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Neurocognitive predictors of source monitoring in schizophrenia

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ABSTRACT

Rationale: Source monitoring (SM) is a metacognitive process involved in making judgments about the origin of information by recruiting cognitive processes. Deficits in SM have been linked to positive symptoms of schizophrenia. We investigated whether certain neurocognitive functions – specifically attention, working memory, and organizational sequencing – were associated with SM in a sample of schizophrenia patients.
Methods: Attention (Auditory Continuous Performance Test), organizational sequencing (Trail-Making Test B–A), working memory (Digits Backward), and internal SM were assessed in 45 outpatients diagnosed with schizophrenia or schizoaffective disorder.
Results: Standard multiple regression analysis showed attention, working memory and organizational sequencing together predicted SM. Organizational sequencing was the only significant individual predictor, with better organizational sequencing ability being associated with better SM. Hierarchical regression analysis showed that working memory by itself did not result in a significant predictive model of SM, but adding organizational sequencing led to a significant change from the working memory model and resulted in a significant overall model, accounting for 26% of the variance in SM.
Conclusions: Neurocognitive functions were associated with SM in schizophrenia. Organizational sequencing, which requires an awareness of self-generated actions, predicted SM performance even after controlling for working memory.

1. Introduction

A fundamental idea underlying source monitoring (SM) theory is that memories, images, and feelings do not come with abstract labels specifying their source for us; rather, we attribute information in memory to particular origins or sources using heuristic and systematic decision processes, based on evaluation of cues such as contextual and sensory/perceptual information, cognitive operations and semantic detail (Johnson et al., 1993; Johnson and Raye, 2000; Lindsay, 2008). SM may involve discriminating between externally derived sources of information—external SM (e.g. determining which of two people made a statement); between internally generated sources—internal SM (e.g. determining whether one said, or only thought about, a statement); or discriminating internal from external sources—reality monitoring (e.g. determining whether one thought of, or heard, the statement) (see Johnson et al., 1993). Cognitive functions can affect the evaluative processes involved in making these judgments (e.g. Hashtroudi et al., 1994; also see Lindsay, 2008).

SM deficits have been observed in schizophrenia (see Mitchell and Johnson, 2009). More specifically, studies have shown that schizophrenia patients with symptoms like delusions and hallucinations have greater SM deficits than patients without these symptoms and healthy control subjects (Brunelin et al., 2007; Keefe et al., 2002). It has therefore been theorized that poor SM may underlie some of the positive symptoms in schizophrenia. For instance, an inability to monitor self-generated thoughts and actions can result in the conclusion that they come from an external source, which may form the basis for hallucinations and some kinds of delusions (Brebion et al., 2000; Brunelin et al., 2007; Keefe et al., 2002).

The current study investigated whether specific facets of neurocognitive functioning are associated with SM in schizophrenia. Lindsay (2008) suggested that manipulations that impair encoding or retrieval of source-specifying information can affect SM. Decreased attention, for instance, may interfere with binding of perceptual detail with content and reduce source accuracy (Hashtroudi et al., 1994), while working memory and organizational sequencing could be related especially to systematic processing of source information. Working memory may help in deliberate reasoning about the event with respect to additional information, such as discovering inconsistencies among memories or evaluating the plausibility of a target memory, while

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organizational sequencing may facilitate source judgments by helping in the evaluation of supporting memories, such as remembering other events which took place before or after the target memory (for discussion of systematic processes, see Johnson and Raye, 2000). We hypothesized that attention, working memory and organizational sequencing would predict SM performance in schizophrenia patients.

Although internal SM (Franck et al., 2000; Henquet et al., 2005; Nienow and Docherty, 2004) and reality monitoring deficits (Anselmetti et al., 2007; Brebion et al., 2000; Vinogradov et al., 1997) have been observed in schizophrenia, external SM deficits have generally not been found, unlike in bipolar disorder (Fisher et al., 2008; Harvey, 1985). Also, SM deficits in schizophrenia are usually characterized by patients having a greater tendency to misidentify self-generated thoughts as actions (Franck et al., 2000; Henquet et al., 2005; but see Franck et al., 2001), and to attribute self-generated information to external sources (Anselmetti et al., 2007; Brebion et al., 2000; Vinogradov et al., 1997), which has led some authors to propose that SM in schizophrenia may be characterized by a specific inability to identify and process self-generated information (Fisher et al., 2008; Keefe et al., 2002). Although tests of both organizational sequencing and working memory involve self-generation of information, tests that measure the former place greater demands on sequencing and temporal structuring of responses (Wolwer and Gaebel, 2002), which requires greater discrimination of responses that have been implemented (actions) from those held in mind during task performance. We therefore hypothesized that performance on an organizational sequencing task would predict SM even after controlling for general working memory.

2. Methods

2.1. Sample

The sample consisted of 45 outpatients with a DSM-IV diagnosis of schizophrenia or schizoaffective disorder who were part of a larger project examining emotion, neurocognition, and communication disturbance (see Docherty et al., 2003). The Schedule for Affective Disorders and Schizophrenia—Lifetime Version (Spitzer and Endicott, 1978), adapted slightly for use with DSM-IV criteria, was used to arrive at the DSM diagnosis. A clinical psychologist who had acceptable inter-rater reliability with another research group ($k=88$) arrived at the diagnoses based on information gathered from the interview and clinical records. Patients were excluded if they reported a history suggestive of possible organic brain damage or met DSM-IV criteria for substance abuse. All patients (except one) were receiving psychiatric medications at time of the study.

The study was carried out with due approval of the Kent State University Institutional Review Board, and informed consent was obtained from all participants prior to enrollment in the present study, thus conforming to the ethical standards laid down in the 1964 Declaration of Helsinki. Table 1 shows descriptive characteristics of the sample.

2.2. Measures

Attention, working memory and organizational sequencing tests were administered at the initial sessions, and a SM task was administered in a follow-up session 9 months later.

2.2.1. SM task

An internal SM task we previously developed (see Nienow and Docherty, 2004) was used for the present study. Briefly, participants have to generate single word responses to 16 incomplete statements. The statements are ones for which there is only one appropriate response (e.g. "The first month of the year is _______"). On one half the trials the participants only think of the answer to themselves, and on the other half they say the answer out loud. Immediately after this, they are given a source recognition sheet with all the responses they said, thought, and with eight new words (24 words total), and they have to identify whether they had said or thought each word on the list, or if the word was new. The task was piloted on 39 college students, who showed 99% agreement on the words they used to complete the statements. The total correct score was used for the present analysis.

Table 1
Descriptive information for sample ($n=45$).

Mean age in years (S.D.)	35.66 (8.23)
Mean years of education	12.41 (1.59)
% Female	48.9
% Caucasian	64.4
% African-American	33.3
Mean age at first psychiatric treatment	20.31 (5.97)
% Schizophrenia	68.9
% Schizoaffective disorder	31.1
Mean GAF score (initial session)	50.22 (11.99)
Mean GAF score (follow-up session)	53.82 (9.46)
Mean score CPT-A[a]	36.18 (3.89)
Mean score Digits Span Backward	5.78 (2.16)
Mean score TMT B–A (Time taken)	107.24 (49.05)
Mean score source monitoring	15.02 (2.89)

GAF=Global Assessment of Functioning Scale; CPT-A=Auditory Continuous Performance Test; TMT=Trail-Making Test.

[a] $n=39$.

2.2.2. Attention

The continuous performance test is a measure of sustained attention (see Lezak, 2004). We administered the Auditory Continuous Performance Test (CPT-A; see Strub and Black, 1988) in which the participant listens to a 7 min audiotape presentation of a quasi-random series of letters read at 1 s intervals, and has to respond every time the target letter 'A' is heard. The total correct score was used for the present analysis.

2.2.3. Working memory

The Digits Backward (Digits-B), part of the Weschler Adult Intelligence Scale—Revised (Wechsler, 1981), is a measure of working memory (Garlinghouse et al., 2010). The participant has to listen to a set of numbers and repeat it in the reverse order (see Lezak, 2004). The total correct score was used for the present analysis.

2.2.4. Organizational sequencing

We used part B of the Trail-Making Test (Reitan and Davison, 1974) as a measure of organizational sequencing ability. The participant has to connect letters and numbers in alternating order (1–A–2–B–3–C… etc.), as quickly as possible. We followed Reitan's (1958) revised procedure which requires the experimenter to point out errors as they occur, resulting in the participant always completing the test without errors so scoring can be based on time alone. To arrive at a measure of organizational sequencing after controlling for psychomotor speed, score on part A (which only involves connecting numbers 1–2–3–4…) was subtracted from part B. The resulting score (Trails B–A) was used.

2.3. Statistical analysis

Statistical analyses were carried out using SPSS 16.0 (www.spss.com). Correlations were calculated between all variables. Standard multiple regression analysis was used to determine whether measures of attention, working memory and organizational sequencing together predicted SM. Hierarchical multiple regression was used to determine whether organizational sequencing predicted SM after controlling for working memory. A significance level of $p<0.05$ (two-tailed) was employed for all analyses.

3. Results

3.1. Preliminary analysis

Complete data were available for 39 participants for the standard regression and 45 participants for the hierarchical regression analysis. No multivariate outliers were found among the cases using $p<0.001$ criterion for Mahalanobis distance. After CPT-A and Trails B–A were log-transformed to reduce skewness and improve homoscedasticity, all assumptions for multiple linear regression analysis were met. Means and standard deviations (non-transformed) for the variables are presented in Table 1, and correlations between them (transformed) are presented in Table 2.

3.2. Hypothesis tests

A standard multiple regression was performed with SM as criterion, and CPT-A, Digits-B, and Trails B–A as predictor variables. Table 3 shows regression coefficients for the analysis. R for the model was significant [R=0.53; F(3, 35)=4.65, $p<0.01$] and indicates that 28% of the variance in SM was predicted by CPT-A, Digits-B, and Trails B–A (R^2=28). Trails B–A was the only significant individual predictor in this model [t(35)=−3.42, $p<0.01$], with one standard deviation decrease in time taken for Trails B–A being associated with over half a standard deviation increase in SM performance ($\beta=-0.53$).

Hierarchical regression was used to determine whether Trails B–A predicted SM after controlling for Digits-B. Table 4 shows regression coefficients for each step of the analysis. In Block 1, R for the model was not significant [R=0.19; F(1, 43)=1.55, $p>0.05$] when Digits-B was the only predictor of SM. In Block 2, when Trails B–A was added as the predictor, it significantly improved the model R [F-change (1, 42)=12.47, p=0.001] and the overall model also became significant [R=0.51; F(2, 42)=7.22, p=0.01], accounting for 26% of the variance in SM (R^2=0.26).

4. Discussion

In the present study we looked at cognitive predictors of SM performance and found that attention, working memory and organizational sequencing together predicted SM in schizophrenia patients. Organizational sequencing was a significant individual predictor in this model, while working memory and attention were not. Attention has been shown in non-psychiatric populations to be associated with SM (Hashtroudi et al., 1994; Zaragoza and Lane, 1998) and a ceiling effect on the attention task (for 25% of the sample) may have partly contributed to its not being a significant individual predictor in the present study, although our findings are generally in agreement with other studies which have not found a relation between attention and SM deficits in schizophrenia (Ferchiou et al., 2010; but also see Brébion et al., 1996).

Table 2
Correlations among variables.

	SM	CPT-A (log)	Digits-B
CPT-A (log)	−0.12		
Digits-B	0.21	−0.34*	
Trails B–A (log)	−0.53**	0.07	−0.38**

CPT-A=Auditory Continuous Performance test; Digits-B=Digit Span Backward; SM=Source Monitoring; TMT=Trail-Making Test.

* $p<0.01$ (two-tailed).
** $p<0.01$ (two-tailed).

Table 3
Standard multiple regression of CPT-A, Digits-B, and Trails B–A on source monitoring (n=39).

	B	SE	β	pr^2
Intercept	30.12	5.12		
CPT-A (log)	−0.67	1.12	−0.09	−0.10
Digits-B	−0.03	0.22	−0.02	−0.02
Trails B–A (log)	−7.46**	2.18	−0.53	−0.50
R	0.53**			
R^2	0.28			

CPT-A=Auditory Continuous Performance test; Digits-B=Digit Span Backward; TMT=Trail-Making Test.

** $p<0.01$.

Table 4
Hierarchical regression analysis of Digits-B and Trails B–A on source monitoring (n=45).

	B	SE	β	pr^2
Block 1				
Intercept	13.58	1.23		
Digits-B	0.25	0.20	0.19	0.19
R	0.19			
Block 2				
Intercept	29.91	4.75		
Digits-B	−0.001	0.19	−0.00	−0.00
Trails B–A (log)	−7.49**	2.12	−0.51	−0.48
R	0.51**			
R^2	0.27			

Digits-B=Digit Span Backward; TMT=Trail-Making Test.

** $p<0.01$.

Organizational sequencing predicted SM even after controlling for working memory. The Trail-Making Test is a complex measure which asesses psychomotor speed (Lezak et al., 2004), organizational sequencing (Levitt et al., 1995), and working memory (Garlinghouse et al., 2010), while digit span backward is a specific measure of working memory (Lezak et al., 2004). We controlled for psychomotor speed by subtracting Trails A from B, and controlled for the working memory by regressing out digit backward, and still found that Trails B–A predicted SM. Although the and digit-span backward test is also a measure of organization to some extent (Garlinghouse et al., 2010; Partington and Leiter, 1949), the Trail-Making Test requires a much longer, ongoing response than the digit span task (participants took an average of 127.56 s (S.D.=51.49) to complete Trail Making Test-B). Functionally, the organizational sequencing task requires the participant to not only hold the letter–number sequence in mind (which constitutes the working memory component) but also to actively monitor and distinguish the part of the sequence they have completed drawing (actions) from those they have not yet completed as they go along (see Levitt et al., 1995). SM is a metacognitive process that requires higher level integration of several basic cognitive processes (see e.g. Hashtroudi et al., 1994; Lindsay, 2008). We suggest that the cognitive mechanisms underlying the sense of awareness about past and ongoing self-generated events in organizational sequencing may also contribute to an individual's ability to retrospectively distinguish actions they have carried out ('said' words) from those they have only imagined ('thought' words) on the internal SM task.

One limitation of our study is that the SM test provides three options ('said', 'heard', and 'new') simultaneously, which makes it more susceptible to response bias in patients (see Achim and Weiss, 2008). One way of arriving at a more accurate measure of discrimination would be to first provide participants with an old/new recognition test, and then examine SM accuracy (said/heard) for the items correctly recognized as old. Another limitation of this study is the time difference (9 months) between collection of data on neurocognitive variables, and on the SM task. Previous studies have shown that SM deficits in schizophrenia are stable and trait-like, and tend to persist over long periods (e.g., 8 months (Harvey et al., 1990), and 2 years (Vinogradov et al., 1997)) despite changes in medication and clinical status. Several studies also have shown that cognitive functions [including attention (Irani et al., 2012), working memory (Irani et al., 2012) and Trail-Making Test performance (Heaton et al., 2001)], tend to be stable over long periods of time (Heaton et al., 2001) and are not associated with duration of illness (Gold et al., 1999). Still, we cannot rule out that our results might have been affected to some degree by the fact that all the neurocognitive and metacognitive processes were not assessed simultaneously. If so, the effect would have been to diminish the associations.

Recent studies (Subramaniam et al., 2012) have shown that cognitive remediation programs that succeed in improving cognitive functions can also improve SM as well as real-world functioning. There has been a gradual shift in focus of schizophrenia research from the psychotic symptoms, to the more enduring cognitive impairments (Green, 2010). Our findings suggest that neurocognitive deficits merit attention not only due to their association with functional disability (Green, 1996) but also because they may indirectly contribute to psychotic symptoms due to their influence on metacognitive processes.

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