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Body Ownership in Youth at Risk of Developing Schizophrenia and Bipolar Disorder and Healthy Controls using the Rubber Hand Illusion

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Abstract

Previous research has indicated a more flexible sense of body ownership in schizophrenia patients, as measured with the Rubber Hand Illusion (RHI) paradigm. To assess whether a disturbance in body ownership may be a vulnerability marker for the development of schizophrenia, the current study compared the effects of the RHI between three groups: children with high familial risk of schizophrenia (SZ), children with high familial risk of bipolar disorder (BD), and a control group (HC). Furthermore, the RHI was compared between children with and without psychotic symptoms. Results indicated no differences in the RHI between the SZ, BD and HC group. However, the current study does suggest a stronger subjective RHI in children with subclinical psychotic symptoms. Hence, disturbances in body ownership may be related to clinical instead of familial risk. Due to the small sample size, these results have to be interpreted carefully.

Keywords: schizophrenia, bipolar disorder, self-disorder, body ownership, rubber hand illusion, high risk youth

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1. Introduction

Schizophrenia is a very debilitating and heterogeneous psychiatric disorder (Tandon et al., 2013) that is originally believed to involve three different symptom clusters, namely positive symptoms (e.g. hallucinations and delusions), negative symptoms (e.g. poverty of speech, affective flattening), and disorganization symptoms (e.g. incoherence of speech, distractibility) (American Psychiatric Association, 2013). It has been suggested that intervention prior to the onset of psychotic symptoms may result in better outcome for schizophrenia patients (e.g. Tarbox & Poque-Geile, 2008). For an early intervention to be possible, identification of vulnerability markers is necessary. At present, no clear early markers for the development of schizophrenia are known that precede psychotic symptoms.

Recently, much research has emerged on social cognition in schizophrenia (Addington, Saeedi & Addington, 2006; Green et al., 2012; Lee, Altshuler, Glahn, Miklowitz, Ochsner & Green, 2013). According to Beer and Ochsner (2006) social cognition can be defined as "the perception of others, the perception of self, and interpersonal knowledge" (p.99). These three social stimuli can be perceived at low or high levels of complexity (Beer & Ochsner, 2006). Low-level processes involve perception and recognition of socioemotional information and high-level processes involve inferences about the mental states of others, empathy and emotional regulation (Lee et al., 2013). In accordance with this, the broad construct of social cognition is often subdivided in different aspects in the schizophrenia literature, namely Emotion Perception (EP), Social perception (SP), Theory of Mind (ToM) and Attributional Style (AS) (Green, Olivier, Crawleys, Penn & Silverstein, 2005). Difficulties in these aspects of social cognition are found in schizophrenia patients (Green et al., 2012).

Disturbances in self-processing may underlie these difficulties in social cognition (Nelson, Sass, Thompson, Yung & Francey, 2009) and are often claimed to be at the core of schizophrenia (Sass & Parnas, 2003; Waters & Badcock, 2010; Nelson, Whitford, Lavoie & Sass, 2014a, 2014b). More specifically, Sass and Parnas (2003) claim that an *ipseity* disturbance (ipse is Latin for "self" or "itself", p. 428) underlies schizophrenia, which is a disturbance in experiencing the world in first person. This phenomenological description of self-disturbances in schizophrenia is put in a neurocognitive perspective by Nelson et al. (2014a, 2014b). They claim that these disturbances are associated with source monitoring deficits and aberrant salience in this patient population, which involve difficulties in distinguishing between internal and external stimuli (Nelson et al., 2014a), and excessive attention to irrelevant stimuli (Nelson et al., 2014b), respectively. According to them, "these neurocognitive disturbances may constitute the neural correlates or cause of an abnormal sense of basic selfhood or ipseity" (Nelson et al., 2014b, p. 25).

These disturbances in self-processing may be a target for early intervention in the development of schizophrenia. First, because they may be specific to schizophrenia in comparison to (psychotic) bipolar disorder (Parnas, Handest, Sæbye & Jansson, 2003; Haug et al., 2012; Lee et al., 2013), a disorder that shows resemblances to schizophrenia when it, for instance, comes to certain symptoms and susceptibility genes (Murray, Sham, Van Os, Zanelli, Cannon and McDonald, 2004). Second, self-disturbances, as measured by the Examination of Anomalous Self-Experience (EASE; developed by Parnas et al., 2005), were found in youth at *high clinical risk* of developing schizophrenia, who had attenuated psychotic symptoms and/or functional problems (Davidsen, 2009; Nelson, Thompson and Yung, 2012). In addition, Parnas, Carter and Nordgaard (2014) assessed self-disturbances in offspring

of patients with schizophrenia, which are at *high familial risk* of developing schizophrenia. In general, offspring of patients with severe mental illness have a higher risk of developing psychopathology (Rasic, Hajek, Alda & Uher, 2014). Moreover, having a first-degree biological relative with schizophrenia is the strongest known predictor of the disorder (Glatt, Stone, Faraone, Seidman, & Tsuang, 2006). Parnas et al. (2014) point to self-disturbances in children at high familial risk before the onset of clinical symptoms (premorbidly) and hence the potential predictive value of these disturbances for the development of schizophrenia.

One concept involved in self-processing is body ownership, which is "the sense that one's own body is the source of sensations" (Tsakiris, Prabhu & Haggard, 2006, p. 424), and can be assessed using the Rubber Hand Illusion paradigm (RHI; originally described by Botvinick and Cohen, 1998), in which a rubber hand is stroked synchronously or asynchronously with the own (unseen) hand. According to the neurocognitive model of body ownership by Tsakiris (2010), feelings of ownership result from both bottom-up and top-down processes. The bottom up process involves the multisensory integration of visual, tactile and proprioceptive information. This integration of sensory information is important for a coherent representation of the body and the world (Tsakiris, 2010). The top-down process involves an internal representation of the body. During synchronous stroking in the RHI paradigm a match between visual and tactile information is present, which can result in the feeling of the rubber hand belonging to the own body and the feeling that one's own hand is shifted towards the rubber hand (Tsakiris, 2010).

Results obtained in studies assessing body ownership in schizophrenia patients using the RHI point to body ownership disturbances in these patients (Peled, Hirschmann, Geva & Modai, 2000; Thakkar, McIntosh, Nichols & Park, 2011).

Patients experienced the RHI stronger than controls, which suggests that these patients have a more flexible sense of body ownership (Thakkar et al., 2011). There is some evidence that this may be related to the experience of positive symptoms, such as hallucinations, delusions of reference, and delusions of control in schizophrenia patients (Peled et al., 2000; Thakkar et al., 2011). Asai, Mao, Sugimori and Tanno (2011) also suggest a relationship with passivity phenomena in these patients. Only two studies (Peled et al., 2000 and Thakkar et al., 2011) have assessed the RHI in schizophrenia patients, hence more research is required in this field.

To assess whether disturbances in the sense of body ownership are present in youth at high familial risk of developing schizophrenia and may be a possible early vulnerability marker for the development of the disorder, the current study compares the RHI between three groups: children with high familial risk of schizophrenia, children with high familial risk of bipolar disorder, and a control group. Two outcome measures for the RHI are used, namely a perceptual (proprioceptive drift) and a subjective (self-reported RHI) measure (see Cowie, Makin & Bremner, 2013). To our knowledge, the current study is the first to assess the RHI in children at risk of developing schizophrenia or bipolar disorder. However, the RHI has been assessed in control children (Cowie et al., 2013; Cascio, Foss-Feig, Burnette, Heacock & Cosby, 2012). These studies suggest that control children show a comparable RHI as adults on a perceptual and a subjective level of the illusion.

Based on the described literature, it is expected that the children from the control group will show effects of the RHI on both outcome measures (proprioceptive drift and self-reported RHI). Furthermore, it is expected that the children with high familial risk of schizophrenia will experience the RHI stronger, resembling the patient population, since disturbances in self-processing are already observed in high risk

youth. Moreover, it is expected that the children with high familial risk of bipolar disorder will show a similar RHI as the control children, since much less evidence points to disturbances in self-processing in bipolar disorder than in schizophrenia. Lastly, it is expected that children at high familial risk of developing schizophrenia or bipolar disorder with psychotic symptoms (high clinical risk) will show a stronger RHI than children without these symptoms, based on findings from earlier studies on the relationship between the presence of psychotic symptoms and the strength of the RHI.

2. Method

2.1. Participants

The current study was part of the SCIP (Social Cognition and Imaging in Psychiatry) study, which is a study on social cognition in schizophrenia patients and high risk youth and the relationship between possible disturbances in social cognition, self-other processing, and social functioning. The children in this study all participated in the BRIDGE (Brain Imaging Development and Genetics) study as well, which is a study on the development of children at familial risk of developing psychosis. Three groups were included in the current study: children with high familial risk of schizophrenia (SZ), children with high familial risk of bipolar disorder (BD), and a control group with no high familial risk of psychopathology (HC). The majority of children in the two high familial risk groups (SZ and BD) had a parent with schizophrenia or bipolar disorder, with the exception of two children from the SZ group who had two second-degree biological relatives with schizophrenia. Furthermore, the high familial risk groups (SZ and BD) were divided in two clinical risk groups: a group with psychotic symptoms (psychotic+) and a group without these

symptoms (psychotic-). The psychotic+ group suffered from at least one mild or severe positive symptom in the previous three years (based on the K-SADS-PL interview described below). The RHI was assessed in 30 children. Furthermore, 19 children from the high familial risk groups were assessed using the K-SADS-PL. In table 1 participant characteristics are summarized.

Table 1

Participant Characteristics by Familial and Clinical Risk Groups

Group	N	Age, Mean Years (SD)	% Male	% Right-handed
SZ	12	15.91 (1.52)	8.3	83.3
BD	10	16.60 (2.85)	50.0	90.0
HC	8	14.69 (0.99)	75.0	100.0
Statistics		$F = 2.11$	$\chi^2 = 9.57$[a]	$\chi^2 = 1.31$[a]
		$p = .14$	$p = .01$	$p = .76$
Psychotic+	5	15.84 (0.79)	0	92.9
Psychotic-	14	16.46 (2.65)	35.7	60
Statistics		$t = 0.77$[b]	$\chi^2 = 2.42$[a]	$\chi^2 = 2.99$[a]
		$p = .45$	$p = .26$	$p = .16$

Note. [a]Fisher's exact tests. [b]Equal variances not assumed.

The inclusion criteria for all participants at baseline (T1) were: aged 8-18, written informed consent by child and parent, no major medical history, no history of neurological illness, Dutch speaking and IQ>70. Furthermore, for the BD group at least one first-degree biological relative or more than one second-degree biological relatives had to be diagnosed with bipolar disorder and for the SZ group at least one

first-degree biological relative or more than one second-degree biological relatives had to be diagnosed with schizophrenia. Last, for the HC group the following inclusion criteria were used: no history of psychiatric illness, no first-degree family member with a psychotic and/or mood disorder or other psychiatric illness and no use of psychotropic medication.

2.2. Design

The independent variables in the current study were familial risk group (BP, SZ, HC) and clinical risk group (psychotic+, psychotic-). The dependent variable was the RHI, which consisted of two outcome measures: proprioceptive drift and self-reported RHI. Within subjects, effects of synchronous and asynchronous stroking on the RHI were measured. These effects were compared between groups.

2.3. Procedure

Participants were assessed at the UMC Utrecht, department of psychiatry. The total data collection process of the BRIDGE study took approximately nine hours per participant, spread over two or three visits. Before the data collection process started, all inclusion criteria were checked and participants and their parents signed informed consent. The BRIDGE study is a longitudinal study in which the children are assessed three times, with a period of three years in between each assessment. During each assessment (T1, T2 and T3) the same measurements are obtained. Since the tasks from the SCIP study are obtained during T2 only, the current study included only T2 measurements. Furthermore, only the measurements relevant for the current study, the RHI and a diagnostic interview, are described here.

2.4. Measurements

Rubber Hand Illusion (RHI). With the RHI a sense of body ownership was assessed. In this paradigm (originally described by Botvinick and Cohen, 1998)

participants' own left (or right) hand is kept out of sight. Instead, participants see a rubber hand on their left (or right). Both their own (invisible) hand and the (visible) rubber hand are then synchronously or asynchronously stroked. In case of synchronous stroking, the match between the tactile perception on their own hand and the visual perception on the rubber hand can create the illusion that the rubber hand is the participant's own or belongs to their body. In the current study, we measured proprioceptive drift towards the rubber hand and self-reported RHI. A schematic illustration of the experimental set up is given in figure 1. Furthermore, supplement 1 contains the score form used for the RHI.

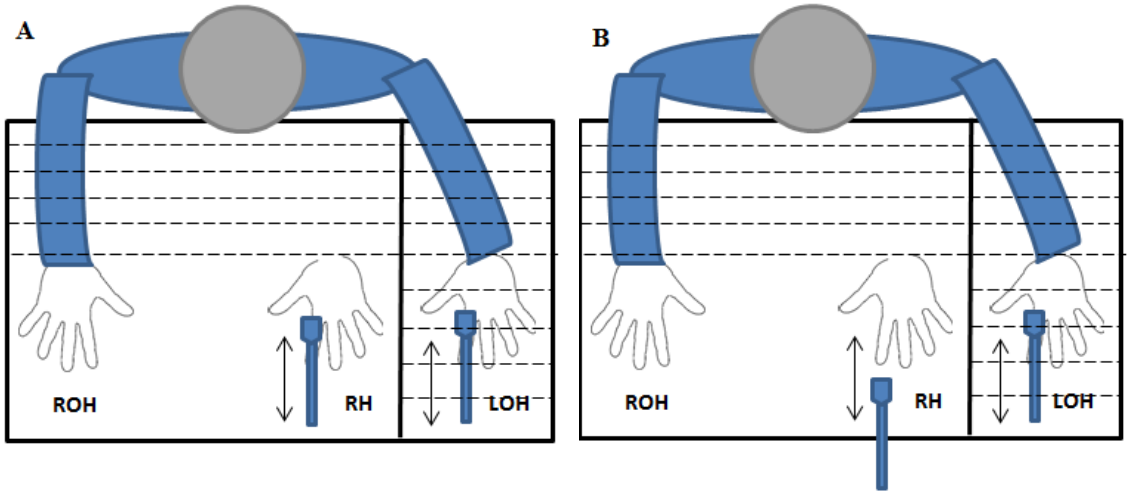

Figure 1. Schematic illustration of a bird's eye view of the RHI set up, with A representing the synchronous and B the asynchronous stroking condition. ROH = right own hand; RH = rubber hand; LOH = left own hand. Dotted lines cover the areas not seen by the participant during the stroking of the hands.

Proprioceptive drift. Proprioceptive drift involves the perception that one's own hand is spatially closer to the rubber hand than it really is and is a perceptual measurement of the RHI. Participants' hands were placed on fixed locations within

the experimental set up (such that their left index finger was placed on 50% of arm length from the middle of the body, the index finger from the fake hand on 25% from the middle, and their right index finger on 25% from the middle) and a cape was placed over their wrists to cover the end of the rubber hand. Baseline measurements of the perceived hand location before stroking were obtained, in which the test leader slowly moved the own index finger along the top of the experimental setup and the participants were asked to say 'stop' when they had the feeling that the index finger of the test leader was aligned with their own left or right index finger. A screen was placed horizontally on the experimental setup during these measurements, so the participants could not see the hands. For both fingers two baseline measurements were obtained, one from the left of the experimental setup and one from the right. These four baseline locations were noted by the test leader (a ruler was attached to the experimental setup). The participants were asked to close their eyes and the screen was placed vertically between their left hand and the fake hand, so the participants could not see their own left hand. Then they were asked to open their eyes again and they were told that the test leader was going to stroke both their own hand and the rubber hand, that they should look at the rubber hand, and that they should keep their own hands still. The stroking of both the rubber hand and the left hand began. After each period of stroking the screen was placed horizontally on the experimental setup again, so the participants could no longer see the hands. Subsequently, proprioceptive drift in both the left and right finger was measured four times after stroking using the same procedure described for the baseline measurements: after one period of 120 seconds of stroking and three times after 20 seconds of stroking (two times from the right of the experimental setup and two times from the left). This procedure was equal

for a synchronous and asynchronous condition. The order in which the stroking conditions were assessed was counterbalanced between participants.

Self-reported RHI. The self-reported RHI is a subjective measurement of the RHI and involved two items (based on Cowie et al., 2013): one on the perceived location of the brush strokes (location item: "Did you feel the touch at the location of the fake hand, when I touched your hand with the brush?") and the second on the sense of ownership (ownership item: "When I touched your hand with the brush, did it sometimes seem like the fake hand was yours, or belonged to your body?"). The questions were scored on a 7-point answer scale: 0 = no, not at all; 1 = no; 2 = no, not really; 3 = in between; 4 = yes, a little; 5 = yes, a lot; 6 = yes, lots and lots. After both conditions of stroking (synchronous vs. asynchronous) participants were asked to answer the two questions.

Clinical interview. Psychopathology was measured by the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL) (Kaufman et al., 1997). The K-SADS-PL is a semi-structured diagnostic interview that assesses current and past DSM IV symptoms. It involves questions on the following five categories: affective disorders, psychotic disorders, anxiety disorders, behavioral disorders and substance abuse and other disorders (e.g. eating and tic disorders). The interview assesses diagnoses in children and adolescents aged 6 to 18 years. The K-SADS-PL was conducted in all participating children and one of their parents. Parent and child were interviewed separately. They answered the same questions, which were combined to establish a composite score.

2.5. Statistical Analyses

For the analysis of proprioceptive drift, the mean of four measurements of the perceived index finger location after stroking was subtracted from the mean of two

baseline measures (before stroking) for both the left and right finger. This resulted in two drift scores per participant: one for the left finger and one for the right finger. To control for drift of the right finger in the analysis, the absolute drift score for the right finger was subtracted from the drift score for the left finger. A positive outcome indicated a greater perceived shift towards the rubber hand for the left than for the right finger. This was done for both the synchronous ($drift_S$) and asynchronous ($drift_A$) stroking condition. For the analysis of self-reported RHI the scores on the self-report location and ownership items (7-point answer scale) were used.

Importantly, two children were excluded from the analysis of proprioceptive drift prior to data exploration. In the first case (BD) measures of the right finger were missing and in the second case (SZ) the child used knowledge about the location of the hand relative to the side of the experimental setup, instead of a feeling of where the hand was located. Furthermore, possible distorting outliers were removed from the proprioceptive drift analysis (deviating more than 2SD from the mean proprioceptive drift for the synchronous or asynchronous stroking condition).

Familial risk. To test for statistically significant effects of synchronicity of stroking and familial risk group on proprioceptive drift a one-way repeated measures ANOVA with an α of .05 was performed with synchronicity of stroking ($drift_S$ versus $drif_A$) as a within subjects variable and familial risk group (SZ, BD or HC) as a between subjects variable. Furthermore, paired samples *t* tests were used to assess the effect of synchronicity of stroking within familial risk groups.

Since the self-reported RHI was assessed at an ordinal level of measurement, non-parametric tests with an $\alpha = .05$ (unless stated otherwise) were used in the analysis. To test for a main effect of synchronicity of stroking in the total group and within familial risk groups separately, Wilcoxon signed-rank tests were used on the

self-report items scores, with synchronicity of stroking as a within subjects variable. To test for a main effect of familial risk group a Kruskal-Wallis test was used on the mean scores on the self-report items (M synchronous and asynchronous stroking), with familial risk group as a between subjects variable. To test for an interaction effect between synchronicity and familial risk group a Kruskal-Wallis test was used on the difference scores on the self-report items (Δ synchronous and asynchronous stroking), with familial risk group as a between subjects variable.

To assess the relationship between the two self-report items and the relationships between proprioceptive drift and the two self-report items, Spearman's correlation coefficients (with an α of .05) were calculated on the difference scores (Δ synchronous and asynchronous stroking) of these three measures.

Clinical risk. To test for statistically significant effects of synchronicity of stroking and clinical risk group on proprioceptive drift a one-way repeated measures ANOVA with an α of .05 was performed with synchronicity of stroking ($drift_S$ versus $drif_A$) as a within subjects variable and clinical risk group (psychotic+, psychotic-) as a between subjects variable. Furthermore, paired samples *t* tests were used to assess the effect of synchronicity of stroking within risk groups.

Again, non-parametric tests with an $\alpha = .05$ (unless stated otherwise) were used in the analysis of the self-report items. To test for a main effect of synchronicity of stroking in the total group and within clinical risk groups separately, Wilcoxon signed-rank tests were used on the self-report items scores, with synchronicity of stroking as a within subjects variable. To test for a main effect of clinical risk group a Mann-Whitney *U* test was used on the mean scores on the self-report items (M synchronous and asynchronous stroking), with clinical risk group as a between subjects variable. To test for an interaction effect between synchronicity and clinical

group a Mann-Whitney *U* test was used on the difference scores on the self-report items (Δ synchronous and asynchronous stroking), with clinical risk group as a between subjects variable.

The analyses described above were also performed on a group with psychotic and/or affective (symptom+) symptoms and a group without these symptoms (symptom-), to assess whether possible effects of psychotic symptoms on the RHI were specific for these symptoms or whether a more general relationship between symptom presence and the RHI exists. The symptom+ group suffered from at least one mild or severe positive psychotic symptom and/or at least five mild or severe symptoms of depressions and/or at least three symptoms of mania in the previous three years.

3. Results

3.1. Familial Risk

See Table 2 for an overview of the statics and descriptives of the familial risk analyses of proprioceptive drift and the two self-report items.

Proprioceptive drift. In addition to the above described exclusions prior to data exploration, three participants (SZ:1, BD:1, HC:1) were outliers on the proprioceptive drift measure and were thus excluded. Hence, a total of 25 participants was included (SZ:10, BD:8, HC:7) in the analysis of proprioceptive drift. In supplement 2, the same analysis (non-parametric equivalent) without exclusion of these three outliers is presented, which reveals approximately the same results. After exclusion of the three outliers, the assumption of normality was supported for all three groups, as indicated by Shapiro-Wilk statistics and visual inspection of the

distribution of scores. Furthermore, the assumptions of homogeneity of variance (Fmax <10) and sphericity (Mauchly's Test) were supported.

A one-way repeated measures ANOVA revealed a main effect of synchronicity of stroking on proprioceptive drift. Furthermore, three paired samples *t* tests (Bonferroni corrected: $\alpha = .017$) revealed a significant effect of synchronicity only within the BD group and not within the SZ and HC groups. The repeated measures ANOVA revealed no main effect of risk group on proprioceptive drift and no interaction between risk group and synchronicity of stroking. Figure 2 illustrates the results on proprioceptive drift.

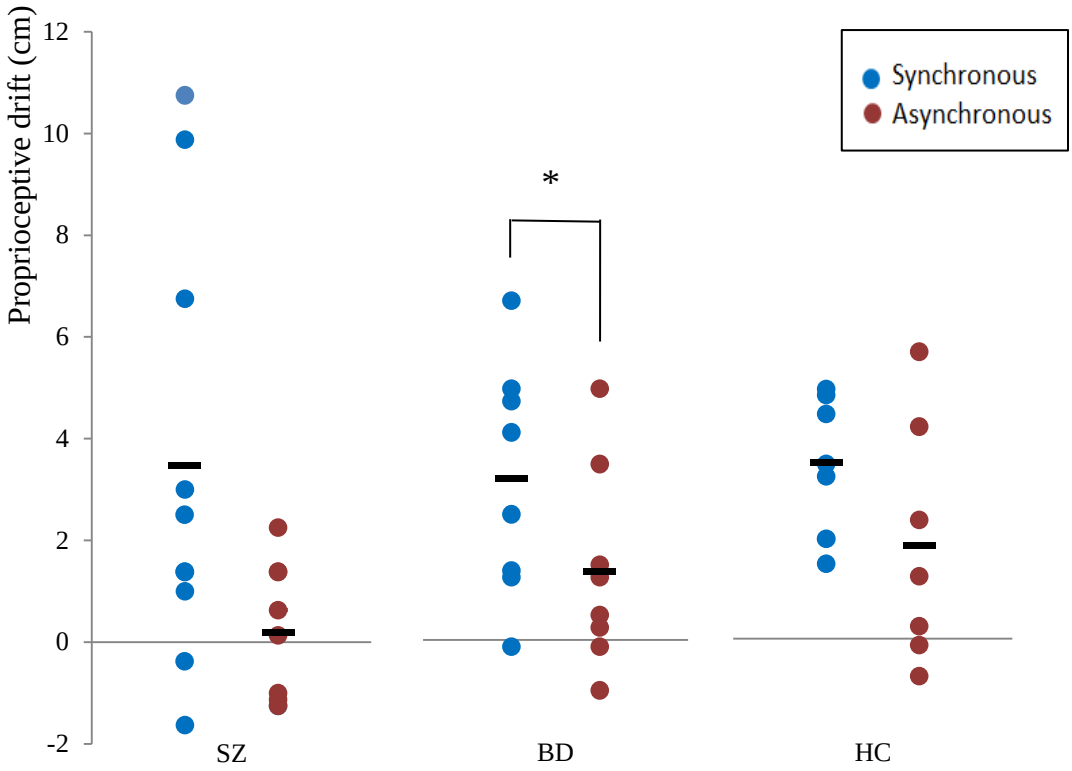

Figure 2. Proprioceptive drift in centimeter by familial risk group and synchronicity of stroking, with horizontal bars representing the mean. * = Significant mean difference between synchronous and asynchronous stroking within group ($p < .017$).

Table 2

Familial Risk Statistics and Descriptives for the RHI measures: Proprioceptive Drift, Self-Report Location item, and Self-Report Ownership item

RHI measure	Effect	Synchronous M (SD)	Asynchronous M (SD)	Test statistic (df)	*p*	Effect size
Drift (cm)	S	3.40 (2.97)	1.03 (1.94)	F (1,22) = 11.75	.002	η_p^2 = .35
	SZ	3.46 (4.24)	0.18 (1.28)	t (9) = 2.23	.053	d = 1.19
	BD	3.20 (2.32)	1.36 (1.99)	t (7) = 3.88	.006	d = 0.86
	HC	3.52 (1.38)	1.86 (2.41)	t (6) = 2.08	.083	d = 0.88
	G			F (2,22) = 0.41	.67	η_p^2 = .04
	S * G			F (2,22) = 0.66	.52	η_p^2 = .06
Location score	S	4.53 (1.50)	2.03 (2.01)	T = 4.00	< .001	r = .85
	SZ	4.67 (1.23)	1.83 (1.70)	T = 1.00	.007	r = .86
	BD	4.00 (2.16)	2.40 (2.41)	T = 1.00	.045	r = .82
	HC	5.00 (0.54)	1.88 (2.10)	T = 0.00	.017	r = .90
	G			H (2) = 0.52	.77	η^2 = .02
	S * G			H (2) = 2.54	.28	η^2 = .09
Ownership score	S	4.03 (1.67)	1.90 (1.99)	T = 12.00	< .001	r = .81
	SZ	3.83 (2.08)	1.08 (1.62)	T = 1.00	.007	r = .86
	BD	4.00 (1.76)	2.50 (2.42)	T = 4.00	.049	r = .70
	HC	4.38 (0.74)	2.38 (1.69)	T = 0.00	.017	r = .90
	G			H (2) = 1.93	.38	η^2 = .07
	S * G			H (2) = 1.93	.40	η^2 = .06

Note. S = main effect synchronicity; G = main effect familial risk group; S*G = interaction effect synchronicity and familial risk group.

Self-report location item. A Wilcoxon signed-rank test revealed a main effect of synchronicity of stroking. Furthermore, three Wilcoxon signed-rank tests (Bonferroni corrected: $\alpha = .017$) revealed that the effect of synchronicity was significant only within the SZ and the HC group and not within the BD group. Moreover, Kruskal-Wallis tests revealed no main effect of familial risk group and no interaction between synchronicity and familial risk group. Frequency distributions of the scores on the location item are presented in supplement 3.

Self-report ownership item. A Wilcoxon signed-rank test revealed a main effect of synchronicity of stroking. Furthermore, three Wilcoxon signed-rank tests (Bonferroni corrected: $\alpha = .017$) revealed that the effect of synchronicity was significant only within the SZ and the HC group and not within the BD group. Kruskal-Wallis tests revealed no main effect of familial risk group and no interaction between synchronicity and familial risk group. Frequency distributions of the scores on the ownership item are presented in supplement 3.

Correlations. A significant positive correlation was found between the two self-report items, $r_s(22) = .63$, $p < .001$. Furthermore, a significant positive correlation was found between proprioceptive drift and the self-report location item, $r_s(22) = .42$, $p = .037$, which is illustrated in figure 3. Moreover, no significant relationship was found between proprioceptive drift and the self-report ownership item, $r_s\ (22) = .34$, $p = .096$. This trend towards a positive relationship is illustrated in figure 4.

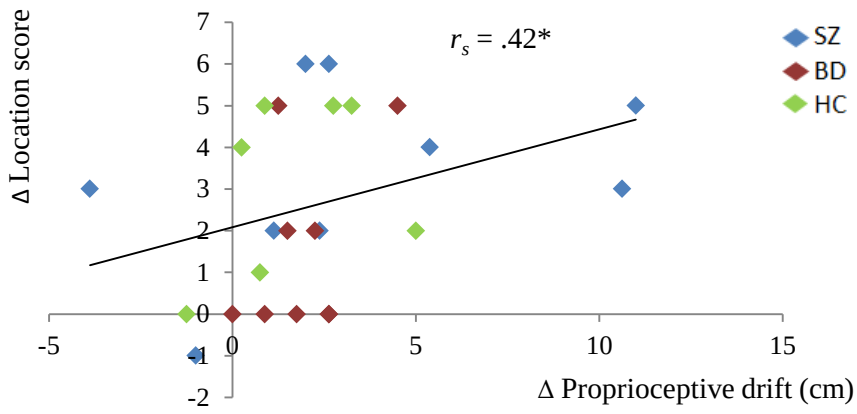

Figure 3. Relationship between the difference scores (Δ synchronous and asynchronous stroking) of proprioceptive drift and the self-report location item. * = Significant spearman correlation ($p < .05$).

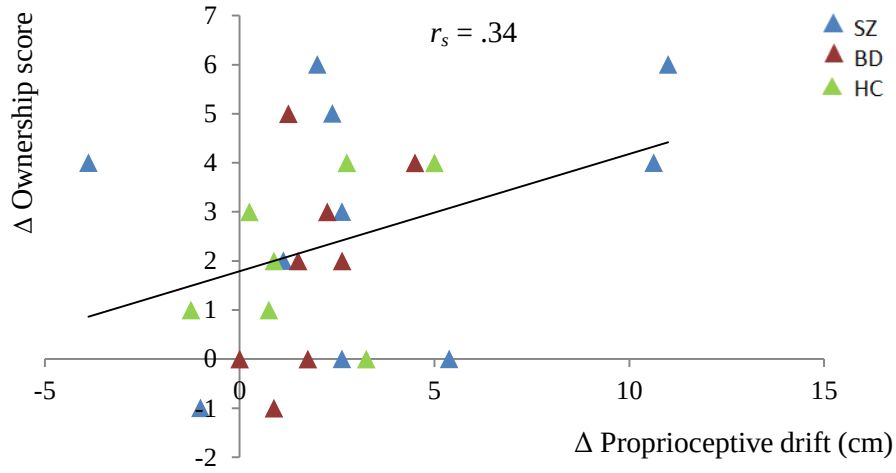

Figure 4. Relationship between the difference scores (Δ synchronous and asynchronous stroking) of proprioceptive drift and the self-report ownership item.

3.2. Clinical Risk

See table 3 for an overview of the statics and descriptives of the clinical risk analyses of proprioceptive drift and the two self-report items.

Proprioceptive drift. The assumption of normality was supported for the two clinical risk groups (psychotic+, psychotic-), as indicated by Shapiro-Wilk statistics and visual inspection of the distribution of scores. Furthermore, the assumptions of homogeneity of variance (Fmax <10) and sphericity (Mauchly's Test) were supported. A one-way repeated measures ANOVA revealed a main effect of synchronicity of stroking on proprioceptive drift. Furthermore, two paired samples *t* tests (Bonferroni corrected: $\alpha = .025$) revealed a significant effect of synchronicity only within the psychotic- group and not within the psychotic+ group. Moreover, the repeated measures ANOVA revealed no main effect of clinical risk group and no interaction between synchronicity of stroking and clinical risk group.

A one-way repeated measures ANOVA revealed similar results for the comparison of children with and without psychotic and/or affective symptoms (symptom+, symptom-). Specifically, no main effect of symptom group ($F(1,15) = 1.55$, $p = .23$, $\eta_p^2 = .094$) and no interaction between synchronicity and symptom group ($F(1,15) = 0.031$, $p = .86$, $\eta_p^2 = .002$) were found.

Self-report location item. A Wilcoxon signed-rank test revealed a main effect of synchronicity of stroking. Furthermore, two Wilcoxon signed-rank tests (Bonferroni corrected: $\alpha = .025$) revealed a significant effect of synchronicity only within the psychotic- group and not within the psychotic+ group. A Mann-Whitney U test revealed no main effect of clinical risk group. However, a Mann-Whitney U test did reveal a significant interaction between synchronicity and clinical risk group. Figure 5 illustrates the observed pattern.

For the comparison of the symptom+ and symptom- group, Mann-Whitney *U* tests revealed no main effect of symptom group ($U = 25.50$, $p = .11$, $r = 0.37$) and no interaction between synchronicity and symptom group ($U = 28.50$, $p = .17$, $r = 0.31$).

Table 3

Clinical Risk Statistics and Descriptives for the RHI measures: Proprioceptive Drift, Self-Report Location item, and Self-Report Ownership item.

RHI measure	Effect	Synchronous M (SD)	Asynchronous M (SD)	Test statistic (df)	*p*	Effect size
Drift (cm)	S	3.40 (3.53)	0.66 (1.73)	F (1,15) = 8.93	.009	η_p^2 = .37
	Psychotic+	3.48 (4.70)	0.05 (1.64)	t (4) = 21.42	.23	d = 1.08
	Psychotic-	3.36 (3.17)	0.92 (1.78)	t (11) = 2.90	.015	d = 0.49
	G			F(1,15) = 0.11	.75	η_p^2 = .01
	S * G			F(1,15) = 0.24	.63	η_p^2 = .02
Location score	S	4.37 (1.83)	2.05 (2.12)	T = 3.00	.002	r = .83
	Psychotic+	5.40 (0.89)	0.60 (0.89)	T = 0.00	.042	r = .91
	Psychotic-	4.00 (1.96)	2.57 (2.21)	T = 3.00	.020	r = .77
	G			U = 30.50	.67	r = .10
	S * G			U = 6.00	.006	r = .63
Ownership score	S	3.95 (1.99)	1.74 (2.21)	T = 7.50	.003,	r = .69
	Psychotic+	4.40 (2.51)	0.60 (0.89)	T = 0.00	.066,	r = .92
	Psychotic-	3.79 (1.85)	2.14 (2.41)	T = 7.50	.022	r = .69
	G			U = 31.50	.74	r = .08
	S * G			U = 17.00	.092	r = .39

Note. S = main effect synchronicity; G = main effect clinical risk group; S*G = interaction effect synchronicity and clinical risk group.

Self-report ownership item. A Wilcoxon signed-rank test revealed a main effect of synchronicity. Furthermore, two Wilcoxon signed-rank tests (Bonferroni corrected: α = .025) revealed a significant effect of synchronicity only within the psychotic- group and not within the psychotic+ group. Mann-Whitney U tests

revealed no main effect of clinical risk group and no significant interaction between synchronicity and clinical risk group. However, a trend towards a significant interaction was found. Figure 5 illustrates the observed pattern.

For the comparison of the symptom+ and symptom- group, Mann-Whitney *U* tests revealed no main effect of symptom group ($U = 26.50$, $p = .13$, $r = .35$) and no interaction between synchronicity and symptom group ($U = 40.00$, $p = .68$, $r = 0.09$).

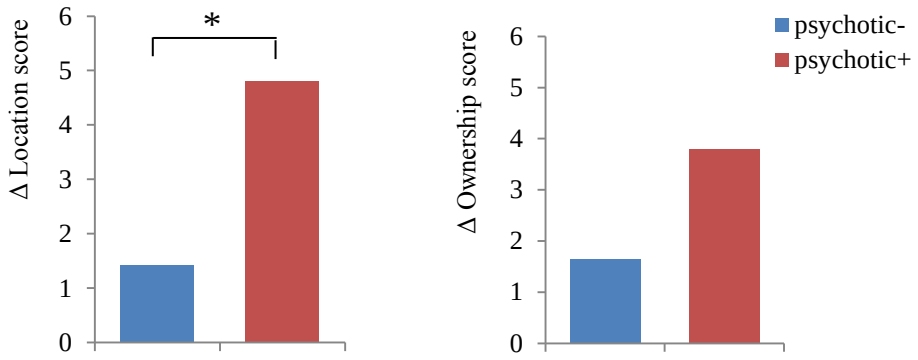

Figure 5. Mean difference score on the self-report location and ownership items between synchronous and asynchronous stroking, for children with versus children without psychotic symptoms. * = Significant difference in mean difference score ($p < .05$).

4. Discussion

It has been suggested that intervention prior to the onset of psychotic symptoms in schizophrenia may result in better outcome for these patients (e.g. Tarbox & Poque-Geile, 2008). For an early intervention to be possible, identification of vulnerability markers is necessary. A possible marker might be self-disturbances, such as disturbances in body ownership. To assess whether a disturbance in body ownership is present in youth at high familial risk of developing schizophrenia the

current study compared the effects of the RHI between three groups: children with high familial risk of schizophrenia (SZ), children with high familial risk of bipolar disorder (BD), and a control group (HC). Furthermore, to assess whether the presence of psychotic symptoms was related to the sense of body ownership, we compared children from the two high familial risk groups (SZ, BD) with and without psychotic symptoms on the RHI.

4.1. Familial Risk

A main effect of synchronicity was found on proprioceptive drift and the two self-report items (location and ownership), with more proprioceptive drift and higher scores on the self-report items during the synchronous stroking condition, compared with the asynchronous stroking condition. These results correspond with earlier findings (Cowie et al., 2013; Cascio et al., 2012; Peled et al., 2011; Asai et al., 2011; Thakkar et al., 2012) and validate the experimental manipulation used. Moreover, positive correlations were found between the two self-report items and a relationship was found between proprioceptive drift and the self-report location item. A relationship between proprioceptive drift and the self-report ownership item was found at trend level. These correlations indicate that the methods used to assess the sense of body ownership are reliable.

For proprioceptive drift and the self-report items, no main effects of familial risk group and no interaction effects between synchronicity and familial risk group were found. Contrary to the expectation, these results indicate that the children at high familial risk of developing schizophrenia did not show a more flexible sense of body ownership than the other two groups, at both the perceptual and the subjective level.

A possible explanation for the current findings is that these body ownership disturbances may develop later in life in those individuals with psychotic symptoms

or a diagnosis in the schizophrenia spectrum, instead of being present premorbidly. Previous studies do point to self-disturbances in individuals at high risk of developing schizophrenia (Davidsen, 2009; Nelson et al., 2012). However, Davidsen (2009) and Nelson et al. (2012) included high risk youth that already suffered from mild psychotic symptoms or functional problems (clinical high risk), which is different from the sample of the current study, in which we used children at familial risk. The greater RHI previously observed in schizophrenia patients (Peled et al., 2000; Thakkar et al., 2011) indicates a more flexible sense of body ownership, which Peled et al. (2000) suggest might result from both disconnection and overconnection in the brain of these patients. They suggest that lower neural systems are overconnected and less top-down control (disconnection) over these lower systems is present. These disturbances in functional connections in the brain might not appear until shortly before the onset of schizophrenia (review by Lawrie, McIntosh, Hall, Owens & Johnstone, 2008). This hypothesis may explain the absence of body ownership disturbances before the onset of other symptoms found in the current study.

In contrast, Parnas et al. (2014) also suggest self-disturbances in youth at high familial risk that can be detected premorbidly. They followed children at high familial risk longitudinally and found more premorbid self-disturbances in children who later developed a disorder in the schizophrenia spectrum than in children who did not develop psychopathology. Hence, an alternative explanation for not finding differences between familial risk groups would be that disturbances in body ownership are present before other symptoms only in those children that actually develop a disorder in the schizophrenia spectrum instead of being present in all children at high familial risk.

4.2. Clinical Risk

To assess whether the presence of psychotic symptoms (high clinical risk) was related to the sense of body ownership, we subsequently compared children from the two high familial risk groups with and without psychotic symptoms. Again, a main effect of synchronicity was found on both proprioceptive drift and the self-reported RHI items, indicating that our experimental manipulation also worked in this subsample. Furthermore, no main effect of clinical risk group and no interaction between clinical risk group and synchronicity were found on proprioceptive drift.

For the self-reported RHI items, no main effects of clinical risk group were found. However, an interaction between synchronicity and clinical risk group was found on the self-report location item, with the children with psychotic symptoms showing a greater effect of synchronicity of stroking on the reported feeling of displacement of touch towards the location of the rubber hand. Furthermore, a trend towards significance was found for the this interaction for the self-report ownership item, with children with psychotic symptoms showing a greater effect of synchronicity on the reported feeling that the rubber hand belonged to their own body. These results suggest that the children with psychotic symptoms do have a more flexible sense of body ownership at the subjective level, which is in accordance with previous findings on the relationship between psychotic symptoms and the RHI (Peled et al., 2000; Thakkar et al., 2011; Asai et al., 2011). Importantly, these results should be interpreted with caution, because of the small sample size and uneven distribution of children within the groups.

For the comparison of children with versus without psychotic and/or affective symptoms, no main effects of symptom group and no interaction effects between synchronicity and symptom group were found, for both proprioceptive drift and the

self-reported RHI questions. These results suggest a specific relationship between the RHI and psychotic symptoms, instead of a more general relationship between the RHI and symptom presence. This corresponds with the proposed specificity of basic self-disorders for schizophrenia in comparison to bipolar disorder (Parnas et al., 2003; Haug et al., 2012).

4.3. Limitations and Suggestions for Future Research

A limitation of the current study was the small sample size per group, which resulted in a lack of power. For example, this conceivably resulted in the effects of synchronicity not being significant within all separate groups. Additionally, because of the small sample size no reliable comparison between children with versus without psychotic symptoms could be made. Hence, a first suggestion for future work would be to assess the RHI in a larger sample of children at high familial risk. Related to this, matching the groups on variables such as age and gender is recommended for future work. Particularly, in the current study the gender distribution was not equal between groups, which may have confounded the results. However, since no familial risk group differences were found on the strength of the RHI and (to our knowledge) no studies are available that suggest clear gender differences in the RHI this possibility was not further explored.

Furthermore, to assess the hypothesis that disturbances in body ownership are present only in those children at high familial risk that actually develop schizophrenia in later life, three groups of children could be compared, namely: high family risk children who develop a disorder in the schizophrenia spectrum, high family risk children who do not develop a disorder in the schizophrenia spectrum and a healthy control group. The children included in the current study will be followed longitudinally in the coming years within the BRIDGE study, so this comparison can

be made in the future. Associated with this, it should be noted that the children in the BD group also have a higher risk of developing a disorder in the schizophrenia spectrum than the children in the HC group (Rasic et al., 2014). Therefore, if this alternative explanation is supported, it is conceivable that some children of the BD group who might develop a disorder in the schizophrenia spectrum in later life also show disturbances in the sense of body ownership before the onset of other symptoms. However, those children that may develop other psychotic disorders, such as psychotic bipolar disorder, are not expected to show disturbances in self-processing, because evidence points to these basic self-disturbances being specific to the schizophrenia spectrum (Parnass et al., 2003; Haug et al., 2012).

Moreover, it should be noted that the current study used a different and more specific method of assessing self-processing than the earlier studies cited (Davidsen, 2009; Nelson et al., 2012; Parnas et al., 2014). These earlier studies used the EASE (or a proxy scale) to assess self-disorders, which is a comprehensive symptom checklist on disorders of basic self-awareness (Parnas et al, 2005). Body ownership disturbances as measured by the RHI may involve a different form of self-disturbance and may develop later in those individuals with psychotic symptoms or a diagnosis in the psychotic spectrum, instead of being present premorbidly. To further explore the relationship between basic self-disturbances and body ownership in high risk youth and in schizophrenia patients, it is recommended to assess these individuals with both the EASE instrument and the RHI paradigm.

Importantly, abnormal patterns of body ownership using the RHI have been detected in other psychiatric disorders as well. For example, decreased flexibility of the sense of ownership has been found in autism spectrum disorder (Cascio et al., 2012) and an incread flexibility in anorexia nervosa (Eshkevari, Rieger, Longo,

Haggar & Treasure, 2012), which may be related to other pathological processes than the basic self-disturbances observed in schizophrenia. Future work should compare the RHI between different psychiatric disorders, to get more insight in these underlying processes.

4.4. Conclusion

The current study assessed the sense of body ownership in children at high familial risk of schizophrenia, as previous studies showed disturbances in self-processing in high risk youth. No differences in the flexibility of the sense of body ownership, measured using the RHI, were found between children with high familial risk of schizophrenia, children with high familial risk of bipolar disorder, and a control group. However, the current study does indicate that disturbances in body ownership may be related to clinical (presence of psychotic symptoms) instead of familial risk. Due to the small sample size of the current study, no definite conclusions can be drawn upon whether disturbances in body ownership can help in the early identification of those individuals most at risk of developing schizophrenia. To further explore this possibility, additional work on the relationship between (subclinical) psychotic symptoms in high risk youth and disturbances in body ownership is recommended. Furthermore, longitudinal assessment of the children from the current study into early adulthood can give more insight into the utility of disturbances in body ownership at identifying those people that have the highest risk of developing schizophrenia before the onset of other symptoms. Identification of vulnerability markers is necessary for early intervention, which may results in better outcome for schizophrenia patients.

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6. Supplements

6.1. Supplement 1

Rubber Hand Illusion

lengte hand	cm
(onderkant handpalm-topje middelvinger)	
armlengte (schouder - topje middelvinger)	cm
50% armlengte	cm
25% armlengte	cm

Volgorde condities	
S-A	A-S

Startposities	daadwerkelijk	Condities																	
linker wijsvinger	cm	synchroon										asynchroon							
op 50% armlengte		baseline		2 min		20 sec		20 sec		20 sec		baseline		2 min		20 sec		20 sec	
nep linker wijsvinger	cm	R:	cm	R:	cm	L:	cm	R:	cm	L:	cm	R:	cm	R:	cm	L:	cm	R:	cm	L:	cm
op 25% armlengte		L:	cm									L:	cm						
midden van het lichaam	cm																		
rechter wijsvinger	cm	R:	cm	R:	cm	L:	cm	R:	cm	L:	cm	R:	cm	R:	cm	L:	cm	R:	cm	L:	cm
op 25% armlengte		L:	cm									L:	cm						

Vragen

Voelde je de aanraking op de plek waar de nephand lag, toen ik je hand aanraakte met de kwast?

na..... conditie						
nee, helemaal niet	nee	nee, niet echt	neutraal	ja, een beetje	ja, erg	ja, heel erg
0	1	2	3	4	5	6
na..... conditie						
nee, helemaal niet	nee	nee, niet echt	neutraal	ja, een beetje	ja, erg	ja, heel erg
0	1	2	3	4	5	6

2. Toen ik je hand aanraakte met de kwast, leek het soms alsof de nephand van jou was, of bij jouw lichaam hoorde?

na..... conditie						
nee, helemaal niet	nee	nee, niet echt	neutraal	ja, een beetje	ja, erg	ja, heel erg
0	1	2	3	4	5	6
na..... conditie						
nee, helemaal niet	nee	nee, niet echt	neutraal	ja, een beetje	ja, erg	ja, heel erg
0	1	2	3	4	5	6

6.2. Supplement 2

Figure A illustrates the results of the analysis of proprioceptive drift, without the exclusion of the three outliers. The assumption of normality was violated for the SZ group (asynchronous stroking) and the HC group (synchronous stroking), as indicated by Shapiro-Wilk statistics and visual inspection of the distribution of scores. Therefore, non-parametric tests were used.

A Wilcoxon signed-rank test revealed a main effect of synchronicity of stroking, $T = 51.50$, $p = .002$, $r = 0.62$. Furthermore, three Wilcoxon signed-rank tests (Bonferroni corrected: $\alpha = .017$) revealed no significant effects of synchronicity of stroking within the three separate familial risk groups (SZ $T = 8.00$, $p = .026$, $r = 0.67$; BD $T = 7.00$, $p = .24$, $r = 0.69$; HC $T = 4.00$, $p = .050$, $r = 0.57$).

Furthermore, Kruskal-Wallis tests revealed no main effect of familial risk group on proprioceptive drift (using the mean drift score for synchronous and asynchronous stroking), $H(2) = 3.47$, $p = .18$, $\eta^2 = .13$, and no interaction between familial risk group and synchronicity (using the difference drift score for synchronous and asynchronous stroking), $H(2) = 1.84$, $p = .40$, $\eta^2 = .071$.

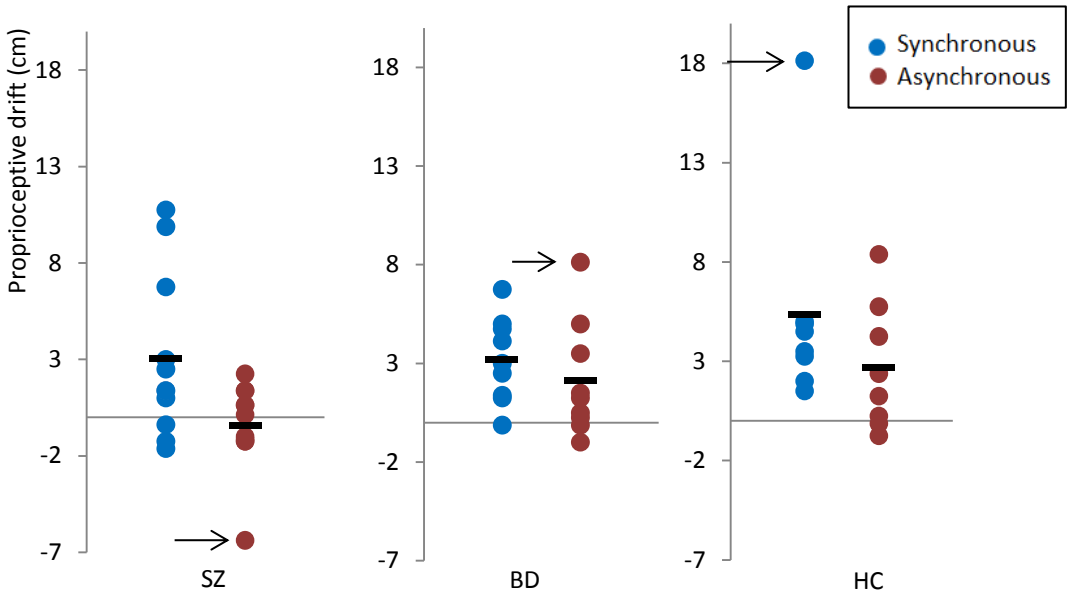

Figure A. Proprioceptive drift in centimeter by familial risk group and synchronicity of stroking, with horizontal bars representing the mean. Outliers indicated with an arrow.

6.3. Supplement 3

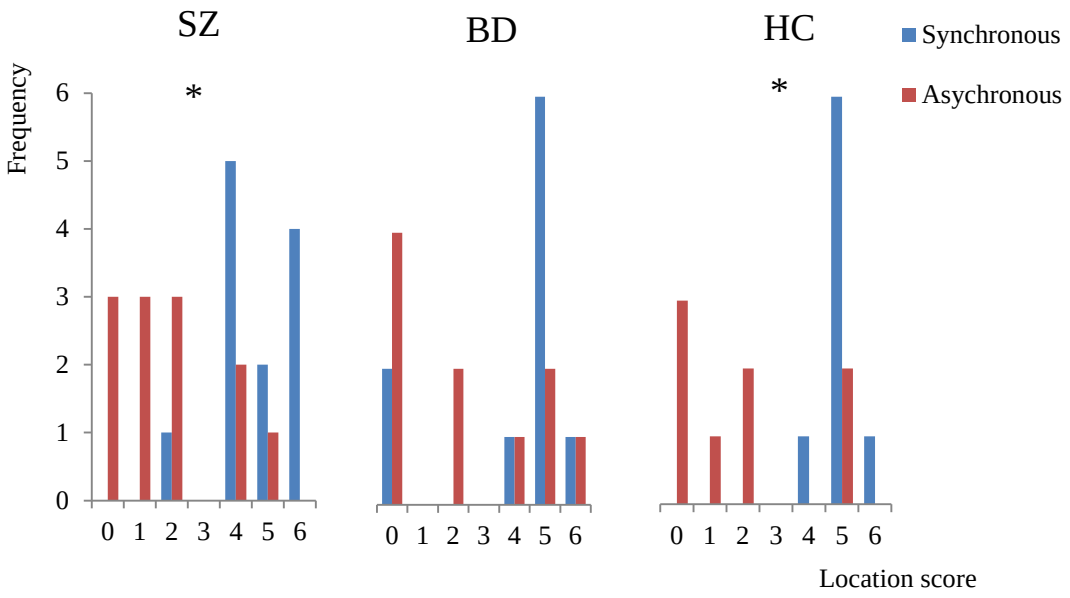

Figure 2. Frequency distribution of self-report location item scores by familial risk group and synchronicity. * = Significant difference between synchronous and asynchronous stroking within group ($p < .017$).

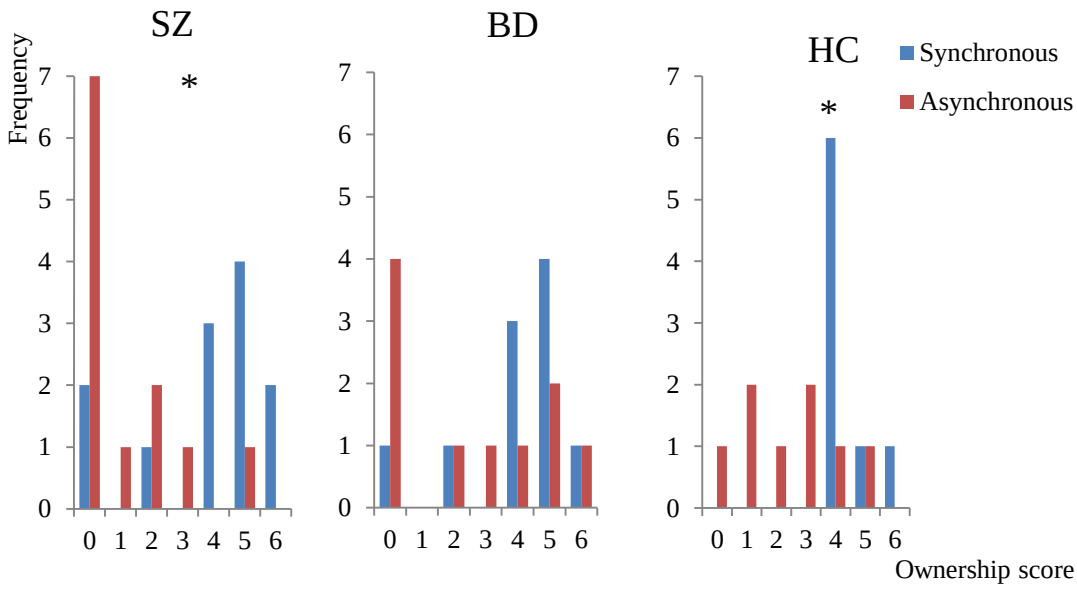

Figure 3. Frequency distribution of self-report ownership item scores by familial risk group and synchronicity. * = Significant difference between synchronous and asynchronous stroking within group ($p < .017$).