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Schizophrenia is currently conceptualized as a neurodevelopmental disorder in which subtle brain dysmaturation is expressed across a continuum of impairment referred to as schizotypy. Recently, schizophrenia researchers have attempted to identify markers that are present during all stages of the illness, as well as in subclinical manifestations of the disorder. The discovery of markers for schizophrenia should enhance our knowledge about the etiology and development of the disorder, as well as facilitate the identification of individuals at increased risk for developing the disorder. Neuropsychological impairment has long been recognized as a central feature of schizophrenia. Furthermore, neuropsychological impairment has been purported to be present before the onset of schizophrenia and indicative of liability for the disorder. The present study examined the relationship of attention, executive functioning, and memory with ratings of positive and negative schizotypy in a sample of 156 college students. Results indicated that positive schizotypy was associated with neuropsychological deficits, above and beyond the variance associated with intellectual functioning and general psychological distress. Surprisingly, negative schizotypy was not related to impaired neuropsychological performance.

NEUROPSYCHOLOGICAL FUNCTIONING IN INDIVIDUALS AT-RISK FOR SCHIZOPHRENIA: A MULTIDIMENSIONAL INVESTIGATION OF ATTENTION, EXECUTIVE FUNCTIONING, AND MEMORY

by

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CHAPTER I

INTRODUCTION

The present study examined the relationship between neuropsychological functioning and the positive and negative symptom dimensions of schizotypy. Neuropsychological impairment is widely described as a central feature of schizophrenia and related disorders, and it is hypothesized that this impairment will also be associated with nonpsychotic manifestations of vulnerability to schizophrenia. It is specifically hypothesized that neuropsychological impairment will be inversely correlated with ratings of positive and negative schizotypy. In addition, consistent with findings in samples of patients with schizophrenia, it is predicted that negative symptoms of schizotypy will be more strongly related to neuropsychological impairment than the positive symptoms of schizotypy.

Schizophrenia and Schizotypy

Schizophrenia appears to be best conceptualized as a neurodevelopmental brain disorder. Current models of the etiology of schizophrenia (e.g., Meehl, 1989; Gottesman, 1991; Andreason, 1999) assume that there are schizophrenia-prone, or "schizotypic," individuals who are vulnerable to developing schizophrenia and related disorders. While the exact mechanisms are not fully understood, this vulnerability is presumed to result from an accumulation or interaction of multiple genetic, neurodevelopmental, and

psychosocial factors or hits. These risk factors produce a continuum of schizophrenia-like adjustment that has been referred to as schizotypy. It is hypothesized that the majority of schizotypic individuals will not decompensate into psychosis, although they may experience attenuated or transient symptoms of schizophrenia. These symptoms fall on a continuum from relatively healthy to subclinical deviance to schizophrenia-spectrum personality disorders to full blown psychosis. Thus, schizotypy is expressed across a dynamic continuum of adjustment with severity contingent on the interaction of biopsychosocial factors (Gooding & Iacono, 1995).

Schizotypy has been described as a multidimensional construct consisting of two or more factors. Consistent with multidimensional models of schizophrenia, candidate factors include positive symptom schizotypy, negative symptom schizotypy, cognitive disorganization, paranoia, and nonconformity (e.g., Raine et al., 1994; Claridge et al., 1996; Vollema & van den Bosch, 1995; Mason, Claridge, & Williams, 1997; Stefanis et al., 2002). Positive and negative symptom schizotypy are the most consistently replicated factors. While there is not a universally agreed upon latent structure of schizotypy, the proposed factors appear to be consistent with those hypothesized to comprise schizophrenia, such as positive, negative, and disorganized dimensions (e.g., Bilder, Mukherjee, Rieder, & Pandurangi, 1985; Liddle, 1987; Arndt, Alliger, & Andreason, 1991; Peralta, Cuesta, & de Leon, 1992). This parallel structure adds empirical support to the hypothesis that the biological/genetic vulnerability to schizophrenia is expressed across the continuum of schizotypy. Positive symptoms of schizophrenia include excesses in behavior, such as hallucinations and delusions, while

negative symptoms refer to deficits in behavior, such as loss of volition, social withdrawal, and flattened affect. Positive and negative symptom schizotypy appear to reflect milder and non-psychotic manifestations of the symptoms seen in schizophrenia.

The reliable identification of markers of schizotypy and schizotypic individuals should improve our understanding of the etiology of schizophrenia and facilitate the development of prophylactic treatment interventions. Psychometric scales with established validity and reliability have been developed to assist in the identification of schizotypy. Although there are alternative methods of assessing risk for schizophrenia, such as identifying relatives of individuals with schizophrenia, or examining individuals with related disorders (e.g., paranoid, schizotypal, and schizoid personality disorders), Lenzenweger (1998) noted several advantages of the psychometric method. Perhaps the greatest advantage is that psychometric measures can be used to screen large numbers of individuals from the general population in a very time-efficient manner. They also tend to be relatively non-invasive and inexpensive to administer and score. Finally, they can be used in conjunction with other measures of risk, including family studies, which has been demonstrated by research such as the New York High Risk Project (e.g., Erlenmeyer-Kimling et al., 1992). The present study focuses on the use of symptom and trait-based screening measures in conjunction with a battery of neuropsychological tests. It is proposed that neuropsychological impairment in the at-risk population may help us make sense of the variability that characterizes schizophrenia.

The heterogeneity of schizophrenia has created limitations for researchers studying the etiology, development, and treatment of this disorder. The phenotypic

variation exhibited by patients with schizophrenia has made it challenging for investigators trying to identify relevant etiological and developmental factors. Moreover, the changes that are associated with the onset of this disorder, such as medication, hospitalization, social stigma, and drug abuse make it difficult to disentangle the factors that are etiologically relevant to the disorder from those that are consequences of the disorder. As a result, investigators have begun to look for characteristics that may be present in individuals at-risk for the schizophrenia and related conditions. This strategy minimizes confounds associated with the onset of the schizophrenia and also allows for the possibility of discovering underlying traits that occur in the premorbid, acute, and residual phases of the disorder.

Neuropsychological Impairment as a Marker of Risk

Ever since Kraeplin (1919) used the term dementia praecox to describe the disease we now call schizophrenia, there has been recognition that neuropsychological impairment is a hallmark of the disorder. If neuropsychological impairment is representative of vulnerability for schizophrenia, it should be evident during all stages of the disorder, including those individuals at-risk for schizophrenia. Consistent with the neurodevelopmental model of schizophrenia, neuropsychological impairment has been found in milder degrees in at-risk samples (e.g., Byrne, Hodges, Grant, Owens, & Johnstone, 1999; Cornblatt, Obuchowski, Roberts, Pollack, & Erlenmeyer-Kimling 1999; Cadenhead, Perry, Shafer, & Braff, 1999; Suhr, 1997). Thus, it appears that mild neuropsychological deficits may be evident before schizophrenia develops and indicative of increased risk for the disorder. These deficits may also be etiologically related to the

development of schizophrenia. For example, underactivity and dysregulation of frontal lobe functioning might lead to avolition, a feature of schizophrenia that can be measured with executive functioning tasks. In addition, hippocampal abnormalities may play a role in the development of schizophrenia and manifest as mild memory deficits before the onset of schizophrenia.

Trying to link neuropsychological impairment to the vulnerability for schizophrenia before the onset of clinical psychosis has many advantages. Most importantly, if areas of impairment can be reliably defined in individuals at-risk for the disorder, geneticists, pharmacologists, and other researchers trying to pinpoint the biological underpinnings of the disorder can examine more homogeneous populations. Further insights into the specific pathology, the processes responsible for conferring liability, and the temporal sequence of neuropsychological and symptomatic change should help us better understand the etiological roots that lead to the vulnerability for and development of schizophrenia. These findings should facilitate the development of treatment interventions, perhaps even prophylactic treatments. The following section will review the major areas of neuropsychological functioning that are typically measured when assessing for neuropsychological impairment.

Neuropsychological Constructs

Studies of neuropsychological functioning in individuals at-risk for schizophrenia have typically examined one or more of the following constructs: 1) Attention; 2) Executive functioning; and 3) Memory.

Attention. Mirsky et al. (1991) used factor analysis to derive four components of attention. These components of attention have been replicated by five independent research teams (Kendler et al., 1991; Kremen, Seidman, Faraone, Pepple, & Tsuang, 1992; Pogge, Stokes, & Harvey, 1994; Steinhauer et al., 1991; Tatman, 1992). The first factor of attention, "Focus/Execute," measures the capacity to focus on and scan stimuli, as well as quickly execute responses. According to Mirsky, this aspect of attention can be assessed with tests like the Stroop Color and Word Test (Golden, 1978), the Trail Making Test (Reitan, 1958), and the Digit Symbol-Coding subtest from the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 1997). The second factor of attention, "Sustain," involves the capacity to maintain focus of attention and is measured with sustained vigilance or continuous performance tests. This component differs from the Focus/Execute component in that there is limited scanning of stimuli and more of a demand for prolonged vigilance. The third component of attention, "Shift", is the capacity to shift attentional focus from one stimulus to another in a flexible manner and can be measured by tasks like the Wisconsin Card Sorting Task (WCST; Heaton, Chelune, Talley, Kay, & Curtis, 1993), which are also used to assess one component of executive functioning. The final attentional factor, "Encoding," is the capacity to use attention for encoding purposes. This aspect of attention assesses an individual's ability to serially incorporate, manipulate, store, and recall information and can be measured by tasks like the Arithmetic and Digit Span subtests from the WAIS-III (Mirsky, 1988, 1989; Mirsky et al., 1991).

Despite evidence that attention is a multidimensional construct, most investigations in the schizotypy or at-risk literature have only examined the sustain component as measured by the Continuous Performance Test-Identical Pairs (CPT-IP; Cornblatt & Erlenmeyer-Kimling, 1985; Erlenmeyer-Kimling & Cornblatt, 1992) or the Degraded Stimulus-Continuous Performance Test (Nuechterlein, 1983; Nuechterlein & Asarnow, 1997). Studies investigating CPT-IP performance and other measures of attention in at-risk samples have yielded mixed results (Lenzenweger, 2001; Obiols, Garcia-Domingo, de Trincheria, & Domenech, 1993; Laurent et al. 1999; Rybakowski & Borkowska, 2002; Cadenhead et al., 1999; Laurent et al., 2000; Keefe et al., 1994; Byrne et al., 1999; Cosway et al., 2002; Laurent et al., 2002; Rybakowski & Borkowska, 2002; Keefe et al., 1994).

Executive functioning. Executive functioning describes several higher-order cognitive processes, such as the integration of multimodal sensory input, generation of multiple response alternatives, maintenance of set and goal-directed behaviors, adaptation to changes in environment, planning abilities, and self-evaluation (Stuss & Benson, 1986; Dubios et al., 1994). Lezak (1995) conceptualizes executive functions as comprising four components: 1) volition; 2) planning; 3) purposive action; and 4) effective performance. According to Lezak, these subcomponents of executive functioning measure the ability to determine wants and needs, generate alternatives, formulate and carry out goals, inhibit impulses, and monitor performance. Lezak also describes conceptual functions, which are characterized by mental flexibility and abstract thinking. Many other researchers have classified conceptual functions as falling under the rubric of executive functioning.

Similar to the literature on attentional functioning, most investigations of executive functioning utilize one task (the WCST) as a representation of executive functioning. Based upon a review of the literature, there are additional tests that measure this multifaceted component of neuropsychological functioning, including the Mazes subtest from the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991), the Tower of London (Shallice, 1982) and Toronto (Saint Cyr & Taylor, 1992) tasks, the Ruff Figural Fluency Test (Ruff, 1996), the Controlled Oral Word Association Test (Spreen & Strauss, 1991) and the Stroop Color and Word Test.

Also similar to the literature on attentional functioning, an inconsistent pattern of impairment has been reported regarding executive functioning in individuals at-risk for schizophrenia. Several studies have reported significant differences (Faraone et al., 1999; Laurent et al., 2001; Rybakowski & Borkowska, 2002; Wolf, Cornblatt, Rogers, Shapiro, & Erlenmeyer-Kimling, 2002; Buchsbaum et al., 1997; Diforio, Walker, & Kestler, 2000; Gooding, Kwapil, & Tallent, 1999; Tallent & Gooding, 1999; Suhr, 1997; Diaz, Dickerson, & Kwapil, 2003), while others failed to detect differences (Laurent et al., 2001; Laurent et al., 2002; Dollfus et al., 2002; Stratta et al., 1997; Byrne et al., 1999).

Memory. Considerable evidence indicates that individuals with schizophrenia and related disorders (as well as individuals at-risk) have abnormally developed temporal lobes and hippocampi (Cannon, 1998; Green, 1998). These areas of the brain are critically involved in memory formation and functioning (Alvarez & Squire, 1994; Squire & Alvarez, 1995). Memory functions include short-term memory, long-term memory, working memory, learning, recognition, recall, and interference. Short term memory is

seen as a storage system that temporarily holds information (usually up until 30 seconds) (Lezak, 1995). Tasks that assess this cognitive function include the Digit Span subtest from the WAIS-III (Wechsler, 1997), first trial performance on learning tasks, such as the California Verbal Learning Test-Second Edition (CVLT- II; Delis, Kramer, Kaplin, & Ober, 2000) or Brief Visuospatial Memory Test-Revised (Benedict, 1997), and the pairing and free recall components of the Digit Symbol-Coding subtest (Wechsler, 1997).

Long-term memory is generally measured with tests like the CVLT-II and Brief Visuospatial Memory Test-Revised (Benedict, 1997) that involve a delayed recall component administered approximately 20 to 30 minutes after hearing a list of words or seeing an array of images. Short-term and long-term memory can also be measured when an individual is provided with recall cues or provided with an array or list of stimuli and asked to identify the target stimuli (i.e., recognition memory). Interference, both proactive and retroactive, can also be assessed by tests like the CVLT-II. Proactive interference occurs when recently encoded material decreases an individual's capacity to encode new information. Retroactive interference occurs when newly encoded information disrupts an individual's ability to recall previously stored material. Studies investigating short-term and long-term memory processes in individuals at-risk for schizophrenia have yielded both significant (O'Driscoll et al., 2001; Faraone et al., 1999; Byrne et al., 1999; Mitropoulou et al., 2002; Egan et al., 2001; Bergman et al., 1998; Voglmaier et al., 1997) and non-significant results (Egan et al., 2001; Voglmaier et al., 2000; LaPorte, Kirkpatrick, & Thaker, 1994). Interference has not been studied in the at-risk population.

Working memory is an area of neuropsychological functioning that has received increasing attention in the study of schizophrenia. Baddeley (1992) regards working memory as a short-term storage system that involves the manipulation of recently stored information. It can be measured by tasks, such as the Letter Number Sequencing subtest from the WAIS-III (Wechsler, 1997), which requires participants to encode, rearrange, and verbally output a series of letters and numbers. Investigations of working memory performance in individuals at-risk for schizophrenia have produced both significant (Cadenhead et al., 1999; Park & McTigue, 1997; Tallent & Gooding, 1999; Myles-Worsley & Park, 2002) and non-significant (Lenzenweger & Gold, 2000) results.

Overall, studies of neuropsychological functioning in the at-risk population have provided inconsistent results. One potential explanation for these inconsistencies may be that neuropsychological impairment varies according to the specific type of vulnerability for schizophrenia. The Chapman Scales (Perceptual Aberration (Chapman, Chapman, & Raulin, 1978), Magical Ideation (Eckblad & Chapman, 1983), Physical Anhedonia (Chapman, Chapman, & Raulin, 1976), Revised Social Anhedonia (Eckblad, Chapman, Chapman, & Mishlove, 1982)) allow for the examination of neuropsychological impairment in relation to differing levels of positive and negative schizotypy. A summary of the investigations examining neuropsychological performance in schizotypy samples identified by the Chapman Scales is illustrated in Table 1. The results listed in this table are similar to the findings of investigations using alternative methods to identify individuals at-risk for schizophrenia. Studies, in general, have provided inconsistent evidence that neuropsychological impairment is characteristic of vulnerability for

schizophrenia. However, there are a variety of methodological shortcomings that characterize these and other studies examining the relationship of schizotypy and cognitive functioning that must be addressed before making any definitive conclusions regarding the importance of neuropsychological impairment as a means of informing us about risk for schizophrenia.

Critique of the Literature

Many of the studies in the at-risk literature do not control for crucial variables that can impact neuropsychological performance, such as intellectual ability and general psychological distress at the time of testing. Even when studies have controlled for these variables, few have explored interactions between them. For example, it is possible that individuals at-risk for schizophrenia with a high IQ may display a different pattern of neuropsychological impairment than those at-risk with a low IQ. Byrne et al. (1999) noted such a pattern in their investigation of relatives of patients with schizophrenia. The authors, examining the predicted values for neuropsychological tasks in an ANCOVA model using IQ as the covariate found that for two tests, the Rivermead Behavioural Memory Test (Wilson, Cockburn, & Baddeley, 1985) and the Hayling Sentence Completion Test (Burgess & Shallice, 1996), at-risk participants performed worse than controls when IQ was low. However, when IQ was high (e.g., 110 or above), at-risk participants performed better than control participants. Thus, intellectual ability may interact significantly with risk to impact neuropsychological performance. Simply noting that the two groups were equivalent in intellectual ability in this case would have lead to the oversight of this potentially important finding.

Another shortcoming in the literature involves the consideration of the positive and negative symptom dimensions in relation to neuropsychological performance. Considering the marked heterogeneity of symptoms in schizophrenia, it is possible that different vulnerabilities lead to different symptomatic outcomes. Therefore, analyzing all at-risk participants as a seemingly homogenous group might obscure effects. For example, individuals exhibiting positive symptoms of schizotypy might be characterized by a different pattern of neuropsychological dysfunction than individuals exhibiting negative symptoms of schizotypy. It may also be the case that underlying brain abnormalities are more prevalent in determining the expression of negative symptoms rather than positive symptoms, as some researchers have hypothesized (Tsuang, Stone, & Faraone, 2000). For example, multiple investigations of patients with schizophrenia have indicated that neuropsychological impairment is much more strongly related to the negative symptom dimension than the positive dimension. Associations with the positive symptom dimension have been weak (Heydebrand et al., 2004; Nieuwenstein et al., 2001; O'Leary et al., 2000). In accordance with the neurodevelopmental model of schizophrenia, which emphasizes a continuum of vulnerability and schizophrenia-like adjustment, we would expect that the negative symptom dimension of schizotypy should be associated with greater neuropsychological impairment than the positive symptom dimension. If this were the case, grouping all schizotypic participants together would result in the weakening of power in statistical analyses.

Another shortcoming in the literature is the use of a limited number of neuropsychological tasks. Investigations that administer a variety of measures typically

do not adequately cover the construct(s) of interest (e.g., researchers may tap one area of attentional functioning, one area of executive functioning, and a few memory processes), or just analyze one domain of functioning (e.g., memory) and compare groups on individual test variables. Administering a larger variety of tests would increase the chance that constructs are sufficiently covered and would also enhance detection of true differences if they were present.

Although it seems appropriate to choose a wide range of neuropsychological tests to assess impairment in the at-risk population, there has been considerable debate regarding how to analyze the abundance of data produced by such a battery. Many researchers have chosen to perform *t*-tests or regression analyses on individual neuropsychological indices. However, this approach increases the probability of the Type I error and the individual neurocognitive measures may not adequately represent the underlying constructs the battery of tests are thought to be collectively measuring. Another approach is to create overall construct scores by averaging performance on all indices from a particular domain, such as attention. Similar to the analysis of individual variables, this method also has its faults, including reliance on hypothetical formulations of which tests are measuring which abilities, the yielding of less complete information regarding the construct of study, and indices with questionable reliability. For example, researchers have proposed various models of neuropsychological functioning and some tests have been conceptualized as emphasizing more than one domain (e.g., the Stroop Test has been viewed as a test of attention as well as executive functioning). Moreover, although an individual test may measure one ability more so than another (e.g., Digit

Span may tap memory processes more than attentional processes), tests may contribute valuable information to more than one domain of interest. Thus, averaging test scores to represent a single construct precludes consideration of the influences a variable may have on multiple neuropsychological functions.

One way to address these limitations is to perform a principal components analysis, which minimizes the chance for the Type I error, while providing valuable information regarding the underlying constructs the tests are measuring. This method also allows single variables to contribute weighted information to multiple constructs of interest. Liu, Zhang, Gehan, and Clarke (2002) have suggested using block principal component analysis when analyzing data sets with a very large number of variables, such as gene microarray studies that can include over 500 variables. Block principal component analysis involves forming subgroups of conceptually related variables and performing multiple parallel factor analyses. Afterwards, the variables that explain the most variance from each analysis are selected and combined for a final factor analysis.

Hypotheses and Goals of the Current Study

The goals of the present study are to examine the relationships between psychometrically assessed schizotypy and neuropsychological performance in a sample of nonpsychotic college students. Schizophrenia is characterized by a variety of neuropsychological deficits. Neurodevelopmental accounts of schizophrenia postulate that certain etiologically relevant biological abnormalities present in schizophrenia are likely represented to a milder degree prior to the onset of psychosis. Consistent with this account, neuropsychological impairment should be evident in those at-risk for

schizophrenia if it is not merely a secondary consequence of having the disorder. Given that risk and eventual symptom presentation are conceptualized as being expressed across a dynamic continuum, impairment should also vary according to level of risk and severity of illness (i.e., those at high risk for schizophrenia, or with chronic schizophrenia, should display greater neuropsychological impairment than those who are at low risk or exhibit a milder course of the disorder). The current study separately assessed the relationship of positive schizotypy, negative schizotypy, and their interaction, with multiple domains of neuropsychological functioning. It is hypothesized that elevations in schizotypy will be associated with neuropsychological impairment above and beyond the effects of intellectual ability and general psychological distress. Given that neuropsychological impairment has been more closely tied to the negative symptoms of schizophrenia, it is further hypothesized that the negative symptom dimension of schizotypy will be more strongly associated with neuropsychological impairment than the positive symptom dimension of schizotypy. Lastly, in order to evaluate the possibility that intellectual ability might differentially impact neuropsychological functioning for those at-risk for schizophrenia, the interaction between the schizotypy dimensions and estimated IQ will be examined. Note that college students appear to provide an appropriate sample for examining the relationship between schizotypy and cognitive functioning. Although college graduates exhibit a slightly lower lifetime prevalence of schizophrenia than the general population (Robins et al., 1984), longitudinal studies have reported that psychometrically identified schizotypic college students are at heightened risk for

developing psychotic disorders and schizophrenia-spectrum illnesses (e.g., Chapman et al., 1994; Kwapil, 1998).

CHAPTER II

METHOD

Participants

Participants were identified by scores on the Perceptual Aberration, Magical Ideation, Physical Anhedonia, and Revised Social Anhedonia Scales. These scales were administered to approximately 1800 undergraduate students enrolled in general psychology courses at the University of North Carolina at Greensboro over the course of four semesters. Putatively schizotypic participants who received standard scores of at least + 1.96 on any of these scales, and a subset of control participants who received standard scores of less than + 0.5 on each scale, were invited to participate in the neuropsychological assessment. This selection process ensured variation at both ends of the schizotypy dimension (i.e., the study was guaranteed to contain the low and high scorers necessary for evaluating the effect of schizotypy on neuropsychological impairment). In addition, high scorers on one of the schizotypy scales typically had a range of scores on the other scales, which ensured variation across the entire distribution. The items from the schizotypy scales were intermixed with a 13-item infrequency scale (Chapman & Chapman, 1983) that was designed to screen out participants who responded in a random or "fake-bad" manner. Participants who endorsed three or more items on the infrequency scale were omitted from participation in the study. Over the

four semesters, a total of 156 participants completed the neuropsychological assessment (67 controls, 89 at-risk). With regard to race and gender, the sample consisted of 119 Caucasian and 37 African-American participants, and 125 females and 31 males. Participants had a mean age of 19.1 years (*SD* = 3.2 years, range = 17-43 years of age).

Materials

Schizotypy inventories. The Revised Social Anhedonia Scale consists of 40 items that tap asociality and indifference to others. Sample items include, "Having close friends is not as important as people say" [keyed true] and "I sometimes become deeply attached to people I spend a lot of time with" [keyed false]. The Perceptual Aberration Scale consists of 35 items that tap schizotypal perceptual experiences and bodily distortions. Sample items include, "I sometimes have the feeling that some parts of my body are not attached to the rest of me" [keyed true] and "My hands and feet have never seemed far away" [keyed false]. The Magical Ideation Scale is made up of 30 items that measure belief in implausible or invalid causality. Sample items include, "I have occasionally had the silly feeling that a TV or radio broadcaster knew I was listening to him" [keyed true] and "Numbers like 13 and 7 have no special powers" [keyed false]. The Physical Anhedonia Scale includes 61 items that measure deficits in sensory and aesthetic pleasure. Sample items include, "There are not many things that I ever really enjoyed doing" [keyed true] and "Beautiful scenery has been a great delight to me" [keyed false].

The schizotypy scales were constructed using Jackson's (1970) method for rational scale development. All items were carefully selected to ensure high item-scale

correlations while ruling out correlations with acquiescence and social desirability. The coefficient alpha internal consistency reliabilities of each scale were in the .80's in the present sample and they are reported to have test-retest reliability of .75 to .84 over a six week interval (Chapman, Chapman, & Miller, 1982). The Chapman scales have been widely used in cross-sectional and longitudinal studies of schizotypy. Groups identified as at-risk by the schizotypy scales tend to show psychological and physiological deficits similar to those seen in patients with schizophrenia (e.g., Edell, 1995; Fernandes & Miller, 1995) and to be at an elevated risk for developing schizophrenia-spectrum disorders (Chapman, Chapman, Kwapil, Eckblad, & Zinser, 1994; Kwapil, 1998).

Principal components analysis of the four Chapman Scales with approximately 6000 college students assessed in our laboratory produces a two-factor solution that accounts for approximately 80% of the variance in the scales. An oblique (Promax) rotation results in a Positive Schizotypy factor (with loadings of .91 from both the Perceptual Aberration and Magical Ideation Scales and .39 from the Revised Social Anhedonia Scale) and a Negative Schizotypy factor (with loadings of .85 from the Physical Anhedonia and .79 from the Revised Social Anhedonia Scales). The two factors are minimally correlated (r = .10). Each participant in the present study was assigned a dimensional score on the Positive and Negative Schizotypy factors based upon the original analysis of the unselected sample.

Head injury and drug abuse. In order to rule out the impact of head injury on neuropsychological performance participants were asked if they have ever experienced a concussion ("Have you ever lost consciousness after a blow to the head or been

diagnosed with a concussion? If so, how many times?"). According to guidelines used in similar studies (e.g., Kremen, Seidman, Faraone, Toomey, & Tsuang, 2004), participants were excluded from the study if they reported loss of consciousness for more than 5 minutes or suffered a head injury that was accompanied by documented neuropsychological impairment. Participants were also precluded from participation if they endorsed current substance abuse. No participants met the exclusion criteria, although one participant was excluded from the study because he admitted to substance use on the day of testing. This participant was not contacted to return at a later date to complete the experiment.

Intelligence. The Vocabulary and Block Design subtests from the WAIS-III were used as an estimate of Full Scale IQ based upon the recommendations of Brooker and Cyr (1986).

General Psychological Distress. The Brief Symptom Inventory (Derogatis, 1993), a 53-item self-report scale, is a measure of general psychological distress and includes 9 dimensional symptom scales and 3 global indices. Items are rated on a 5-point scale and the measure takes about 5-10 minutes to complete. The Global Severity Index reflects the average rating per item and serves as a measure of general psychological distress. *T*-scores were computed using norms for adult nonpatient males and females (Derogatis, 1993).

Continuous Performance Test-Identical Pairs. The CPT-IP measures sustained attention by requiring the participant to focus on a computer screen that presents various four-digit numbers (in one condition) and shapes (in a separate condition) for a short

duration. Both of these conditions are also presented on separate trials with distraction, making for a total of four conditions. The participant is instructed to release the computer mouse button whenever two identical stimuli appear on consecutive trials. A signal detection index, *d'*, is the most commonly studied variable of the CPT-IP and is considered to be a relatively pure measure of sustained attention since it controls for response bias. Each participant's *d'* score was averaged across the four conditions (α = .78) to establish an overall *d'* score for that individual.

The Stroop Color and Word Test. The Stroop Color and Word Test requires participants to focus on a single stimulus aspect and provide a verbal response, while ignoring other stimulus characteristics. During the first part of the task, the color trial, the participant is instructed to name the color of a series of stimuli (i.e., XXXX) printed in different colors of ink. In the second part of the task, the word component, the participant sees a list of color names but must verbalize the color of the ink the word is printed in rather than the actual word (color name). This component of the task is much more difficult since people have an automatic tendency to read words when they enter their visual field. Some researchers have considered this component of the Stroop test to be a measure of executive functioning given the emphasis on response inhibition. Four indices of this test were used in analyses, including the total number of correctly completed items for the color and word conditions, and the time needed to complete the stimulus set for the color and word conditions.

The Trail Making Test. Part A of this task involves connecting lines between circumscribed, randomly distributed numbers presented on a sheet of paper, in a

consecutive fashion from 1 to 24. Part B involves connecting numbers to letters in an alternative fashion. Completion times for each part of the test were used as the dependent variables for this test.

Digit Symbol-Coding. This test is part of the WAIS-III and involves quickly filling in empty boxes with symbols within a two-minute time frame. Each empty box is below a number and each number has its own unique symbol which the examinee can reference at the key at the top of the test form. The age-normed standard score was used as the dependent variable for this task.

Arithmetic and Digit Span. These two measures are also from the WAIS-III. The Digit Span task requires the participant to verbally recall a string of digits orally presented at the rate of one digit per second. The Arithmetic subtest presents the participant with a series of math problems that must be solved without the use of a pencil and paper. The age-normed standard scores from each of these tasks were used as dependent variables from these tasks.

Wisconsin Card Sorting Test. During this computerized task, participants must sort 128 cards with various figures on them based on three unspecified sorting rules (color, number, and shape). It is considered to tap the conceptual functions component of executive functioning, but has also been described as a measure of attention (Mirsky et al., 1991). The primary dependent variables that were analyzed from this task were the number of categories achieved, percent conceptual level response, percent perseverative errors, and percent non-perseverative errors. The degree to which a participant perseverates has been a widely studied variable in individuals at-risk for schizophrenia

and is thought to measure sensitivity to contingent feedback (Wagman & Wagman, 1992). Categories completed and percent conceptual level response measure an individual's ability to shift mental sets and discover underlying guiding principles to completing the task.

Controlled Oral Word Association Test. This task requires participants to say as many words as possible that begin with a particular letter within a one-minute time frame. The version of this task used in this investigation included three trials, one for each of the letters C, F, and L. The dependent variable examined from this task was the total number of words produced across the three trials. Verbal fluency tasks have been associated with left frontal lobe damage (Milner, 1975). Some researchers have viewed this task as a measure of memory since the individual must retrieve information from long-term memory in order to perform well (Gabrielli et al., 1998; Raichle et al., 1994).

Mazes. The Mazes task from the WISC-III is thought to assess planning ability (Lezak, 1995). This task involves presenting the participant with a printed maze and asking them to find their way out by drawing a path with a pencil from the starting point to the ending point within a short period of time. Errors are noted when the individual enters a blind alley (i.e., a pathway that is closed off) or draws through a wall. Since all participants completed all of the mazes, the total number of errors was used as the dependent variable for this task.

Ruff Figural Fluency Test. This test requires the participant to draw as many unique designs as possible by connecting pre-arranged dots with straight lines within a one-minute time period. This test contains five different stimulus sheets, but for this

study only parts 3 and 5 were used in order to shorten the administration time. The sum of designs across trials 3 and 5 and the error ratio, which reflects the percentage of duplicate designs, were used as the dependent variables for this task.

California Verbal Learning Test-Second Edition. The CVLT-II was used as a measure of short-term memory, long-term memory (recognition, free recall, cued recall), learning strategies, and interference (retroactive and proactive). During this task, participants are orally presented a list of 16 words (List A) and asked to repeat as many words as they can remember. List A contains four categories of words (furniture, vegetables, ways of traveling, animals) each represented by four words. The list is presented for 5 trials after which the participant is presented with a distractor word list that they must immediately recall (List B). Participants are then given a free recall trial of List A, cued recall trials, and then a break of 20 minutes. After the break, long-term free and cued recall are assessed. Two learning strategy variables, semantic and serial clustering, provide insight into the participant's encoding strategies. High semantic clustering scores indicate that a participant tended to group words together according to category when recalling the list (a more efficient encoding strategy), whereas high serial clustering indicates that the participant tended to recall words in a rote fashion (generally a less efficient strategy).

Brief Visuospatial Memory Test-Revised. This task involves the 10 second presentation of a 2 x 3 array of geometric figures on an 8 ½ x 11 inch stimulus card for three learning trials. After each trial, the card is taken away, and the participant is asked to draw as many figures as they can recall on a separate page. After a 25-minute delay,

the participant is asked to once again draw the figures. First trial performance and percent recall of the delay trial were used as dependent variables for this task.

Letter-Number Sequencing. This task from the WAIS-III was designed to measure verbal working memory. During this task, participants hear a string of letters and numbers and are then asked to first recall the numbers in order (from smallest to largest) and then the letters (in alphabetical order). The Letter-Number Sequencing task has seven levels, each containing three trials. The first level includes a two-item string, and each consecutive level has a string increased by one, making the most challenging level an eight-item string. Testing is discontinued when an individual fails all three trials within a level. The age-normed standard score was used as the dependent variable for this task.

Selection of Variables for Analysis. The current investigation incorporated a variety of neuropsychological variables that were chosen based upon their established psychometric properties, frequency of use in the schizophrenia literature, ability to convey unique information, and their coverage of the three major multidimensional neuropsychological constructs (attention, memory, and executive functioning). For example, the total number of errors was chosen as the most relevant variable for the Mazes subtest because the overall item score does not convey as much information (e.g., once a person makes a certain number of errors, they are given a zero score for a particular item, which can limit information about the number of errors for that item). Moreover, the overall score for the Mazes subtest was excluded because it conveys nearly the same information as the error score. Similarly, it was thought most efficient and

meaningful to choose one variable (the three trial sum) on the verbal fluency task rather than four variables that include redundant information, such as each trial score and the overall score. This line of reasoning was applied to each measure until a final set of 29 variables was achieved. Table 2 displays the final measures selected and the relevant variables from each test that were used in analyses.

Procedure

Schizotypy questionnaires. The schizotypy questionnaires were administered at the beginning of the Fall 2003, Spring 2004, Fall 2004, and Spring 2005 semesters to students enrolled in general psychology courses at UNCG. Candidate at-risk and control participants were contacted by telephone and invited to participate in the neuropsychological assessment. Participants who had corrected vision or audition, were not allowed to participate if they did not wear corrective lenses or devices on the day of testing.

Neuropsychological assessment, IQ, and questionnaires procedure. The entire assessment lasted approximately two and a half hours. Participants were informed that they could withdraw from the project at any point if they felt uncomfortable or distressed, although no participants requested to do this during the study. All of the measures were administered by the principal investigator (an advanced graduate student) and four undergraduate assistants who were extensively trained in the administration of these measures and received ongoing weekly supervision throughout the course of the study. All materials were scored by the principal investigator. Data entry was completed by the principal investigator and verified by an undergraduate assistant. Participants, the

principal investigator, and the experimenters were unaware of each participant's performance on the schizotypy scales.

CHAPTER III

RESULTS

Reduction of Neuropsychological Data

Table 3 provides correlation matrices of the variables typically viewed as belonging to the attention, executive functioning, and memory constructs of neuropsychological functioning, as they relate to all of the selected variables. As can be seen, there were generally modest intra-correlations among the neurocognitive measures presumed to assess the three *a priori* defined areas of cognition. Therefore, a principal components analysis with oblique rotation was conducted on all of the neuropsychological measures. Given that the number of variables in the investigation was not particularly large, and yielded a participant-to-variable ratio of 5.4, principal components analysis, rather than block principal component analysis, was the appropriate method of data reduction for the neuropsychological data. This method was selected in order to minimize the chance of the Type I error, allow for individual variables to contribute weighted information to multiple constructs, and to provide robust underlying neuropsychological factors that could be used to determine the relationship between neuropsychological impairment and schizotypy. A similar approach has been endorsed recently in the MATRICS project, a nationwide research effort investigating neuropsychological impairment in patients with schizophrenia (Nuechterlein et al., 2004).

As illustrated in Table 4, the analysis yielded five factors that accounted for 47% of the variance in neuropsychological performance. The five factors were labeled as follows: 1) Executive Functioning; 2) Processing Speed; 3) Sustained Attention; 4) Long-term Memory; and 5) Interference. Based upon the factor analysis for the neuropsychological measures, each participant was assigned a dimensional score for each factor. Table 5 displays the correlations between the neuropsychological factor scores.

Schizotypy and Cognitive Functioning

Hierarchical regressions were computed using each of the five neuropsychological factor scores as dependent variables with the following order of predictor variables. In order to determine the impact of schizotypy on neuropsychological performance above and beyond the influence of current psychological distress and intellectual ability, the Brief Symptom Inventory-Global Severity Index was entered at Step 1, followed by Estimated IQ at Step 2. In order to examine the differential impact schizotypy type might have on neuropsychological performance, Negative Schizotypy was entered at Step 3 followed by Positive Schizotypy at Step 4. Negative schizotypy was entered before positive schizotypy because of the stronger relationship that exists between negative symptoms and neuropsychological functioning in studies of patients with schizophrenia. The interaction term between Positive and Negative Schizotypy was entered at Step 5. Lastly, in order to evaluate the hypothesis that differing levels of intellectual functioning and level and/or type of schizotypy may interact with each other to impact neuropsychological performance, steps 6, 7, and 8 were added that consisted of interaction terms between these constructs

(Negative Schizotypy x IQ, Positive Schizotypy x IQ, Positive x Negative x IQ). It should be noted that while the Positive and Negative Schizotypy factor scores were derived using principal components analysis with an oblique rotation, the two schizotypy factors were not significantly associated with IQ (r = .02 and .05 respectively). Likewise, IQ was not associated with current symptoms as measured by the Brief Symptom Inventory-Global Severity Index (r = -.03). However, current symptoms were correlated significantly with Positive Schizotypy (r = .57, p < .001) and Negative Schizotypy (r = .32, p < .001).

As Table 6 illustrates, intellectual functioning explained a significant proportion of the variance in the Processing Speed, $F(1,138) = 5.71$, $p < .05$, Sustained Attention, $F(1,138) = 30.64$, $p < .001$, and Long Term Memory, $F(1,138) = 11.33$, $p < .001$, factor scores. In each case, neuropsychological impairment was associated with lower IQ scores. General psychological distress did not explain a significant amount of the variance in neuropsychological performance. However, a trend was evident for Sustained Attention, $F(1,139) = 3.56$, $p < .10$, although, paradoxically, the endorsement of symptoms was associated with improved performance. With regard to schizotypic symptom type, Positive Schizotypy accounted for a significant amount of variance for the Executive Functioning, $F(1,136) = 4.26$, $p < .05$, Sustained Attention, $F(1,136) = 6.41$, $p < .01$, and Interference factors, $F(1,136) = 3.69$, $p < .05$, above and beyond the independent effects of intellectual functioning, general psychological distress, and negative schizotypy. In each case, neuropsychological impairment was associated with elevated Positive Symptom schizotypy scores (i.e., greater endorsement of schizotypy

was associated with more neurocognitive impairment). In contrast, Negative Schizotypy, as well as the interaction between Negative and Positive Schizotypy, did not account for a significant proportion of variance for any of the neuropsychological factors. One interaction term, a three-way interaction between Positive Schizotypy, Negative Schizotypy, and IQ, was evident for the Processing Speed factor $F(1,132) = 4.79$, $p < .05$. Specifically, high scores on both of the schizotypy, combined with low IQ, was associated with poorer Processing Speed. None of the other interaction terms involving schizotypy and IQ were significant. Note, that recomputations of the regression analyses separately for males and females did not produce any substantive differences in the results.

CHAPTER IV

DISCUSSION

The current study investigated neuropsychological functioning in relation to the degree of schizotypy. A principal components analysis yielded five underlying neuropsychological factors of Executive Functioning, Processing Speed, Sustained Attention, Long Term Memory, and Interference. Although the factor structure of the measures used in this investigation did not map onto the *a priori* view of attention, executive functioning, and memory, it was consistent with other current findings in the literature that have employed factor analysis (Nuechterling et al., 2004). It should also be noted that the focus of the current study was not to describe the underlying factor structure of cognitive abilities, but rather to examine the relationship between symptom dimensions of schizotypy and neuropsychological performance. Furthermore, the nature of the sample and selection procedures precludes making broader interpretations about the structure of neuropsychological functioning in young adults.

For three of the neuropsychological factors, Processing Speed, Sustained Attention, and Long Term Memory, intellectual ability explained a significant amount of the variance in neuropsychological performance, highlighting the need for researchers to control for this variable when investigating neuropsychological functioning. Consistent with the main hypothesis, neuropsychological impairment was associated with

schizotypy. High scores on the Positive Schizotypy factor were associated with deficits in neuropsychological functioning for three of the five factors (Executive Functioning, Sustained Attention, Interference). Moreover, general psychological distress did not account for significant variation in neuropsychological performance. It should be noted, however, that the Brief Symptom Inventory, which was used as a measure of general psychological distress, does not include items related to Attention Deficit/Hyperactivity Disorder, which potentially may have impacted the current findings. In contrast, Negative Schizotypy factor scores were not associated with neuropsychological impairment despite fairly consistent evidence to the contrary in samples of patients with schizophrenia (Heydebrand et al., 2004; Nieuwenstein et al., 2001; O'Leary et al., 2000). Lastly, one interaction term was related to neuropsychological performance. Specifically, impaired processing speed was associated with a combination of high factor scores on Positive and Negative Schizotypy and low scores on estimated IQ. In this regard, higher IQ scores may have served as a protective factor against neuropsychological impairment for those participants with high positive and negative schizotypy features. This finding is similar to a performance pattern noted in Bryne et al. (1999).

Taken together, these findings warrant several considerations. First, the inconsistencies noted in the at-risk literature may be partially explained by the grouping of schizotypes with differing levels and types of impairment. If positive schizotypes are more neuropsychologically impaired than negative schizotypes, grouping all of these individuals together when making statistical comparisons may weaken the power of the

statistical analyses. In addition, given the evidence in this study that intelligence can explain a significant proportion of the variance in neuropsychological performance, failure to account for this variable could lead to misleading statistical results.

The absence of a significant relationship between neuropsychological dysfunction and Negative Schizotypy is contradictory to the hypothesis that this dimension is associated with neuropsychological impairment across the continuum of vulnerability for schizophrenia. There are several possible explanations for this finding. The most reasonable explanation seems to be that the heterogeneity that characterizes neuropsychological functioning in the schizophrenic population is mirrored by heterogeneity of less deviant deficits in the at-risk population. For example, the literature concerning neuropsychological impairment in the at-risk population has been inconsistent. Likewise, the relationship between Positive Schizotypy and neuropsychological performance in the current study was modest, suggesting that neuropsychological impairment does not seem to be a prominent trait of individuals at-risk for schizophrenia. Thus, it seems that the phenotypic neuropsychological heterogeneity that has been noted in the schizophrenic population appears to be present in the at-risk population as well. However, the importance of neuropsychological impairment should not be discounted. It is possible that a subgroup of individuals with high schizotypy scores and neuropsychological impairment are at especially heightened risk for developing schizophrenia. Perhaps, in this particular sample, there were not as many individuals with neuropsychological impairment and high Negative Schizotypy scores to account for a significant amount of variance in neuropsychological

performance. The present sample was predominantly female and although not extensively studied, the literature suggests that males may be more prone to negative symptoms and neuropsychological deficits (Leung & Chue, 2004). Perhaps a more substantial representation of male schizotypes would have strengthened the relationship between negative symptoms and cognitive dysfunction. An analysis of individual profiles might help to identify a group of individuals at-risk who have an etiologically specific vulnerability for schizophrenia. Identifying such individuals and tracking their development in a longitudinal investigation would help address these issues.

An alternative hypothesis is that the vulnerability for negative symptom schizophrenia may not significantly impact neurocognition prior to the onset of the first episode. The findings of this study highlight the possibility that there are crucial developmental changes that occur as one moves along the continuum from vulnerable to symptomatic. As the presumed anatomical and functional changes that produce negative symptoms become more prominent, they may have a qualitatively different impact on an individual's ability to process information in comparison to the substrates of positive symptoms. Such a conjecture would be consistent with the social drift hypothesis that individuals experience debilitating effects after the onset of their first episode of schizophrenia that cause them to drift downward on the socioeconomic ladder. In contrast, the disrupted neural networks responsible for the development of positive symptoms may impair neuropsychological functioning in a more consistent and mild manner throughout the course of the illness. While these ideas are indeed speculative,

there is a distinction in this sample between schizotypy symptom type and neuropsychological ability.

Another potential explanation for the lack of an association between negative symptoms and neuropsychological impairment is that schizotypic individuals with primarily attenuated negative features are able to utilize alternative areas of the brain to enhance their performance. This hypothesis can be examined by studying the metabolic activity in different areas of the brain while engaging in neuropsychological tasks. A study by Volz et al. (1999) found differential brain activation patterns in individuals with schizophrenia and control participants while performing the Continuous Performance Test. Specifically, the authors found that when patients were matched with controls for performance, patients with low Continuous Performance Test scores displayed greater activation in the right temporal lobe and less activation in the left dorsolateral prefrontal cortex in comparison to poor performing control participants. Such findings highlight that latent neuroanatomical and neurophysiological abnormalities may be evident in those at-risk for schizophrenia even though their manifest neuropsychological performance is indistinguishable from controls. As neuroimaging techniques become more advanced and cost-effective, this paradigm of analysis will likely elucidate the relationship between risk for schizophrenia and neuropsychological impairment, as well as the veracity of claims that such impairment is indicative of vulnerability for the disorder. This methodological approach to studying neuropsychological functioning should also help clarify the relationship between cognitive impairment and pre- and post-morbid symptom variation.

Another advancement in the future study of neuropsychological impairment in the development of schizophrenia will be the inclusion of more comprehensive test batteries. As noted earlier, the most effective way to test neuropsychological functioning is to ensure adequate coverage of the constructs which serve as the basis for conclusions. Recent cooperative efforts by researchers from academic, government, and patient advocate groups have reached a similar consensus since forming the NIMH-Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) Initiative. One of the major goals of this initiative is to scientifically demonstrate the importance that cognitive impairment has on everyday functioning for patients with schizophrenia (Nuechterlein et al., 2004). The battery chosen for the current study was chosen prior to the formation of this committee. However, as Table 7 demonstrates, the MATRICS battery is very similar to the one employed in this investigation. One notable absence from the MATRICS battery is the WCST, which was not included because the authors only selected tests suitable for longitudinal assessments.

The battery chosen by the MATRICS Neurocognition Committee was constructed after carefully examining all factor analytic studies conducted with patients with schizophrenia. This review of the literature provided the authors with confidence that there are meaningful and separable cognitive factors in schizophrenia. These factors are included in Table 7 as "Cognitive Domains" and are similar to the factors extracted in the current investigation (Nuechterlein et al., 2004). The authors noted that the inclusion of the Social Cognition factor, which was not evident in factor analyses, was based upon new research suggesting that social cognition may serve as a mediator between

neuropsychological impairment and functional outcome in schizophrenia (Brekke et al., 2003). The consistency between these two independent efforts approximates a cross-validation of these underlying neuropsychological functions and encourages the use of similar comprehensive batteries in future examinations of neuropsychological functioning in schizophrenia and those at-risk for the disorder.

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APPENDIX A

TABLES

Table 1

Summary of Neuropsychological Findings in Samples Using Chapman Scales

Study	Sample	Neuropsychology Measures	Findings
Lenzenweger (2001)	31 schizotypic 26 controls Per-Ab	CPT-IP	d': NS ln β: NS Hits: NS False Alarms: NS Reaction Time: C < S
Obiols (1993)	35 Per-Ab 33 controls	CPT-IP	d': Per-Ab < C
Laurent et al. (1999)	23 schizophrenia 45 first-degree relatives 36 controls Soc & PhyAnh	CPT-IP	Fast Numbers (3FN): d': NS ln β: NS ln random: NS Fast Numbers (4FN): d': NS ln β: NS ln random: Sc < R, C Slow Numbers: d': NS ln β: NS ln random: Sc < R, C Fast Shapes: d': Sc, R < C ln β: NS ln random: NS Slow Shapes: d': NS ln β: NS ln random: NS Soc & Phy Anh not related to d'

Table 1 (continued)

Study	Sample	Neuropsychology Measures	Findings
Franke et al. (1994)	35 schizophrenia 26 healthy siblings 35 controls Per-Ab, PhyAnh	CPT-IP	d': Sc, R < C ln β: Sc < C Per-Ab, Phy Anh not related to CPT-IP variables
Gooding et al. (1999)	97 Per-Mag 58 SocAnh 104 controls	WCST	Categories Completed: Per-Mag, SocAnh < C Perseverative Errors: Per-Mag, SocAnh > C Non-Perseverative Errors: NS Trials to 1st: NS Conceptual Level Response: NS Failure to Maintain Set: Per-Mag, SocAnh > C
Tallent & Gooding (1999)	49 SocAnh 66 Per-Mag 63 controls	WCST Working Memory task	Categories Completed: SocAnh < Per-Mag, C Perseverative Errors: NS Non-Perseverative Errors: NS Trials to 1st: NS Conceptual Level Response: NS Failure to Maintain Set: Per-Mag, SocAnh > C Working Memory: % Correct: SocAnh, Per-Mag < C Reaction Time: SocAnh > C

~~Table 1 (continued)~~

Study	Sample	Neuropsychology Measures	Findings
Suhr (1997)	56 Per-Mag 42 controls	WCST Stroop Color & Word Trail Making Test Tower of Hanoi COWAT	Perseverative Errors: Per-Mag > C % Perseverative Errors: Per-Mag > C Categories Completed: NS Failure to Maintain Set: NS Stroop Color & Word: Interference: Per-Mag > C Trail Making Test- Part B: Time to Completion: NS Tower of Hanoi: Number of Moves: NS COWAT: Total Fluency Score: NS
LaPorte et al. (1994)	409 participants Per-Mag, SocAnh Scales	Wechsler Memory Scale- Revised	Logical Memory: Immediate Recall: NS Delayed Recall: NS % Retained: NS
Lenzeweger & Gold (2000)	31 Per-Ab 26 controls	Verbal Memory Task Letter Number Span	Verbal Memory Test: Immediate Recall: NS Delayed Recall: NS Letter Number Span: Total Correct: NS Longest String: NS
Gooding et al. (2001)	63 Per-Mag 62 SocAnh 83 controls	WCST	Categories Completed: Per-Mag, SocAnh < C Non-Perseverative Errors: NS Trials to 1st: NS Conceptual Level Response: NS Failure to Maintain Set: NS Perseverative Errors: NS

Table 1 (continued)

Study	Sample	Neuropsychology Measures	Findings
Franke et al. (1993)	57 Schizophrenia 32 healthy siblings 32 controls PhyAnh Scale	WCST Verbal Fluency Test Trail Making Test	Perseverative Errors: Sc, R > C Non-Perseverative Errors: Sc > C Conceptual Level Response: Sc, R < C Categories Completed: Sc, R < C Trail Making Test: Time to Completion A & B: Sc, R > C Verbal Fluency Test: Number of Words Produced: Sc, R < C PhyAnh associated with impairment on WCST, TMT, & Verbal Fluency Test
Barrantes-Vidal et al. (2003)	270 normal adolescents Per-Ab, SocAnh PhyAnh (Positive, Negative, Mixed, Control)	Digit Span Digit Symbol COWAT CPT-IP WCST Trail Making Test A	Digit Span: NS Digit Symbol: Mixed < Positive, C CPT-IP: NS COWAT: Mixed < Positive, C WCST- Failure to maintain set: Negative > Positive, Mixed Trail Making Test A: NS
Rosa et al. (2000)	260 young adolescents Per-Ab, PhyAnh, SocAnh Factor Analysis yielded Positive and Negative Schizotypy Scores	WCST (Factor 1) Trail Making Test Controlled Oral Word Association Test Raven Progressive Matrices (Factor 2)	Factor 1: NS Factor 2: Negative Schizotypy related to impairment

Table 1 (continued)

Per-Ab = Perceptual Aberration Scale
Per-Mag = Combination of Perceptual Aberration and Magical Ideation Scales
PhyAnh = Physical Anhedonia Scale
SocAnh = Social Anhedonia Scale

Sc = Patients with schizophrenia
R = Relatives of patients with schizophrenia
S = Schizotypy participants
C = Control participants
NS = Not significant

CPT-IP = Continuous Performance Test- Identical Pairs
WCST = Wisconsin Card Sorting Test
COWAT = Controlled Oral Word Association Test

Table 2

Selected Measures of Attention, Executive Functioning, and Memory

Attention

Trail Making Test
Part A- Completion time
Part B- Completion time

Digit Symbol- Coding subtest (WAIS-III)
Standard score

Stroop Color and Word Test
Color- Number correct, time to completion
Word- Number correct, time to completion

Continuous Performance Test- Identical Pairs
d' overall

Arithmetic subtest (WAIS-III)
Standard score

Digit Span subtest (WAIS-III)
Standard score

Executive Functioning

Wisconsin Card Sorting Test
% perseverative errors
% nonperseverative errors,
% conceptual level response
Categories completed

Mazes subtest (WISC-III)
Total number of errors

Controlled Oral Word Association Test (CFL)
Number of correct responses

Ruff Figural Fluency Test
Trials 3 and 5- Total score
Error ratio

Table 2 (continued)

Memory

California Verbal Learning Test- Second Edition (CVLT-II)
- Trial 1
- Long delay retention % change
- Long delay cued recall
- Proactive interference
- Retroactive interference
- Recognition discriminability
- Semantic clustering
- Serial clustering

Digit Span subtest (WAIS-III)
- Standard score

Brief Visuospatial Memory Test- Revised (BVMT-R)
- Trial 1
- Delay- % retained

Letter Number Sequencing subtest (WAIS-III)
- Standard score

Table 3

Correlation Coefficients for Measures of Attention, Executive Functioning, and Memory

Attention

	d'	AR	SCC	SCT	SWC	SWT	DS	TAT	TBT	CG
d'	1									
AR	.24**	1								
SCC	.09	.08	1							
SCT	-.36**	-.05	-.22**	1						
SWC	.08	.06	.23**	-.22**	1					
SWT	-.34**	-.09	-.14	.61**	-.30**	1				
DS	.33**	.33**	-.02	-.27**	.19*	-.28**	1			
TAT	-.06	-.03	-.01	.24**	.00	-.15	.03	1		
TBT	-.14	-20*	-.10	-.24**	-.20*	.35**	-.15	.31**	1	
CG	.20*	.05	.09	-.43**	.11	-.43**	.08	-.28**	-.40**	1
MZ	-.16*	.20*	.09	.10	.03	.03	-.19*	-.08	.12	.05*
VF	.26*	.15	.11	.24**	.07	-.17*	.32**	.00	-.03	.06
RF	.19*	.01	.16	.27**	.15	-.20*	.14	.30**	-.21**	.26**
CC	.14	.14	.04	.07	.23**	-.09*	.14	.02	-.09*	-.05
PP	-.16	-.19*	-.01	-.07	-.19*	.05	-.18*	-.05	-.02	.17*
NP	-.15	-.25**	-.03	-.01	-.17*	.10	-.07	.11	.14	.03
CLR	.17*	.24**	.03	.07	.17*	-.07	.13	-.03	-.06	-.11
ER	-.18*	-.12	-.07	.00	.03	.06	-.17*	-.05	.05	.10
CV1	.12	.10	-.09	-.15	.24	.20*	.21*	-.06	-.22**	.27**
DC	.07	.15	.07	-.12	.14	-.18*	.20*	-.12	-.19*	.26**
DF	.09	.12	.07	-.13	-.04	-.27*	.13	-.07	-.06	.06
SC	-.02	.08	-.05	.02	.12	-.12	-.05	-.15	-.22	.20*
SER	.04	-.02	.07	-.04	.04	.03	.13	.19	.18	-.08
PI	.03	.12	.13	.07	-.13	.10	.09	.04	.05	-.04
RI	.04	.03	-.05	.13	.09	.11	.00	.08	-.02	.12
RC	.08	.13	.04	.09	.15	.01	.12	.05	-.18	.14
BV1	.12	.02	.00	.01	.16*	-.05	.12	-.12	-.25**	.09
BVD	.09	.05	-.05	.05	.08	.04	.13	.10	.10	.17*
LNS	.34**	.37**	.10	-.25*	.08	-.18	.60**	-.06	-.18*	.07

Table 3 (continued)

d'=CPT, d'; AR=WAIS-III, Arithmetic; SCC=Stroop Color and Word Test, Color- Number Correct; SCT=Stroop Color and Word Test, Color- Time to Completion; SWC=Stroop Color and Word Test, Word- Number Correct; SWT=Stroop Color and Word Test, Word- Time to Completion; DS=WAIS-III, Digit Span; TAT=Trail Making Test, Part A- Time to Completion; TBT=Trail Making Test, Part B- Time to Completion; CG=WAIS-III, Coding

Executive Functioning

	MZ	VF	RF	CC	PP	NP	CLR	ER
MZ	1							
VF	.01	1						
RF	.14	.06	1					
CC	-.01	.09	-.04	1				
PP	.02	-.09	.02	-.70**	1			
NP	-.12	-.03	-.02	-.61**	.58**	1		
CLR	.07	.07	-.02	.76**	-.84**	-.89**	1	
ER	.16	-.12	.02	-.09	.11	.08	-.09	1
d'	-.16*	..26**	.19*	.14	-.16	-.16	.17*	-.18*
AR	-.20*	.15	.01	.14	-.19*	-.25*	.24**	-.12
SCC	-.09	.11	.16	.04	.00	-.03	.03	-.07
SCT	.10	-.24**	-.27**	.07	-.08	-.01	.07	.00
SWC	.03	.07	.15	.23**	-.19*	-.17*	.17*	-.17*
SWT	.03	-.17*	-.20*	-.09	.06	.10	-.07	.06
DS	-.19*	.32**	.14	.14	-.18*	-.07	.13	-.17*
TAT	-.08	.00	-.30**	.02	-.05	.11	-.03	-.05
TBT	.12	-.03	-.21**	-.09	-.02	.14	-.06	.05
CG	.05	.06	.26**	-.05	.17*	.03	-.11	.10
CV1	-.10	.03	.05	.14	-.06	-.10	.09	.16
DC	.08	.03	.15	-.02	.03	-.03	.00	-.06
DF	-.06	.12	.04	.04	-.06	-.09	.06	-.09
SC	.03	.06	.06	.02	.04	-.09	.03	.06
SER	-.12	-.05	-.18*	.06	-.08	-.02	.04	-.07
PI	.04	.12	-.03	-.01	.02	.02	.00	-.18*
RI	-.03	-.04	-.03	.02	-.01	.07	-.02	.10
RC	.02	.06	-.13	.13	.00	-.13	.08	-.03
BV1	.02	.14	.10	.08	-.03	-.17*	.10	-.05
BVD	-.10	.02	.15	.12	-.18*	-.17*	.19*	-.14
LNS	-.23	.23**	.06	.08	-.09	-.01	.06	-.15

Table 3 (continued)

MZ=WISC-III, Mazes- Total Number of Errors; VF=Controlled Oral Word Association Test- Number of Correct Responses; RF=Ruff Figural Fluency Test, Trials 3 and 5- Total Score; CC= Wisconsin Card Sorting Test, Categories Completed; PP=Wisconsin Card Sorting Test, % Perseverative Errors; NP=Wisconsin Card Sorting Test, % Nonperseverative Errors; CLR=Wisconsin Card Sorting Test, % Conceptual Level Response; ER=Ruff Figural Fluency Test, Error Ratio

Memory

	CV1	DC	DF	SC	SER	PI	RI	RC	BV1	BVD	LNS
CV1	1										
DC	.22**	1									
DF	-.12	.04	1								
SC	.36**	.17*	-.01	1							
SER	.11	-.04	-.07	-.70**	1						
PI	-.54**	-.01	.25**	-.14	.07	1					
RI	.23**	.17*	-.61**	.20*	-.02	-.18*	1				
RC	.23**	.36**	-.19*	.25**	.04	.25**	-.46**	1			
BV1	.15	.10	.01	.03	.02	.00	.07	.28**	1		
BVD	-.08	.03	.09	-.12	.04	.10	-.03	-.01	.18*	1	
LNS	.20*	.14	.07	-.04	.11	.00	.06	.10	.12	.00	1
MZ	-.10	.08	-.06	.03	-.12	.04	-.03	.02	.02	-.10	-.23**
VF	.03	.03	.12	.06	-.05	.12	-.04	.06	.10	.02	.23**
RF	.05	.15	.04	.06	-.18*	-.03	-.03	-.13	.08	.15	.06
CC	.14	-.02	.04	.02	.06	-.01	.02	.13	-.03	.12	.08
PP	-.06	.03	-.06	.04	-.08	.02	-.01	.00	-17*	-.18*	-.09
NP	-.10	-.03	-.09	-.09	-.02	.02	.07	-.13	.10	-.17*	-.01
CLR	.09	-.01	.06	.03	.04	.00	-.02	.08	-.05	.19	.06
ER	-.16	-.06	-.09	.06	-.07	-.18*	.10	-.03	.13	-.14	-.15
d’	.13	.07	.09	-.02	.12	.03	.04	.08	.02	.24**	.34**
AR	.10	.15	.12	.08	-.02	.12	.03	.13	.00	.09	.37**
SCC	-.09	.07	.03	-.05	.07	.13	-.05	.04	.01	-.07	.10
SCT	.16	-.12	-.13	.02	-.04	.07	.13	.09	.16*	.08	-.25**
SWC	.24**	.14	-.04	.12	.04	-.13	.09	.15	.16*	.17*	.08
SWT	-.20*	-.18*	-.27**	-.12	.03	.10	.11	.01	-.05	-.06	-.18*
DS	-.21**	.20*	.13	-.05	.13	.09	.00	.12	.12	.18*	.60**
TAT	-.07	-.12	-.07	-.15	.19*	.04	.08	.05	-.12	.03	-.06
TBT	-.22	-.19*	-.06	-.22**	.18*	.05	-.02	-.18*	-.25**	-.11	-.18*
CG	.27**	.26**	.06	.20*	-.08	-.04	.12	.14	.09	-.04	.07

Table 3 (continued)

CV1=CVLT-II, Trial 1; DC=CVLT-II, Long Delay Cued Recall; DF=CVLT-II, Long Delay Retention % Change; SC=CVLT-II, Semantic Clustering; SER=CVLT-II, Serial Clustering; PI=CVLT-II, Proactive Interference; RI= CVLT-II, Retroactive Interference; RC=CVLT-II, Recognition Discriminablity; BV1=BVMT-R, Trial 1; BD= BVMT-R, Delay- % Retained; LNS=WAIS-III, Letter Number Sequencing

Table 4

Principal Components Analysis of Neuropsychological Variables with Promax Rotation

Variables	Factors				
	1	2	3	4	5
WCST- % Perseverative Errors	**-.855**	-.047	-.194	.066	-.013
WCST- % Nonperseverative errors	**-.857**	.115	-.080	-.149	.049
WCST- % Conceptual Level Response	**.967**	-.020	.138	.050	-.022
WCST- Categories Completed	**.829**	.009	.183	.066	.047
Stroop Color- Time to Completion	.046	**.747**	-.328	.050	.018
Stroop Word- Time to Completion	-.060	**.722**	-.299	-.134	.069
Trails A- Time to Completion	-.070	**.539**	.086	-.160	.051
Trails B- Time to Completion	-.100	**.504**	-.256	**-.474**	-.096
Digit Symbol Coding- Standard Score	-.155	**-.630**	.062	.336	.085
RFFT- Total Number Correct- Trials 3 + 5	.014	**-.543**	.022	.088	.010
Digit Span- Standard Score	.179	-.194	**.732**	.080	.033
Arithmetic- Standard Score	.280	-.027	**.519**	.176	-.068
Letter Number Sequencing- Standard Score	.108	-.197	**.710**	.053	.070
COWAT- Fluency Total Score	.067	-.136	**.458**	.147	-.152
CPT-IP- D prime (*d'*) Overall	.237	-.355	**.540**	.040	.058
Mazes- Total Number of Errors	.034	-.093	**-.403**	.066	-.089
CVLT-II- Total Recognition Score	.054	.185	.348	**.586**	.350
CVLT-II- Long Delay Cued Recall Total Score	-.044	-.173	.262	**.463**	.095
CVLT-II- Semantic Clustering Raw Score	.020	-.158	-.189	**.774**	.114
CVLT-II- Serial Clustering Raw Score	.030	.172	.369	**-.595**	.117
BVMT-R- Trial 1 Raw Score	.150	-.160	.266	**.421**	.153
CVLT-II- Trial 1 Raw Score	.142	-.301	.122	.381	**.640**
CVLT-II- Proactive Interference	-.034	.234	.217	-.010	**-.635**
CVLT-II- Retroactive Interference	-.082	.312	.143	.325	**.704**
CVLT-II- Long Delay Retention % Change	.154	-.308	.016	.002	**-.687**
RFFT- Error Ratio	-.119	-.114	-.370	-.055	.278
BVMT-R- Delayed Recall % Retained	.292	.096	.108	-.021	-.089
Stroop Color- Total Number Correct	-.073	-.184	.272	-.060	-.157
Stroop Word- Total Number Correct	.190	-.219	.288	.241	.195
Variance Accounted for in Analysis	14.5%	11.4%	8.8%	7.5%	5.2%

Bolded values signify factor loadings $\geq$ .400.

Table 5

Correlation Coefficients of the Five Neuropsychological Factors

	Executive Functioning	Processing Speed	Sustained Attention	Long Term Memory	Interference
Executive Functioning					
Processing Speed	-.06				
Sustained Attention	.17*	-.12			
Long Term Memory	.07	-.15	.09		
Interference	-.01	.04	.09	.18*	

* $p < .05$

Table 6

Linear Regression Analysis for Neuropsychology Factors

	Executive Functioning			Processing Speed			Sustained Attention		
	R	Δ R^2	beta	*R*	Δ R^2	beta	*R*	Δ R^2	beta
Brief Symptom Inventory-Global Severity Index	.100	.010	-.100	.012	.000	.012	.158	.025	.158
Estimated IQ	.177	.021	-.091	.200	.040*	-.200	.450	.177***	.422
Negative Schizotypy	.177	.000	.001	.215	.006	-.084	.454	.004	.067
Positive Schizotypy	.246	.029*	-.208	.215	.000	-.003	.492	.036**	-.229
Negative Schizotypy x Positive Schizotypy	.254	.004	.067	.217	.001	.036	.495	.003	.060
Negative Schizotypy x IQ	.266	.006	.086	.219	.001	.029	.495	.001	.028
Positive Schizotypy x IQ	.266	.000	-.019	.227	.004	.064	.498	.003	-.054
Negative x Positive Schizotypy x IQ	.289	.013	-.137	.291	.033*	-.223	.502	.004	-.080
Total R^2		.083			.085			.252***	

Table 6 (continued)

	Long Term Memory			Interference		
	R	Δ R^2	beta	*R*	Δ R^2	beta
Brief Symptom Inventory-Global Severity Index	.133	.018	-.133	.074	.006	.074
Estimated IQ	.304	.075***	.274	.096	.004	-.061
Negative Schizotypy	.304	.000	-.015	.098	.000	.018
Positive Schizotypy	.305	.000	.019	.194	.028*	.203
Negative x Positive Schizotypy	.313	.005	-.081	.198	.001	-.042
Negative Schizotypy x IQ	.332	.012	-.121	.198	.000	.017
Positive Schizotypy x IQ	.335	.002	.044	.214	.007	-.087
Negative x Positive Schizotypy x IQ	.344	.006	.097	.227	.006	-.091
Total R^2		.119*			.051	

*$p < .05$ **$p < .01$ ***$p < .001$

Table 7

MATRICS Provisional Consensus Cognitive Battery

Cognitive Domain and Tests
Speed of Processing
Category Fluency
Brief Assessment of Cognition in Schizophrenia (BACS)- Symbol-Coding
Trail Making Test- Part A
Attention/Vigilance
Continuous Performance Test– Identical Pairs (CPT-IP)
Working Memory
University of Maryland- Letter Number Span
Wechsler Memory Scale- Third Edition (WMS-III)- Spatial Span
Verbal Learning
Hopkins Verbal Learning Test- Revised (HVLT-R)
Visual Learning
Brief Visuospatial Memory Test- Revised (BVMT-R)
Reasoning and Problem Solving
Neuropsychological Assessment Battery (NAB)- Mazes
Social Cognition
Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT)- Managing Emotions