

more strongly than healthy individuals or finding no difference between the groups). In all these studies, the RHI experiment has been conducted in a single trial, making it difficult to understand the learning process that actually takes place. Honma et al. [15] were the first to report multiple trials of the RHI. They assessed healthy adults for 3 consecutive days, following baseline assessment. In their study they found that the RHI could be improved by training, and that processes that affect learning (such as sleep) can affect the leaning process of the RHI.

Many studies have revealed the extent of learning and memory impairments in schizophrenia [21,24]. However, research has shown that some cognitive processes are impaired whereas others are not. One explanation might be that for schizophrenia there may be differences in explicit memory, such as recall and recognition, from conscious memory, but not from implicit memory for which consciousness is less required [13]. We feel that it may actually be sensory memory that is deficient in this disorder. In order to test this hypothesis, we conducted an experiment in which the RHI was used as a tool aimed at examining the learning response over time.

This study has two novel approaches to the known methodology concerning the RHI. First, to date, the RHI has almost always been performed using a one trial paradigm. In this study, we repeated the RHI for five different trials (on three different dates) over a two-week period. In accord with previous studies, we hypothesized that for healthy controls, the initial time it would take to feel the illusion (start time 1) would be longer than for SZs, but that for all participants the illusion strength would not change throughout repetition. Healthy controls would get better at learning the illusion over time (their start times would decrease from trial to trial). As this experiment has not been conducted on multiple trials for SZs, we had no directional hypotheses for this group. Second, using this approach we could follow both the start time and illusion strength over time, and also explore the relationship between psychotic symptoms and the RHI. Following previous research, we hypothesized that the stronger the psychotic symptoms, the stronger the illusion strength would be.

2. Methods

2.1. Participants

A total of 60 right-handed adults participated in this study; 30 were schizophrenia inpatients, diagnosed by a senior psychiatrist using the Clinical Interview for DSM-IV. All were hospitalized at Sha'ar Menashe Mental Health Center. The healthy controls were either undergraduate students at Ruppin Academic Center (who participated in the study as a research course requirement) or had previous acquaintance with the authors, having volunteered their participation. All the participants signed consent forms after being given a full explanation of the study. All students but one participated in all parts of the study.

Inclusion criteria consisted of a 3-month history of drug abuse free, and all healthy controls had no known psychiatric history. Exclusion criteria consisted of a history of neurologic disorders or drug abuse or the inability to sign an informed consent.

For schizophrenia, current hospitalization lasted between 11 days and 10.3 years, with a mean of 1.31 years ($SD = 2.44$ years). There had between 0 and 47 previous hospitalizations (mean = 10.43, $SD = 10.45$), and they had been diagnosed between almost one year and 30 years (mean = 13.02, $SD = 8.61$).

There was a significant difference between the different groups in age. SZs were significantly older (mean = 37.37 years, $SD = 11.16$) than healthy controls were (mean = 30.90, $SD = 12.62$; $t_{(58)} = -2.10$; $P = .05$). There was also a significant difference between the groups in education. Healthy controls had

more education years (mean = 13.10 years, $SD = 2.11$) than SZs did (mean = 11.27, $SD = 1.60$; $t_{(57)} = 3.78$; $P = .000$). There was a significant difference between groups concerning sex of the participants. In the schizophrenia group, there were 24 (80%) males, compared to 15 (50%) in the control group ($\chi^2_{(1)} = 5.93$, $P = .02$).

There were no significant differences between groups in religion. Of the SZ, 23 (76.7%) were Jewish, 5 (16.7%) were Muslim, 1 (3.3%) was Christian, and 1 (3.3%) did not report his religion. Of the controls, 28 (93.3%) were Jewish, and the remaining 2 (6.7%) did not report their religion. No control participants were taking medication, and participants in both groups denied recreational drug use during an initial screening interview and a diagnostic interview.

2.2. Consent

The Helsinki committee residing in the hospital assessed all ethical issues and gave its consent to the study. An independent psychiatrist assessed the SZ's ability to give written and oral consent. Before beginning the experiment, all participants gave written consent and were asked to participate in all three parts of the study over a two-week period. On each of the remaining trials, they were asked again to give oral consent to participate, and were informed that they had a right to discontinue their participation in the study at any moment.

2.3. Measures

After completing the RHI on the first day, all participants filled out online questionnaires that included questions regarding demographic data, illusion strength, and body perception. A research assistant assisted the SZs to complete the online questionnaires, if they had questions. There were no dropouts in either group. One SZ was discharged before he could complete one of the online questionnaires. One of the healthy controls completed his class requirements early, and thus did not complete one of the online questionnaires. Both participants were included in the study, nonetheless.

2.3.1. Start time

Start time was reported as the first time the change was described as "feeling the rubber hand as my own" [2,23]. In order to refrain from any confounding of suggestibility, we used a very amorphous phrase: "Please tell me if you feel any change in your hand". When participants said they felt something that did not exactly reflect feeling the rubber hand as their own, we continued with the trial. Start time was reported in each trial (the illusion was performed once on the first day, twice on the second day, and twice on the third day). The participant was then instructed to report if and when the illusion ceased. If the illusion did not stop, brushing was ceased after the subject felt the illusion for three continuous minutes.

2.3.2. Illusion strength

The definition of illusion strength was adapted from former experiments [2,23]. After concluding the experiment on each of the trial days, participants were asked to rate the perceptual effect of the RHI by answering the question "I feel as if the rubber hand was my hand" on a 1–7 Likert type scale rating 1 as "not at all" and 7 as "very much".

2.3.3. Learning strength

Learning strength was described as the subtraction between the number of minutes it took for the participant to feel the illusion on the first trial and the time it took to feel the illusion on the fifth trial (the third day).



Fig. 1. Demonstrative description of the Rubber Hand Illusion.

2.3.4. Severity of schizophrenia symptoms

The Brief Psychiatric Rating Scale (BPRS) was used to assess severity of symptoms for SZs only. The BPRS is commonly used to measure psychotic symptoms. It has been noted for its high resolution, flexibility and simplicity as a general rating scale [20]. The patient's current doctor assessed each of the symptoms (e.g., guilt, hostility, distractibility) on a 7-point Likert scale and reflected the patient's current psychiatric state. This study used the standard shortened version, which includes 24 items. The BPRS has excellent reliability, and the Cronbach alpha for this study was .81. Inter-rater variability was achieved by first discussing a few mutual patients and reached Kappa = .95. When differences emerged, a senior doctor (the head of the department) made the final decision. The BPRS was reported on only by SZs, while all other questionnaires were reported on by all participants.

2.3.5. Feeling of body distortion

The Body Distortion Questionnaire (BDQ; [10]) was used to assess subjective feelings of body distortion. The BDQ was specifically designed to test subjective body distortion in schizophrenia, and has since been tested on other populations as well [4]. The BDQ consists of 82 phrases concerning different aspects of body distortion (such as boundaries or feeling that one's body parts are bigger or smaller than usual). The answers are 0 = "no", 1 = "undecided", and 2 = "yes". The sum of answers is calculated for each subscale. The BDQ consists of seven subscales (big, small, body is changing, boundaries, dirty, blocked openings, skin, depersonalization, and miscellaneous) and has good internal consistency.

2.3.6. Psychological distress

Symptom levels were measured by means of the Brief Symptom Inventory (BSI; [7]). The BSI is a 53-item self-report symptom inventory designed to assess the psychological distress status of study participants. It is essentially a brief form of the extensively used SCL-90-R questionnaire [6]. Participants rate the frequency of their symptoms on a 5-point scale, ranging from 0 (not at all) to 4 (extremely). The scale was adapted to an Israeli population by Canetti et al. [3]. The BSI has nine subscales (somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism), and can be used as an overall global score to capture global psychological distress.

2.4. Procedure

2.4.1. The Rubber Hand Illusion test (RHI)

In this procedure, participants are seated with their right arm resting on a small table. A standing screen is positioned beside the

arm to hide it from the participant's view, and a life-sized rubber model of a right arm and hand is placed on the table directly in front of the participant (see Fig. 1, following the protocol of Botvinick and Cohen's [2] study, and Peled et al. [22,23]). The participant sits with eyes fixed on the rubber hand while two small paintbrushes are used to stroke (synchronous brushing) the rubber hand and the participant's hidden hand. Strokes are delivered at a frequency of 1-second intervals, approximately 900 strokes for each experiment (lasting 15 min).

All participants were given the instruction, "Please tell me if you feel any change in your hand". Participants who said they felt a change were asked to describe the change. If the change included anything other than feeling the rubber hand as their own, they were instructed to continue focusing on the rubber hand as brushing of both hands continued.

On the second day, before the RHI, the participants were told that the objective of the first trial was to see if they felt as if the rubber hand was their own. The experiment was then repeated twice for 15 minutes on this day, the first trial acting as the "learning trial", which meant that the trial was considered a warm-up trial, and the results of this trial were not used in statistical analysis. Upon conclusion of both trials, participants were again asked to rate the extent to which they felt the rubber hand was their own hand. This procedure (the rubber hand illusion and the question) was then repeated on the third day. All three days were administered within a two-week period.

All participants underwent five trials of the illusion, on three different days. On the first trial, indices pertaining to the illusion were calculated.

Start time 1 indicates the amount of time in minutes it took for the participant to claim that he feels the rubber hand as his own on the first trial. On the second and third days, two trials each were administered. The first of the two trials, on each day, was considered a "warm-up" trial and therefore was not reported or analyzed. The second of the two trials was considered the "real" trial. As such, Start time 2 and Start time 3 represent the amount of minutes it took on trial 3 (day 2 trial 2) and on trial 5 (day 3 trial 2) to report feeling the rubber hand as one's own. At the conclusion of every day, the participants were asked to report on one question pertaining to how much they felt the rubber hand was actually their own. This was termed Illusion strength 1, Illusion strength 2, and Illusion strength 3, respective of the day of the experiment.

The difference between Start time 1 and Start time 3 was calculated and termed "learning strength". When the delta between start time 1 and start time 3 is positive, start time 1 is higher than start time 3. An individual with a large delta would be someone who learned the illusion well.

3. Results

3.1. Differences in symptomology

In order to examine the difference between groups on psychological distress and body distortion we ran a MANCOVA test where the group was the independent variable, body distortion and psychological distress indices were the dependent variables, and age, education and sex were inserted as covariates. For psychological distress, only somatization, phobic anxiety and psychoticism were found to be significantly different between groups. However, for body distortion, all indices were higher for SZs, as compared to controls (see Table 1).

3.2. Correlations between RHI indices

Overall correlations (for both groups) between start times, illusion strength, and learning strength are reported in Table 2.

As can be seen in Table 2, Start time 1 was positively significantly correlated with Start time 2, meaning that the longer it took to feel the illusion on the initial trial, the longer it took in the following trials. All three start times were negatively significantly correlated with illusion strength on all three trials, meaning that the longer it took to feel the illusion, the less strength the illusion had. Start time 1 was also positively significantly correlated with learning strength, meaning that the longer it took to feel the illusion initially, the stronger the learning strength, namely the less time it took to learn the illusion on trial 5. It should be noted that learning strength is a direct calculation of start time 1 and start time 3.

3.3. Start time

In order to test the hypothesis that healthy controls' start time would lessen over time, suggesting learning the illusion, and to assess the SZs' start times over the different trials, we conducted a Repeated Measures test in which the group was the independent variable and the three start times were the dependent variables. As there was a significant difference between groups in age, education and sex, all analyses were conducted using these variables as covariates (see Fig. 2).

As can be seen in Fig. 2, a main effect for trial emerged ($F_{(2,57)} = 8.05$, $P = .001$), meaning that there was an overall difference between the three trials: Start time 1 was the highest (mean = 10.30 minutes, SD = 5.68), followed by Start time 2 (mean = 7.33, SD = 7.04), and finally Start time 3 was the lowest (mean = 6.81, SD = 7.02). No main effect for group emerged ($F_{(1,58)} = 1.84$, $P = .18$), meaning that there was no overall difference between the two groups on start time. A significant interaction between group and trials emerged ($F_{(2,116)} = 9.99$, $P = .001$). Post-hoc tests revealed that the main difference between trials emerged between trials 1 and 2 (the mean of trial 1 was significantly higher than the mean of trial 2; $P = .001$). Fig. 2 indicates, as was hypothesized, that healthy controls' start time lessened over time compared to SZs.

Table 2

Pearson correlations between RHI indices.

	Start time 2	Start time 3	Illusion strength 1	Illusion strength 2	Illusion strength 3	Learning strength
Start time 1	.39*	.33	-.51*	-.26	-.23	.45*
Start time 2		.82*	-.58*	-.82*	-.71*	-.48*
Start time 3			-.41*	-.76*	-.85*	-.69*
Illusion strength 1				.43*	.37*	-.001
Illusion strength 2					.77*	.52*
Illusion strength 3						.62*

* Significant correlations at $P < .002$ after Bonferroni corrections.

Table 1

Differences between groups on body distortion and psychological distress, controlling for education, age and sex.

	Healthy controls Mean (SD)	Schizophrenia patients Mean (SD)	<i>P</i>
<i>Body distortion</i>			
			$F_{(9,47)} = 8.20$
			$P = .000$
Body too big	.56 (1.74)	17.55 (11.90)	$P = .000$
Body too small	.19 (.56)	17.59 (12.59)	$P = .000$
Body is changing	.04 (.19)	5.07 (3.48)	$P = .000$
Don't know where my boundaries are	.15 (.46)	12.28 (8.37)	$P = .000$
Feel dirty	.56 (.75)	7.10 (5.21)	$P = .000$
My openings are blocked	.37 (.74)	12.31 (8.27)	$P = .000$
My skin feels weird	.74 (1.16)	12.17 (8.39)	$P = .000$
I feel out of my body	.22 (.51)	12.45 (8.56)	$P = .000$
Miscellaneous	.07 (.27)	4.93 (3.44)	$P = .000$
<i>Psychological distress</i>			
			$F_{(10,49)} = 3.09$
			$P = .004$
Somatization	1.26 (.38)	1.55 (.65)	$P = .04$
Obsession-compulsion	1.71 (.40)	1.81 (.82)	NS
Interpersonal sensitivity	1.55 (.64)	1.78 (.72)	NS
Depression	1.60 (.62)	1.59 (.62)	NS
Anxiety	1.60 (.44)	1.60 (.67)	NS
Hostility	1.42 (.52)	1.41 (.71)	NS
Phobic anxiety	1.11 (.24)	1.49 (.60)	$P = .004$
Paranoid ideation	1.56 (.76)	1.87 (.87)	NS
Psychoticism	1.30 (.39)	1.65 (.67)	$P = .02$

At times 1, 2, and 3, 13, 20, and 23 of the healthy controls (respectively) reported feeling that the rubber hand was their own during the 15-minute trial period. The median time it took to feel the illusion in this group was 15, 1.41, and 1.19 minutes, respectively. For the SZs, 16, 13, and 12 (at times 1, 2, and 3, respectively) felt the rubber hand as their own, and their median time was 7.80, 15, and 15 minutes, respectively.

When examining the individual levels of change between start times, 8 (26.6%) of the healthy controls showed no changes in start times between time 1 and time 2 and then between time 2 and time 3. Moreover, 14 (46.7%) of the healthy controls showed a consistent decrease in start time from time 1 to time 2 and from time 2 to time 3. However, for SZs, the start times were inconsistent, even on an individual level. 12 (40%) of them had no change in start time between times 1 and 2 or between times 2 and time 3. 3 (10%) of the SZs actually increased start time between time 1 and time 2, but then showed no change between times 2 and 3. 2 (6.7%) first increased start time and then decreased start time, whereas another 4 (13.3%) first decreased start time and then increased it. Only 9 (30%) of the SZs decreased start times twice.

3.4. Illusion strength

In order to test the hypothesis that illusion strength would not change over time, we conducted a Repeated Measures test in which the group was the independent variable and the three

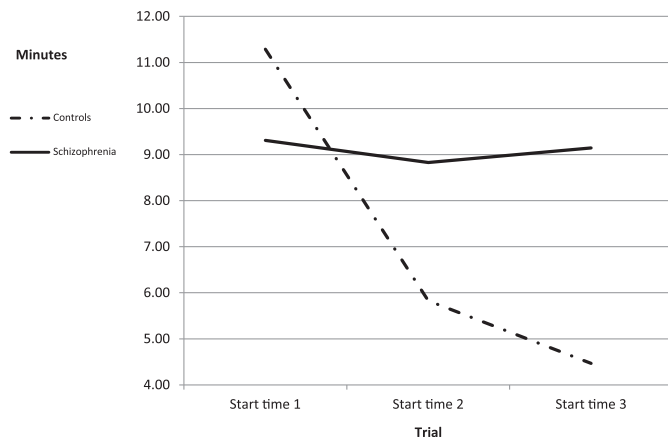


Fig. 2. Repeated measures between groups for start time over three trials.

illusion strengths were the dependent variables. As there was a significant difference between groups in age, education and sex, all analyses were conducting using these variables as covariates. The results for this test are depicted in Fig. 3.

As can be seen in Fig. 3, no significant difference between trials emerged ($F_{(2,56)} = .37, P = .69$). However, a significant difference between groups on illusion strength emerged ($F_{(1,57)} = 4.32, P = .04$), and a significant interaction between group and trial emerged ($F_{(2,114)} = 6.99, P = .001$). Healthy controls and SZs started out with the same illusion strength. Healthy controls' illusion strength increased over the trials, while SZs' illusion strength decreased, overall.

3.5. Learning strength

In order to test the hypothesis that healthy controls would have greater learning strength than SZs, we conducted an independent *t*-test with the group as the independent variable and learning strength the dependent variable. The learning strength of the healthy controls (mean = 6.82, SD = 7.13) was much higher than that of the SZs (mean = .16, SD = 6.23; $t_{(58)} = 3.85, P = .000$), meaning that healthy controls have a higher learning ability than SZs do.

As there was much variability in the SZs' sickness characteristics, we further examined correlations between the duration of hospitalization, frequency of previous hospitalizations and years of sickness with RHI indices. We found no significant correlations between these measures.

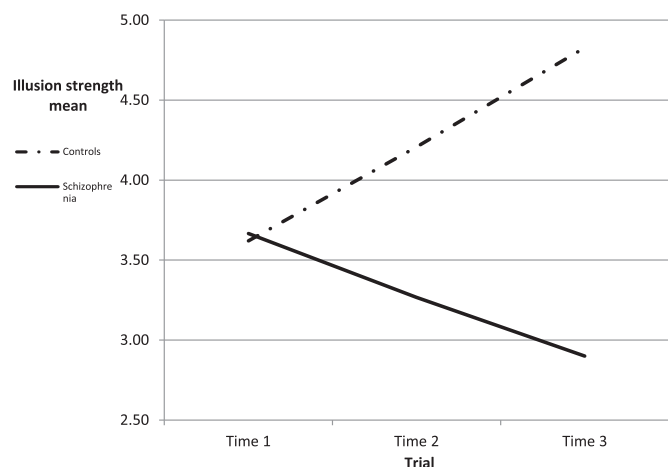


Fig. 3. Repeated measures between groups for illusion strength over three trials.

3.6. Combining symptomology and the RHI

Pearson correlations were conducted in order to assess the relationship between psychotic symptoms and body distortion with the RHI (i.e. Start time 1, Illusion strength 1, and learning strength; psychotic symptoms were assessed only for the SZs, all other correlations are for both groups combined). No correlations emerged between psychotic symptoms and any of the RHI indices. A negative correlation emerged between body distortion and Start time 1 ($r = -.30, P = .02$), meaning that the stronger the body distortion, the harder it was for the participants to feel the initial illusion. A negative correlation also emerged between body distortion and learning strength ($r = -.26, P = .05$), meaning that the higher the body distortion, the lower the ability to learn the illusion is.

4. Discussion

This study's aims were two-fold:

- to replicate previous studies concerning RHI in SZ and to try and shed light on previous inconsistencies with regard to the initial illusion;
- to expand this experiment in order to try and understand SZs' ability to learn the illusion over time.

We found that the three start times were influenced by the group. Healthy controls' start time lessened over the three trial periods, suggesting that they had learned the illusion, while the SZs' start time was inconsistent, reflecting their inability to learn the illusion. Assessing the data on the individual level reveals that healthy controls learn the illusion over time, and if they do not, they stay consistent in their unlearning. However, SZs are inconsistent in their learning process. They may learn or show no changes or actually unlearn the illusion between time 1 and time 2 and then either learn or show no changes or unlearn the illusion between time 2 and time 3.

We believe that the RHI actually reflects a cognitive test of sensory learning ability. Sensory memory is a kind of implicit memory [11]. Deciding to accept or to reject a stimulus is at the heart of this belief. Studies that have focused on the extent of the similarity between the real hand and the stimulus [29] or on the discrepancy of the alignment between the real hand and the rubber hand [19] have tried to further the understanding of the underlining cognitive process of the RHI. Tsakiris et al. [29] stress the fact that in order to feel the illusion there must be multi-modality synchronization, and this strengthens their explanation that the RHI is a top-down process. Makin et al. [19], on the other hand, view this multi-modality integration as representing a bottom-up process. In our study, we have shown that for healthy controls there is continual improvement in learning the illusion, which is linked directly to the number of trials the participant underwent. Thus, the RHI, in fact, reflects a cognitive process of learning.

In our mind, there is no doubt that this learning includes both bottom-up and top-down processes, but the crux of our study is that we can compare the SZs with healthy controls. When comparing these two groups, the healthy controls' learning is viewed as the normative process. We found that SZs had an easier time feeling the initial illusion, but had a harder time learning it throughout the trials. The initial feeling of the illusion represents top-down processes of regulation, also termed latent inhibition, whereas the inability to learn the illusion throughout the trials represents a failure of the sensory multi-modality integration, implying a failure of bottom-up processes. Thus, in our opinion, both processes are involved in the ongoing learning of the RHI and both are compromised in SZs.

SZs had a hard time learning the illusion just as they have a hard time on other cognitive tests [17]. To our knowledge, this type of sensory memory has not yet been studied in this way, however, it coincides with previous studies in which extinction memory was found to be impaired in schizophrenia when using sensory parameters [14].

Thakkar et al. [27] compared SZs to healthy controls in synchronized and asynchronous situations regarding the RHI. They found that SZs felt the illusion faster than healthy controls did, regardless of the synchronization state. Other studies have also shown that SZs feel the initial illusion faster than healthy controls do, and that this is in direct positive correlation with their psychotic symptoms (i.e. the sicker they are, the faster they feel the illusion) [12,22,23]. Our study also found that the first start time (which represents latent inhibition) was lower for SZs than for healthy controls. However, we were not interested only in this start time, but rather focused on the learning process in SZs and in healthy controls. Under this framework, we did not find any relationships between symptom severity and the learning process. This actually strengthens our hypothesis that this represents a damaged cognitive process and not a product of psychotic symptoms as assessed by the BPRS.

Treating the RHI as a cognitive test, along with the fact that no correlations were found between it and psychotic symptoms in SZs, furthers latest understanding that the cognitive deficit in schizophrenia is mainly independent of the psychotic process, which waxes and wanes over time [9]. When looking at the RHI from this point of view, one might ask why schizophrenics react more quickly and strongly to the illusion, when compared to healthy individuals. When treating the RHI as a cognitive test, we can interpret the SZs' first initial strong reaction as a type of latent inhibition [18,25]; however, healthy individuals have an initial inhibition to feel the rubber hand as part of their own body. The brain tries to filter faulty information in an attempt to avoid "errors" when dealing with reality. Once the healthy individuals in the study realize that the objective of the trial is to try to feel the rubber hand as their own, these initial inhibitions are lifted and the feeling of the rubber hand is implemented through the learning process. For SZs, however, the initial inhibition is faulty and thus, their initial reaction is stronger. These individuals have a hard time learning and implementing new tasks, and therefore do not improve through the trials. The fact that no correlation was found between psychotic symptoms and the RHI furthers our understanding that this represents a cognitive test, and is not a hallucinatory psychotic function.

This study has some limitations. The first is sample size. It is very hard to convince SZs to participate in this type of study. A sample of this size makes it difficult to sub-categorize the participants on different characteristics that might have shed further light on the complexities of the learning process in this group. Nonetheless, 30 SZs did participate and there were no dropouts.

Secondly, this study was based on subjective reports by all participants as to when and for how long they felt the illusion, and therefore lacks any objective measure of the illusion (for instance EEG, fMRI or proprioceptive drift). Further studies should try to implement this experiment using added objective measures, which would help to validate the effect of the RHI.

5. Conclusion

There is a conceptual difference between the first experience of the illusion, and the ability to relearn the experience in SZs as compared to healthy controls. The strength of the first illusion trial represents pathological severity, while learning the illusion reflects a vital cognitive function. Healthy individuals showed a delayed reaction to the first point and a good level of learning process. The sum of the SZs had an initial heightened strength of illusion

(individually there was much variability), but the ability to learn the illusion was inconsistent. Our study shows that SZs are unable to utilize the repetition of the process as other healthy individuals can. This study describes a specific sensory modality that is deficient in schizophrenia and has not gained much research to date.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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