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Neurophysiological evidence for diminished monitoring of own, but intact monitoring of other's errors in schizophrenia

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ABSTRACT

Schizophrenia is characterized by social deficits. Correctly monitoring own and others' performance is crucial for efficient social behavior. Deficits in monitoring own performance as reflected in reduced error-related negativity (rERN) amplitudes, have been demonstrated repeatedly in schizophrenia. A similar ERP component (observed ERN; oERN) is elicited when observing others' mistakes. However, possible deficits in monitoring others' performance have never been investigated in schizophrenia. The current ERP-study compared a group of schizophrenia patients ($N=22$) and healthy controls ($N=21$) while performing a Simon task and the social Simon task, enabling the investigation of own (rERN) and others' (oERN) performance monitoring. Patients showed slower reaction times, but comparable accuracy and compatibility effects in both tasks. As expected, patients' rERN amplitudes were reduced. Importantly however, oERN amplitudes were comparable between both groups. While monitoring own performance is compromised in schizophrenia, monitoring others' performance seems intact. This divergence between internal and external performance monitoring in patients is in line with studies showing normal neurophysiological responses to negative feedback. The presently found dissociation may improve our understanding of cognitive and neural mechanisms underlying monitoring of own and others' performance and may stimulate treatment development aimed at learning from external rather than internal error information in schizophrenia.

1. Introduction

Schizophrenia is a severe mental disorder that is besides the well-known positive and negative symptoms also characterized by various social deficits and distortions in self-monitoring (Knoblich et al., 2004). Accurate monitoring is an important aspect of daily functioning since a malfunctioning self-monitoring system may underlie problems in distinguishing self-initiated from externally generated stimuli. Studies have shown that distortions in the self-monitoring system are responsible for attributing auditory hallucinations to external sources (Waters et al., 2012) and that these distortions may form the basis of other positive symptoms like 'delusions of alien control' (Frith and Done, 1988).

Research on self-monitoring has mainly focused on internal performance-monitoring processes that are responsible for detecting one's own errors in order to improve performance. These studies usually measure a response-locked event-related potential (ERP) known as the error-related negativity (rERN; Falkenstein et al., 1990; Gehring et al., 1993). The rERN is an event-related potential (ERP) occurring about 70–100 ms after the onset of an erroneous response and is characterized by a strong negative deflection generated in the anterior cingulate cortex (ACC; Mathalon et al., 2003). However, observing other persons' mistakes is an important way to learn and internalize appropriate social norms and rules (Brazil et al., 2011). Moreover, accurately monitoring others' performance is crucial for efficient social interactions, as one needs to flexibly adapt to other people's actions and possible errors.

More recently, studies have also identified an ERN-like component elicited when participants observe an error made by another person (Miltner et al., 2004; van Schie et al., 2004), the so-called observed ERN (oERN). The discovery of the oERN suggested that similar neural mechanisms are involved in monitoring own

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and others' errors. This idea was supported by fMRI studies showing the same medial frontal cortex regions being active during the detection of errors committed by oneself and by others (de Bruijn et al., 2009; Shane et al., 2008).

In contrast to the oERN, the rERN has been extensively investigated in healthy populations as well as in different psychiatric populations (for a review see de Bruijn and Ullsperger, 2011). In schizophrenia, smaller rERN amplitudes compared to healthy controls have been demonstrated repeatedly (Bates et al., 2004, 2002; Kopp and Rist, 1999; Mathalon et al., 2002; Morris et al., 2008, 2006; but see Araki et al., 2013), providing support for ACC-related problems in self-monitoring (Kopp and Rist, 1999; Mathalon et al., 2002).

To our knowledge only one study so far investigated the oERN in a psychiatric population. Brazil et al. (2011) showed that criminal offenders with high psychopathic traits display normal monitoring of own performance but have specific problems with monitoring other's actions as reflected in reduced neural responses to both observed errors (oERN) and correct responses (oCRN). The authors suggested that people with psychopathy not only have problems with observing others' errors, but that they suffer from a broader deficiency to process the consequences of others' actions in general.

Importantly, schizophrenia patients experience difficulties adapting their behavior to the appropriate social expectations of the environment (Green et al., 2004). This may result from an impaired performance-monitoring system leading to problems in monitoring their own performance and poor insight in their mistakes. However, correctly monitoring others' mistakes is also crucial for making appropriate behavioral adaptations when people act together. Despite the frequently reported social cognitive dysfunctions and error-monitoring deficits in schizophrenia, no studies have yet investigated whether this group of patients also shows performance-monitoring disturbances while observing mistakes made by another person.

To this aim, healthy subjects and schizophrenia patients are compared during the performance of both a classic (individual) Simon task (IST) and a social Simon task (SST) while EEG and behavioral measures are recorded. Using these measures, we first aim to investigate whether schizophrenia patients have problems monitoring others' performance in terms of smaller oERN amplitudes during the observation of errors committed by others. Second, we aim to replicate the commonly found attenuated rERN amplitudes in schizophrenia.

2. Methods

2.1. Participants

We included 29 patients and 29 age and sex matched healthy controls. Patients with the DSM-IV diagnosis of schizophrenia were recruited in three psychiatric centers in Belgium (PC Sint-Norbertus Duffel, PC Sint-Amadeus Mortsel and PC Brothers Alexians Boechout). Diagnosis was based on the Structured Clinical Interview for DSM-IV Disorders (SCID-I). Patients with current depression or recent substance use disorder were excluded. All patients had at least 2 weeks of stable antipsychotic medication. Healthy controls denied any past or current psychiatric or neurological disorder. Symptom severity of the patients was determined based on the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984) and the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1983). All participants provided written informed consent. The study was approved by the committees on human experimentation of the different participating institutions and is in accordance with the latest version of the declaration of Helsinki.

2.2. Design and procedure

Participants performed an IST and a SST in a counterbalanced order. During the IST participants were seated next to an empty chair in front of a 17″ widescreen monitor. A 5×5 mm^2 white fixation cross centered on a black background was permanently visible during the task. Red or green circles with a diameter of 2 cm were presented 4.3 cm to either the left or the right side from the fixation cross. Participants were asked to place their respectively left and right index finger on the 'w' and '?' key of a Belgian 'azerty' keyboard. The instruction was to respond as fast and accurately as possible by pressing the 'w' key when a red circle was presented or pressing the '?' key when a green circle was presented.

In order to achieve reliable error-related ERPs, participants need to make enough errors during task performance. To accomplish this we added a response deadline according to the following procedure; first, each participant started with 12 practice trials followed by 64 test trials. For each participant the average reaction time (RT) plus a half standard deviation of this test was calculated (cf. Spronk et al., 2014). Second, the calculated value served as the individual deadline value for the subsequent experimental task so that every time the RT of a single trial exceeded this deadline, a 250 ms tone of 1 kHz was presented 450 ms after the late response. Participants were instructed to avoid this feedback tone by responding quickly. The experimental task with implemented deadline consisted of 2 blocks of 128 trials. Each block consisted of 64 randomly presented trials with a spatially compatible stimulus-response relationship (i.e. a red circle to the left side of the fixation cross or a green circle to the right side of the fixation cross) and 64 trials with a reversed spatially incompatible stimulus-response relationship. Each trial began with a 1000 ms presentation of the fixation cross followed by the stimulus. The stimulus disappeared immediately after response or rested for a maximum of 1500 ms in case no response was given.

During the SST, the co-actor seated next to the participant in front of the same monitor. Participants performed a go/no-go variant (i.e. responding with a single button press to only one color) of the same Simon paradigm as described above. The co-actor performed the same task in a complementary way by responding to the other color. The instruction was to respond as quickly and accurately as possible. After 12 practice trials, participants again performed a test condition consisting of 128 trials (64 go trials) in order to obtain the individual average RT added with a half standard deviation to determine the response time deadline. Because during the SST responses are divided over both players three blocks of 128 trials (192 go trials) with the same stimulus-response relation as described above needed to be executed.

2.3. Electrophysiological recordings

EEG was recorded from 31 active electrodes (ActiCap, Brainproducts, Munich, Germany) at a sampling rate of 500 Hz with 27 scalp electrodes arranged according to the extended 10–20 system. Recordings were referenced to the left mastoid and electro-oculography recordings were also collected for vertical and horizontal eye movements. All data were offline re-referenced to both mastoids and digitally filtered with a 1–14 Hz band-pass filter. Reaction times below 150 ms and above 1000 ms were excluded from the data (0.74%).

Before averaging the individual EEG signals in both conditions to ERPs, a matching procedure was used to minimize the impact of stimulus-related activity on the ERN. Through this procedure each