

Wisconsin Card Sorting Test deficits in schizotypic individuals

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Abstract:

The present study investigates executive functioning in schizotypic college students and control subjects using the Wisconsin Card Sorting Test (WCST). Inhibitory control and working memory, two aspects of executive functioning, were examined in deviantly high scorers on the Perceptual Aberration and Magical Ideation Scales (n=97), high scorers on the revised Social Anhedonia Scale (n=58), and in control subjects (n=104). The schizotypic groups displayed significantly more perseverative errors and achieved fewer categories than the control group. The two schizotypic groups did not differ from each other. We identified a subset of schizotypic individuals who also produced clinically deviant WCST profiles. The findings support the hypothesis that executive function deficits may precede the onset of schizophrenia and related illnesses.

Keywords: executive functioning | schizophrenia | schizotypy | wisconsin card sorting test | psychology

Article:

1. Introduction

The present study investigates whether hypothetically schizotypic young adults demonstrate executive functioning deficits consistent with those reported in patients with schizophrenia. The Wisconsin Card Sorting Test (WCST) is used as a measure of 'executive' or higher-order

cognitive functions such as working memory, abstraction, maintenance of set, and response to feedback ([Lezak, 1983] and [Weinberger et al., 1994]). The task requires a subject to sort a card to one of four cue cards; the card can be sorted by color, number, or form, but only one of these categories is considered correct on a given trial. Once the subject discovers the sorting principle, it shifts unexpectedly, and the subject must respond to the changing environmental contingencies and infer the new correct sorting strategy.

People with schizophrenia are typically unable to perform the WCST successfully ([Goldberg and Seidman, 1991] and [Weinberger et al., 1994]). For example, Gold et al. (1997) demonstrated that schizophrenia patients complete significantly fewer categories, and make considerably more perseverative errors than normal controls. WCST performance in schizophrenia patients has been correlated with their long-term social functioning and negative symptoms (see Breier et al., 1991).

WCST deficits may serve as cognitive state markers or they may be independent of psychotic symptomatology. There has been considerable research interest in determining whether the WCST deficits observed in schizophrenia patients represent a more fundamental disturbance that is possibly related to the underlying pathophysiology of the disorder but which might predate the onset of psychosis. If WCST deficits were somehow related to the fundamental disorder, then these deficits would be expected to precede the manifestation of the disorder in vulnerable individuals.

Studies of at-risk individuals are advantageous because they avoid potential confounds of medication status, duration of hospitalization, and florid psychoses. Two main research strategies, namely the genetic high-risk and the psychometric high-risk approaches, have been used to study the relationship between WCST performance and schizophrenia. Researchers have examined the WCST performance of unaffected monozygotic twins ([Berman et al., 1992] and [Van der Does and Van der Bosch, 1992]), healthy siblings (Franke et al., 1993) and/or offspring of schizophrenia patients (Stratta et al., 1997). To date, the findings have been equivocal, with some first-degree relatives displaying impaired WCST performance (Franke et al., 1993) and others performing similarly to normal controls ([Berman et al., 1992], [Stratta et al., 1997] and [Van der Does and Van der Bosch, 1992]). These mixed findings can be reconciled if one assumes that WCST performance may serve as a vulnerability marker that is not genetically transmitted (see Iacono, 1998).

Prior investigations of WCST performance in schizotypic individuals identified by the psychometric high-risk method provide findings that are consistent with the view of WCST deficits as a vulnerability marker. The Chapman et al. (1994) 10 year follow-up study indicated that the Perceptual Aberration Scale identifies a subgroup of schizotypic individuals who eventually manifest a psychotic disorder. Individuals with excessively high scores on the Perceptual Aberration Scale differ from controls in terms of their number of WCST categories achieved (Lenzenweger and Korfine, 1994) and in terms of their failure to maintain set ([Lenzenweger and Korfine, 1994] and [Park et al., 1995]). Typically, individuals who score high on the Magical Ideation scale also score high on the Perceptual Aberration scale, so the predictive ability of these scales appears to be enhanced by considering the Magical Ideation scale along with the Perceptual Aberration scale (Chapman et al., 1995). Schizotypic individuals identified on the basis of deviant scores on the Perceptual Aberration Scale and/or the Magical Ideation scale (Per-Mag individuals) produced a significantly higher number of perseverative errors relative to controls ([Poreh et al., 1995] and [Suhr, 1997]).

Several studies have indicated the multidimensional nature of schizotypy. There are at least two orthogonal factors of schizotypy, namely a cognitive/perceptual distortion factor and an anhedonia factor ([Kelley and Coursey, 1992] and [Lipp et al., 1994]). There has been heightened interest in the anhedonia factor since Kwapil (1998) demonstrated that the revised Social Anhedonia scale (SocAnh; Eckblad et al., 1982) may identify individuals at specific risk for the development of schizophrenia-spectrum disorders.

Studying executive functioning in psychosis-prone individuals may help answer whether executive functioning deficits exist prior to the onset of schizophrenia and schizophrenia-spectrum disorders. At the onset of this investigation, we had three goals in mind: to determine whether the WCST deficits previously observed in some subjects endorsing cognitive-perceptual traits would also be displayed by subjects endorsing social-interpersonal aspects of schizotypy; whether schizotypic individuals identified by cognitive-perceptual traits differed from those with social-interpersonal traits on WCST performance; and whether there is an association between psychotic-like experiences and WCST deficits.

Schizophrenia is often viewed as the extreme end of the continuum of schizotypy ([Meehl, 1962] and [Meehl, 1990]). Such models assume that schizotypy and schizophrenia share a common neurobiological substrate (see Gottesman, 1991). Given our assumption that schizotypy and schizophrenia are dimensional variants (i.e. they lie on a continuum of pathology) that share a common neurobiological substrate, we hypothesize that individuals endorsing schizotypal traits (as measured by the Chapman psychosis-proneness scales) would perform more poorly on the

WCST than control subjects. On the basis of prior research that deviant Social Anhedonia scale scores are specifically predictive of later schizophrenia-spectrum disorders, we hypothesize that individuals with deviantly high SocAnh scores would display greater WCST deficits than individuals with deviantly high scores on the Per-Mag scales. Assuming that poor performance on the WCST serves as an indicator of heightened vulnerability for schizophrenia, we hypothesize that WCST deficits would be a correlate of psychotic-like experiences.

2. Method

2.1. Selection procedure

The high-risk and control subjects were drawn from a sample of 1700 male and 2300 female undergraduate students who were screened using a 179-item true-false self-report questionnaire called the ‘Survey of Attitudes and Experiences’. This questionnaire is a random mixture of items from the Chapman Psychosis-proneness scales, namely Perceptual Aberration, Magical Ideation, revised Physical Anhedonia, and revised Social Anhedonia scales ([Chapman et al., 1976], [Chapman et al., 1978], [Eckblad and Chapman, 1983] and [Eckblad et al., 1982]) as well as the Chapman Infrequency Scale (Chapman and Chapman, 1983).

There were two groups of at-risk subjects, namely, the Per-Mag group and the Soc Anh group. The Per-Mag group consisted of individuals who endorsed an excessively high number of deviant items (at or beyond two SDs from the same-sex sample mean) either on the Perceptual Aberration and/or Magical Ideation scales (the Per-Mag group). An example of an item on the Perceptual Aberration scale is “Parts of my body occasionally seem dead or unreal” (keyed true). An example of an item on the Magical Ideation scale is “Good luck charms don’t work” (keyed false). The SocAnh group consisted of individuals who endorsed an excessively high number of deviant items (at or beyond two SDs from the same-sex sample mean) on the revised Social Anhedonia scale. The revised Social Anhedonia scale includes items such as “I sometimes become deeply attached to people I spend a lot of time with” (keyed false). The controls were individuals who received gender-normed standardized scores of less than 0.5 SD on all of the Chapman scales.¹

2.2. Participants

Following psychometric screening, subjects were invited to participate in a multiple-session study of ‘individual differences and brain functioning’. Individuals who gave their informed consent were screened for a history of learning disabilities, epilepsy, or traumatic brain injury, and other medical conditions that would preclude their full participation (e.g. red–green color

blindness). Potential participants were also screened for personal history of psychotic illness and/or any psychoactive substance use disorder. In addition, all participants were right-handed, free of any current or past mood disorder, and had normal or corrected to normal vision. Control subjects were also screened for a family history of psychotic illness. The resultant sample consisted of 259 undergraduates. There were 97 Per-Mag (33 male, 64 female) subjects, 58 SocAnh (25 male, 33 female) subjects, and 104 control (43 male, 61 female) subjects.

2.3. Procedure

2.3.1. Neurocognitive assessment

A computerized version of the WCST (Harris, 1988) was administered using the standardized guidelines provided in the test manual (see Heaton et al., 1993). Card stimuli were presented on a computer monitor and the subjects were instructed to infer the matching principle from the feedback provided (either 'right' or 'wrong' is flashed upon the screen, depending upon the subject's response). The WCST was scored using the Harris (1988) program provided with the computerized version. Performance on the WCST was scored in terms of number of categories achieved, number and percentage of perseverative errors, number of nonperseverative errors, number of trials to complete first category, conceptual level achieved, and failure to maintain set.

Some investigators, such as Heaton (1981), regard the number of perseverative errors as the most useful measure derived from the WCST. Perseverative errors occur when the subject persists in using a previously successful principle and/or an incorrect matching principle despite feedback indicating that the principle is incorrect. Perseverative errors provide a measure of a subject's sensitivity to contingent feedback (Wagman and Wagman, 1992). Nonperseverative errors occur when the subject incorrectly sorts the cards without perseverating on the wrong response (Spreen and Strauss, 1991). The number of nonperseverative errors is typically used as an indicator of nonfrontal cortical functioning (see Katsanis and Iacono, 1991). The total number of categories achieved reflects overall success, whereas number of trials to complete the first category provides an index of conceptual ability. The failure to maintain set index is a measure of the loss of the correct sorting principle during the course of the testing; this index can be construed as a measure of working memory.

IQ was measured to insure that any possible group differences on the WCST could not be attributed to differences in intellectual ability. Time constraints precluded the use of the entire revised Wechsler Adult Intelligence Scale (WAIS-R; Wechsler, 1981). Vocabulary and Block Design subtests were administered in order to obtain an estimate of participants' full-scale IQ.

This two-subtest short form of the WAIS-R (Silverstein, 1982) yields scores that are highly correlated with full-scale scores (see [Hoffman and Nelson, 1988] and [Missar et al., 1994]), though they overestimate full-scale IQ by an average of two points (Ryan et al., 1988).

2.3.2. Clinical assessment

After completing the neurocognitive assessment, participants were invited to return for a diagnostic interview. The interview included the mood disorder and psychoactive substance use disorder modules from the Structured Clinical Interview for DSM-IV diagnoses (SCID-IV, Patient Version; First et al., 1995). Psychotic and psychotic-like experiences were rated using an interview-based method known as the Wisconsin Manual of Psychotic-Like Experiences (Chapman and Chapman, 1980)². The Wisconsin Manual is an interview-based assessment measure that allows ratings for the presence, frequency, and severity of the following psychotic-like experiences: transmission of thoughts, passivity experiences, auditory experiences, thought withdrawal, aberrant beliefs, visual experiences, and olfactory experiences. Examples of rating criteria and the rating scales can be found in Kwapil et al. (1999). All assessments were conducted by research staff members who were trained by a licensed psychologist and who were unaware of individuals' group status.

3. Results

Table 1 provides the mean Chapman scale scores, age, and estimated full-scale IQ scores for each group. The three groups did not differ in age, $F(2, 256)=0.08$; the mean age was 18.72 years. There were no significant between-group differences in terms of estimated IQ, $F(2, 256)=1.07$.

Table 1. Demographic characteristics and Chapman scale scores

Variable	Group					
	Per-Mag (<i>n</i> =97)		Soc Anh (<i>n</i> =58)		Controls (<i>n</i> =104)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Age	18.70	0.86	18.76	0.86	18.72	0.86

Variable	Group					
	Per-Mag (<i>n</i> =97)		Soc Anh (<i>n</i> =58)		Controls (<i>n</i> =104)	
	<i>M</i>	SD	<i>M</i>	SD	<i>M</i>	SD
Estimated IQ	117.30	11.85	119.21	12.45	116.26	12.56
Perceptual aberration	20.33	6.75	7.90	5.57	3.24	2.83
Magical ideation	21.42	4.31	10.67	5.58	6.75	3.76
Social anhedonia	8.13	4.54	20.98	4.00	4.26	2.75
Physical anhedonia	7.76	4.47	15.86	7.97	8.01	4.07

Nonparametric tests were used to compare the groups' WCST performance scores because of violation of the assumption of homogeneity of variance. The groups were compared first with the Kruskal–Wallis test (Siegel, 1956). Follow-up group comparisons were performed with the Mann–Whitney U-test, with U scores transformed into the normally distributed z-statistic. Table 2 provides the groups' mean scores on each of the WCST performance indices. Comparisons between low schizotypy scoring subjects and those scoring at the extreme (greater than two SDs above the mean) revealed significant differences in WCST performance. Overall, there was a significant group difference in terms of number of categories achieved, $\chi^2(2)=15.52$, $p<0.001$. The Per-Mag group achieved fewer categories than the controls, $Z=-4.00$, $p<0.001$, as did the SocAnh group, $Z=-3.60$, $p<0.001$. However, the Per-Mag and SocAnh subjects did not differ from each other in terms of number of WCST categories achieved.

Table 2. Mean scores on the Wisconsin Card Sorting Test performance indices^a

WCST performance index	Per-Mag (<i>n</i> =97)		SocAnh (<i>n</i> =58)		Control (<i>n</i> =104)		
	<i>M</i>	SD	<i>M</i>	SD	<i>M</i>	SD	χ^2
Estimated IQ	117.30	11.85	119.21	12.45	116.26	12.56	
Perceptual aberration	20.33	6.75	7.90	5.57	3.24	2.83	
Magical ideation	21.42	4.31	10.67	5.58	6.75	3.76	
Social anhedonia	8.13	4.54	20.98	4.00	4.26	2.75	
Physical anhedonia	7.76	4.47	15.86	7.97	8.01	4.07	

WCST performance index	Per-Mag (n=97)		SocAnh (n=58)		Control (n=104)		
	<i>M</i>	SD	<i>M</i>	SD	<i>M</i>	SD	χ^2
No. of categories achieved	5.61	1.1	5.67	1.1	6.00	0.0	15.52***
No. of perseverative errors	10.91	7.51	10.74	8.46	7.58	3.2	11.35**
No. of nonperseverative errors	10.93	8.94	10.66	7.10	8.29	4.2	4.22
Failure to maintain set	0.79	1.2	0.62	1.1	0.33	0.5	7.76*
Trials to complete first category	14.61	12.1	17.40	20.2	13.08	4.27	0.13
WCST conceptual level	45.36	29.2	45.69	28.8	37.21	29.8	4.04

a Groups were compared first with the Kruskal–Wallis χ^2 -test. Follow-up group comparisons were performed with the Mann–Whitney *U*-test with *U* transformed into the normally distributed *z* statistic.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

The groups differed significantly on the number of WCST perseverative errors. The control subjects made significantly fewer perseverative errors than either the Per-Mag group ($Z = -3.31$, $p < 0.001$) or the SocAnh group ($Z = -2.03$, $p < 0.05$). However, the two at-risk groups did not differ significantly from each other, $Z = 0.66$, n.s.

We examined whether any of the subjects' performance fell within the clinically significant range using the cut-off of 15% perseverative errors, based on published norms ([Heaton et al., 1993] and [Suhr, 1997]). Overall, 10% of the entire sample had more than 15% perseverative errors. Of

that group, 56% (14 of 25) had elevated scores on the Perceptual Aberration and/or Magical Ideation scales and 40% (10 of 25) had elevated scores on the Social Anhedonia scale. Only 4% of the group with a clinically significant percentage of perseverative errors (1 of 25) had scores that were within normal limits on all of the Chapman scales. The two schizotypic groups were disproportionately more likely to have a clinically significant level of perseverative errors, $\chi^2(2)=15.38, p<0.001$.

The three groups did not differ significantly from each other in terms of their number of WCST nonperseverative errors, $\chi^2(2)=4.22, n.s.$ However, they differed in terms of their failure to maintain set scores, $\chi^2(2)=7.76, p<0.05$. Follow-up analyses revealed that only the Per-Mag subjects differed significantly from the controls, $Z=-2.82, p<0.01$. None of the groups differed significantly in terms of the number of trials to complete the first category, nor did they differ in terms of their conceptual level responses.

As hypothesized, the schizotypic groups exceeded the control group on ratings of psychotic-like experiences. The Per-Mag subjects endorsed a greater number of psychotic-like experiences than the SocAnh subjects or the controls, $\chi^2=47.70, p<0.001$. The SocAnh group was also more likely to endorse a psychotic-like experience than the controls, $Z=3.05, p<0.01$. We observed no significant associations between ratings of psychotic-like experiences and WCST performance indices, r values ranged from 0.02 to 0.10, $n.s.$

4. Discussion

Despite being equivalent in terms of both age and estimated IQ scores, the three subject groups performed differently on the WCST. Our results, namely that college students with schizotypal traits display deficits in aspects of executive functioning, i.e. inhibitory control and working memory, as measured by WCST performance, are consistent with prior studies ([Lenzenweger and Korfine, 1994], [Poreh et al., 1995] and [Suhr, 1997]). The present study not only replicates prior research, but also extends it by including individuals identified by deviantly high scores on the SocAnh scale, studying a larger group of Per-Mag subjects, and conducting clinical assessment on all the participants.

In our investigation, we observed that the psychotic-like experiences were not associated with WCST performance. This finding is analogous to prior findings (see Weinberger et al., 1994) that indicated the independence of schizophrenia patients' 'positive' or florid psychotic symptoms and their neurocognitive dysfunction. Our sample consisted of a high functioning,

high IQ group who did not suffer from past or current psychosis. Thus, although we were looking at the psychiatrically healthiest of schizotypes, we found significant differences between their WCST performance and that of control subjects. Moreover, our findings are consistent with those derived from investigations of less select groups, such as community-based individuals (see Tien et al., 1992). These findings provide strong support for the hypothesis that such deficits exist prior to illness onset. The performance of some of the individuals in both at-risk groups fell within the clinical range. These observations further buttress support for regarding WCST deficits as a vulnerability marker.

Factor analytic studies of the WCST (see Bell et al., 1997) generally yield three factors, namely perseveration, nonperseverative errors, and failure to maintain set. We were especially interested in comparing the three subject groups on those factors. Consistent with earlier investigations of WCST performance in Perceptual Aberration subjects ([Lenzenweger and Korfine, 1994] and [Park et al., 1995]) and clinically identified schizotypes (Lyons et al., 1991), we found that the individuals in the Per-Mag group displayed a significantly higher rate of failure to maintain set. Failure to maintain set has been construed as a measure of working memory; working memory deficits have been observed in both schizophrenia patients and in schizotypal individuals (see [Park and Holzman, 1992] and [Park et al., 1995]).

The at-risk groups could be distinguished from the control subjects in terms of their number of perseverative errors, though not their number of nonperseverative errors. Increased perseverative errors have also been reported in a prior investigation (Suhr, 1997) using the Per-Mag scales in combination. Investigators frequently use perseverative errors as a measure of frontal cortical functioning, and nonperseverative errors as an index of nonfrontal cortical functioning. Our findings could be considered as partial support for a prefrontal explanation of individual differences in schizotypal personality. However, although the WCST has been regarded as a probe of prefrontal physiological functioning (Weinberger et al., 1986), debate continues regarding the specificity of this measure.

In general, patients with frontal cortical lesions achieve fewer categories and make a greater number of perseverative errors than other neurological patient groups ([Drewe, 1974] and [Milner, 1963]), though the WCST does not always discriminate frontal lesion patients from nonfrontal patients (see Anderson et al., 1991). Indeed, when Barcelo et al. (1997) measured event-related potentials (ERPs) from normal volunteers while they performed the WCST, the investigators identified several prominent ERP components, including an early-appearing one at the left fronto-temporal region and a posterior P3b wave. These findings suggest that brain regions other than the frontal cortex are also implicated in WCST performance. Further

evaluation involving functional brain imaging techniques such as functional magnetic resonance imaging (fMRI) would be helpful in terms of elucidating whether schizotypic individuals displaying WCST deficits have frontal lobe dysfunction.

The prediction that individuals endorsing social-interpersonal schizotypal traits would perform more poorly than individuals endorsing cognitive-perceptual schizotypal traits was not supported. Given the multifactorial nature of the WCST (see Greve et al., 1997), it is not surprising that there are many ways to perform poorly on the measure. The Per-Mag group may have performed poorly on the WCST because of an attentional deficit, whereas the Social Anhedonia group may have performed poorly because of an inability to inhibit inappropriate responses.

Longitudinal studies (Chapman et al., 1994) have suggested that the Perceptual Aberration and Magical Ideation Scales identify individuals at heightened risk for psychosis, but not specifically schizophrenia. In contrast, the revised Social Anhedonia scale appears to identify individuals who are more specifically at risk for schizophrenia-spectrum disorders. Longitudinal follow-up studies of these individuals would be useful in order to determine whether the putatively at-risk individuals who display subtle impairments in executive functioning are more likely to display greater social maladjustment and/or more likely to develop schizophrenia-spectrum disorders than those at-risk subjects who do not display these neurocognitive deficits. The present findings are consistent with prior research indicating that patients diagnosed with schizotypal personality display significant decrements in WCST performance (e.g. [Trestman et al., 1995] and [Vogelmaier et al., 1997]). Comparing the psychiatric outcome of putative schizotypes with and without WCST deficits would clarify the feasibility of WCST performance deficits as a vulnerability marker of schizophrenia.

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1 The cut-off scores were based upon means and standard deviations of the sample. These scores are consistent with the unpublished norms gathered by Chapman and Chapman (1989).

2 The SCID psychosis section was not administered because the rates of psychotic illnesses in previous college student samples (see Chapman et al., 1994) have been extremely low. We opted to interview participants with the Wisconsin Manual because, in addition to detecting frank psychosis, it is considerably more sensitive to the attenuated types of psychotic-like experiences that are seen in samples of psychosis-prone college students.