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Executive Functioning in Schizophrenia: The Contributions of Attention, Working Memory, Processing Speed, and General Intelligence

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The purpose of this study was to assess the degree to which executive functioning performance may be associated with indices of attention, working memory, processing speed, and general intelligence in 45 individuals with schizophrenia from a multicultural sample. It was hypothesized that relatively higher performances on measures of these cognitive processes would be positively associated with higher executive functioning performance, as measured by the Wisconsin Card Sorting Test (WCST). Contrary to expectations, results indicated that attention, working memory, and processing speed did not significantly correlate with executive functioning performance. However, Wechsler Adult Intelligence Scale, Third Edition (WAIS-III) Full-Scale IQ scores did significantly correlate with WCST performance, suggesting that general intellectual deficits may underlie executive functioning impairments in schizophrenia.

Schizophrenia is a psychotic disorder often characterized by delusions and hallucinations (American Psychiatric Association, 2000). Schizophrenia may also be conceptualized as a chronic neurocognitive disorder with varied levels of functioning and symptom presentations, including deficits in attention, memory, processing speed, and executive functioning. Such cognitive deficits appear to predate clinical symptoms (Murray, 1994), remain relatively stable after the onset of schizophrenia (Heaton et al., 2001; Hoff et al., 1999; Rund, 1998), and remain stable regardless of baseline and changes in clinical state (Heaton et al., 2001). Deficits in cognitive functioning may be considered core symptoms of schizophrenia (Weickert et al., 2000) and have been associated with relapse and functional outcome (Chen et al., 2005; Green, Kern, Braff, & Mintz, 2000; Sergi, Kern, Mintz, & Green, 2005; Woonings, Appelo, Kluiter, Slooff, & van den Bosch, 2002). In addition, functional outcome may be more reliably related to cognitive impairment than positive symptomatic variables (Axelrod, Goldman, Tompkins, & Jiron, 1994).

One such cognitive deficit that has been widely studied in individuals with schizophrenia is executive functioning, a broad term comprised of several components, including determining what one wants or needs, conceptualizing the future realization of that want or need, identifying and organizing the steps and resources required to achieve the goal, weighing alternatives and making choices, and the translation of a plan into action via sequences of complex behavior in an orderly fashion (Lezak, 1995). Executive functioning has also been described as involving volition, planning, purposive action, and self-monitoring of behavior (Green et al., 2000; Lezak, 1995), which enable the performance of complex and high-level tasks. Lezak (1995) has characterized executive abilities as "those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior" (p. 42). Maintaining or shifting mental sets, establishing goals, and planning are crucial aspects of executive functioning (Stuss & Benson, 1986) and can be measured by neuropsychological tests specifically designed to assess executive functioning.

One of the most established and widely used measures of executive functioning is the Wisconsin Card Sorting Test (WCST; Berg, 1948; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993), a complex task designed to assess the ability to shift cognitive strategies in response to changing environmental contingencies. The test requires subjects to perceive and abstract relevant attributes and ignore irrelevant ones, to engage in hypothesis generation and testing, and to abandon irrelevant hypotheses or principles when necessary (King & Snow, 1981). Successful WCST performance is thought to involve strategic planning, organized searching, goal-oriented behavior, modulation of impulsive responding, and the ability to use

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environmental feedback to shift cognitive sets (Spreen & Strauss, 1998).

In individuals with schizophrenia, performances on the WCST are often impaired relative to normal and psychiatric controls (Beatty, Jocic, Monson, & Katzung, 1994; Everett, Lavoie, Gagnon, & Gosselin, 2001; Ilonen et al., 2000; Johnson-Selfridge & Zalewski, 2001; Metz, Johnson, Pliskin, & Luchins, 1994; Reed, Harrow, Herbener, & Martin, 2002), and some of the research seeking to explain the WCST performance impairment associated with schizophrenia has centered on correlations with intellectual or cognitive abilities, such as attention and working memory, measured by tests commonly used in neuropsychological batteries. Results from these studies, however, have often been unclear or conflicting, and much remains to be known about the specific cognitive processes involved in WCST performance and what processes contribute to the relatively impaired WCST performance associated with schizophrenia.

Some researchers, for example, have suggested that attention may underlie WCST performance (Perry, Potterat, & Braff, 2001; Stratta, Mancini, Mattei, Casacchia, & Rossi, 1994). Differences between individuals with schizophrenia in an inpatient setting and controls on WCST performance may be eliminated after controlling for attention using analysis of covariance (Kenny & Meltzer, 1991), and attention training may remediate WCST deficits (Lopez-Luengo & Vazquez, 2003). Other studies, however, suggest that attention may be insufficient in explaining WCST performance or have found no significant correlation between WCST performance and attention (Chen et al., 1997; Delahunty, Morice, & Frost, 1993; Frost et al., 1991; Goldberg, Weinberger, Berman, Pliskin, & Podd, 1987; Greve, Ingram, & Bianchini, 1998). Similarly, while some studies have found evidence of an association between working memory and executive functioning in schizophrenia (Glahn, Cannon, Gur, Ragland, & Gur, 2000; Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997; Gooding & Tallent, 2002; Morice & Delahunty, 1996; Stone, Gabrieli, Stebbins, & Sullivan, 1998), others have not (Bellack, Mueser, Morrison, Tierney, & Podell, 1990; Goldman, Axelrod, & Tompkins, 1992; Greve et al., 1998; Stratta et al., 1997; Vollema, Geurtsen, & van Voorst, 1995). Thus, while attention and working memory have yet to fully explain WCST performance impairments, many studies do suggest some degree of impairment, and differences in sample composition and instruments across studies likely contribute to inconsistent findings. In addition, few studies have directly assessed the association between attention and executive functioning, and of those that have, many studies relied on visual rather than auditory stimuli when measuring attention. As individuals with schizophrenia may be relatively more impaired on auditory measures of attention (Borgaro et al., 2003; Mirsky, Yardley, Jones, Walsh, & Kendler, 1995; Mussgay & Hertwig, 1990), a more sensitive measure of impairment may yield more consistent, significant results.

Research appears relatively more limited with regard to assessing processing speed in schizophrenia and its potential contribution to impaired WCST performance. Individuals with schizophrenia have been found to have impaired processing speed (Egeland et al., 2003; Hong et al., 2002; Saccuzzo & Braff, 1981), and this impairment may result in a disrupted flow of information as new stimuli enter before other stimuli have transferred (Felsten & Wasserman, 1980; Saccuzzo & Braff, 1981). This slowed processing speed may cause individuals with schizophrenia to lose information before being able to use it (Brebion et al., 2000; Hartman, Steketee, Silva, Lanning, & Andersson, 2003), and thus may contribute to impaired WCST performance. However, this hypothetical association has yet to be directly assessed.

Finally, it is also possible that WCST performance impairments associated with schizophrenia may be due to deficits in generalized intelligence (Laws, 1999). While some argue that WCST performance may not be fully accounted for by IQ scores (Elliott, McKenna, Robbins, & Sahakian, 1995; Morice, 1990), many studies have demonstrated significant associations between WCST and IQ scores (Dieci et al., 1997; Gold et al., 1997; Goldberg, Kelsoe, & Weinberger, 1988; Ilonen et al., 2000; Laws, 1999; Seidman et al., 1991), as well as IQ estimates (Koren et al., 1998; Sweeney, Kelip, Haas, Hill, & Weiden, 1991) in individuals with schizophrenia. One study reported that IQ scores account for approximately 40% of the variance in WCST performance (Gold et al., 1997).

Additional support for a possible association between IQ and WCST performance has been found in several studies that compared groups of individuals with different levels of IQ or WCST performance impairment. For example, in a study by Goldstein, Beers, and Shemansky (1996), individuals with poor WCST performance had significantly lower IQ subtest scores compared to those individuals that did not exhibit WCST performance impairment. Weickert et al. (2000), also found relatively impaired WCST performance in individuals with schizophrenia with lower IQ estimates. In the same study, a minority of patients with schizophrenia demonstrated an average level IQ, and, to a lesser degree, they too demonstrated some WCST performance impairment compared to normal controls (Weickert et al., 2000). Similarly, Kremen, Seidman, Faraone, and Tsuang (2001), found that based on WCST and Visual-Verbal Test scores (Feldman & Drasgow, 1981), abstraction-executive function was relatively more impaired in individuals with schizophrenia who had an estimated low-average IQ compared to those with average IQ, although both groups demonstrated impaired abstraction-executive function compared to IQ-matched normal controls.

Finally, in a study by Dieci et al. (1997), WCST performance was not able to better discriminate healthy controls from individuals with schizophrenia when compared to IQ scores, suggesting that WCST may not represent a pronounced deficit separate from a general intellectual deficit. Not all studies, though, have found a significant

association; in a study by Morice and Delahunty (1996), the correlation between WCST perseverative errors and IQ was not statistically significant (r = -0.34), and WCST performance impairments appeared to be present independent of any apparent deterioration in general intelligence from premorbid levels. However, this study used a small sample size (n = 17) and may also have been unusual in that while IQ scores were relatively lower compared to normal controls, the mean IQ for the schizophrenia group was still in the average range. Furthermore, as schizophrenia is a heterogeneous disorder, patterns of cognitive impairment may differ when looking at different levels of IQ (Weickert et al., 2000).

Overall, a review of the literature indicates some equivocal and contradictory findings, and not much is known about the actual processes that contribute to the poor WCST performance by persons with schizophrenia. As current research has yet to fully explain WCST performance impairments, the purpose of this study was to examine some of the hypothesized underlying cognitive processes that may contribute to the relatively impaired executive functioning of individuals with schizophrenia in a multicultural sample. To this end, measures of attention, working memory, processing speed, and general intelligence were correlated with executive functioning performance, as measured by the Wisconsin Card Sorting Test. It was hypothesized that relatively higher performances on measures of these cognitive processes would be positively associated with higher executive functioning performance.

Method

Participants

Participant data was obtained from archived neuropsychological reports from Hawaii State Hospital, a state forensic and psychiatric hospital serving a multicultural population. Subjects had been referred for neuropsychological testing, were found to have adequate vision and hearing, and completed a neuropsychological battery. A review of reports from April 1998 to August 2002 yielded 54 subjects. After excluding 9 subjects due to missing data, a total of 45 subjects remained in the study. At the time of their evaluation, individuals were either currently in an inpatient setting at Hawaii State Hospital (n = 43), in an outpatient setting (n = 1), or in community placement awaiting trial (n = 1). There were 37 (82.2%) males and 8 (17.8%) females. The average age was 36.42 (SD = 8.25), and the average number of years of education was 10.76 (SD = 2.10). Approximately half of the sample was of mixed ethnicity (n = 23, 51.1%). Other represented ethnicities included Caucasian (n = 8, 17.8%), Pacific Islander (n = 7, 15.6%), Asian American (n = 5, 11.1%), and African American (n = 2, 4.4%). Of those of mixed ethnicity, common ethnic combinations included individuals classified as "part Hawaiian" (n = 8, 17.8% of total sample), Caucasian and Pacific Islander (n = 3, 6.7%), and Asian American and Caucasian (n = 2, 4.4%).

Within the sample, 33 (73.3%) individuals had a primary diagnosis of schizophrenia, and 12 (26.7%) had a diagnosis of schizoaffective disorder. A comorbid substance abuse or dependence diagnosis was found in a majority (n = 29, 64.4%) of the participants. Drug use included alcohol (n = 18, 40%), marijuana (n = 12, 26.7%), cocaine (n = 7, 15.6%), methamphetamine (n = 4, 8.9%), amphetamine (n = 1, 2.2%), inhalants (n = 2, 4.4%), heroin (n = 1, 2.2%), PCP (n = 1, 2.2%), sedatives (n = 1, 2.2%), and unspecified polysubstance use (n = 7, 15.6%).

Measures

Indicators of general intelligence, working memory, and processing speed were derived from Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997) Full-Scale IQ, Working Memory Index, and Processing Speed Index scores, respectively. The Working Memory Index consists of scores on the Arithmetic, Digit Span, and Letter-Number Sequencing subtests. The Processing Speed Index consists of the Symbol Search and Digit Symbol-Coding subtests. The indicator of the cognitive process of attention was derived from the total number of errors on the Continuous Performance Test of Attention (CPTA-I), an auditory test of attentional vigilance (Cicerone, 1997; Nuechterlein, Buchsbaum, & Dawson, 1994). The Wisconsin Card Sorting Test (WCST) Categories Completed score yielded a measure of executive functioning.

Procedure

Data collection was based on an archived set of neuropsychological reports, which included demographic information, psychiatric diagnoses, and cognitive test scores. Participants were administered standard versions of neuropsychological tests by trained hospital staff, from which scores of cognitive and intellectual functioning were derived. Psychiatric diagnoses were determined from multidisciplinary group meetings, which routinely included hospital staff from psychiatry, psychology, nursing, and additional departments.

Statistical Analyses

Correlational analyses assessed the degree to which scores of attention, working memory, processing speed, and general intellectual functioning were associated with executive functioning. Statistical significance was set at the $p \leq 0.05$ level. A data transformation was also conducted on CPTA-I scores due to non-normal skewness and kurtosis; in accordance with Tukey's ladder of powers (1977), a square root transformation was able to successfully approximate normal skewness and kurtosis values for this

distribution. All other variables demonstrated normal distributions. The contribution of each WAIS-III subtest to the variance of executive functioning was not computed due to the sample size.

Results

Individuals with schizophrenia demonstrated impairment on cognitive tests, including the CPTA-I total number of errors (M = 33.93, SD = 22.53), WAIS-III Working Memory Index (M = 78.67, SD = 11.90), WAIS-III Processing Speed Index (M = 78.36, SD = 9.65), WAIS-III Full-Scale IQ (M = 78.69, SD = 10.18), and WCST Categories Completed (M = 2.91, SD = 1.84). Zero-order correlations between executive functioning scores and measures of attention (r = -0.23, p = 0.135), working memory (r = 0.18, p = 0.245), and processing speed (r = 0.21, p = 0.177) yielded only non-significant associations, which did not support the hypothesis that measures of attention, working memory, and processing speed would help explain or account for deficits in WCST performance in schizophrenia. However, executive functioning was significantly correlated with general intellectual functioning (r = 0.39, p = 0.009). Thus, the hypotheses of this study were partially supported. A post hoc analysis also found that even after controlling for attention, working memory, and processing speed, executive functioning was still significantly correlated with general intellectual functioning (r = 0.36, p = 0.020).

Discussion

It was hypothesized that relatively higher performances on measures of attention, working memory, processing speed, and general intellectual functioning would be positively associated with higher executive functioning performance, as measured by the Wisconsin Card Sorting Test (WCST). Contrary to expectations, results indicated that the specific cognitive processes of attention, working memory, and processing speed did not significantly correlate with executive functioning performance. However, scores of general intellectual functioning did significantly correlate with WCST performance, even after controlling for attention, working memory, and processing speed. These results suggest that general intellectual deficits may underlie executive functioning impairments in schizophrenia.

The results of this study appear consistent with findings that IQ often correlates with and can often be used to predict performance on a wide variety of neuropsychological tests (Diaz-Asper, Schretlen, & Pearlson, 2004). Even in healthy, non-clinical samples, IQ scores may be significantly associated with WCST performance in adults (Diaz-Asper et al., 2004; Heaton, 1981) and children (Arffa, Lovell, Podell, & Goldberg, 1998; Chelune, & Baer, 1986), although correlations appear more modest than in clinical samples (Heaton, 1981). However, while general intellectual functioning is often thought to be relatively stable, remediation studies indicate that the deficits associated with schizophrenia with respect to WCST performance do not appear wholly unremediable (Bellack et al., 1990; Delahunty et al., 1993; Metz et al., 1994; Perry et al., 2001; Vollema et al., 1995; Young & Freyslinger, 1995). In addition, it has been shown that the skills measured on commonly used IQ tests are trainable (Staats, 1989; Staats, 1990; Staats & Burns, 1981). Thus, the results of this study may also suggest the importance of examining cognitive processes that are associated with each WAIS-III (Wechsler, 1997) subtest, particularly those not included in the computation of Working Memory and Processing Speed Index scores.

Perceptual organization and verbal comprehension, for example, may contribute to WCST performance. Scores from individual subtests that compose the WAIS-III Verbal Comprehension and Perceptual Organization Index scores were not able to be analyzed in this study due to a small sample size. However, the skills necessary for each of these subtests may also be important for WCST performance. For example, skills measured by WAIS-III verbal subtests not directly analyzed in this study include distinguishing essential from non-essential detail, using abstract symbols, and abstract reasoning (Groth-Marnat, 2003). Planning ability, attention to detail, accurate responding to visual-spatial material, visual-spatial reasoning, and visual alertness and concentration are other skills measured by WAIS-III performance subtests (Groth-Marnat, 2003) not directly analyzed in this study. Furthermore, additional WAIS-III score configurations, such as Horn's (1985; Kaufman & Lichtenberger, 2002) Broad Visualization, as well as Bannatyne's (1974) Spatial Abilities, involve groupings of subtests not included in the Working Memory and Processing Speed Index scores. As WCST performance also involves the use of visual cues, reasoning, and planning, these skills may prove to be significant contributors to understanding WCST performance impairment.

It is also possible that cognitive processes not as explicitly measured by the WAIS-III may be impaired in schizophrenia and factor into impaired WCST performance. Cognitive processes, for example, such as concept formation and attribute identification (Perrine, 1993) or insight and metacognition (Koren et al., 2004) may better account for WCST performance impairments in individuals with schizophrenia. In terms of treatment implications, the identification of these potentially important cognitive processes may translate into improved WCST performance and executive functioning in individuals with schizophrenia. However, based on the results of this study, it would appear that a specific focus on improving attention, working memory, and processing speed may not carry over to improved WCST performance within this population of individuals with schizophrenia.

The results of this study may be limited in their generalizability. First, the sample of the present study was drawn from a relatively understudied multicultural population

(Leong, 1989) living in the Hawaiian Islands and thus consisted of a relatively large proportion of individuals of Asian Pacific Islander descent. As such, related factors that were not included in the archived data used in this study (e.g., language proficiency, acculturation, familiarity with cognitive testing, etc.) may have impacted the statistical findings of this study. A review of the literature indicates that few studies have examined WCST performance deficits in ethnic minorities, and, in general, there is a need for more psychological studies on ethnic minorities (Sue, 1999). This appears particularly relevant as IQ scores vary across ethnic groups (Lynn, 1996; Suzuki & Valencia, 1997), and ethnic background may predict performance on neuropsychological tests (Gladsjo et al., 1999). Individuals from disadvantaged cultural groups may also have higher rates of schizophrenia (Eaton & Harrison, 2000) and thus be at more risk for cognitive impairment.

A second characteristic of the sample that may have implications for generalization is the inclusion of subjects with dual diagnoses. Individuals with dual diagnoses are often excluded from neuropsychological studies, which may not be justified given that significant differences in WCST performance between non-affective psychotic patients with and without a dual diagnosis of comorbid substance use may not exist (Liraud & Verdoux, 2002). In addition, the high degree of comorbid substance use in individuals with schizophrenia (Regier et al., 1990) suggests that many studies to date have looked at only a small subset of the larger population of individuals with schizophrenia due to the exclusion of comorbid substance use. Comorbid substance use in this population may also be of great importance due to its association with poorer functional outcomes, more frequent hospitalizations, treatment noncompliance, a more severe course of the disorder, more severe symptomatology, and increased risk of suicide (Bartels et al., 1993; Jackson, Fein, Essock, & Mueser, 2001; Mueser, Bellack, & Blanchard, 1992). However, the research practice of combining data from individuals with different diagnoses invariably results in an increase in heterogeneity and may interfere with targeting what cognitive processes may be important to consider for executive functioning performance and the impairment that may be associated with specific disorders. The interpretation of statistical findings and the role that various cognitive processes may play in executive functioning in schizophrenia may have been clouded by the inclusion of dual diagnosis subjects. Further research examining potential differences between individuals with schizophrenia with and without substance abuse problems may help clarify this issue and whether similar research in the future would benefit from the inclusion or exclusion of such dual diagnosis subjects.

Several additional limitations of this study may be noted. Due to the correlational nature of the study, significant findings should not be interpreted as evidence of causation. Also, several potentially relevant factors were not able to be addressed adequately by the archived data set, such as diagnostic reliability, medication use, symptom severity, and the reason for referral for neuropsychological testing. Executive functioning performance and its relationship to other cognitive processes may differ for individuals with schizophrenia who are stable and on medications compared to those with more active and severe symptoms. Future research may help to address these limitations and clarify what cognitive processes may help explain WCST performance in schizophrenia.

Addressing potentially relevant factors such as medication use and symptom severity, as well as measuring cognitive processes not addressed in this study, may illustrate key aspects to understanding executive functioning impairment. A comparison of individuals with and without dual diagnoses may also shed light on the degree to which executive functioning impairment and its related cognitive processes may be affected by substance use and have to be taken into consideration. Furthermore, remediation studies with individuals with schizophrenia may provide the clearest evidence of the best path to cognitive rehabilitation.

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