high on a measure of schizotypy. Schizotypal Personality Disorder (SPD) is characterized by deficiencies in social and interpersonal relationships (e.g., no close friends; known as negative schizotypy), cognitive or perceptual distortions (e.g., hallucinations; known as positive schizotypy), and eccentricities of behaviour (e.g., odd speech; known as disorganized schizotypy) (American Psychiatric Association, 2013; Cohen, Mohr, Ettinger, Chan, & Park, 2015; Fonseca-Pedrero et al., in press). This three-factor structure of schizotypy has been supported across several studies (Fonseca-Pedrero et al., 2009, 2011, in press; Mata, Mataix-Cols, & Peralta, 2005; Ortuño-Sierra et al., 2013; Reynolds, Raine, Mellingen, Venables, & Mednick, 2000; Tran, Stieger, & Voracek, 2015), although other models have been proposed (see Fonseca-Pedrero et al., 2018, for more information). People high in schizotypal traits, or those diagnosed with SPD, have similar, but milder, deficits relative to those individuals diagnosed with schizophrenia (Burns, 2004; Ettinger, Meyhöfer, Steffens, Wagner, & Koutsouleris, 2014; Fonseca-Pedrero et al., 2018) or psychotic disorders (Kwapil & Barrantes-Vidal, 2015). Researchers (e.g., Barrantes-Vidal, Grant, & Kwapil, 2015; Fonseca-Pedrero & Debbané, 2017) have suggested that the presence of schizotypal traits puts people at an increased risk for schizophrenia-spectrum disorders. That said, the traits common to both schizophrenia and schizotypy exist at sub-clinical levels in the general population (Ettinger et al., 2014), suggesting that these traits lie on a continuum (Fonseca-Pedrero et al., 2018; Kwapil & Barrantes-Vidal, 2015), and are not necessarily always pervasive or distressing.

The literature pertaining to body swapping experiments and disorders has, for the most part, been limited to clinical samples of individuals with schizophrenia and the RHI. Peled, Ritser,

Hirschmann, Geva, and Modai (2000) found that people with schizophrenia experienced the RHI more quickly, and reported a more vivid illusion, than did healthy controls. Other research has substantiated reports of a more vivid RHI in individuals with schizophrenia. For example, a study by Thakkar, Nichols, McIntosh, and Park (2011) found that people with schizophrenia rated the illusion as being significantly stronger than did a non-clinical control group. Thakkar et al. (2011) also found that the experimental group reported greater degrees of proprioceptive drift (i.e., the feeling that the position of a person's real hand had moved to the location of the rubber hand) compared to the control group. Relatedly, Asai, Mao, Sugimori, and Tanno (2011) found that, amongst university students, those scoring higher on measures of schizotypy and empathy were more susceptible to the RHI. They proposed that excessive empathy "might lead to deficits in self-other representation" (p. 1479), which explains the susceptibility to body ownership illusions. Asai et al. (2011) also suggest that this susceptibility can be linked to the positive symptoms of schizotypy where people substitute their lost sense of ownership (or agency) with the body (or action) of another person or object. In relation to agency and action, Louzolo, Kalckert, and Petrovic (2015) showed that healthy people who score higher on a measure of delusion-proneness were more likely to attribute passive movements (i.e., those without a motor command) as self-produced during the moving RHI. These authors suggest that these people may experience ownership "in the absence of motor intentions, purely due to heightened reliance on external sensory signals" (p. 7).

Interestingly, McCreery and Claridge (1996) found that individuals who scored high on a measure on schizotypy reported more instances of out-of-body experiences (OBEs) than individuals who scored lower on the same measure. Although the current study is not assessing OBEs *per se*, these findings are relevant in that individuals high on a measure of schizotypy may be more susceptible to illusions where their sense of body ownership is altered. Given the information above, we suspect that the distinct anomalies in body ownership associated with schizophrenia (see Burrack & Brugger, 2005; Mohr, Blanke, & Brugger, 2006) and schizotypy contribute to a greater susceptibility to body swapping illusions.

This study aimed to extend van der Hoort and colleague's (2011) research into the Barbie Doll Illusion. Specifically, we assessed whether non-clinical schizotypal personality traits increase susceptibility to the Barbie Doll Illusion. Given past research (e.g., Peled et al., 2000) has found a relationship between susceptibility to this kind of illusion and symptoms of schizophrenia, and given the similarities between schizophrenia and schizotypy, it was hypothesized that individuals who score high on the cognitive-perceptual factor (i.e., positive schizotypy) of a measure of schizotypy (relative to those who score low on the same factor) would report higher levels of immersion in the illusion. Secondly, it was hypothesised that immersion in the illusion would result in individuals perceiving a cube as being larger than when the same cube was presented to participants not immersed in the illusion.

Method

2.1 Participants

Forty-four members of the Australian general public (17 men, 27 women) took part in the experiment. They had a mean age of 29.36 years (*SD* = 8.14 years; range 18-58 years). They had no reported visual, tactile, or muscular abnormalities. Participants were recruited via three main sources: (1) advertisements placed on student noticeboards, (2) through social media outlets such as Facebook®, and (3) via a local classified listing. Federation University's Human Research Ethics Committee and RMIT's Human Research Ethics Committee approved the project. All participants provided written informed consent before beginning the experiment.

2.2 Materials

2.2.1 Experimental set-up

Participants were required to wear a pair of Head-Mounted Display (HMD) goggles (Sony HMZ-12H Head Mounted Unit 5.6V). The HMD goggles were connected to a video-camera

(Sony Handy-Cam HDR-XR260) via a High Definition Multimedia Interface (HDMI) box (Sony HMZ-T2P). This enabled the vision in the camera to be seen through the HMD goggles. The camera was mounted onto a tripod facing an artificial doll (see Figure 1). The artificial doll (69cm long x 25cm wide) was placed on a small table, with its lower extremities (waist and legs) visible to the participants through the HMD goggles (see Figure 2).

Figure 1. Experimental set-up. The participant lays down on the mattress beside the video camera and table while wearing the HMD goggles. The participant would then see the world from the doll's perspective.

Figure 2. The participant's view through the HMD goggles. The image in the highlighted square is what the participants saw while wearing the goggles. *Note:* The TV was covered with a black cloth, and thus there was no reflection.

To mimic the posture of the doll, participants were asked to lay on a foam mattress on the floor next to the artificial doll. They rested their head on three cushions, so that their head was angled such that they were "looking" down at their legs.

The 'stroking devices' used in the experiment were two wooden sticks with a polystyrene ball attached to the end of each (see Figure 1). The polystyrene balls were different sizes – a small one to stroke the doll and a large one to stroke the participant. This ensured that the ball appeared to be proportional to body size.

After each condition, a cube (15 × 15 × 15 cm) on a string was presented to participants at the feet of the doll. Participants indicated the perceived size of the cube by holding both hands

the relevant distance apart. This distance was measured and deemed to be an estimate of cube size.

2.2.2 Immersion questionnaire

Immersion in the illusion was measured using a self-report questionnaire comprised of seven statements, each answered on a seven-point Likert scale, ranging from (1) *strongly disagree* to (7) *strongly agree*. This questionnaire was identical to one developed by van der Hoort et al. (2011) (see Table 1).

Table 1. Immersion questionnaire. Statements 1-3 were designed to capture the subjective experience of owning an artificial body, while Statements 4-7 were designed to control for task compliance and suggestibility (van der Hoort et al., 2011).

Statement no.	Statement text
1	I felt as if the doll's body was my body
2	It seemed as though the touch I felt was caused by the object touching the doll
3	It seemed as if I was feeling the touch that was applied to the doll
4	I felt as if I had two bodies
5	I felt younger than I actually am
6	I felt as if my body was turning 'artificial'
7	The doll began to resemble my own body in terms of shape, skin tone, or some other visual feature

Statements 1-3 reflect the experiences that would typically be characteristic of a body swapping illusion (in this case, the Barbie Doll Illusion). This includes the feeling that the doll's body was the participant's own body, and the feeling that they could feel the touch applied to the doll (van der Hoort et al., 2011). Statements 4-7 describe experiences that are not typical of the illusion. These questions are asked in an attempt to ensure participants' answers are accurate, rather than being the result of task compliance or suggestibility. It is assumed that if the participant experiences immersion in the illusion, then S1-S3 would be highly endorsed. Scores on each of the groups of statements (S1-S3 and S4-S7) were averaged to form (1) an overall 'immersion' score, and (2) an overall 'control' score.

2.2.3 Schizotypal Personality Questionnaire (SPQ)

Participants completed the Schizotypal Personality Questionnaire (SPQ; Raine, 1991), a 74-item self-report questionnaire assessing thoughts and feelings across nine domains (Ideas of Reference, Excessive Social Anxiety, Unusual Perceptual Experiences, Odd or Eccentric Behaviour, No Close Friends, Odd Speech, Constricted Affect, and Suspiciousness), which are grouped into three factors: cognitive/perceptual symptoms, interpersonal symptoms, and disorganised symptoms (as outlined in Raine, 1991; Wuthrich & Bates, 2005). Sub-scale scores are taken as the average of responses to items on the relevant sub-scale, while the total SPQ score is the average of all items. For each questionnaire item (e.g., "I rarely laugh or smile" and "I often feel that others have it in for me"), participants respond using a five-point Likert scale, ranging from (1) *strongly disagree* to (5) *strongly agree*. Although originally administered in a forced-choice format (see Raine, 1991), Wuthrich and Bates (2005) demonstrated that administering the SPQ in a Likert format had benefits such as improving (1) internal reliability, especially for certain subscale scores (i.e., constricted affect, unusual

perceptual experiences, no close friends), and (2) the ability to identify high scorers missed by the original version. As such, we used the Likert version. The SPQ was modelled on the *Diagnostic and Statistical Manual for Mental Disorders 3rd Edition Revised (DSM-III-R)* definition of schizotypal personality. That said, and as Fonseca-Pedrero et al. (2018) note, the SPQ is consistent with the *Diagnostic and Statistical Manual for Mental Disorders 5th Edition* "because the nine symptoms have not changed" (p. 454). Overall, the forced-choice SPQ has excellent internal consistency (α = 0.90; Raine, 1991), as does the paper-based Likert version (α = 0.96; Wuthrich & Bates, 2005), and we got a similar figure (i.e., α = 0.96). For this study, and consistent with Asai et al. (2011), we focused on the effect of the positive, cognitive-perceptual symptoms (e.g., unusual perceptual experiences) on perceived immersion in the illusion.

Procedure

Participants were asked to lay down on a foam mattress beside the artificial body while the experimenter placed the HMD on their heads. A sheet covering the artificial body was then removed, at which time the participant could see the lower body and legs of the artificial body through the HMD.

The experimenter then used two rods to stroke the participant's right leg, above or below the knee, and the doll's left leg, above or below the knee, in an asynchronous manner for two minutes. That is, the participant's right leg was stroked at different times to when, and in different directions to which, they saw the doll's left leg being stroked. Each stroke lasted for approximately one second. After the two-minute period, the participant was presented with a cube, in front of the camera and above the doll's feet. They were asked to estimate the size of the cube by holding their hands the relevant distance apart. A measuring tape was used to measure this distance, and it was recorded. After this 'asynchronous' stroking condition, the doll was covered up, the HMD was removed, and participants were asked to fill out the immersion questionnaire to gauge their experience.

In the second condition, both the right thigh of the participant and the right thigh of the doll were stroked synchronously for two minutes (i.e., the touch on the participant's leg was matched to the direction and timing of the touch they saw on the doll's leg). Again, each stroke lasted approximately one second. After two minutes, the participant was, again, presented with the cube and the size estimation process was repeated. After estimating the size of the cube, the doll was covered up, the HMD removed, and participants completed the immersion questionnaire. The order of the synchronous and asynchronous stroking conditions was counterbalanced between participants.

After completing these conditions, participants were asked to fill out the SPQ. The SPQ was always completed last in an attempt to remove the possibility that participant behaviour would be influenced by demand characteristics. We also recorded participant's age and gender at this time.

Results

3.1 Data screening

Before inferential analyses were run, data were checked for missing values; Field (2005) suggests that missing values exceeding 5% are problematic. The dataset did not contain any missing values due to participant drop-out/non-response. The data were then checked for outliers using Hoaglin and Iglewicz's (1987) outlier labelling rule. One outlier was identified in the Unusual Perceptual Experiences subscale of the SPQ. This data point was not discarded because (1) it was a legitimate observation, and (2) the Unusual Perceptual Experiences subscale was not subjected to an analysis but, rather, was amalgamated with other subscales and the influence of the cognitive-perceptual (i.e., positive) factor was assessed.

3.2 MANCOVA

In order to investigate the effect of 'touch type' and 'cognitive-perceptual schizotypy scores' on subjective ratings of how strong the body swapping illusion was (i.e., 'immersion ratings', S1-3) and control questions (S4-7), a MANCOVA was run. Here, touch type (synchronous vs. asynchronous) was the within-subjects factor, and continuous cognitive-perceptual SPQ scores were included as a covariate. Age and gender were also included as covariates to control for their effects. No main effect of touch type on participant responses was observed, nor were there any significant effects of gender or age. There was a significant main effect of cognitive-perceptual scores on participant responses [$F(2,39) = 7.69$, $p = .002$, $\eta_p^2 = .283$, wilks' $\lambda = .717$]. Univariate analyses showed this was significant for both the immersion scores [$F(1,40) = 14.10$, $p = .001$, $\eta_p^2 = .261$] and the control question scores [$F(1,40) = 12.37$, $p = .001$, $\eta_p^2 = .236$]. This could simply mean that people rating themselves higher on schizotypy are more prone to issues associated with task compliance and suggestibility. However, it could also mean that these people had a greater tendency to experience body perceptual distortions. Importantly, there was a significant interaction between touch type and cognitive-perceptual SPQ scores [$F(2,39) = 3.79$, $p = .031$, $\eta_p^2 = .163$, wilks' $\lambda = .837$]. Univariate analysis showed that this was due to a significant positive schizotypy scores × touch type effect on immersion scores [$F(1,40) = 5.71$, $p = .022$, $\eta_p^2 = .125$], but not on control question scores ($p = .111$).

Considering the continuous scores on the schizotypy measure, the correlation between cognitive-perceptual scores and immersion scores was strong for the synchronous condition ($r = 0.58$, $p < .001$), while the association was weaker in the asynchronous condition ($r = .40$, $p = .008$). Using Cocor (see Diedenhofen & Musch, 2015) to compare the correlations, with an overlapping, matched sample and a two-tailed test, the synchronous *r*-value was significantly higher than the asynchronous *r*-value ($z = 2.02$, $p = .043$). Given this, and the significant interaction in the MANCOVA reported above, it is clear that the positive symptoms of schizotypy were associated with higher immersion ratings in the synchronous condition than in the asynchronous condition. These data are shown in Figure 3.

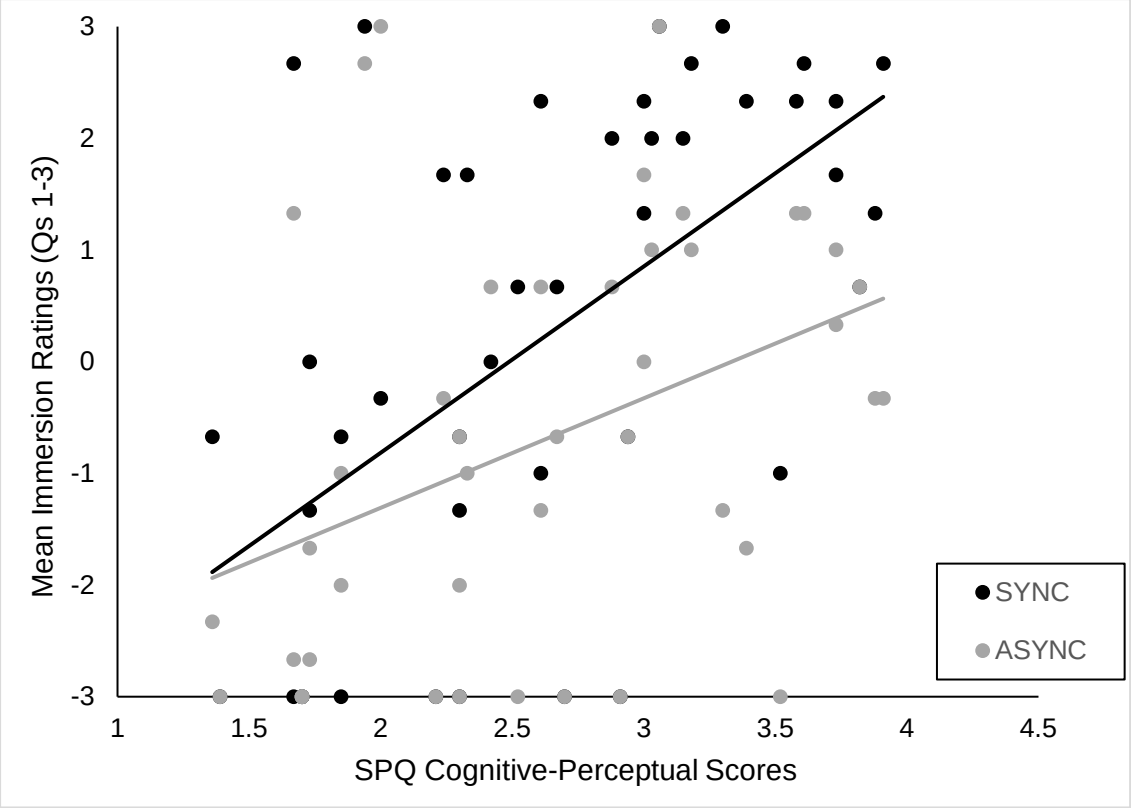

Figure 3. Immersion ratings in synchronous and asynchronous touch conditions as a function of cognitive-perceptual scores (SPQ).

In order to investigate the effects of interpersonal schizotypy scores, and disorganised schizotypy scores, two more MANCOVAs were run; this time including these factor scores as covariates (along with age and gender). When interpersonal scores were included, a main effect of interpersonal SPQ scores on participant ratings was observed [$F(2,39) = 6.20$, $p = .005$, $\eta_p^2 = .241$, wilks' $\lambda = .759$]. A univariate analysis showed that this was significant for both the immersion scores [$F(1,40) = 12.58$, $p = .001$, $\eta_p^2 = .239$] and the control question scores [$F(1,40) = 7.67$, $p = .008$, $\eta_p^2 = .008$]. Again, there was a significant touch type × interpersonal SPQ scores interaction [$F(2,39) = 4.01$, $p = .026$, $\eta_p^2 = .170$, wilks' $\lambda = .830$]. Univariate analyses showed that this was due to a significant interaction between interpersonal scores and touch type on immersion scores [$F(1,40) = 5.51$, $p = .016$, $\eta_p^2 = .138$], but not for control question scores ($p = .126$). Similarly, the correlation between interpersonal scores and immersion scores was strong for the synchronous condition ($r = 0.57$, $p < .001$) and weaker in the asynchronous condition ($r = 0.37$, $p = .013$), and these values were significantly different ($z = 2.21$, $p = .027$).

Finally, when disorganised scores were used as a covariate (as well as age and gender), the main effect of disorganised scores on participants' ratings was significant [$F(2,39) = 4.74$, $p = .001$, $\eta_p^2 = .302$, wilks' $\lambda = .698$]. Univariate analyses showed that this was significant for both the immersion scores [$F(1,40) = 17.10$, $p < .001$, $\eta_p^2 = .299$] and the control question scores [$F(1,40) = 7.04$, $p = .011$, $\eta_p^2 = .150$]. While the multivariate interaction between disorganised scores and touch type did not reach statistical significance ($p = .074$), the univariate analyses showed a significant interaction for immersion ratings only [$F(1,40) = 4.72$, $p = .036$, $\eta_p^2 = .106$]. Again, the correlation between disorganised scores and the immersion scores was strong for the synchronous condition ($r = 0.57$, $p < .001$), and slightly weaker for the asynchronous condition ($r = 0.44$, $p = .003$). However, this difference was not significant ($p > .05$). Therefore, while all schizotypy factors increased the tendency to answer in the affirmative to all questions, only the cognitive-perceptual and interpersonal scores had a significant effect on the perceived strength of the Barbie Doll Illusion.

3.3 Ratings of cube size

We also ran a one-way ANCOVA to examine the effect of touch type (asynchronous vs. synchronous) on estimates of cube size. Here, touch type was the within-subjects factor, and continuous cognitive-perceptual SPQ scores were included as a covariate. Age and gender were also included as covariates to control for their effects. Preliminary analyses revealed that assumptions of normality were not violated. There were no statistically significant differences in estimates of cube size between touch types [$F(1,42) = 0.13$, $p = .717$]. As such, estimates of cube size in the asynchronous touch condition ($M = 27.87$ cm; 95% CI [26.25, 29.48]) did not differ from those in the synchronous touch condition ($M = 28.10$ cm; 95% CI [26.28, 29.93]). This result was not expected given previous findings (see van der Hoort et al., 2011). The interaction between touch type and positive SPQ scores did not achieve significance [$F(1,40) = 0.02$, $p = .888$], nor did the main effect of cognitive-perceptual SPQ scores [$F(1,40) = 0.22$, $p = .641$][1]. No effects were revealed when exploring the effects of touch type and interpersonal SPQ scores on estimates of cube size, nor were there any effects when disorganised SPQ scores were assessed.

[1] These results replicated pilot data we collected. A one-way ANCOVA was conducted, with estimates of cube size (in cm) as the dependent variable (actual cube size in the pilot study = 8.7cm). The main effect of the within-subjects factor 'touch type' failed to reach significance, $F(1,37) = 0.10$, $p = .749$. As such, estimates of cube size in the asynchronous touch condition ($M = 13.39$ cm, $SE = .67$ cm) did not differ significantly from the synchronous touch condition ($M = 13.61$ cm, $SE = .96$ cm). The main effect of cognitive-perceptual SPQ scores did not achieve significance in the pilot study, $F(1,37) = 0.45$, $p = .508$. Finally, the interaction between SPQ scores and touch type was not significant, $F(1,37) = 0.18$, $p = .672$. No effects were revealed when exploring the effects of touch type and interpersonal SPQ scores on estimates of cube size, nor were there any effects when disorganised SPQ scores were assessed.

Discussion

The purpose of this experiment was to explore the influence of schizotypal personality traits on susceptibility to body ownership illusions. Here, we used the Barbie Doll Illusion. Based on earlier research (e.g., Asai et al., 2011), the first hypothesis stated that those who scored high on the cognitive-perceptual factor of the Schizotypal Personality Questionnaire (SPQ) would report higher levels of immersion in the Barbie Doll Illusion, relative to those who scored lower on this factor. This hypothesis was supported. That said, the relationship between immersion and positive schizotypy was not the same in the synchronous and asynchronous touch type conditions. Although immersion ratings increased as positive SPQ scores increased, this effect was stronger in the synchronous touch condition. This is interesting as an increase in agreement with the control questions was also observed but, here, there was no interaction between SPQ and the touch conditions. The second hypothesis stated that immersion in the illusion (and hence a perceived reduction in body size) would result in individuals perceiving a cube as being larger than when the same stimulus was presented to participants not immersed in the illusion (and hence did not experience a change in the perceived size of their body). This hypothesis was not supported.

The degree of positive schizotypy experienced by individuals influenced the experience of immersion in the illusion, or the feelings of ownership over the artificial body. These findings are consistent with those from past research that suggest that symptoms of schizophrenia predispose individuals to being more susceptible to this type of illusion. Earlier research (e.g., Peled et al., 2000, 2003, Thakkar et al., 2011, Waters & Badcock, 2010) has shown that individuals with schizophrenia experience more vivid RHIs in comparison to non-clinical controls. Relatedly, Asai and colleagues (2011) found that individuals scoring higher on a measure of positive schizotypy were more susceptible to the RHI. The results presented here suggest that higher sub-clinical levels of positive schizotypy symptoms *created* the finding that synchronous touch leads to greater immersion in the Barbie Doll Illusion than does asynchronous touch. While it is possible that those individuals high in positive schizotypy may have made a naïve hypothesis about the experiment, and responded accordingly (that is, guessed that the synchronous touch should lead to greater immersion), it seems just as likely (given responses to the control questions) that these people are more prone to perceptual distortions associated with their bodies than are people scoring lower on the positive dimension of the SPQ.

Relatedly, the degree of negative (or interpersonal) schizotypy experienced by individuals also influenced the experience of immersion in the illusion. It is known that subjective evaluations are susceptible to effects of task compliance and suggestibility; participants who give high ratings on one questionnaire tend to give high ratings on another questionnaire. Given the domains (i.e., Excessive Social Anxiety, No Close Friends, Constricted Affect, and Suspiciousness) that are grouped together to form the interpersonal factor (Raine, 1991; Wuthrich & Bates, 2005), it could argued that people who gave high ratings on this factor also gave high ratings on the ownership questionnaire because they are prone to issues associated with task compliance and suggestibility; the responses to the control statements seem to support this position. However, an intriguing alternative is that higher scores on the interpersonal factor are associated with excessive empathy. To explain, Chikovani, Babuadze, Iashvili, Gvalia, and Surguladze (2015) found that, when uncertain about facial expressions, people with excessive empathy tend to categorise the expression as being sad or fearful, rather than neutral. This anomaly could provoke anxiety in those with excessive empathy regarding social interactions (see Aron & Aron, 1997, for a similar idea regarding highly sensitive people). Thus, and consistent with Asai et al. (2011), the interpersonal factor may be associated with excessive empathy which, in turn, is associated with a deficit in self-other representation and a greater tendency to experience body perceptual distortions. Decoupling this issue requires further research.

A seemingly logical question that needs to be addressed is: Why would people scoring high on the positive and interpersonal factors of the SPQ give higher ratings in the synchronous

touch condition than in the asynchronous touch condition? The difference between synchronous and asynchronous touch is in the internal consistency of the sensory stimuli. Specifically, synchronous touch suggests that the 'seen' leg is the 'touched' leg, whereas asynchronous touch does not. Of course, in the synchronous touch condition there is 'external' inconsistency with one's true background belief that one cannot change size and feel touch on a small doll's leg. However, people scoring high on the positive and interpersonal dimensions of the SPQ seem to give greater credence to the internal consistency of current sensory input; thus, they are less concerned about the tension between current stimuli and prior background beliefs, given the immediate, internal consistency of the stimuli in synchronous touch. This is of interest because it suggests a bias towards perceptual inferences ("that's my leg") that neatly accommodate much of the immediate sensory input at the expense of properly weighting less immediate evidence ("my body could never be a doll"). This is reminiscent of previous findings (in probabilistic urn tasks) of a tendency of people with schizophrenia to jump to conclusions (i.e., concluding on the basis of relatively restricted evidence) (Garety, Hemsley, & Wessely, 1991; Hemsley & Garety, 1986). Here, though, there is the added requirement that jumping to (perceptual) conclusions happens when the restricted evidence has 'internal consistency' (i.e., that it can easily be explained away by the selected hypothesis). This speaks to the notion of the body image arising through Bayesian perceptual inference (Apps & Tsakiris, 2014; Hohwy, 2013; Hohwy & Paton, 2010), subject to various reasoning deficits.

Participants' ratings of cube size did not differ between the asynchronous stroking condition and the synchronous stroking condition. This finding suggests one of two possibilities. One possibility is that the illusion induced in our set-up was too weak to affect object perception. An alternative possibility is that synchronous visual-touch stimulation was not sufficient to alter the participant's perception of body size, which seems to be supported by the fact that we did not find a significant main effect of touch type in either the experiment or in pilot research. This finding is interesting because it contradicts previous research. For example, van der Hoort et al. (2011) found that synchronous visual-touch stimulation induced a feeling of ownership over a small artificial body which, in turn, altered the individual's perception of the external environment (e.g., cube size). Specifically, if participants perceived their body to be smaller, they estimated the cube's size as being larger.

There are a few reasons as to why our findings might differ from those of previous research. Firstly, it is worth noting that each stroking condition in van der Hoort and colleagues' (2011) study lasted for four minutes, compared to the two minutes used in the current experiment. Although this was not described as an essential element of the illusion, it is one element where the current experiment differs from the original. It is possible that this may have had some effect on the illusory experience, which seems to be borne out in the mean immersion scores (here M = ~0.2, whereas in van der Hoort et al.'s paper M = ~2.0). However, Petkova and Ehrsson (2008) conducted a body swapping experiment where visual-touch stimulation was applied for two minutes and found that participants' felt that the mannequin's body was their own. Similarly, Hohwy and Paton (2010) conducted research using the RHI in a virtual reality setting and found that 10 to 20 seconds of visual-touch stimulation was sufficient to create the feeling that participant's 'owned' the rubber hand. Thus, it is unlikely that stroking time could explain this non-significant effect.

Another difference is that, to induce the illusion, the HMDs were connected to a single video camera filming the doll's perspective (see Figure 1). A potential problem here is that the doll's body was not presented in stereoscopic view to the participants. Thus, they were deprived of eye convergence cues as to the size of body, which could contribute to the absence of an object (i.e., cube) effect here. That said, there were landmarks in the visual field (e.g., a table) and participants often commented on how "weird" the experience was. Relatedly, the digital video camera (i.e., Sony Handy-Cam HDR-XR260) has a relatively long inherent delay, which may have reduced the vividness of the illusion (see Shimada, Fukuda, & Hiraki, 2009) compared to earlier studies (e.g., van der Hoort et al., 2011; van der Hoort & Ehrsson, 2014;

van der Hoort & Ehrsson, 2016). That said, there was an attempt to match the visual and tactile stimuli (i.e., the experimenter monitored the visual stimuli in the camera while generating the tactile stimuli). Furthermore, only one cube and a single, artificial body was used here. Previous researchers (e.g., van der Hoort et al., 2011; van der Hoort & Ehrsson, 2014; van der Hoort & Ehrsson, 2016) have used 3 or 4 differently-sized cubes to, apparently, avoid the risk of participants relying on memory when making object judgements. This, in conjunction with the use of only one body, may have decreased the sensitivity of the estimation task. Finally, although the findings are consistent with those from earlier RHI studies (i.e., higher scores on a schizophrenia-related measure were associated with greater immersion in an illusion; Peled et al., 2000, 2003; Thakkar et al., 2011; Waters & Badcock, 2010), the RHI and body swapping illusions (e.g., the Barbie Doll Illusion) can differ in important ways (e.g., anatomical specificity of the illusion [see Chen, Huan, Lee, & Liang, 2018]). These procedural differences may contribute to differences in results, and this has implications for theory. It is, perhaps, the case that the RHI is weaker in individuals scoring high on positive schizotypy relative to the body swapping illusion experienced by people with high scores on this factor. If true, this difference could be a consequence of people with schizophrenia experiencing significant aberrations in the perception of the size of their legs (Priebe & Rohricht, 2001); an anatomical feature appearing in body swapping illusions that is not present in RHIs.

The current study investigated the relationship between schizotypal personality traits and one's susceptibility to a body swapping illusion. We show that cognitive-perceptual and interpersonal schizotypal traits influence one's susceptibility to manipulations of body ownership. This is consistent with findings showing that people with schizophrenia report more vivid illusions than do non-clinical controls (Peled et al., 2000). This is remarkable because it suggests that sub-clinical deficits play a role in the susceptibility to body swapping illusions, and thus may be involved in key cognitive processes involved in shaping body ownership. This finding is also remarkable in the context of the general discussion of body illusions, like the much studied RHI: it is, perhaps, the case that the RHI is much weaker in low cognitive-perceptual and interpersonal SPQ scoring individuals and stronger in people with higher scores on these factors. Perhaps reported RHIs (and other body illusions) are driven to a significant degree by higher schizotypy individuals. Future research may reveal the degree to which schizotypy is involved in this seemingly innocuous multisensory illusion.

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