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Declarative memory and WCST-64 performance in subjects with schizophrenia and healthy controls

Glenn J. Egan [a,b,*], Wendy Hasenkamp [b], Lisette Wilcox [b], Amanda Green [c], Nancy Hsu [d], William Boshoven [a], Barbara Lewison [a,b], Megan D. Keyes [e], Erica Duncan [a,b]

[a] Department of Psychiatry and Behavioral Sciences, Emory University School of Medicine, Atlanta, GA, USA
[b] Atlanta VA Medical Center, Decatur, GA, USA
[c] Grady Memorial Hospital, Atlanta, GA, USA
[d] Nancy Hsu, Virginia Commonwealth University Medical Center, Richmond, VA, USA
[e] Birmingham VA Medical Center, Birmingham, AL, USA

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ABSTRACT

The Wisconsin Card Sorting Test (WCST) is a set-switching task used extensively to study impaired executive functioning in schizophrenia. Declarative memory deficits have also been associated with schizophrenia and may affect WCST performance because continued correct responding depends on remembering the outcome of previous responses. This study examined whether performance in visual and verbal declarative memory tasks were associated with WCST performance. Subjects comprised 30 patients with schizophrenia or schizoaffective disorder (SCZ) and 30 demographically matched healthy controls (CON) who were tested on the WCST, the Benton Visual Retention Test (BVRT), the California Verbal Learning Test (CVLT), and the Continuous Performance Test (CPT). SCZ subjects showed significant correlations between visual and verbal declarative memory and performance on the WCST-64 that were in the hypothesized direction such that worse memory performance was associated with worse performance on the WCST. CON subjects did not show a significant relationship between visual or verbal memory and WCST-64 performance. Fisher's r to z transformations indicated that the associations between declarative memory and WCST-64 performance in the SCZ subjects differed significantly from those of CON subjects. The findings suggest that interpretations of WCST-64 scores for subjects with schizophrenia should be considered in light of their declarative memory functioning.

1. Introduction

1.1. The WCST/WCST-64 in the study of schizophrenia

Impaired cognitive function in schizophrenia is receiving increasing attention as the link with impaired functional outcomes has come to light (Green, 1996; Green et al., 2000). Cognitive deficits in areas such as attention, memory, visual-motor speed, and executive functioning are frequently reported (Braff et al., 1991; Reichenberg and Harvey, 2007) and are thought to represent a core feature of the illness (Green et al., 2004). Two of the most popular tests of executive function, the 128-item Wisconsin Card Sorting Test (WCST) and its 64-item version (WCST-64) have been used in well over 250 studies of schizophrenia. The WCST was developed in 1948 as a measure of abstract reasoning and the ability to shift cognitive sets (Kongs et al., 2000). The WCST-64, an abbreviated version of the WCST, is highly correlated with the longer original version (Spearman's correlations of 0.90 for raw scores, 0.80 for T-scores, Kongs et al., 2000). Most studies have demonstrated impaired WCST performance in subjects with schizophrenia compared to healthy controls (Reed et al., 2002; Goldberg and Green, 2002; Prentice et al., 2008).

The WCST-64 manual indicates that the WCST is a measure of executive function because it requires the ability to use an appropriate problem-solving strategy across changing stimulus conditions to obtain a goal (Kongs et al., 2000). Research suggests that WCST performance reflects a function of the dorsolateral prefrontal cortex (Ritter et al., 2004). In a study comparing the WCST performance of patients with schizophrenia with patients with brain tumors, only patients with right frontal lobe tumors showed deficits similar to that of patients with schizophrenia, namely, significantly more perseverations, longer strings of perseverations, and poorer conceptual level response scores (Haut et al., 1996). In examinations of the factor structure of WCST deficits in schizophrenia, perseveration (which is the behavioral result of a lack of appropriate set switching) has been found to be the most diagnostically useful and characteristic WCST feature distinguishing schizophrenia subjects from controls (Koren e al., 1998). However, a number of studies

* Corresponding author at: Department of Psychiatry, Emory University School of Medicine, 49 Jesse Hill Jr. Drive, SE, Atlanta, GA, USA 30303-3049. Tel.: +1 404 778 1483; fax: +1 404 778 1492.
E-mail address: glenn.egan@emory.edu (G.J. Egan).

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have not found that subjects with schizophrenia make significantly more perseverative errors on the WCST than do healthy controls (Braff et al., 1991; Mattes et al., 1991; Saykin et al., 1994; McGrath et al., 1997; Stratta et al., 1997).

1.2. Declarative memory and schizophrenia

Declarative memory (the retrieval of factual information) is one of the most consistent and severe cognitive deficits in schizophrenia (Cirillo and Seidman, 2003; Reichenberg and Harvey, 2007). Deficits in declarative memory in schizophrenia subjects have been found in both verbal and visual tasks (Tracy et al., 2001).

Despite the prominence of declarative memory deficits in schizophrenia, the relationship of declarative memory to WCST performance has received little attention. Stimuli from the WCST were used to create a declarative memory task (the Paired Associate Recognition Test, PART) using WCST stimuli (Ragland et al., 1995). In a study of 30 subjects with schizophrenia and 30 healthy matched controls, Ragland et al. (1996), found that the schizophrenia group was equally impaired in the PART and the WCST. The CATIE study examined 1263 subjects with schizophrenia in multiple sites across the United States and found a significant correlation ($r=0.27$, $P<0.0001$) between the Hopkins Verbal Learning Test (HVLT) (Brandt, 1991) and the WCST-64 scores in subjects with schizophrenia (Keefe et al., 2006).

1.3. Cognition and fronto-temporal dysfunction in schizophrenia

Recent functional imaging studies implicate neurocircuitry dysfunction in schizophrenia that is consistent with a potential relationship between executive function and declarative memory. Executive function performance as measured by the WCST depends heavily on the frontal cortex (Milner, 1963; Berman et al., 1988), although not exclusively (Nyhus and Barcelo, 2009), whereas declarative memory is a function most dependent on the temporal lobe (Squire et al., 2004). In a twin study, it was shown that the hippocampal volume of the twins with schizophrenia was strongly related to prefrontal activation during the WCST (Weinberger et al., 1992). Replacing earlier ideas of an isolated frontal lobe or temporal lobe dysfunction in schizophrenia, current models of cognition in schizophrenia have proposed dysfunction of distributed fronto-temporal networks that link frontal and temporal lobes (Friston et al., 1992; Friston and Frith, 1995; Ragland et al., 2007).

1.4. Goal of the present study

The hypotheses underlying this article stemmed from clinical observations that schizophrenia patients with deficits in the WCST also tended to show memory deficits, as well as from the development of the fronto-temporal network dysfunction model of schizophrenia as described earlier. Since the WCST/WCST-64 requires subjects to recall previous trial results in order to perform subsequent trials correctly, it would seem reasonable that declarative memory ability as well as executive function skills could affect the test results. Although the WCST is mainly a visual test, instructions and feedback are presented aurally, which suggests that verbal as well as visual declarative memory could affect test performance. The goal of this study was therefore to examine the impact of verbal and visual declarative memory on WCST-64 performance. Specifically, we hypothesized that better memory performance would be positively correlated with better WCST-64 scores, and that this relationship would be more robust in subjects with schizophrenia than in healthy controls. The Perseverative Errors and the Categories Completed scores were the targets of this study because these scores are the scores most frequently analyzed in studies of schizophrenia (Reichenberg and Harvey, 2007). However, other scores from the WCST-64 were also analyzed for comparison. In addition, because attentional deficits are frequently seen in schizophrenia and can also affect cognitive performance across a variety of domains, the relationship of a test of attention to the WCST-64 was also examined.

2. Methods

2.1. Subjects

Subjects comprised 30 subjects with schizophrenia or schizoaffective disorder (SCZ) and 30 healthy control subjects (CON) matched to the SCZ group in age, sex, and race. These subjects were part of a larger study on heritability of sensorimotor gating in schizophrenia (Hasenkamp et al., 2010). All subjects indicated their informed consent for their participation by signing a consent form approved by the Emory University Institutional Review Board and the Atlanta Veterans Administration Research and Development Committee. A screening interview was conducted on all participants to obtain demographic data and determine eligibility for the study. A urine drug screen was performed to rule out recent substance use that might affect test performance.

The patient edition of the Structured Clinical Interview for DSM-IV (SCID-P) was used to confirm a diagnosis of schizophrenia or schizoaffective disorder in the patient group (First et al., 1998). In the SCZ group, current symptoms were evaluated with the Brief Psychiatric Rating Scale (BPRS) (Overall and Donald, 1962) and the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1988). Although the PANSS incorporates the BPRS items, the subscales and summary scales of the two scales are based on somewhat different items. Results of both scales are provided for the convenience of readers who are more familiar with one scale than the other. Potential CON subjects were excluded for current or past diagnosis of any Axis I disorder as confirmed by the non-patient edition of the SCID (SCID-I/NP) (First et al., 2007). Subjects were also excluded from the CON group if any of their first-degree relatives had been diagnosed with a psychiatric disorder.

Potential subjects in both groups were excluded if they met any of the following criteria: history of mental retardation, a head trauma with loss of consciousness for greater than 5 min, current unstable clinically significant medical problems, substance dependence (except for tobacco) during the prior 3 months, significant hearing or visual problems, or colorblindness.

The Mini-Mental Status Exam (Folstein et al., 1975) was used as a screener to examine both groups for the possibility of mental retardation. In addition, the two subtest form of the Wechsler Abbreviated Scales of Intelligence (WASI) (Psychological Corporation, 1999) was also administered to the SCZ group to verify that none of these subjects had a general intellectual deficit. The two-subtest form of the WASI consists of the Vocabulary and the Matrix Reasoning subtests and provides a Full Scale IQ estimate.

2.2. Cognitive measures

The hypotheses of this study were examined using the following tests of cognitive function:

1) The Benton Visual Retention Test—Fifth Edition (BVRT), Administration A (10 sec exposure) (Sivan, 1991). The BVRT is a test of visual memory in which subjects are shown a geometrical figure for 10 sec and are then asked to draw the figure immediately after the presentation. A total of 10 figures are shown. The total number correct (BVRTNumCorr) and the total number of errors (BVRTNumErr) are used as measures of visual declarative memory performance. A larger number on BVRTNumCorr signifies better performance; a larger number on BVRTNumErr signifies worse performance. The BVRT takes about 15–20 min to administer.
2) The California Verbal Learning Test—Second Edition, Short Form (CVLT-II SF), (Delis et al., 2000). The CVLT-II is a test of verbal memory in which subjects are read nine words and are then asked to recall the words in any order. This immediate recall procedure is repeated four times and results in a composite score. This composite score for the four trials (CVLT4Trials) was used as a measure of verbal declarative memory performance and was chosen because it resembles the short term recall involved in going from trial to trial during performance of the WCST-64. A larger number on this variable signifies better performance. The CVLT-II SF takes about 15 min to administer.
3) Conner's Continuous Performance Test (CPT), computerized AX version. The CPT AX is a visual test of attention in which subjects are asked to press a key when they see the letter “X” preceded by the letter “A” (Conners and Staff, 2000). The d′ (Attentiveness) score, CPTd, was used as the target variable and measures how well subjects discriminate between the target and non-target letters and takes into account both commission and omission errors. A larger number on this variable signifies better performance. This test takes about 14 min to administer.
4) The WCST-64 card version (Kongs et al., 2000). This version typically takes about 10–15 min to administer. The variables used to assess performance on the WCST-64 in this study are:

a) The number of categories completed (WCSTCat), the number of blocks of 10 consecutive correct matches. A larger number on this variable signifies better performance.
b) Nonperseverative Error Score (WCSTNPErr), the number of incorrect responses that do not match the perseverated-to principle. A larger number on this variable signifies worse performance.

c) Perseverative Error Score (WCSTPErr), the number of responses that matches the perseverated-to principle and does not match the presently correct principle. A larger number on this variable signifies worse performance.
d) Failure to Maintain Set (WCSTSet), the number of times a respondent completes five or more consecutive correct matches and then makes an error. A larger number on this variable signifies worse performance.
e) Conceptual Level of Response (WCSTLevResp), consecutive correct responses that occur in three or more trials in a row. A larger number on this variable signifies better performance.

2.3. Statistical analysis

Tests of normality were performed on all cognitive variables by means of the Kolmogorov–Smirnov test. Correlations were performed to examine the relationships between WCST variables and variables from the BVRT, CVLT, and CPT. Since all WCST-64 variables were found to be nonparametric, Spearman's rho correlations were performed for the SCZ and CON groups separately. In order to test for significant differences in correlations between these two groups, Fisher's *r* to *z* transformations were performed. Group differences between SCZ and CON subjects were examined with Student's *t*-tests (2-tailed) for parametric variables (age, years of education, CVLT4Trials and CPT-d) and with the Mann–Whitney *U* test (2-tailed) for nonparametric variables (BVRTNumCorr, BVRTNumErr, and all WCST-64 variables). Levene's test for equality of variances was performed and significance was reported for equal or nonequal variances as appropriate. All analyses were conducted using SPSS version 17 (SPSS, Inc., Chicago, IL).

3. Results

3.1. Demographic and clinical variables

Table 1 displays demographic and clinical information about the subject groups. They were carefully matched according to age, race, and sex as can be seen in this Table. Years of education were significantly lower in the SCZ group ($P<0.0001$). Symptom ratings were available on 28 of the 30 SCZ subjects. BPRS and PANSS scores indicated that the group as a whole exhibited mild to moderate symptoms of schizophrenia. Of the SCZ subjects, 20 were taking atypical antipsychotic medications, three were taking typical antipsychotic medications, four were taking both atypical and typical medications, and three were not taking antipsychotic medications. Subtypes within the SCZ group are as follows: 21 with schizophrenia (one disorganized, nine paranoid, two residual, nine undifferentiated), and nine with schizoaffective disorder (five bipolar, four depressed).

3.2. Correlations of WCST performance with declarative memory and attention

Spearman's rho correlations revealed robust correlations between WCST-64 variables and measures of declarative memory in the SCZ subjects (Table 2). Specifically, the variables from the BVRT and CVLT correlated with all variables from the WCST-64 except the WCSTSet (Failure to Maintain Set). For all significant correlations, the direction of the relationships confirmed our hypotheses: worse performance in declarative memory as measured by the BVRT or the CVLT predicted worse performance in the WCST-64. These correlations ranged from $P\leq0.01$ to $P\leq0.001$ when a 2-tailed test was used, as is shown in Table 2. Using a Bonferroni corrected significance level of $P\leq0.0125$ (or 0.05/4), all these correlations survived this correction. The level necessary for significance was corrected by dividing the P-value needed for significance by 4 rather than by 20 because the WCST-64 is one test with correlated scores rather than five separate tests. Dividing the P-value by 20 could unreasonably increase the chance of Type II errors. However, since the hypothesis was directional from the beginning of this study, a 1-tailed test could have been used and would have produced P-values that would have survived even a Bonferroni correction of 0.05/20 (0.0025). The only variable that correlated with WCSTSet was the attention variable, CPTd ($P\leq0.01$), and this variable did not correlate with any other WCST-64 variable.

Table 1
Demographic and clinical characteristics.

	SCZ Subjects[a]		CON Subjects[a]	
	$N=30$		$N=30$	
	N	(%)	*N*	(%)
Gender				
Male	13	(43.3)	13	(43.3)
Female	17	(56.7)	17	(56.7)
Race				
African American	18	(60.0)	18	(60.0)
Caucasian American	12	(40.0)	12	(40.0)
	Mean	(SD)	Mean	(SD)
Age (yrs)[b]	36.3	10.8	36.1	11.2
Education (yrs)[c]	13.6	−1.8	15.7	−1.9
Clinical characteristics of SCZ subjects				
Age at onset of symptoms	20.1	(7.5)	–	–
Length of illness	16.2	(11.6)	–	–
BPRS total	39.0	(12.1)	–	–
BPRS positive symptoms	22.4	(7.8)	–	–
BPRS negative symptoms	6.1	(3.3)	–	–
PANSS total	60.2	(18.0)		
PANSS positive symptoms	16.7	(6.2)	–	–
PANSS negative symptoms	12.9	(4.2)	–	–
PANSS general psychopathology	30.6	(9.6)	–	–

[a] SCZ: subjects with schizophrenia; CON: healthy control subjects.
[b] Age difference between the groups was not significant.
[c] Education between the groups was significant ($t=-4.53$, df$=58$, $P<0.0001$).

The pattern of correlations was strikingly different in the CON group. For these subjects, only CVLT4Trials was significantly related to WCSTPErr at a level of $P\leq0.05$, and this relationship did not survive correction for multiple comparisons. Table 2 displays the correlations coefficients and significance levels for these correlations in the SCZ and CON groups. Fig. 1 shows a scatter plot for a representative correlation, that of CVLT4Trials vs. WCSTLevResp for the SCZ and CON groups. As can be seen in this figure, the correlation is quite robust in the SCZ group and clearly nonsignificant in the CON group.

3.3. Comparison of correlations between subject groups

In order to examine whether the above correlations were significantly different in our SCZ and CON groups, Fisher's *r* to *z* transformations were performed for those correlations that were significant in the SCZ group and nonsignificant in the CON group. The results of these analyses are shown in Table 3. As can be seen in Table 3, a majority of the correlations between visual or verbal declarative memory WCST-64 variables differed significantly between SCZ and CON subjects. However, WCSTSet did not differ in significance of correlations between our subject groups, and WCSTCat only differed in the correlation with the BVRTNumCorr. Fisher's *r* to *z* transformation did not yield significant differences for the attention measure CPTd in relation to any of the WCST-64 variables. Overall our results indicate a significantly more robust relationship between visual and verbal declarative memory and WCST-64 performance in SCZ subjects than in CON subjects.

3.4. Differences in cognitive performance between subject groups

Differences in cognitive performance were tested between the SCZ and CON groups using either the Students' *t*-test for parametric variables (as per the Kolmogorov–Smirnov test, CVLT4Trials and CPTd) or the Mann–Whitney *U* test for nonparametric variables (as per the Kolmogorov–Smirnov test, BVRTNumCorr, BVRTNumErr, WCSTCat, WCSTNPErr, WCSTPErr, WCSTSet, and WCSTLevResp). The raw scores of these tests for each group and the results of between group testing are displayed in Table 4 along with WASI scores for the SCZ group. As can be seen in this Table, SCZ subjects were not

Table 2
Spearman's rho correlations between cognitive variables.

Subject group	Test	WCSTCateg	WCSTNPErr	WCSTPErr	WCSTSet	WCSTLevResp
Schizophrenia	BVRTNumCorr	0.54[a]	−0.55[a]	−0.62[b]	−0.14	0.67[b]
	BVRTNumErr	−0.47[a]	0.52[a]	0.53[a]	0.13	−0.61[b]
	CVLT4Trials	0.56[b]	−0.51[a]	−0.62[b]	−0.23	0.62[b]
	CPTd	−0.02	0.04	−0.03	−0.47[a]	−0.02
Control	BVRTNumCorr	−0.06	0.11	0.13	−0.01	−0.06
	BVRTNumErr	−0.07	0.02	−0.13	0.25	−0.02
	CVLT4Trials	0.11	−0.07	−0.38	0.23	0.18
	CPTd	0.07	0.01	−0.07	−0.09	0.14

Bonferroni correction: $P = 0.05/4 = 0.0125$.
[a] Correlation is significant at $P < 0.01$ (2-tailed).
[b] Correlation is significant at $P < 0.001$ (2-tailed).

impaired in comparison to CON subjects in verbal declarative memory (CVLT) or any of the WCST variables. However, SCZ were impaired in comparison to CON in performance on visual declarative memory (BVRT) and attention (CPT).

4. Discussion

The major finding of this study is that SCZ subjects demonstrated significant correlations between visual and verbal declarative memory and performance in the WCST-64. All of these correlations were in the hypothesized direction such that worse memory performance was associated with worse performance in the WCST. CON subjects, on the other hand, did not show a significant relationship between visual or verbal memory and WCST-64 performance. The only correlation seen in the CON subjects was between attention (CPTd) and perseverative errors in the WCST-64, but this correlation did not survive Bonferroni correction. Fisher's r to z transformations indicated that the associations between declarative memory and WCST-64 performance in the SCZ subjects differed significantly from those of CON subjects.

Our finding of an association between declarative memory performance and WCST performance does not seem surprising when one considers the nature of the WCST. To perform a correct sort on the WCST, subjects have to remember whether they were told that the previous sorts were correct or incorrect and associate particular visual stimuli with a correct answer. If memory ability is impaired, subjects could have difficulty remembering the correct sorting rule and whether their previous responses were correct.

These results complement the study of Ragland et al. (1996). In that study, performance on the WCST and on a visual recognition memory task (Paired Associate Recognition Test, PART) developed for use in functional imaging were compared in subjects with schizophrenia and healthy controls. Performances on both tasks were comparably impaired in the schizophrenia group. Our study, however, focused on the correlation between the WCST-64 and verbal and visual free recall declarative memory tasks and attention.

The results of this study are in accord with recent hypotheses stemming from imaging studies that posit a dysfunction in the fronto-temporal connectivity in schizophrenia and linked dysfunctions in the frontal and temporal cortex (Friston et al., 1992; Friston and Frith, 1995; Ragland et al., 2007). This hypothesis rests in part on the finding of reduced activation of the prefrontal cortex and increased temporal activation during a verbal memory task (Ragland et al., 2004). This hypothesis of disturbed fronto-temporal connectivity in schizophrenia may underlie our finding that only SCZ subjects and not CON showed an association between declarative memory and WCST-64 performance.

Of note, in our SCZ subjects, attentiveness (CPTd) was only correlated with one WCST-64 variable, Failure to Maintain Set, but this was the only WCST-64 variable that did not correlate with visual or verbal memory. Although the WCSTSet (Failure to Maintain Set) may be a false positive, the fact that the CPT was significantly correlated only with the WCSTSet and had little correlation with the other WCST-64 scores suggests that the WCSTSet score is related to attention. According to the WCST-64 manual, when a principal components analysis with varimax rotations was performed on the normative adult sample and on the adult clinical sample, Failure to

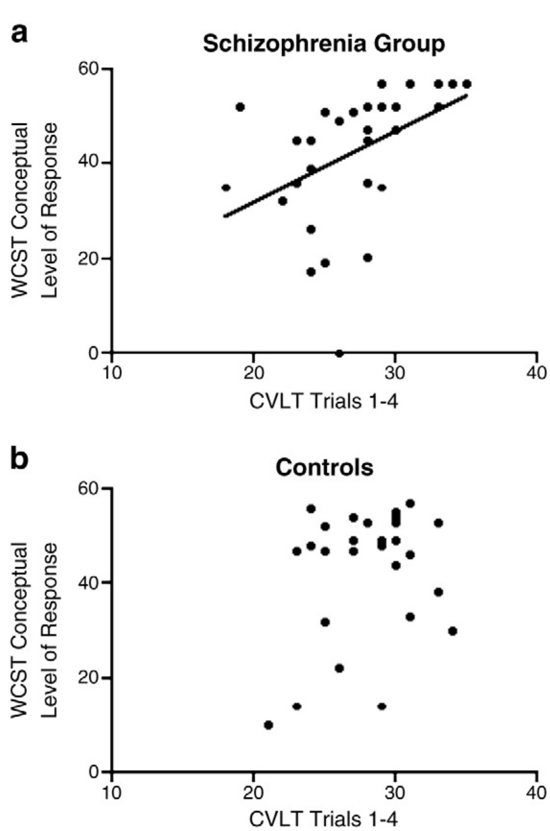

Fig. 1. Scatter plot of scores on the California Verbal Learning Test items 1–4 and the Wisconsin Card Sorting Test Conceptual Level of Response for (a) schizophrenia group, and (b) healthy controls. Spearman's rho correlations: (a) $r = 0.62$, $P < 0.001$ (2-tailed); (b) $r = 0.18$, $P = 0.3$ (2-tailed).

Table 3
Fisher's r to z tranformations comparing correlations between SCZ and CON subjects.

Test	WCSTCateg	WCSTNPErr	WCSTPErr	WCSTSet	WCSTLevResp
BVRTNumCorr	2.41[a]	−2.65[b]	−3.14[b]	−0.16	3.21[b]
BVRTNumErr	−1.59	2.06[a]	2.65[b]	−0.44	−2.52[a]
CVLT4Trials	1.92	−2.31[a]	−1.21	−1.74	1.97[a]
CPT	−0.33	0.09	0.12	−1.54	−0.58

[a] Correlation is significant at $P < 0.05$ (2-tailed).
[b] Correlation is significant at $P < 0.01$ (2-tailed).

Table 4
Cognitive performance of SCZ and CON subjects.

Test score	SCZ Subjects [a]				CON Subjects [a]				
	$N = 30$				$N = 30$				
	Mean	Median	Std. Dev	Range	Mean	Median	Std. Dev	Range	*P*-value
BVRTNumCorr	6.2	6.0	2.2	2.0–9.0	8.4	8.0	0.8	7.0–10.0	²0.001[b]
BVRTNumErr	6.1	6.0	4.1	1.0–17.0	2.1	2.0	1.4	0.0–6.0	²0.001[b]
CVLT4Trials	27.0	27.5	4.1	18.0–35.0	27.8	28.5	3.4	21.0–34.0	²0.4[c]
CPTd	4.0	4.0	0.6	2.5–5.4	4.5	4.4	0.7	3.5–6.2	²0.002[c]
WCSTCat	3.3	4.0	1.4	0.0–5.0	3.6	4.0	1.5	1.0–5.0	²0.4[b]
WCSTNPErr	7.6	6.0	5.3	2.0–23.0	7.9	6.5	5.4	3.0–24.0	²0.8[b]
WCSTPErr	10.0	7.0	6.4	4.0–29.0	8.2	6.0	5.8	3.0–26.0	²0.1[b]
WCSTSet	0.5	0.0	0.6	0.0–2.0	0.4	0.0	0.7	0.0–2.0	²0.3[b]
WCSTLevResp	42.3	47.0	14.3	0.0–57.0	43.5	48.0	13.3	10.0–57.0²0.7[b]	
MMSE	28.5	29.0	1.3	26.0–30.0	29.0	29.0	1.2	26.0–30.0	0.1[c]
WASI (IQ)	103.7	102.0	15.5	82.0–135.0	–	–	–	–	–

[a] SCZ, subjects with schizophrenia; CON, healthy control subjects.
[b] Nonparametric variable; group comparison performed by Mann–Whitney *U* (2-tailed).
[c] Parametric variable; group comparison performed by *t*-test (2-tailed, equal variances not assumed).

Maintain Set emerged as a separate factor for both groups (Kongs et al., 2000). The close relationship between the Failure to Maintain Set score and attention has been suggested by previous research (Greve et al., 1996, Greve et al., 1997). The finding that CPTd had no significant relationship with the other WCST-64 variables that did correlate with memory suggests that the declarative memory association with WCST-64 performance was not merely mediated by poor attention.

Somewhat surprisingly, the SCZ subjects were not impaired in verbal memory (CVLT) or in any of the WCST-64 variables compared to the CON group. SCZ subjects were impaired on both variables of visual declarative memory (BVRTNumCorr and BVRTNumErr) as well as on attentiveness (CPTd). The finding that visual memory was different between groups may have to do with the abstract geometrical nature of the stimuli used in the BVRT. A recent study found that stimulus characteristics and not just executive functioning deficits contribute to impaired WCST performance by subjects with schizophrenia (Kantrowitz et al., 2009). In that study, when faces were substituted for the abstract shapes of the WCST, patients with schizophrenia performed significantly better in the WCST. Based on this finding, our subjects might not have been impaired in a visual memory task using faces, had we used such a task.

The lack of correlation between memory scores and the WCST-64 performance in the CON subjects could be due to a ceiling effect such that the memory tasks were not challenging enough to these subjects. While the range of scores (presented in Table 4) is indeed wider in the SCZ group for the BVRT variables, the CVLT scores have very similar ranges in SCZ and CON subjects but had no significant relation (after Bonferroni correction) to any of the WCST-64 variables in the CON subjects. For this reason, we hypothesize that the correlations amongst variables in the SCZ group reflects specific dysfunctions in circuits linking frontal and temporal areas in the SCZ subjects.

One limitation of this study is the modest sample size. Another limitation is that most of our SCZ subjects were outpatients who had been stabilized on their medication for quite some time. Their current level of symptoms was not particularly severe, and they were able to achieve comparable performance to the CON in verbal memory and the WCST-64. Thus the generalizability of our results may be limited.

In conclusion, the finding that visual and verbal declarative memory scores were significantly correlated with the WCST-64 scores by the SCZ group and not by CON group suggests that memory functioning is associated in a unique way with the set-switching performance of SCZ subjects. Verbal and visual declarative memory should be taken into account when interpreting the test results of patients with schizophrenia.

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