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Abnormalities in the experience of self-agency in schizophrenia: A replication study

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ABSTRACT

People usually experience agency over their actions and subsequent outcomes. These agency inferences over action-outcomes are essential to social interaction, and occur when an actual outcome corresponds with either a specific goal (goal-based), and matches with action-outcome information that is subtly pre-activated in the situation at hand (prime-based). Recent research showed that schizophrenia patients exhibit goal-based inferences, but not prime-based inferences. Intrigued by these findings, and underscoring their potential role in explaining poor social functioning, we replicate patients' deficit in prime-based agency inferences. Additionally, we exclude the account that patients are unable to visually process and attend to primed information.

1. Introduction

Problematic social interactions with family, friends and peers are only some of the debilitating consequences of schizophrenia (Walker et al., 2004). These problems may result from abnormalities in processes underlying the experience of self-agency — i.e., the feeling that one causes one's own actions and the consequences of those actions. Indeed, patients often experience difficulties in distinguishing their own actions and subsequent outcomes from those produced by others (Schneider, 1957; Blakemore and Frith, 2003).

Two processes have been proposed to shape the experience of self-agency (Moore and Fletcher, 2012; van der Weiden et al., 2013a). Motor prediction processes deal with comparing the sensory consequences of an action with internal copies of motor prediction signals (i.e., efference copies) generated by the motor system. Self-agency is experienced over action when the sensory consequences match these internal predictions (Wolpert et al., 1995). Non-motor prediction processes are particularly relevant when motor prediction signals are unreliable or ambiguous (as is often the case in social situations) and therefore cannot inform self-agency. Here, self-agency experiences are shaped by *retrospective inferences* via a goal-based (or explicit) and prime-based (or implicit) route (Wegner, 2002; Aarts et al., 2005). In the context of an explicitly set goal to obtain an outcome, people readily infer self-agency when the actual outcome matches this goal. When the goal is not explicitly set but subtly pre-activated in the situation at hand, self-agency might be inferred when the actual outcome matches the primed outcome information. Accordingly, observing outcomes that are primed in the mind during action performance provides the feeling that one caused the action-outcomes, and hence, priming action-outcome information can enhance the experience of self-agency. In healthy individuals both routes are suggested to support successful social interactions (Waters and Badcock, 2008; Frith, 2013; van der Weiden et al., 2013b).

Disturbances of agency processing in schizophrenia patients are mostly studied in terms of abnormal functioning of the sensorimotor system (Daprati et al., 1997; Franck et al., 2001; Haggard et al., 2003; Voss et al., 2010), suggesting that mismatches between motor-predictive signals and sensory feedback give rise to delusions of alien control, auditory verbal hallucinations, and other perturbations of self-agency (Frith, 1992, 2005a,b, 2012; Frith et al., 2000). However, a recent study demonstrated that the inference process underlying experiences of self-agency might also be impaired in schizophrenia (Renes et al., 2013). Here, schizophrenia patients and healthy controls performed a task in which their action could produce several outcomes (i.e., pressing a key could cause a rotating square to stop on one of eight locations). The outcome could also be determined by another cause (the computer). In actuality, the computer always determined the outcome, and therefore, motor prediction processes could not contribute to the sense of agency. The outcome was either set as a goal or it was primed before performing the action and observing the outcome. While both groups experienced enhanced self-agency in the goal-based inference condition, only healthy controls showed enhanced self-agency in the prime-based inference condition.

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These findings were not explained by differences in task motivation and attention.

Intrigued by these recent findings, the present study serves two goals. First, we aim to replicate the impairment of prime-based inferences in an independent sample of schizophrenia patients. Second, we aim to exclude the possibility that impaired prime-based agency inferences are attributable to patients' inability to visually process and attend to the primes in the context of the experimental procedure.

2. Methods

2.1. Subjects

Based on the effect size (Cohen's $d_s = 0.73$) of the group-by-matching interaction effect within the prime-based condition observed in Renes et al. (2013), and a power of 80% ($\alpha = 0.05$), we needed 62 participants to replicate the effect. Accordingly, 31 schizophrenia patients and 31 healthy controls participated. Patients were recruited from the psychiatry departments of the University Medical Centre Utrecht (UMCU) and Amsterdam Medical Centre. The UMCU's Humans Ethics Commission approved the study. See Table 1 for participant characteristics.

2.2. Procedures and measures

2.2.1. Agency inference task

The agency inference task (Fig. 1) was identical to the prime-based inference condition used in Renes et al. (2013). The general idea behind this task is that both the participant and computer can stop the rapid movement of a square traversing across 8 white tiles on a computer screen. Participants then indicate the extent to which they feel they caused the displayed square to stop at the position when pressing the key in response to a stop cue [not at all (1)–strongly (9)]. Just before pressing the stop-key, one of the tiles is briefly highlighted, representing the so-called prime (17 ms). The outcome location either matches or mismatches the primed tile (see Supplementary materials for task details). There were 32 trials; 16 (2×8) match trials and 16 (2×8) mismatch trials.

2.2.2. Prime detection task

After the agency task participants performed a prime detection task, measuring the accuracy in detecting the primed location (one of the eight locations) was used in the agency task. Note that participants usually are unaware of these primes in the agency task (Aarts et al., 2005; Belayachi and Van der Linden, 2010; van der Weiden et al., 2010; Dannenberg et al., 2012). In contrast, in the detection task participants intentionally and fully attend to the primed location. Therefore, we expect prime detection performance to be above chance. To ensure contextual compatibility between the agency task and the prime detection task, the procedure was identical with one exception: instead of seeing the stopped location, the eight locations were numbered. Participants reported which number they thought corresponded to the briefly presented location. Furthermore, participants indicated their confidence in reporting the correct answer [unsure (1)–sure (9)]. There were 32 trials, presenting each of the eight locations four times.

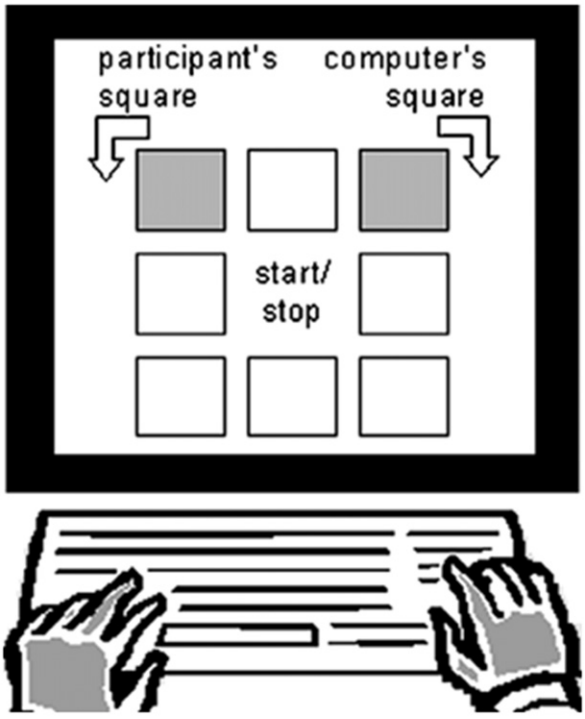

Fig. 1. Illustration of the experimental task showing how the square of the subject and the square of the computer move in opposite directions.

Table 1
Characteristics of patients with schizophrenia and control subjects (standard deviations in parentheses.

	Schizophrenia Patients ($N = 31$)	Healthy Controls ($N = 31$)
Age	29.4 (7.1)	31.3 (6.5)
Male/Female	28/3	28/3
Years of education[a]	13.1 (1.8)	13.2 (3.9)
Parental years of education	14.7 (2.6)	14.1 (3.1)
Premorbid intelligence[b]	102.0 (8.0)	107.7 (6.7)
Illness duration (years)[c]	9.1 (7.9)	–
PANSS positive score[d]	10.1 (2.7)	–
PANSS negative score	11.8 (4.2)	–
PANSS general score	21.7 (3.4)	–
Typical/Atypical medication	3/25	–

Patients and controls did not statistically differ on any of the characteristics.

[a] Education information was estimated as part of the *Comprehensive Assessment of Symptoms and History* (CASH; Andreasen et al., 1992).

[b] Premorbid intelligence was estimated with the Dutch Adult Reading Test (Schmand et al., 1992).

[c] Time between onset of psychotic symptoms and inclusion in the study.

[d] Symptom levels were assessed with the *Positive and Negative Syndrome Scale* (PANSS; Kay et al., 1987) by trained raters.

3. Results

3.1. Self-agency experiences

Mean self-agency experiences were subjected to an ANOVA with Group (patient/control) as a between- and Matching (match/mismatch) as a within-subjects variable (see Fig. 2 for means, Table 2 for statistics). A main effect for matching was found, indicating that participants experienced more self-agency when outcomes matched rather than mismatched the primed outcome information. Importantly, this effect was solely driven by healthy controls, as patients did not show an effect of matching. Although the group-by-matching interaction did not reach statistical significance, the effect size is moderate (Cohen's $d_s = 0.36$; CI: −0.15–0.86), and the 95% confidence interval largely overlaps with the interval of the Renes et al. (2013) study (Cohen's $d_s = 0.73$; CI: 0.12–1.31). Furthermore, examining the difference in effect size between the two studies yielded a Cohen's $d_s = 0.37$ (CI: −0.41–1.15), indicating that the effect sizes do not differ.

Task attention and motivation did not explain the pattern of findings (see Supplementary materials).

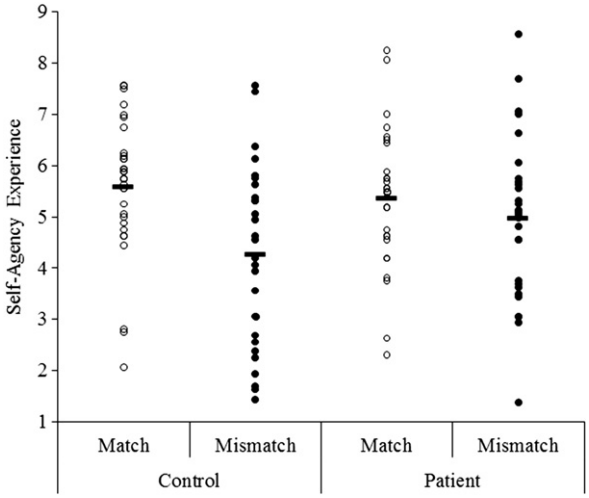

Fig. 2. Self-agency experiences as a function of Group (patient/control) and Matching between the primed outcome and actual outcome (match/mismatch). The black horizontal line indicates the mean.

3.2. Prime detection task

Patients' and controls' accuracy was similar and well above chance level (chance: 12.5% [1 out of 8], patients: 87.4% (SD = 8.7); controls: 89.7% (9.2)), $F(1,60) = 1.36$, $p = .313$, $\eta_p^2 = .017$. Furthermore, both patients and controls reported equal confidence in their assessment of the prime location (patients: 7.34 (0.98); controls[1]: 7.63 (1.19)), $F(1,58) = 1.04$, $p = .313$, $\eta_p^2 = .018$. This suggests that both groups were able to visually process the primes and act upon them accordingly.

4. Discussion

The present study replicates previous findings (Renes et al., 2013), showing that schizophrenia patients (compared to healthy controls) display disturbances in prime-based inferences of agency. This suggests that patients are not able to use implicitly available information about the outcome of an action that would normally lead to a sense of self-agency. Importantly, we ruled out that these disturbances are due to impaired visual processing of the primed outcome in schizophrenia. Whereas some research suggests impaired visual prime processes in schizophrenia (e.g., Cadenhead et al., 1998), the observation that schizophrenia patients and controls were equally able to detect the briefly presented location primes (17 ms) concurs with other recent findings showing intact response-, semantic-, and spatial priming in schizophrenia (Del Cul et al., 2006; Kiefer et al., 2009; Spencer et al., 2011).

Whereas the exact nature of disturbances of prime-based agency inferences in schizophrenia requires further delineation, recent neuroimaging and electroencephalography studies might offer some clues (Dogge et al., 2014; Renes et al., 2014). Specifically, this research points to a frontoparietal network dedicated to agency inferences. Interestingly, whereas strong connectivity between frontal and parietal regions is displayed during goal-based agency inferences, similar but weaker and more diffuse connectivity occurs in prime-based agency inferences. Crucially, as these latter inferences do not seem to engage attentional control processes (Renes et al., submitted for publication), they may primarily rely on frontoparietal white matter fibers to broadcast agency-relevant information. Impairments in these fibers in schizophrenia have been well-established (Ellison-Wright and Bullmore, 2009; de Weijer et al., 2011; Whitford et al., 2011). Although the evidence is indirect, the impairment of this vital frontoparietal network may underlie patients' abnormalities in prime-based agency.

[1] Due to technical issues, confidence data of the first 3 control participants were lost.

Table 2
Statistical analyses for self-agency experiences.

Main analyses ($df = 60$)	F	p	η_p^2
Group	1.68	.200	.027
Matching	6.78	.012	.101
Matching × Group	2.01	.162	.032
Planned simple main effects ($df = 60$)			
Matching controls	8.08	.006	.119
Matching patients	0.70	.405	.012

In conclusion, we replicated schizophrenia patients' disturbance in the processing of prime-based agency-relevant information. These abnormalities might underlie poor social interactions that often unfold implicitly and outside of awareness, posing a daily struggle for patients with schizophrenia.

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Contributors
Author Renes aided in study design and data collection, conducted statistical analyses, interpreted results, and wrote the first draft of the manuscript. Authors Kahn and van der Weiden aided in directing data collection and editing the manuscript. Author Prikken aided in data collection and editing the manuscript. Author Aarts aided in designing the study, directed data collection, provided conceptualization and theory used to integrate the findings, interpreted results, and edited the manuscript. Author van Haren aided in study design, obtained grant funding, directed data collection, interpreted results, and edited the manuscript. All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflict of interest
There are no conflicts of interest to report for any of the authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.schres.2015.03.015.

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