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. Schizophrenia Bulletin, 20(2): 345–357, 1994.

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 etiologic 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 (Gottesman and Bertelsen 1989). Previous 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 psychometrically 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, respectively (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.

A substantial body of literature supports the view that the PAS is a measure of schizophrenia. 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 university 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; Stangler 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-
get identification on a backward masking task (Balogh and Merritt 1985), evidence of reaction-time crossover (Simons et al. 1982), eye movement dysfunction (Simons and Katkin 1985), sustained attentional dysfunction (Lenzenweger et al. 1991; Obiols et al. 1993), and abnormal platelet monoamine oxidase activity (males only; Yehuda et al. 1987). High PAS scorers also display Rorschach deviance (Edell and Chapman 1979) comparable to that observed among patients with schizophrenia. Chapman et al. (1982) observed that PAS deviance was associated with some forms of deviance on the Minnesota Multiphasic Personality Inventory (MMPI; Hathaway and McKinley 1943) that is frequently 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 schizophrenic patients (Lenzenweger 1991) and schizotypic subjects (Lenzenweger and Korfine 1992b). In nonpsychotic psychiatric patients, elevated PAS scores are closely associated with schizotypal symptoms 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, submitted for publication) reveal that the scale taps into a taxonic latent entity with a general population base rate of approximately 10 percent for the schizotypy taxon as conjectured by Meehl (1990). Thus, multiple converging lines of evidence show that the PAS is a valid, though fallible, psychometric indicator of schizotypy (cf. Cronbach and Meehl 1955).

We emphasize, however, that the specificity and long-term predictive criterion validity of the PAS for detecting schizotypy remains to be established firmly. The potential for false-positive classification in detecting schizotypy with the PAS and the need for extended followup of high PAS scorers have been recognized (Chapman and Chapman 1985).

The WCST. This test is a well-known neuropsychological measure of abstraction ability that is associated (although the association is somewhat debated) with DLPFC functioning (Milner 1963; Nelson 1976; Robinson et al. 1980; Weinberger et al. 1986). In the WCST, subjects are required to match response cards to the four stimulus cards along one of three dimensions (color, form, or number). Subjects are not informed of the correct sorting principle, nor are they told when the principle shifts during the test, but they are given feedback after each trial. Testing continues until either 6 categories are achieved or all 128 cards have been sorted. The WCST was administered precisely according to the guidelines specified in the WCST manual (Heaton 1981). In the present study, five WCST performance indexes were scored by means of a computerized scoring software program (Harris 1988): (1) categories, (2) percentage perseverative errors, (3) failures to maintain set, (4) trials to complete first category, and (5) “learning to learn.” These indexes represent, respectively, the five general WCST scoring categories: (1) overall success, (2) perseverative tendencies, (3) nonperseverative errors, (4) conceptual ability, and (5) learning.

Psychological state measures. The Beck Depression Inventory (Beck et al. 1961), a well-known 21-item self-report inventory, was used to measure depressive/dysphoric symptoms in the study subjects. The State-Trait Anxiety Inventory (Form Y; Spielberger 1983), a well-known 40-item self-report inventory, was used to measure state and trait anxiety in the subjects.

Procedures. Potential study participants were contacted by telephone and invited to participate voluntarily in a study of young adult development for which they would receive a $10 honorarium. The research assistants were blind to the group status of all potential study participants. Those individuals who consented to participate were scheduled for a testing session that included administration of the WCST as well as measures of anxiety and depression. Subjects were tested approximately 4-6 months after the initial large-scale screening.

All subjects were administered the WCST individually in a quiet, comfortable, and conventionally lighted laboratory room. A complex coding scheme was employed to disguise the group status of the subjects; therefore all study staff, including the principal investigator, were blind to a subject’s group membership throughout the testing. Finally, all study assistants were blind to the study hypotheses under consideration, as were, of course, the study subjects.

Data Analysis. To contrast the WCST performance of the schizotypic and normal control subjects, we conducted a series of analyses focused on group mean differ-
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>$-1.42^1$</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>$-1.31^1$</td>
</tr>
<tr>
<td>Learning to learn</td>
<td>0.91 (1.65)</td>
<td>0.18 (0.48)</td>
<td>$-2.16^3$</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 × WCST correlations were calculated with Spearman's $r$ with combined groups. All statistical tests were unidirectional (see text).

$^1$ $p < 0.10$.  
$^2$ $p < 0.05$.  
$^3$ $p < 0.02$.  

Table 1. Card sorting performance among schizotypic and control subjects
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 \( (p < 0.05). \) 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.\(^1\)

<table>
<thead>
<tr>
<th>State measure</th>
<th>Schizotypic subjects Mean (SD)</th>
<th>Control subjects Mean (SD)</th>
<th>( Z )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( BDI )</td>
<td>8.22 (5.62)</td>
<td>4.61 (5.19)</td>
<td>-2.61(^1)</td>
</tr>
<tr>
<td>State-Trait Anxiety</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(^2)</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.

\(^1p < 0.01.\)

\(^2p < 0.05.\)

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).

**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...
be found among schizotypic subjects (Lyons et al. 1991), whereas studies of discordant twin pairs (Goldberg et al. 1990b) and siblings of schizophrenia patients (Pogue-Geile et al. 1991) provided conflicting results concerning WCST deficits and the liability for schizophrenia. In the present study, unlike these previous investigations using the WCST, we examined a relatively large sample of subjects hypothesized to be at increased risk for schizophrenia rather than individuals already suffering from the illness. To our knowledge, this study represented the first attempt to conduct a study of WCST performance in a relatively large sample of psychometrically identified schizotypic subjects using established conventional WCST administration and scoring procedures (see Heaton 1981). 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-

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3 We are aware that Spaulding et al. (1989) assessed card sorting performance in schizotypal (sic) subjects identified by MMPI-168 profiles as part of a larger cognitive test battery. However, the card sorting measure used was an adaptation of the WCST that generated scores that are not directly comparable to those generated by the conventional WCST. The Spaulding et al. data suggesting the presence of card sorting deficits on a modified WCST are intriguing and are consistent with our findings on a conceptual level.
ever, 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).4 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-

4 To evaluate the differential deficit issue in a more fine-grained manner, one could, of course, study a second specific cognitive process (e.g., memory) on which the two groups might not differ. In this example, evidence of card sorting deficits among schizotypic subjects in the absence of memory processing deficits could suggest a relatively specific (or differential) cognitive dysfunction for schizotypic persons.
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 schizotypy 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

 schizophrenia patients display significantly more perseverative errors and achieve significantly fewer categories than first-episode patients.
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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The Authors

Mark F. Lenzenweger, Ph.D., is Associate Professor, and Lauren Korfine, B.S., was Research Specialist/Project Coordinator, Psychopathology Area, Department of Human Development, Cornell University, Ithaca, NY. Ms. Korfine is now a graduate student in the Psychopathology Training Group, Department of Psychology, Harvard University, Cambridge, MA.

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