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Self-monitoring in patients with schizophrenia

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ABSTRACT

Background. The present study investigated whether a failure of self-monitoring contributes to core syndromes of schizophrenia.

Method. Three groups of patients with a DSM-IV diagnosis of schizophrenia ($n=27$), with either prominent paranoid hallucinatory or disorganization syndrome, or without these symptoms, and a matched healthy control group ($n=23$) drew circles on a writing pad connected to a PC monitor. Subjects were instructed to continuously monitor the relationship between their hand movements and their visual consequences. They were asked to detect gain changes in the mapping. Self-monitoring ability and the ability to automatically correct movements were assessed.

Results. Patients with either paranoid-hallucinatory syndrome or formal thought disorder were selectively impaired in their ability to detect a mismatch between a self-generated movement and its consequences, but not impaired in their ability to automatically compensate for the gain change.

Conclusions. These results support the claim that a failure of self-monitoring may underlie the core symptoms of schizophrenia.

INTRODUCTION

The variety of symptoms in schizophrenia have been subdivided into three syndrome classes: paranoid-hallucinatory (reality distortion), disorganization, and psychomotor poverty syndrome (Liddle, 1987). Core symptoms within the paranoid-hallucinatory syndrome are acoustic hallucinations and delusions of reference. The main defining symptom for the disorganized syndrome is formal thought disorder. A mechanism that has been proposed to explain auditory hallucinations and delusions of control is the failure of a central self-monitoring system (Feinberg, 1978; Frith & Done, 1989; Frith *et al.* 2000; Blakemore & Frith, 2003; Jeannerod *et al.* 2003). However, it has also been suggested that formal thought disorder could in part be explained by a failure in self- or error-monitoring (McGrath *et al.* 1997; Laws *et al.* 1999; Kircher & David, 2003).

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The present study investigated whether disorders of self-monitoring underlie the paranoid-hallucinatory syndrome and formal thought disorder in patients with schizophrenia. Self-monitoring systems enable one to distinguish the products of self-generated actions or thoughts from those of other-generated actions or thoughts. One prominent theory (Frith, 1992; Frith *et al.* 2000; Blakemore & Frith, 2003) claims that self-monitoring in healthy subjects is based on a central process that determines deviations between the predicted and observed consequences of physical or mental actions. When predicted and observed consequences match, the observed consequences are experienced as self-generated. Frith and colleagues further assume that the future consequences of actions are predicted on the basis of an efference copy of each motor program that is issued (von Holst, 1954; Jeannerod, 1994). Others have postulated that self-monitoring is normally based on a more direct comparison between the intention underlying an action and its observed outcome (Jeannerod, 1999; Fourneret *et al.*

2001; Franck *et al.* 2001; Jeannerod *et al.* 2003). Self-monitoring not only occurs in the sensory-motor domain but plays a major role in the production of language as well. During the normal generation of coherent language, feedback loops on different levels of the production process detect self-generated errors (phonological, semantic, syntactic, pragmatic) which are then corrected (Levelt, 1983, 1989). Detection of self-generated errors may be disrupted in patients with formal thought disorder (Kircher *et al.* 2001; Kircher & David, 2003).

Similarly, patients with paranoid-hallucinatory syndrome cannot correctly compare the expected and observed consequences of an action and therefore have problems in identifing their actions and thoughts as the cause for events they perceive. Empirical evidence for this claim was provided in several studies. One study has demonstrated that tactile sensations following self-generated movements are attenuated in healthy subjects, but not in patients with paranoid-hallucinatory syndrome (Blakemore *et al.* 2000). Further experiments have demonstrated that schizophrenic patients with paranoid-hallucinatory syndrome who carried out simple joystick movements could not correct movement errors in the absence of visual feedback, although there were no clinical indications of a disorder of the motor system (Malenka *et al.* 1982; Frith & Done, 1989; Mlakar *et al.* 1994; Stirling *et al.* 1998). Patients with paranoid-hallucinatory syndrome are also less sensitive to deviations between their actual hand movements and the visual consequences of these movements (Daprati *et al.* 1997; Franck *et al.* 2001).

The aim of the current study was to determine whether there is a failure of self-monitoring in patients with paranoid-hallucinatory syndrome or formal thought disorder. We used a task which required subjects to monitor continuously the relationship between a hand movement and its visual consequences (Knoblich & Kircher, in press). Participants were asked to detect gain changes that were introduced in the mapping between movements and their visual consequences. One advantage of this task is that self-monitoring and the ability to correct movements automatically can be assessed simultaneously.

In our experiment, participants were asked to continuously draw circles at medium velocity around a static circle displayed on the screen. A moving dot reproduced the movement of the pen tip on the writing pad on a computer screen, without leaving a trace (see Fig. 1*a*). After some time, the mapping between the movement and its visual outcome was abruptly changed so that the dot movement on the screen was accelerated by a certain amount relative to the movement of the pen tip on the writing pad (see Fig. 1*b*). This resulted in an increase of the radius of the circle on the screen if drawing on the writing pad was continued in the same way as before. Alternatively, if one immediately compensated for the mapping change by drawing circles with a smaller radius, the circle observed on the screen remained the same (see Fig. 1*b*). The task was to lift the pen from the writing pad immediately as soon as such a change in relative velocity was noticed, or to continue drawing when no change was noticed (see Fig. 1*b*).

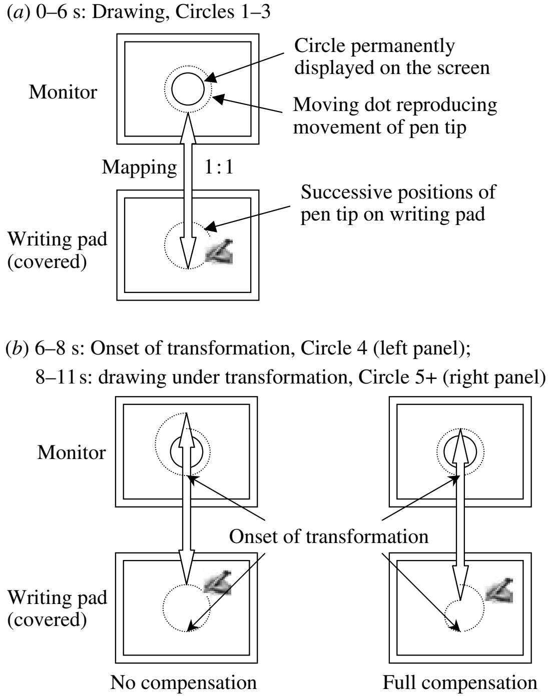

FIG. 1. Illustration of an experimental trial. In each trial $5\frac{1}{2}$ circles were drawn. There was no mapping change while the first three circles were drawn. While drawing the fourth circle, there was an abrupt mapping change. If this gain change was not compensated for, the trajectory of the moving dot on the monitor changed. If the change was fully and immediately compensated for, the trajectory of the moving dot on the screen remained unchanged.

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Table 1. *Sociodemographic, cognitive, and clinical parameters for different experimental groups*

	Patient control group ($n = 14$)	PH patients ($n = 6$)	FTD patients ($n = 7$)	Difference between patient groups	All patients ($n = 27$)	Controls ($n = 23$)	Difference between all patients and controls
		Mean (S.D.)		p*	Mean (S.D.)		p†
Age (years)	38·1 (15·2)	29·7 (7·6)	33·7 (7·6)	0·37	35·1 (12·3)	33·1 (13·3)	0·59
IQ	120 (16)	122 (18)	107 (16)	0·18	118 (15)	112 (15)	0·23
Digit Span test (digits)	6·0 (1·0)	6·0 (0·6)	5·7 (0·8)	0·77	5·9 (0·8)	5·9 (0·9)	0·95
Years of full-time education	16·8 (4·2)	13·6 (2·7)	14·3 (5·0)	0·22	15·4 (4·3)	15·0 (2·1)	0·70
Gender (M : F)	10 : 4	3 : 3	4 : 3	—	17 : 10	10 : 13	—
Mean duration of illness (years)	12·2 (9·9)	5·1 (3·3)	9·9 (9·7)	0·28	10·0 (9·0)	—	—
Chlorpromazine equivalent (mg/day)	263 (131)	233 (186)	711 (511)	$<0·01$	372 (342)	—	—
PANSS total	52·6 (17·0)	84·3 (14·7)	78·7 (15·8)	$<0·001$	66·4 (21·4)	—	—
PANSS positive	12·8 (6·1)	24·2 (3·9)	22·4 (6·0)	$<0·001$	17·8 (7·7)	—	—
PANSS hallucinations and delusions	4·2 (2·6)	10·3 (0·8)	6·6 (3·0)	$<0·001$	6·2 (3·4)	—	—
PANSS formal thought disorder	1·4 (0·9)	2·8 (1·3)	5·3 (0·8)	$<0·001$	2·7 (1·9)	—	—

* One-way ANOVA.
† Two-tailed t test.
PH, Paranoid-hallucinatory syndrome; FTD, formal thought disorder.

By comparing different levels of acceleration, the sensitivity for detecting changes in the mapping between one's movement and its visual consequences can be determined. The analysis of movement kinematics allows one to determine to what extent subjects actually compensate for the mapping change. To control for the motor abilities not related to self-monitoring we assessed tracking performance in a task similar to the one used in the main experiment. Likewise, the ability to interrupt an ongoing movement in response to a perceptual change was assessed in a second control task. We predicted that patients with either paranoid-hallucinatory syndrome or formal thought disorder would be impaired in their ability to detect a mismatch between a self-generated action and its visual consequences, but not impaired in their ability automatically to compensate for the gain change.

METHOD

Subjects

Twenty-seven in- and out-patients with schizophrenia (DSM-IV) were recruited from the Department of Psychiatry, University of Tübingen, Germany. The healthy comparison group consisted of 23 volunteers who were matched with the patients on sociodemographic variables. There were no significant differences between the groups in cognitive (Table 1) and sociodemographic variables. The latter were taken from the hospital chart notes and the participants' self-reports. All subjects were right-handed according to the Edinburgh Inventory of Handedness (Annett, 1970). Twenty-five of the 27 patients were on stable doses of antipsychotic medication; two patients did not receive medication at the time of the experiment.

Two independent psychiatrists established DSM-IV diagnosis during a clinical interview and using hospital chart notes. All patients were clinically assessed by the same rater (F.S.), using the Positive and Negative Syndrome Scale (PANSS; Kay *et al.* 1987) on the day before or after the experiment. The rater had extensive training in the use of this scale. Verbal IQ and immediate memory recall were also assessed, using the Mehrfachwahl-Wortschatztest (MWT-B; Lehrl *et al.* 1995) and the Digit Span Test (Psychological Corporation, 1981). There were no significant differences between the patient groups on these measures (Table 1). Permission for the study was obtained from the local ethical committee. After complete description of the study to the subjects, written informed consent was obtained.

Patients were classified into three groups. If the sum of the two PANSS items 'delusions' and 'hallucinations' was greater than eight they were entered into the paranoid-hallucinatory syndrome group. They entered the 'formal thought disorder' group if this PANSS item was greater than four. Patients who had both formal thought disorder and paranoid-hallucinatory syndrome were classified according to the symptom with the highest score. Patients not fulfilling one of these criteria were entered into the 'patient control' group. The different groups did not differ in sociodemographic characteristics (Table 1).

Materials, procedure and apparatus

Participants were seated in front of the stimulus monitor at a distance of about 60 cm. A writing pad was located between the monitor and the participant. A cover was attached to the writing pad so that participants did not see their drawing hand. In the first part of the experiment they carried out a tracking task to assess their tracking performance. This block consisted of 20 trials. In each trial they tracked a circular target that moved with constant velocity. The location of the pen tip was indicated by a solid, circular dot. Neither of the dots left a trace on the screen. The mapping between screen and writing pad was 1 : 1, that is, the movement of the dot on the screen exactly corresponded to the movement of the pen tip on the writing pad. In each training trial, the target completed five full circles. The target moved with a velocity of 2 s per circle and with an eccentricity of 9° visually for the full circle. The movement of the tracking signal corresponded to a medium drawing velocity and mimicked a trajectory that would have led to optimal performance in the no-acceleration condition of the main experiment. Whenever the target reached the 12 o'clock position participants heard a short beep (200 ms, 1000 Hz).

Just before the main experiment, participants were given 10 training trials. In some of these trials large mapping changes (e.g. 100%, from 1 : 1 to 1 : 2) were introduced to show participants how the external influence (the transformation) affected the mapping between their movements and their visual consequences. The immediately following main experiment consisted of 120 trials.

The course of each trial was as follows. A full circle subtending 7° appeared in the screen center. This circle remained on the screen during the whole trial. In addition, a small quadratic box subtending 1° horizontally and vertically appeared 1·5° above the 12 o'clock position of the circle. The participant moved the dot representing the location of the pen tip to this box and increased pen pressure within its area. The box disappeared and a short beep (200 ms, 1000 Hz) indicated that drawing should be started. During the rest of the trial, only the full circle and a single dot representing the actual pen location were displayed on the screen. After 2, 4, 6, 8 and 10 s the same beep was heard. Participants were instructed to draw around the full circle so that they would pass the 12 o'clock position whenever they heard the tone. Hence, participants had 2 s to draw a full circle. Given a radius of 4·5 cm for the drawn circle, the average writing velocity was 14·1 cm/s. If the pen was not lifted from the writing pad, the dot vanished from the screen after 11 s (corresponding to the drawing of $5\frac{1}{2}$ circles).

During the first 6 s (corresponding to the drawing of three circles) the mapping between screen and writing pad was 1 : 1 (see Fig. 1*a*). During the interval 6–8 s after the start of the trial (roughly the drawing of the fourth circle), different conditions were introduced: in the no-transformation condition (20% of the trials), the mapping between writing pad and screen remained 1 : 1. In the four-transformation conditions (20% of the trials each), the movement of the dot on the screen was accelerated relative to the movement of the pen tip on the writing pad by 20, 40, 60 or 80%. This resulted in a 1·2 : 1, 1·4 : 1, 1·6 : 1 or 1·8 : 1 ratio of the velocity of the dot on the screen relative to the movement of the pen tip on the writing pad (see Fig. 1*b*). The change in mapping could occur at any time during this interval and participants knew that the change would always occur after the third beep. They were instructed to lift the pen as fast as possible as soon as they detected any change in the relation between their own movement and the movement of the dot on the screen. Because the change in mapping persisted until the end of the trial, participants had at least 3 s to indicate that they had detected the change by lifting the pen from the writing pad.

Finally, participants carried out a color change detection task in order to assess difficulties in lifting the pen during an ongoing movement. The only difference to the trials in the main experiment was that instead of the mapping change the dot sometimes changed its color while the fourth circle was drawn.

Participants were instructed to lift the pen when the dot changed its color.

The visual stimuli were presented on an Apple Vision (Apple, Cupertino, CA, USA) 17-inch monitor with a horizontal resolution of 800 pixels and a vertical resolution of 600 pixels. The vertical sync frequency was 75 Hz. The movements of the pen tip were recorded using a pressure-sensitive Wacom writing pad (Wacom Europe GmbH, Krefeld, Germany) with a sampling rate of 75 Hz, a horizontal resolution of 15 000 dots, and a vertical resolution of 11 250 dots. An Apple Power PC (Apple) controlled these devices as well as a 17-inch control monitor. The sampling rate of the writing pad was synchronized with the screen refresh rate. Hence, the constant delay between visual effect and the movement of the pen tip was about 13 ms.

RESULTS

Tracking performance and color detection

Differences in tracking performance and color detection were analyzed to determine whether there were differences between groups for the two main aspects of the task that are not related to self-monitoring. Overall, the tracking performance, as measured by the root square error of the spatial distance from the tracking signal, did not differ significantly ($t=1{\cdot}57$, df$=48$, $p=0{\cdot}12$) between patients (mean$=18{\cdot}9$ mm, S.D.$=9{\cdot}9$ mm) and healthy controls (mean$=14{\cdot}7$ mm, S.D.$=7{\cdot}3$ mm). The tracking performance of patients with formal thought disorder or hallucinatory-paranoid syndrome (mean$=21{\cdot}5$ mm, S.D.$=9{\cdot}2$ mm) was not significantly different ($t=1{\cdot}46$, df$=25$, $p=0{\cdot}16$) from that of the patient control group (mean$=16{\cdot}0$ mm, S.D.$=10{\cdot}2$ mm).

The comparison of the error percentages in the color detection task revealed a significant difference ($t=2{\cdot}54$, df$=48$, $p<0{\cdot}05$) between patients (mean$=5{\cdot}9$%, S.D.$=5{\cdot}5$%) and controls (mean$=1{\cdot}2$%, S.D.$=2{\cdot}4$%). Note, however, that overall the error rates were quite low. There were no significant differences between schizophrenic patients with formal thought disorder (mean$=8{\cdot}3$%, S.D.$=9{\cdot}6$%) or paranoid-hallucinatory syndrome (mean$=8{\cdot}3$%, S.D.$=10{\cdot}5$%), and the patient control group (mean$=3{\cdot}6$%, S.D.$=6{\cdot}3$%).

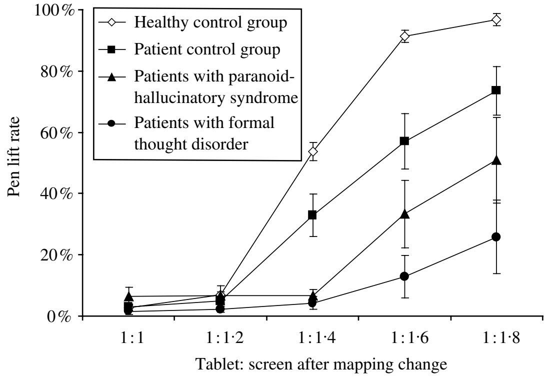

FIG. 2. Percentage of pen lifts as a measure of change detection in the mapping between movements and their visual consequences for schizophrenic patients with formal thought disorder, schizophrenic patients with paranoid-hallucinatory syndrome, a schizophrenic patient control group without these symptoms, and healthy controls. Vertical bars indicate standard error.

Detection of mapping change

The detection rates increased in all groups as the transformations became larger (see Fig. 2). Univariate within subjects analyses of variance (ANOVAs) confirm that this increase was significant for schizophrenic patients with formal thought disorder ($F=3{\cdot}89$, df$=4$, 24, $p<0{\cdot}05$), patients with paranoid-hallucinatory syndrome ($F=7{\cdot}41$, df$=4$, 20, $p<0{\cdot}001$), the patient control group ($F=39{\cdot}87$, df$=4$, 52, $p<0{\cdot}001$), and for healthy controls ($F=725{\cdot}14$, df$=4$, 88, $p<0{\cdot}001$).

However, there were large differences in sensitivity between groups (see Fig. 2). Schizophrenic patients were generally less sensitive for the velocity transformation between movements and their visual consequences compared to healthy controls. Moreover, patients with formal thought disorder and paranoid-hallucinatory syndrome were less sensitive than the patient control group. This difference was especially pronounced at the 1 : 1·4 level. Finally, the detection rates of patients with formal thought disorder were lower than for patients with paranoid-hallucinatory syndrome, especially at the 1 : 1·6 level.

In order to assess the statistical reliability of these effects, the detection rates were entered into a mixed analysis of co-variance (ANCOVA) with the between-factor Group (patients with formal thought disorder, patients with paranoid-hallucinatory syndrome, patient control group, and healthy controls) and the within-factor

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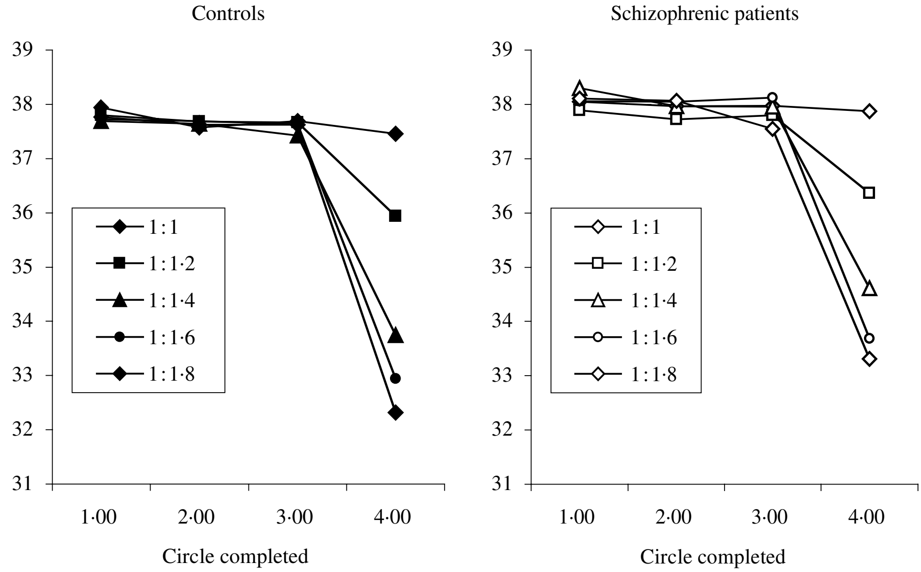

FIG. 3. Radius of the circular movement on the writing pad before and after the mapping change. The points on the *x*-axis refer to the points in time at which the beep occurred (completion of first, second, third, and fourth circles). The drop from the third to the fourth interval indicates the extent to which the radius of the actual movement became smaller after the mapping change.

Extent of Mapping Change (1 : 1, 1 : 1·2, 1 : 1·4, 1 : 1·6, and 1 : 1·8). The spatial error in tracking performance [root square error (RSE)] and the error rate in the color change detection task were entered as co-variates. This allows one to control for the effects of task aspects that are not related to monitoring one's movements. Tracking performance measures effects related to drawing without seeing one's limb movements and writing on a graphics tablet. The color change detection task captures the ability to interrupt a movement while looking for a stimulus change. Note that the mixed ANCOVA takes co-variates only into account when computing main effects for the between-group factor.

The ANCOVA revealed significant main effects of Group ($F=16{\cdot}82$, df = 3, 44, $p<0{\cdot}001$) and Extent of Mapping Change ($F=135{\cdot}12$, df = 4, 184, $p<0{\cdot}001$), and a significant interaction between these two factors ($F=16{\cdot}53$, df = 12, 184, $p<0{\cdot}001$). The detection rates were significantly lower in schizophrenic patients (mean = 24·8 %, S.D. = 18·5 %) than in healthy controls (mean = 50·3 %, S.D. = 6·7 %), as confirmed by a planned contrast ($F=22{\cdot}88$, df = 1, 44, $p<0{\cdot}001$). The detection rates for patients with formal thought disorder and paranoid-hallucinatory syndrome (mean = 14·6 %, S.D. = 12·6 %) were lower than for the patient control group (mean = 34·3 %, S.D. = 18·3 %), as confirmed by a further planned contrast ($F=5{\cdot}85$, df = 1, 22, $p<0{\cdot}05$). *Post hoc* analyses using Newman–Keuls tests showed that differences between patients with formal thought disorder and paranoid-hallucinatory syndrome were significant ($p<0{\cdot}05$) for the 1 : 1·6 condition. Furthermore, the paranoid-hallucinatory group alone differed from the patient control group in the 1 : 1·4 and the 1 : 1·6 conditions ($p<0{\cdot}05$).

Compensation for mapping change

In order to determine to what extent the mapping change was compensated for in the movement, the radial component of the pen tip's coordinates on the writing pad was analyzed at the time of each beep. This component designates the distance between the center of the drawn circle and the pen position on the writing pad. It indicates the extent to which circles with a smaller radius were drawn after the mapping change in order to keep the radius of the dot movement comparable to the one observed before the mapping change.

Fig. 3 shows the mean of the radius before (Circles 1–3) and after the mapping change (Circle 4). Surprisingly, there were no differences in this variable between schizophrenic patients and healthy controls. There were also no differences between schizophrenic patients with formal thought disorder or paranoid-hallucinatory syndrome and the patient control group.

In all groups, the radius of the circular movement on the writing table became smaller as the extent of the mapping change increased. In order to confirm the statistical reliability of this effect for each group 2×5 ANOVAs with the factors Circle (3 and 4) and Extent of Mapping Change (1 : 1, 1 : 1·2, 1 : 1·4, 1 : 1·6, 1 : 1·8) were performed. An interaction between the two factors indicates that the larger the extent of the mapping change was, the smaller the radius of the movement after the mapping change. This interaction was significant for patients with formal thought disorder ($F = 9{\cdot}60$, df = 4, 24, $p < 0{\cdot}001$), patients with paranoid-hallucinatory syndrome ($F = 12{\cdot}93$, df = 4, 20, $p < 0{\cdot}001$), the patient control group ($F = 37{\cdot}54$, df = 4, 52, $p < 0{\cdot}001$), and healthy controls ($F = 57{\cdot}71$, df = 4, 88, $p < 0{\cdot}001$).

DISCUSSION

The present study addressed the question of whether a failure of central self-monitoring contributes to paranoid-hallucinatory syndrome and formal thought disorder, some of the core symptoms of schizophrenia. We simultaneously assessed patients' and controls' ability to automatically detect and correct for experimentally induced changes in the relation between their own movements and the visually perceived consequences of their actions. The results demonstrate that patients with either paranoid-hallucinatory syndrome or formal thought disorder compared to patients without these symptoms were selectively impaired in their ability to detect a mismatch between a self-generated movement and its consequences. At the same time they were not impaired in their ability to automatically compensate for the mismatch. These results imply that paranoid-hallucinatory syndrome and formal thought disorder might in part be due to a failure of central self-monitoring. Our data are in line with previous literature (Delevoye-Turrell *et al.* 2002) and more general information-processing models in schizophrenia, which suggest that the disorder is characterized by impaired controlled but intact automatic processing (Callaway & Naghdi, 1982; Huron *et al.* 1995).

To rule out possible confounding factors related to the disorder in general or medication, we introduced two control conditions that assessed motor performance and the ability to respond to a visual stop signal. Together, these two conditions allowed us to assess the perceptual, executive, and motor components of the main experimental task. There were no significant differences between the patient groups in these tasks. Nevertheless, these factors were included as co-variates in all analyses of the main task. Although there were some differences in medication and general psychopathology between patient groups, they did not obviously influence the key features of our main experimental task. To test whether the results might be a function of mere symptom severity we performed a *post hoc* analysis, where we correlated all PANSS items separately with our dependent variable (detection rate). We found significant correlations (other than the ones hypothesized) only for the items 'emotional withdrawl' (N2), 'attention' (G11) and 'lack of judgement and insight' (G12). Attentional components were partialized out in the ANCOVA in our main analysis by introducing the control conditions as co-variables. Since we did not predict the three items as being related to the detection rate, we attribute them to multiple testing in the *post hoc* analysis.

Sensitivity for mismatches between self-generated movements and their visual consequences is lower in patients with paranoid-hallucinatory syndrome, compared to patients without these symptoms. This result further supports the assumption that self-monitoring is impaired in this group (Frith & Done, 1989; Frith *et al.* 2000). It has been proposed that patients with delusions of control and auditory hallucinations cannot correctly predict the sensory consequences of motor programs specifying the actual movement (Frith, 1992; Frith *et al.* 2000). A forward output model makes predictions about the sensory consequences of the movement, and this prediction is compared with the actual sensory consequences of a movement. According to the theory, patients (with delusions of control and auditory hallucinations) would have impaired awareness of the discrepancy between movement and its consequences, but would not be impaired on the automatic compensation of the gain changes. A second explanation might be that self-monitoring is based on a slow system that compares the intended and actually observed consequences of an action. This system is impaired in patients with paranoid-hallucinatory syndrome (Georgieff & Jeannerod, 1998; Jeannerod, 1999; Franck *et al*. 2001).

Patients with formal thought disorder were most severely impaired in detecting a mismatch between self-generated movements and their visual consequences. This result confirms our prediction that an impairment of self-monitoring is, in part, underlying formal thought disorder (Kircher *et al*. 2001; Kircher & David, 2003). Basic self-monitoring abilities have hardly been addressed in this patient group. There are only a few studies in the language domain suggesting that monitoring of self-generated speech errors is impaired in patients with formal thought disorder (McGrath *et al*. 1997; Laws *et al*. 1999). Given that the samples in the paranoid-hallucinatory group and the formal thought disorder group were relatively small it remains to be seen whether self-monitoring in patients with formal thought disorder is really more severely impaired than in patients with paranoid-hallucinatory syndrome. However, it is very likely that both patient groups are at least equally impaired. It is also worth noting that there is an overlap of symptoms between the two symptom-groups in question. There might be additive factors in the symptomatology that contribute to the self- or error-monitoring ability.

Taken together, the results suggest that an impaired self-monitoring ability characterizes patients with a variety of core symptoms of schizophrenia. Given the diversity of these symptoms it seems unlikely that a single self-concept or self-system is disturbed. Rather, it might be useful to think of specific subsystems that underlie these different symptoms. These systems are connected to a complex self-model (Metzinger, 2003) that is the result of an interaction of multiple systems that embody intentionality and result in the experience to be a self (Kircher & David, 2003; Kircher & Leube, 2003; O'Brien & Opie, 2003). One functional principle that may underlie some these systems is that they generate expectations about what the perceived physical and mental consequences of intentions, actions, and thoughts will be. Paranoid-hallucinatory symptoms and formal thought disorder in schizophrenia could then be conceptualized as impairments of generating reliable predictions in different subsystems of the self-model.

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DECLARATION OF INTEREST

None.

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