Perceptual Aberrations, Schizotypy, and the Wisconsin Card Sorting Test

by Mark F. Lenzenweger and Lauren Korflne

Abstract

This study examined performance on the Wisconsin Card Sorting Test (WCST) by 23 schizotypic subjects and 28 normal control subjects. Schizotypy was measured on the Perceptual Aberration Scale (PAS). Overall, schizotypic (high PAS) subjects performed more poorly than control (low PAS) subjects on the WCST; specifically, schizotypic subjects showed deficits on the failure-to-maintain-set and number-of-categories indexes. Consistent with expectations based on research with high-risk subjects, schizotypic subjects were nearly 10 times more likely than controls to be included in a subgroup of deviant WCST performers identified by a composite performance index. WCST performance was not associated with current levels of anxiety or depression. Our results provide evidence for subtle WCST performance deficits in subjects hypothesized to be at risk for psychosis—perhaps schizophrenia—and are broadly consistent with current speculation about dorsolateral prefrontal cortex functioning in schizophrenia as well as recent speculation concerning spatial working memory and schizophrenia. The heuristic potential of our results is discussed and we encourage replication of the present study. Viewed in this context, our results are hypothesis-generating and do not provide definitive confirmation of specific hypotheses.


The association of schizophrenia with deficits in performance on the Wisconsin Card Sorting Test (WCST; Heaton 1981) has received considerable attention in the research literature (Fey 1951; Kolb and Whishaw 1983; Berman et al. 1986; Goldberg et al. 1987; Weinberger 1987; Williamson et al. 1989; Green et al. 1990; Braff et al. 1991). Although these findings appear to be robust and potentially speak to neuropsychological dysfunction of etiological significance involving the dorsolateral prefrontal cortex (DLPFC) (e.g., Weinberger 1987), the existence of a variety of third variables (Neale and Oltmanns 1980; cf. Braff et al. 1991) precludes an unambiguous interpretation of the meaning of this association. Symptom variation (e.g., paranoid vs. nonparanoid), severity of illness, neuroleptic medication, length of hospitalization, level of education, age, and stigma attached to diagnosis could represent such possibly confounding factors. Additionally, the study of card sorting performance in affected patients does not allow one to illuminate the temporal and causal pathway possibly linking the development of brain dysfunction and the emergence of clinical (i.e., symptomatic) schizophrenia (cf. Fey 1951).

One way to address both the possible third-variable confounds and the temporal issue as well as shed light on the directionality (causal) question is to seek comparable deficits in individuals who are at risk for schizophrenia but who are currently unaffected (i.e., schizotypic persons). Such an approach assumes that schizotypic
individuals carry a latent liability for schizophrenia that places them at heightened risk for developing the illness, although they may not express the liability (Meehl 1990). The concept of a latent liability for schizophrenia has been confirmed through the study of unexpressed genotypes for schizophrenia (Got
tesman and Bertelsen 1989). Previou<s research has shown that both clinically and psychometrically identified schizotypic individuals display a profile of psychological, social, and cognitive features similar to those observed in individuals with schizophrenia, albeit attenuated, thus suggesting that schizotypic persons do, in fact, carry a schizophrenia-related liability. For example, schizotypic persons display schizophrenic-like phenomenology (Kendler 1985), deficits in sustained attention (Lenzenweger et al. 1991), and eye movement dysfunction (Siever et al. 1990). Moreover, elevated rates of schizotypic psychopathology have been observed among the biological relatives of schizophrenia patients (Kendler 1985), and an increased risk for schizophrenia was found in the relatives of psychologically defined schizotypic persons (Lenzenweger and Loranger 1989a).

We suggest that an examination of card sorting performance of schizotypic persons would be useful. However, location of schizotypic pathology is difficult because of its low prevalence in treatment settings. For example, although schizotypy (see Meehl 1990) per se is not isomorphic with current personality disorder definitions, recent research (Loranger 1990) reveals prevalences in clinical populations of 2 and 4 percent for paranoid and schizotypal personality disorders, respec-
tively (i.e., the schizophrenia-related personality disorders). Moreover, hospitalized schizotypic patients frequently represent the most severe expressions of the condition (often coupled with concomitant features such as increased depression, impulsivity, or suicidality). An alternative approach for locating individuals at risk for schizophrenia (i.e., schizotypic individuals) involves detection of such cases in the general population, which could potentially yield a more representative sampling of the latent liability for schizophrenia. One effective and well-established method for locating at-risk persons in the general population is the psychometric high-risk strategy (Chapman and Chapman 1985; Lenzenweger and Loranger 1989a).

We used the Perceptual Aberration Scale (PAS; Chapman et al. 1978) to identify schizotypic subjects. Based in part on Meehl’s (1962, 1964) model and description of schizotypy (Chapman and Chapman 1985), the PAS assesses a variety of nonpsychotic body image and perceptual distortions (not to be confused with hallucinations) conjectured to be subtle manifestations of an underlying liability for psychosis, perhaps schizophrenia. We note that Meehl (1990) refers specifically to body-image distortions in his revised theory of schizotypy, viewing such distortions as an outgrowth of the spatial-kinesthetic-vestibular system aberrations deriving from the ubiquitous central nervous system anomaly (i.e., schizotaxia) and related associative loosening. Data from investigations with both clinical and nonclinical populations support the construct and concurrent criterion validity of the PAS as an index of schizotypy (Chapman and Chapman 1985, 1987). We hypothesized that schizotypic persons as a group would show subtle card sorting deficits relative to normal control subjects. Furthermore, consistent with traditional high-risk research expectations (e.g., Hanson et al. 1977; Cornblatt and Erlenmeyer-Kimling 1985), we anticipated that an identifiable subgroup of the at-risk subjects would reveal particularly deviant card sorting performance. Finally, although we expected that our schizotypic subjects would display higher levels of anxiety and depression than would the control subjects, we conjectured that card sorting performance would not be significantly associated with concurrent anxiety or depression.

1 A substantial body of literature supports the view that the PAS is a measure of schizotypy. The PAS has also been provisionally described as a measure of “psychosis proneness”; however, long-term followup data bearing on the validity of the measure as a predictor of clinical psychosis are currently unavailable. Clearly, this debate represents an area of unresolved, though legitimate, scientific discussion. One possible solution would be simply to designate subjects with elevated scores on the PAS as “high PAS” subjects, though such a designation risks obscuring the rich body of research linking the PAS to schizotypic phenomena and schizophrenia-related laboratory findings in the classic tradition of construct validation. We have chosen to view the PAS as an indicator of schizotypy as conceptualized by Meehl (1990); however, we are mindful that alternative views of the measure exist.
Methods

Subjects. Subjects for the present study were drawn from a sample of 500 entering first-year students from Cornell University who voluntarily completed a 200-item objective psychological inventory entitled “Attitudes, Feelings, and Experiences Questionnaire” that included the PAS. The modal age of the subjects at testing was 18 years.

In this study we sought to select schizotypic and normal control subjects from a large randomly ascertained sample. This approach was chosen to maximize diversity within the pool of potential study subjects and to minimize the effects of and biases associated with subject self-selection factors and group-related test-taking attitudes often found in introductory psychology course-based sampling. To collect a large randomly ascertained sample of study subjects, we selected at random a subsample of 500 individuals from an exhaustive universe roster that contained the names of all entering freshmen during a recent fall term (approximately 3,200). Using a door-to-door, face-to-face, epidemiologic-style survey distribution and collection method, a team of six trained research assistants individually approached each of the 500 potential study participants and asked them to voluntarily complete the psychological inventory mentioned above. The subjects were informed that their inventory responses would remain completely confidential and would be used for research purposes only. All subjects were instructed not to endorse inventory items if the experiences in question were confined to periods of drug and/or alcohol abuse. Study subjects were asked to complete the inventory within 48 hours and the inventories were picked up in sealed envelopes by study staff.

Of the 500 potential subjects who were invited to complete the inventory, 414 did so. The response rate of 82.8 percent suggests that the sample was drawn representatively from the population studied (Kalton 1983). Completed inventories were scored by means of a computerized optical scanning system. To control for pseudorandom responding and invalid test-taking attitudes, a 13-item version of Jackson’s (1984) Infrequency Scale from his Personality Research Form had been included in the inventory completed by the students. Subjects scoring higher than 2 on the Infrequency Scale were dropped from the sample. Of the original 414 subjects, 16 (3.9%) were excluded from the sample on this basis.

From the overall pool of 398 subjects (53.4% female, 46.6% male), two subject groups were composed for the personality assessments. Separate group means and standard deviations (SDs) on the PAS were computed for males and females and served as the basis for subject selection. Following Chapman and Chapman (1985), potential schizotypic subjects were required to have scored at least 2.0 SDs above the group mean on the PAS, whereas normal control subjects were required to have scored no higher than 0.5 SDs above the group mean. On the basis of these criteria, 23 schizotypic subjects (12 female) and 28 normal control subjects (13 female) were selected for study. The proportions of male and female subjects across the two subject groups did not differ significantly ($\chi^2 = 0.17, df = 1.51$, not significant). The mean PAS score of the 23 schizotypic subjects was 24.30 (SD = 5.04), whereas the mean PAS score of the 28 normal control subjects was 4.04 (SD = 2.82).

It is noteworthy that although the individuals contained in the pool of 414 potential study subjects were initially preselected for academic achievement (i.e., university admission), academic ability does not preclude a liability to, or risk of, psychopathology (cf. Rimmer et al. 1978; Haier et al. 1979; Stangier and Printz 1980; Depue et al. 1989). The population from which the sample was drawn was probably somewhat censored for particularly early-onset variants of severe psychopathology. However, one would not necessarily anticipate any diminution in the prevalence of liability for later onset psychoses or schizophrenia spectrum–related personality disorders in the undergraduate population studied.

Measures.

Schizotypy measure. The PAS is a well-established 35-item true–false self-report measure of disturbances and distortions in perceptions of body image as well as other objects (Chapman et al. 1978). It includes items such as “Occasionally I have felt as though my body did not exist” (keyed true) and “I have never felt that my arms or legs have momentarily grown in size” (keyed false).

In nonclinical university samples, individuals who achieve high scores on the PAS exhibit psychotic-like symptoms (Chapman et al. 1980; Allen et al. 1987a), cognitive slippage (i.e., mild thought disorder), communication deficits (Miller and Chapman 1983; Allen et al. 1987b), decreased tar-
show that the PAS is a valid, scale taps into a taxonic latent en-
tered by Meehl (1990). Thus, mul-
tiple converging lines of evidence 
timated for publication) reveal that the 
ated (although the association is 
 notifies that PAS deviance (Edell 
et al. 1987). High PAS scorers also 
sorers also display MMPI profile 
tion that included administration 
ment that included administration 
maintenance. Finally, all study assist-
ected, the study subjects.

Procedures. Potential study par-
technology and invited to participate 
cluded administration of the WCST as well as measures 
of anxiety and depression. Subjects 
months after the initial large-scale 

In the present study, five WCST 
form categories: (1) overall suc-
conceptual ability, and (5) learning.

Psychological state measures. The Beck Depression Inventory 
(21-item self-report inventory, was 
the study subjects. The State-Trait Anxiety 
, 1983), a well-known 40-item self-

Data Analysis. To contrast the 
atic and normal control subjects, 
should be established firmly. The 
The potential for false-positive clas-
thetic Personality Inventory 
that is frequently associated 
neuropsychological measure of 
that is somewhat debated) with DLPFC 
berger et al. 1986). In the WCST, 
years test, but they are given 
not informed of the correct sorting 
 They are correct, not because they are 
and number). Subjects are not infor-
the four stimulus cards along one of three 
version software program (Harris 
by means of a computerized scor-
ysis represent, respectively, the five 
ating and Meehl 1955).

We emphasize, however, that 
the specificity and long-term pre-

The WCST. This test is a well-
known neuropsychological measure of 
the guidelines specified in the 
WCST manual (Heaton 1981).

In the present study, five WCST 
were scored by means of a computerized 
soring software program (Harris 
(1) categories, (2) percentage 
maintain set, (4) trials to complete 
learning to learn.” These indexes represen-
tively, the five general WCST 
scoring categories: (1) overall suc-

Potential study par-
ticipants were contacted by tele-
the study subjects.

Data Analysis. To contrast the 
atic and normal control subjects, 
we conducted a series of analyses 
phoric symptoms in the study 

Screening.

We conducted a series of analyses 

Psychological state measures. 
The Beck Depression Inventory 
(21-item self-report inventory, was 

Eventually, all study assistants 
were blind to the study hypo-
theses under consideration, as were, 


get identification on a backward 
 masking task (Balogh and Merritt 
, evidence of reaction-time 
crossover (Simons et al. 1982), eye 
movement dysfunction (Simons 
and Katkin 1985), sustained atten-
tional dysfunction (Lenzenweger et 
al. 1991; Obiols et al. 1993), and 
abnormal platelet monoamine ox-
idase activity (males only; Yehuda 
et al. 1987). High PAS scorers also 
display Rorschach deviance (Edell 
et al. 1987). High PAS scorers also 
ought fallible, psychometric in-
dicator of schizotypy (cf. Cronbach 
and Meehl 1955).

The WCST. This test is a well-
known general WCST scores are closely 
associated with schizophrenia as well as 
other psychoses (e.g., 2-7-8 total 
scores). Moreover, high PAS 
scorers also display MMPI profile 
characteristics comparable to those 
often observed among psychotic 
patients (Lenzenweger 1991) 
and schizotypic subjects (Lenzen-
weger and Korfine 1992b). In non-
psychotic psychiatric patients, ele-
vated PAS scores are closely 
associated with schizotypal symp-
toms and anxiety as well as an 
increased risk for treated schizophrenia 
among first-degree relatives 
(Lenzenweger and Loranger 1989a, 
1989b). Actual schizophrenia 
patients have elevated PAS scores 
(Chapman et al. 1978). Finally, 
taxometric analyses of the PAS 
(Lenzenweger and Korfine 1992a; 
Korfine and Lenzenweger, sub-
tmitted for publication) reveal that the 
scale taps into a taxonic latent en-
tity with a general population base 
rate of approximately 10 percent 
for the schizotypy taxon as conjectured 
by Meehl (1990). Thus, mul-
tiple converging lines of evidence 
show that the PAS is a valid,
ences, individual differences, and identification of a deviant subgroup. Because of the skewed distributional properties of these variables, we used nonparametric statistical procedures throughout all analyses contained in this report. To examine for group differences, we conducted Mann-Whitney U-tests across each of the five variables. Individual differences were assessed by correlating actual score on the PAS with the WCST indexes (Spearman's rho).

Given the clear-cut a priori directional nature of our hypothesis, namely, the prediction of poor card sorting performance for the schizotypic subjects, we used one-tailed tests of statistical significance throughout our analyses. A one-tailed testing approach offers the greatest statistical power when an unambiguous directional hypothesis is being evaluated.

Consistent with established assumptions of research on genetic high-risk schizophrenia (Hanson et al. 1977) and guided by the high-risk analytic strategy of Cornblatt and Erlenmeyer-Kimling (1985), we anticipated that only a subset of the schizotypic group would truly be at risk for schizophrenia (perhaps more generally, psychosis) and that therefore only these subjects would reveal noteworthy deficits on the WCST. To identify a deviant subgroup of card sort performers, we employed two different strategies in constructing composite WCST deviance indexes based on the five WCST indicators. For the first composite deviance index, following the strategy of Cornblatt and Erlenmeyer-Kimling (1985), we examined the five distributions and established cutoff scores that identified 10 percent of the normal control group scoring highest on each of the indexes in the poor performance direction. We considered all subjects scoring above this cutoff score on each variable deviant and assigned them a score of 1, while those whose performance fell below the cutoff were given the score of 0. We then summed these five dichotomized indicator scores to yield a single composite deviance index score for each subject. We identified as deviant those subjects in either group scoring 2 SDs above the normal control group composite deviance index mean.

For the second composite deviance index, which did not rely on binary cutoffs, we summed for each subject z-transformed scores for each of the five WCST indexes derived from the means and SDs of the normal control group. We again identified as deviant those subjects in either group scoring 2 SDs above the normal control group z-score composite deviance index mean. In analyzing both composite indexes, we adopted relatively rigorous cutoff scores to minimize false positives at the expense of false negatives. To compare the proportions of composite index-identified deviant subjects between the two groups for each of the deviance indexes, we applied the z test of the significance of the difference between proportions (Fleiss 1981).

### Results

Table 1 contains the means and SDs for the five WCST performance variables. Schizotypic subjects failed to maintain set significantly above the normal control group composite deviance index mean.

<table>
<thead>
<tr>
<th>WCST Index</th>
<th>Schizotypic subjects (n = 23)</th>
<th>Control subjects (n = 28)</th>
<th>Combined sample (n = 51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Z</td>
</tr>
<tr>
<td>% Perseverative error</td>
<td>5.35 (1.37)</td>
<td>5.75 (0.93)</td>
<td>-1.42&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Trials to complete first category</td>
<td>0.11 (0.06)</td>
<td>0.11 (0.07)</td>
<td>-0.51</td>
</tr>
<tr>
<td>Failure to maintain set</td>
<td>15.91 (18.25)</td>
<td>11.29 (0.66)</td>
<td>-1.31&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Learning to learn</td>
<td>0.91 (1.65)</td>
<td>0.18 (0.48)</td>
<td>-2.16&lt;sup&gt;3&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>-0.01 (0.06)</td>
<td>0.00 (0.01)</td>
<td>-0.20</td>
</tr>
</tbody>
</table>

Note.— WCST = Wisconsin Card Sorting Test (Heaton 1981); PAS = Perceptual Aberration Scale (Chapman et al. 1978). Groups were contrasted with the Mann-Whitney U-test with U transformed into the normally distributed z statistic. PAS x WCST correlations were calculated with Spearman's r with combined groups. All statistical tests were unidirectional (see text).

<sup>1</sup>p < 0.10.
<sup>2</sup>p < 0.05.
<sup>3</sup>p < 0.02.
more often than control subjects ($p < 0.02$); schizotypic subjects also revealed a tendency to complete fewer categories ($p < 0.08$) and to require more trials to complete the first category ($p < 0.09$). No outliers that might exert undue statistical influence on the observed results were found in any of the group difference analyses. The effect size of the significant group difference on the failure-to-maintain-set variable was 0.60, an effect size at the upper end of what is termed a "medium effect size" (tending, in fact, toward a "large effect size") (Cohen 1988). Effect sizes for the categories and trials-to-complete-first-category variables were 0.34 and 0.36, respectively, both values midway between the small and medium effect size ranges (Cohen 1988).

Table 1 also contains the results of correlating actual score on the PAS with the WCST indexes for the combined sample ($n = 51$). High scores on the PAS were significantly associated with fewer categories completed as well as more frequent failures to maintain set (both $p < 0.05$). These data complement and extend the group differences results by incorporating valuable individual difference variance.

Table 2 contains the means and SDs for levels of state anxiety, trait anxiety, and depressive symptoms in the two subject groups. Schizotypic subjects also displayed more trait anxiety ($p < 0.03$) and a larger number of depressive symptoms ($p < 0.004$) than did controls; however, the groups did not differ on state anxiety.

For the first composite index of deviance (the binary cutoff approach; see figure 1), computed as outlined above and using a cutoff score of 2 SDs above the normal control group mean on the composite index, 3.57 percent ($n = 1$) of the normal control subjects and 26.1 percent ($n = 6$) of the schizotypic subjects were classified as deviant ($Z = 2.33, p < 0.01$). For the second composite index of deviance (the Z-score approach; see figure 2), computed as outlined above and using a cutoff score of 2 SDs above the normal control group mean on the composite index, 3.57 percent ($n = 1$) of the normal controls and 34.8 percent ($n = 8$) of the schizotypic subjects were classified as deviant. The difference between these two proportions is highly significant ($Z = 2.91, p < 0.002$). Taken together, the data from these two composite indexes provide essential support for the existence of the putative at-risk subgroup among the schizotypic subjects as predicted by the methodologic approach discussed by both Hanson et al. (1977) and Cornblatt and Erlenmeyer-Kimling (1985).

### Table 2. Anxiety and depression among schizotypic and control subjects

<table>
<thead>
<tr>
<th>State measure</th>
<th>Schizotypic subjects</th>
<th>Control subjects</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>BDI</td>
<td>8.22 (5.62)</td>
<td>4.61 (5.19)</td>
<td>-2.61\footnote{p &lt; 0.01}</td>
</tr>
<tr>
<td>State-Trait Anxiety Inventory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trait</td>
<td>40.70 (9.44)</td>
<td>35.61 (6.46)</td>
<td>-1.91\footnote{p &lt; 0.05}</td>
</tr>
<tr>
<td>State</td>
<td>39.48 (10.26)</td>
<td>39.29 (8.70)</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

Note.—BDI = Beck Depression Inventory (Beck et al. 1961). Groups were contrasted with the Mann-Whitney U-test with $U$ transformed into the normally distributed $Z$ statistic.

\footnote{\(p < 0.05\).}

\footnote{\(p < 0.01\).}

Discussion

The primary objective of the present study was to examine WCST performance in schizotypic and control subjects. A limited amount of earlier work in this area suggested that WCST deficits might...
Figure 1. Wisconsin Card Sorting Test composite deviance index (binary cutoff approach)

![Bar chart showing frequency of composite index scores for Controls and Schizotypes.]

As a group, schizotypic subjects failed to maintain set more frequently and tended to complete fewer categories and to require more trials to complete the first category than did control subjects. Our data are highly consistent with those reported by Lyons et al. (1991), who found that schizotypic subjects completed fewer categories and had more failures to maintain set than did normal control subjects. The effect size values (Cohen 1988) associated with each of these findings suggest that we were dealing with reasonably strong effects, especially in light of the high level of functioning displayed by our subjects. Elevated PAS scores were associated with fewer categories completed and more frequent failures to maintain set. Schizotypic subjects were more than seven times more likely than normal control subjects to be classified as poor WCST performers on a composite index of deviance. We found that larger amounts of trait anxiety and depression characterized the schizotypic group, as expected (cf. Meehl 1990), yet these mental state factors were not significantly associated with WCST performance in any compelling manner (see footnote 2). Taken together, our results suggest that the WCST performance of the schizotypic subjects was poorer than that of the normal control subjects.

Deficits in WCST performance by schizophrenia patients have been well documented, beginning with Fey's 1951 study and continuing through more recent reports (e.g., Berman et al. 1986; Weinberger et al. 1986). The WCST variables most frequently discussed in conjunction with poor performance by schizophrenia patients have been the number of categories achieved and percentage perseverative errors (Kolb and Whishaw 1983; Berman et al. 1986; Goldberg et al. 1987; Williamson et al. 1989; Braff et al. 1991). How-
Figure 2. Wisconsin Card Sorting Test composite deviance Index (Z-score approach)

<table>
<thead>
<tr>
<th>Frequency (cases)</th>
<th>INT1</th>
<th>INT2</th>
<th>INT3</th>
<th>INT4</th>
<th>INT5</th>
<th>INT6</th>
<th>INT7</th>
<th>INT8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Composite Index Score Intervals

- INT1 = -2.00 to -1.00
- INT2 = -0.99 to 0.00
- INT3 = 0.01 to 1.00
- INT4 = 1.01 to 2.00
- INT5 = 2.01 to 5.00
- INT6 = 5.01 to 10.00
- INT7 = 10.01 to 20.00
- INT8 = 20.01 to high

However, most previous studies have not reported on an extended range of WCST performance indexes (see Heaton 1981), and therefore the performance of schizophrenia patients on several of the variables discussed in the present study is unknown. We suggest that our findings are consistent with those derived from the study of actual patients. We argue that our data enhance the schizophrenia/WCST literature because "third variables" associated with clinical schizophrenia could not have accounted for the schizotypy × WCST deficit relationship observed in our at-risk subjects (cf. Braff et al. 1991). Furthermore, because our subjects were closely matched for age and educational achievement (i.e., all had approximately 13 years' education), it is unlikely that our schizotypic subjects displayed poor WCST performance owing to a generalized cognitive or intellectual impairment. We might cautiously suggest that the WCST deficits observed in the schizotypic subjects were differential in nature (i.e., the subjects were matched for educational level but showed differential WCST performance). Similarly, although the issue of the role of motivation in determining WCST performance by schizophrenia patients has been raised (Goldberg et al. 1987, 1990a; Green et al. 1990; Goldberg and Weinberger 1991; Summerfelt et al. 1991), it is less likely that motivational differences were related to WCST performance in our subjects because of their nonclinical status. Finally, because our at-risk subjects had just attained the age of risk for schizophrenia and had not expressed the condition clinically, the data are consistent with the existence, and perhaps precursor status, of a subtle DLPFC-related cognitive dysfunction before the possible emergence of the illness. Clearly, a prospective longitudinal developmental design would be needed to resolve this issue.

Although our schizotypic subjects tended to achieve fewer categories, a common finding with schizophrenia patients, they did not show an elevated rate of perseverative errors, perhaps the modal deficit noted in the schizophrenia/WCST literature. It may be, however, that an increase in perseverative errors is seen only once schizophrenia per se has begun to unfold. For example, Sweeney et al. (1992) recently reported that multiple-episode schiz-
Psychosis patients display significantly more perseverative errors and achieve significantly fewer categories than first-episode patients. Our subjects, of course, were not yet affected by schizophrenia. An interesting feature of our data concerned the WCST variable failure to maintain set (see Lyons et al. 1991 for a comparable failure to maintain set finding). Specifically, on the WCST a failure to maintain set error involves sorting according to the correct abstract principle for at least five consecutive trials and then switching the principle in error ("losing the set") before achieving the category. This finding provides objective support for a pathologic process (i.e., loss of set) that has long been the focus of theory and research on disturbances in thought, language, and behavior in schizophrenia (Shakow 1962; Harrow et al. 1983). Given our findings for the failure to maintain variable and the interest in set failures in the study of schizophrenia, we suggest that future investigators using the WCST consider reporting on this index.

The overall levels of WCST performance observed in both of our subject groups were relatively high compared with data derived from clinical patient samples (e.g., Berman et al. 1986); we emphasize that the differences in WCST performance between the two groups are relatively subtle (although associated with a robust medium effect size in one case). The levels of WCST performance we observed were most likely due to the nonclinical (i.e., unaffected) status of our subjects as well as their generally high level of intellectual functioning (as evidenced by their university admission). Concerning the magnitude of observed differences between the two subject groups on WCST indexes, we anticipated relatively subtle yet statistically reliable differences between the groups for reasons related to our subject selection strategy and the high-risk research method. First, in selecting our schizotypic group we used a fallible psychometric marker with imperfect validity (i.e., the PAS) that most likely generated an admixture of compensated schizotypic persons (only a subset of whom will ever decompensate; the remainder will remain compensated though vulnerable across the lifespan) and an unknown but small proportion of individuals who were false-positive for schizotypy. Thus, we most likely identified individuals representing a diversity of schizotypic liability, a diversity that was associated with a range of WCST deficits.

Second, we suggest that finding a subtle difference in WCST performance between groups was consistent with modal high-risk findings (cf. Hanson et al. 1977; Cornblatt and Erlenmeyer-Kimling 1985). Clearly, the goal of the high-risk approach in psychopathology research is the isolation of reliable objective markers (e.g., biobehaviors) that might aid in more efficient identification of liability to schizophrenia (or psychosis). Even if such objective markers reflect relatively subtle deviations, taken together they should help to reduce the "noise" associated with the traditional clinical phenotype (i.e., diagnosis) and enable us to better target liability (i.e., genotype; diathesis). Efficient detection of genuine liability might ultimately allow for research that may provide clues to etiology and pathophysiology. We should like to emphasize, however, that replication of our results is warranted before definitive conclusions can be drawn concerning WCST performance and schizotypy.

Within a discussion of caveats, we note that our exclusive focus on schizotypy (i.e., liability to schizophrenia) limits our ability to speak to the issue of the diagnostic specificity of WCST performance deficits. Are WCST deficits unique to schizotypic persons? Clearly, to address this issue, future studies using the WCST with schizotypal personality-disordered subjects should consider including psychiatric controls when studying patients, and studies of persons at risk for schizophrenia should include a sample of subjects at increased risk for other psychopathology (e.g., subjects at risk for affective illness).

We believe that our study extends and enhances the research literature that finds an association between WCST performance deficits and schizophrenia by demonstrating broadly comparable deficits in subjects conjectured to be at risk for schizophrenia. Our high-risk research design allowed us to circumvent possible third-variable confounds that attend clinical research in schizophrenia and to indirectly address temporal/developmental issues concerning the emergence of the illness. Our results also provide evidence for the construct validity of the PAS as a measure of schizotypy and demonstrate the utility of the psychometric high-risk strategy. Furthermore, our findings are consistent with those documenting the existence of spatial working memory deficits in schizophrenia (cf. Goldman-Rakic 1991; Park and Holzman 1992). Finally, we offer our findings for their heuristic potential (i.e., in the context of Weinberger's [1987] conjectures on...
DLPFC dysfunction in schizophrenia), and we emphasize that replication is required before definitive conclusions concerning WCST performance among schizotypic individuals can be drawn.

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