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Self-attribution bias during continuous action-effect monitoring in patients with schizophrenia

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ABSTRACT

The feeling of being the source and controller of one's actions and their effects in the outside world is an important aspect of our sense of self. Disturbances in this sense of agency (SoA) were observed in schizophrenia and have been linked to impairments in sensorimotor integration.

We used a virtual-world action-monitoring paradigm to investigate the SoA in 20 schizophrenic patients and 18 healthy subjects. Participants continuously moved a virtual pen displayed on a computer screen using a touchpad device. The control they exceeded over the virtual pen was switched periodically between the participant and the computer. Participants were requested to monitor their actions and the effects on the virtual pen, and indicate loss or regain of control over the pen's movement by button presses.

The numbers of erroneous external attribution of action effects (false negative agency judgements) and erroneous self-attribution (false positive agency judgements) were not significantly different in patients and healthy subjects. However, patients showed a significant increase in the duration of *false negative agency judgements*. Moreover, the number of *false negative agency judgements* as well as the number and the duration of *false positive agency judgements* were negatively correlated with the performance in cognitive tests (BACS) in the patient group only.

Our findings indicate that the evaluation system to detect a mismatch between actions and their effects in the outside world is probably more rigid in schizophrenic patients, which leads to an increased self-attribution bias for action effects, as commonly found in delusions of control. The impairment in sensorimotor integration may be compensated for by stronger cognitive control.

1. Introduction

In our daily life we constantly perform goal-directed actions, and even though we usually do not reflect upon them, we normally experience them as self-initiated. This feeling of being the agent of our own actions and knowing "that I am the one who is causing an action" has been described as "the sense of agency" (SoA), Gallagher, 2000).

Recent computational theories provide a theoretical account for the underlying mechanisms that may constitute the SoA. Models of sensorimotor prediction (Wolpert and Ghahramani, 2000; Bays and Wolpert, 2007) suggest that internal signals generated by voluntary movement (re-afferences; von Holst and Mittelstaedt, 1950) are processed differently from signals of external origin and sensory input is cancelled or attenuated based on motor command signals (Voss et al., 2006, 2008). In brief, a forward model predicts the sensory consequences of current motor output, and compares this prediction with actual sensory input. Importantly, conscious perception reflects only the error generated by this comparison, since there is no need to perceive what can already be predicted (Blakemore et al., 1998). It has been suggested that prediction based on efference copy may be compromised in schizophrenia (e.g. Frith and Done, 1989; Lindner et al., 2005). Accordingly, positive symptoms such as delusions of control may occur because the comparator lacks a predictive input (Blakemore et al., 2002). The comparator model therefore predicts a *reduced* sense of agency in schizophrenia — as found in delusions of control. Surprisingly, this is at odds with a number of findings. For example, several studies asked patients to identify explicitly whether a visual signal corresponded to an action they had just made or not (Daprati et al., 1997; Franck et al., 2001; Fourneret et al., 2002; Farrer et al., 2004; Knoblich et al., 2004). All studies show that in such situations, where visual feedback of an action is distorted, patients are more likely than controls to identify an action as their own. Patients tend to perceive actions as their own, or originating internally, rather than externally as comparator theories would predict. Comparator models can therefore not entirely explain excessive agency in schizophrenia.

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In extension of the comparator-model, Synofzik et al. (2008) suggested a two-factor account of agency, in which a low-level "feeling" of agency is contrasted with a higher level "judgement" of agency. The feeling of agency (FoA) is conceptualised as a fundamental sense of being an agent of an action and depends mainly on the coherence of motor and sensory cues and its temporal relationship. While the FoA remains implicit, the so-called judgment of agency (JoA) comprises a more cognitive, higher order agency attribution. Based on the integration of complex cognitive cues such as contextual and social cues, prior expectations or core beliefs, an explicit conceptual, interpretative judgement of being the agent of an action is made (Synofzik et al., 2008). The influence of additional cues on the JoA-level may explain the above-mentioned contradiction; the self-attribution bias commonly observed in schizophrenia patients could then be seen as a strong cognitive influence, possibly to compensate for increased uncertainty.

Cue-integration approaches (Synofzik et al., 2009; Synofzik and Voss, 2010; Moore and Fletcher, 2011) may give a clearer understanding of how sensorimotor, perceptual and environmental cues complement, or compete with, each other to form a SoA. Moore and Feltcher (2011) suggested a Bayesian integrative framework, including not only actual, transient internal and external cues, but also more stable priors about the most probable outcome of an action. Synofzik et al. (2013) pointed out the interplay between predictive and retrospective information within this cue integration process, while keeping the distinction between FoA and JoA in mind.

In the present study, we created an experiment, in which participants continuously had to report their subjective agency experience while controlling a virtual pen, similar to controlling a cursor on a screen via a computer mouse. Since visual feedback was de-coupled from participant's hand movements in unpredictable intervals, we created a situation of constant ambiguity with respect to the basic feeling of agency (FoA). However, since the FoA is a low-level, implicit experience, and therefore a direct measure of the FoA is not possible, we forced our participants continuously into an explicit judgement about their agency experience. Importantly, we were able to examine two different situations that occurred during the course of the experiment: in one situation, participants felt that they were in control of the virtual pen, although in fact the pen's movements on the screen were independent of the participant's hand movements (*false positive agency judgement*). In the other situation, participants were in fact controlling the virtual pen with their hand movements but were not aware of it (*false negative agency judgement*). The total number and the duration of such false positive of false negative judgements could be compared between the groups (patients suffering from schizophrenia and healthy subjects) and correlations with psychopathology measures and measures of cognitive performance could be computed. We were therefore able to investigate the potential influence of factors such as psychopathology or cognitive performance on judgements of agency (JoA) in health and disease.

2. Methods

2.1. Subjects

Twenty patients with schizophrenia (paranoid subtype; Sz) and a group of 18 age-, gender- and education-matched healthy subjects were included in the study. Paranoid schizophrenia and other Axis-I psychiatric disorders were diagnosed according to the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000) and International Classification of Diseases 10 (World Health Organization, 2008). Patients with comorbid Axis-I diagnoses were excluded from the study. Healthy subjects were screened for Axis-I and Axis-II psychiatric disorders using the Mini-International Neuropsychiatric Interview (M.I.N.I, (Ackenheil et al., 1999)) and excluded whenever signs of such a disorder were detected. The psychopathology of the patient group was assessed with the scales for the assessment of positive and negative symptoms (SAPS (Andreasen, 1984) and SANS (Andreasen, 1983), respectively) by two experienced psychiatrists. Patients were recruited from the Department of Psychiatry, Charité - Universitätsmedizin Berlin. As a measure of cognitive performance, the Brief Assessment of Cognition in Schizophrenia (BACS (Keefe et al., 2004)) was used. Sociodemographic data, drug information as well as performance in BACS and SAPS and SANS are depicted in Table 1. Drug doses are expressed as Chlorpromazine equivalent (Woods, 2003; Andreasen et al., 2010). We obtained written-informed consent from all participants before the start of the experiment. The local Ethics committee of the Charité University Hospital, Berlin, approved the study.

2.2. Experimental setup

We used a virtual reality (VR) environment, programmed in presentation control language (version 0.71; Neurobehavioral Systems, Inc., Albany, CA). The VR consisted of a photo-realistic virtual representation of a desk; a touchpad device and a pen. Participants sat in front of a computer screen displaying the VR. The touchpad device, the pen as well as a computer keyboard were placed below an extensible shelf to ensure that only the virtual but not real movements were to be observed. The task was to move the pen on the touchpad device in self-paced random movements along four patches that were located at the surface of the virtual touchpad device in a rectangular shape (see Fig. 1).

2.3. Experimental course

The experiment consisted of two conditions: the *sense of agency task* as the experimental condition as well as a *reaction time task* as a control condition. At the beginning of an experimental session, participants were familiarized with the setting (~4 min). Subsequently, four experimental blocks, each of them containing three sense of agency tasks and one reaction time task, were performed.

2.3.1. Sense of agency task

The ongoing movements of the virtual pen were controlled either by the participant or the computer and continuously switched from one to the other every 7 – 14 s. Participants were instructed to detect transitions as fast as possible by releasing (loss of control) or pressing (regain of control) the space bar of a computer keyboard. To provide a continuous motor process and an adequate task difficulty, changes between both periods were kept as smooth as possible. During periods with control the motion of the real pen was continuously recorded and stored with a sampling frequency of 60 Hz. As soon as the duration of controlled motion was ≥7 s and the current motor vector was comparable to one

Table 1
Sample characteristics. Significant differences are highlighted with gray.

	Sz		HC		
	Mean (SD)	n	Mean (SD)	n	p
Age (years)	37.1(7.8)	20	36.7(8.9)	18	.86[a]
Sex (male / female)	15/5	20	13/ 5	18	.85[b]
BACS (sum score)	256.8(40.8)	18	285.3(23.3)	18	.01[a]
SAPS (sum score)	24.5(12.9)	18			
SANS (sum score)	19.3(12.4)	18			
Chlorpromazine equivalents	321.6(334.9)	20			

Abbreviations: SAPS - Scale for the Assessment of Positive Symptoms; SANS - Scale for the Assessment of Negative Symptoms; BACS – Brief Assessment of Cognition in Schizophrenia.
[a] 2-sample *t*-test.
[b] χ^2-Test.