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Performance on the Wisconsin Card Sorting Test Among Adolescents in Taiwan: Norms, Factorial Structure, and Relation to Schizotypy*

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ABSTRACT

The aims of this study were to assess developmental trends in performance on the Wisconsin Card Sorting Test (WCST) among 817 randomly selected adolescents aged 13-15 years, and to explore WCST performance factor structure and relationship to schizotypy. The results showed that of the nine WCST indexes, only the Categories Achieved and Failure to Maintain Set scores were associated with age, and only the Learning to Learn scores reached adult levels. Factor analysis of WCST performance scores yielded a three-factor structure. Psychometrically defined schizotypic subjects did not perform significantly worse than control subjects on any WCST indexes. These findings suggest that performance on various WCST indexes might indicate developmental changes at different ages, and deficits in WCST performance might not be sensitive indicators of vulnerability to schizophrenia in adolescence.

The Wisconsin Card Sorting Test (WCST) is a widely used neuropsychological measure of executive functioning, and is sensitive for assessing frontal lobe disorders (Robinson, Heaton, Lehman, & Stilson, 1980). Most previous studies of the WCST focused on adults, and age-specific normative data have been published (Heaton, 1981). Recently there has been increasing interest in applying the WCST to studies of young people (Axelrod, Goldman, Tompkins, & Jiron, 1994; Carter, Krener, Chaderjian, Northcutt, & Wolfe, 1995; Everett, Thomas, Cote, Lavesque, & Michaud, 1991; Ozonoff, 1995; Rybash & Colilla, 1994). Whether the WCST can sensitively demonstrate brain dysfunction

among children has been debated (Goldman, 1974; Mattes, 1980).

Studies of WCST performance among youths have consistently revealed improving performance with age during the childhood period, but have reported conflicting results regarding the age at which WCST performance reaches adult levels. On the basis of results of 105 school children 6 to 12 years of age, Chelune and Baer (1986) reported that the WCST performance of 10-year-old children is already indistinguishable from that of normal adults. Meanwhile, the study of Paniak et al. (1996) of 685 children 9 to 14 years of age revealed that while children's WCST performance improves with age, it does

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not reach adult levels by age 14. Thus, further investigation is warranted to determine whether and when WCST performance matures during adolescence.

Completion of the WCST requires executive functioning, including strategic planning, organized searching, applying external feedback to shift mental sets, and inhibiting impulsive responses (Heaton, Chelune, Talley, Kay, & Curtiss, 1993). These functions are likely manifestations of several different cognitive processes (Stuss & Benson, 1986). Several previous studies have attempted to decipher the underlying cognitive processes involved via factor analysis of WCST performance indexes. While the factor analyses previously reported are difficult to compare, because different sets of indexes were used, the majority of such studies reported a 3-factor structure of WCST performance (Bell, Greig, Kaplan, & Bryson, 1997; Guesta, Peralta, Caro, & deLeon, 1995; Koren et al., 1998; Paolo, Troster, Axelrod, & Koller, 1995; Sullivan et al., 1993). Only one study, which did not include several meaningful indexes in the analysis, reported a 2-factor structure (Greve, Brooks, Crouch, Williams, & Rice, 1997).

To better understand the processes involved in WCST performance, it would be useful to know whether the same WCST factor structure exists in subgroups of various clinical status and age. Factor analysis of performance indexes has revealed similar WCST factor structures among schizophrenic and schizoaffective patients (Bell et al., 1997; Guesta et al., 1995; Sullivan et al., 1993). Koren et al. (1998) also found such factor structure invariance across samples of schizophrenic patients and non-schizophrenic subjects (controls and relatives of schizophrenic patients). However, Paolo et al. (1995) reported that the factor structures of WCST performance of normal subjects and Parkinson's disease patients were not similar. The factor structure of WCST performance among youths has not been examined before. Further factor analysis of WCST performance incorporating well-defined indexes among adolescents may shed more light on the underlying factor structure of the WCST for this age group.

Although deficits in WCST performance have been noted to be associated with schizophrenia (Braff et al., 1991; Goldberg & Weinberger, 1994; Green, Ganzell, Satz, & Vaclav, 1990; Van der Does & Van den Bosch, 1992), the interpretation of such an association is generally confounded by variations in symptoms, severity of illness, neuroleptic medication, and length of hospitalization among subjects (Braff et al., 1991). One solution for this problem is to examine the WCST performance of schizotypic persons who are thought to have a genetic predisposition to schizophrenia (Kendler, Gruenberg, & Strauss, 1981) but have not yet exhibited symptoms, received neuroleptics, or been hospitalized (Lenzenweger & Korfine, 1994). In this regard, schizotypic adolescents are ideal subjects for studying whether there is a relationship between WCST performance and the genetic component of schizophrenia.

Different impairments in WCST performance have been noted in schizotypic adults. Subjects meeting the DSM-III-R criteria for diagnosis of schizotypal personality disorder have been reported to commit significantly more Perseverative Errors than control subjects (Raine, Sheard, Reynolds, & Lencz, 1992; Trestman et al., 1995). Meanwhile, studies using a psychometric high-risk strategy to identify persons with schizotypy (Lenzenweger & Korfine, 1994; Lyons, Merla, Young, & Kremen, 1991) have reported significantly lower scores on the Categories Achieved and higher scores on the Failure to Maintain Set indexes of the WCST in subjects with higher schizotypy scores. Whether similar associations between schizotypy and WCST performance deficits exist in adolescents, however, has not been examined yet.

Though widely applied since its development, the WCST has had several different versions with variations in administration procedures (manual vs. computerized) and scoring systems (Grant & Berg, 1948; Nelson, 1976). The test procedures and indexes used became more uniform after a WCST Manual was published by Heaton (1981). Results with computerized administration of the WCST were found to be similar to those obtained by standard administration (Artiola i Fortuny & Heaton, 1996; Tien et al.,

1996). In this study we used a computerized version to measure WCST performance norms among a large and randomly selected sample of adolescents and to evaluate the trends in WCST performance across the age range of 13-15 years. Factor analysis using WCST performance indexes was performed to observe the latent structure of WCST performance in adolescents. Relationships between WCST scores and its factor components and schizotypy were also investigated.

METHODS

Subjects

The subjects of this study were junior high school students selected through a multiple-stage sampling procedure. First, 71 public junior high schools in Taipei City were classified, according to the mean education years of residents of the district where the schools were located, into three groups with equivalent total numbers of students. One of the schools in each group was randomly selected and invited to participate in the study. Three classes in each grade (1 to 3) of the participating schools were then randomly selected, and all students in the selected classes were included in the study. In all, 971 persons from 27 classes were selected. All participants were asked to take the WCST and to fill out a questionnaire containing scales measuring schizotypy. Because some of the students refused to participate and some were absent at the time of data collection, 907 students completed the WCST and 906 completed the questionnaire. The WCST data of four students were deleted because they pressed the escape key (Esc) accidentally during the test and terminated the test prematurely. The ages of the remaining 903 participants ranged from 12 to 16 years. Since the numbers of subjects in the age groups of 12 ($n = 33$) and 16 ($n = 53$) years were relatively small, data from these subjects were deleted from further analyses. Thus, the WCST data of 817 students (49% boys and 51% girls) were used for descriptive and factorial analyses. Of these, 809 (48% boys and 52% girls) also completed the personality questionnaires and their data were used to investigate relationships between schizotypy and WCST performance.

WCST

We employed a computerized version of the WCST that was developed by one of the authors

(AYT). This software version runs in DOS on a desktop or portable computer with a color screen (Tien et al., 1996). During the WCST, subjects were required to match response cards to the four stimulus cards along one of three dimensions (color, form, or number) by pressing one of the 1 to 4 number keys on the computer keyboard. Subjects were not informed of the correct sorting principle, nor were they told when the principle would shift during the test, but they were given feedback ("Right" or "Wrong") on the screen after each trial. Unlike one common form of the traditional WCST in which the test ends after six correct categories achieved, the testing in this study continued until all 128 cards were sorted. The test results were scored by the computer software program and saved on diskettes.

All of the indexes defined in the WCST manual (Heaton et al., 1993) except for Total Correct were used for analysis. The Total Correct index was not included since it is complementary to Total Errors. The indexes used were (1) Total Errors: total number of perseverative and nonperseverative errors; (2) Nonperseverative Errors: number of errors that were not perseverative; (3) Perseverative Errors: number of errors that were perseverative, reflecting tendency towards perseveration; (4) Perseverative Responses: number of responses that were perseverative, regardless of whether they were correct or not; (5) Categories Achieved: number of times 10 correct responses in a row were made, reflecting overall success; (6) Trials to Complete First Category: number of trials to successfully complete the first category (counted as 129 if no category was completed), reflecting initial conceptual ability; (7) Conceptual Level Response: proportion of consecutive correct responses occurring in runs of 3 or more, reflecting insight into the correct sorting principles; (8) Failure to Maintain Set: number of times subject makes between 5 and 9 correct responses in a row, reflecting efficiency of sorting; and (9) Learning to Learn: average difference in percent errors between successive categories, reflecting the average change in conceptual efficiency during the test (Heaton et al., 1993). The last index can be calculated only for whom the total numbers of Categories Achieved and categories attempted are larger than 3. Percent Total Errors, Percent Nonperseverative Errors, Percent Perseverative Errors, and Percent Perseverative Response were calculated by dividing the respective raw scores by 128 and multiplying the result by 100.

Questionnaire

The questionnaire used in the study was composed

of questions to assess demographic features; a handedness assessment; the "Juvenile Eysenck Personality Questionnaire" (JEPQ) (Eysenck, 1975); the "Schizotypal Personality Questionnaire" (SPQ) (Raine, 1991); the "Perceptual Aberration Scale" (PAS) (Chapman, Chapman, & Raulin, 1978); the "Chinese Health Questionnaire" (CHQ) (Cheng & Williams, 1986); and the "Tridimensional Personality Questionnaire" (TPQ) (Cloninger, 1987). The SPQ, PAS, and CHQ questions were intermingled to minimize the potential offensiveness of some questions regarding aberrations in bodily perception, as suggested by Chapman et al. (1978).

The reliability and validity in the Taiwanese population of the two schizotypy scales, the SPQ and the PAS, have been reported in detail elsewhere (Chen, Hsiao, & Lin, 1997; Chen, Hsiao, Hsiao, & Hwu, 1998, respectively). Briefly, both the SPQ and PAS were translated from English to Chinese in two-stages. The internal consistency alpha in community samples of 345 adults (.90 for the SPQ and .78 for the PAS) and 115 adolescents (.93 for the SPQ and .70 for the PAS) and the intraclass correlation coefficient on the 1-week test-retest reliability test in 30 adults (.86 for the SPQ and .80 for the PAS) were satisfactory. The mean scores of both scales in the two Taiwanese samples were found to be lower than in Caucasian samples, possibly due to the less permissive Chinese culture. However, confirmatory factor analysis of the SPQ replicated the three-factor structure, i.e., cognitive-perceptual, interpersonal, and disorganization factors (Raine et al., 1994), in both the adult and adolescent samples. Further support for the validity of the two scales as measuring schizotypy in Taiwanese comes from their relationships with Continuous Performance Test (CPT) performance. In adults, higher SPQ and PAS scores were associated with poorer CPT performance. In adolescents, higher PAS scores were associated with poorer CPT performance, while neither total SPQ nor the 3 SPQ factor scores were associated with CPT performance. Thus, the PAS may be a more sensitive indicator of schizotypy in adolescents than the SPQ.

Procedures

All subjects filled out the questionnaire in their classrooms after written informed consent was obtained from the subjects themselves and one of their parents. The WCST was administered on desktop computers with color screens in the computer classrooms at each school. We were usually able to administer the WCST to 10-15 students in a session, depending on the number of desktop

computers available in each school. Standardized instructions (Heaton, 1981) were given prior to administration of the tests.

Statistical analyses

The mean of each WCST index for each age group was compared with the normative data reported by Heaton et al. (1993), using Student's *t*-test. The effects of age and gender on the WCST performance indexes were assessed by two-way analysis of variance (ANOVA). Since the derived percent-form indexes carry the same meaning as the original raw score indexes in this study, the former were not included in the factor analysis procedures. Principle component analyses followed by varimax rotation were then conducted on the nine WCST indexes. Factors with eigenvalues of 1 were retained and factors with loadings of 0.5 or greater were considered significant. The corresponding factor scores were calculated for each subject by summing up the *z*-transformation scores (derived from the total sample mean and standard deviation) of WCST indexes that loaded on the same factor.

Correlations between the WCST indexes and the schizotypy measures were assessed using Pearson correlation coefficients. Following Chapman and Chapman (1985), subjects who scored at least 2.0 SDs above the group mean on the PAS were defined as schizotypic. Modified from their definition of controls as those who scored no more than half a standard deviation above the group mean, those who scored half a standard deviation around the group mean were defined as controls. By this definition, there were 45 schizotypic subjects and 157 controls. Ages of the schizotypic ($M = 14.2$ years, $SD = 0.81$ years) were not significantly different ($t = -1.67$, $df = 200$, $p = 0.10$) from those of control subjects ($M = 14.0$ years, $SD = 0.79$ years). *T*-tests were applied to assess group differences in WCST indexes and factors between schizotypic and control subjects.

RESULTS

Two-way ANOVA revealed that gender had no main effects on the WCST indexes, whereas age had an effect on Categories Achieved [$F(2, 813) = 3.73$, $p < 0.05$] and Failure to Maintain Set [$F(2, 813) = 6.10$, $p < 0.01$] (Table 1). Post hoc comparisons with the Scheffe's test indicated that the differences were mainly between the 13- and 15- year-old age groups. The 13-year-old group also had a significantly higher mean score

than the 14-year-old group on the Failure to Maintain Set index.

The age-specific distribution of each WCST performance index in this study and the corresponding normative data reported by Heaton et al. (1993) are listed in Table 1. It was not feasible to compare directly the raw scores of the two studies because the number of total trials by each subject varied in Heaton et al.'s study. Nevertheless, we compared the percent-form indexes derived from raw score indexes, that is, the Percent Total Errors, Percent Nonperseverative Errors, Percent Perseverative Errors, Percent Perseverative Responses, Conceptual Level Responses, and Learning to Learn score. Though it is a raw score index, the Trials to Complete First Category index could be compared directly between studies because it is not related to the number of total trials.

For most of the indexes that could be compared, the mean scores of the 13- and 14-year-old age groups were not significantly different between the two studies, although the Learning to Learn score in the 13-year-old age group of our study was significantly higher ($t = 3.00$, $df = 267$, $p < 0.01$) than that in Heaton et al.'s (1993) study. However, the 15-year-old age subjects in our study had significantly poorer performance than that in Heaton et al.'s (1993) on Percent Total Errors ($t = 2.00$, $df = 287$, $p < 0.05$), Percent Perseverative Errors ($t = 2.74$, $df = 287$, $p < 0.01$), Percent Perseverative Responses ($t = 2.13$, $df = 287$, $p < 0.05$), Trials to Complete First Category ($t = 2.36$, $df = 287$, $p < 0.01$), and Conceptual Level Responses ($t = 2.30$, $df = 278$, $p < 0.05$). Because no normative data of WCST performance of adults in Taiwan are available, we compared the WCST performance of the adolescents in this study with that of the adults reported by Heaton et al. (1993). The performances on each comparable WCST index except Learning to Learn of all three age groups in this study were significantly poorer than that of adults aged 30-39 years in Heaton et al.'s (1993) report (Table 1).

Principal factor analysis of the nine indexes of the WCST followed by varimax rotation yielded three factors, namely "overall conceptualization / problem solving", "learning" and

"inefficient sorting", with eigenvalues of 5.01, 1.57, and 1.24, respectively (Table 2). These three factors explained 88% of the variance. Most of the WCST indexes loaded unequivocally on one of the three factors, although Trials to Complete First Category loaded on both "overall conceptualization / problem solving" and "learning", with higher loading on the latter.

Pearson product moment correlation coefficients revealed that most of the individual WCST performance index scores did not correlate with any measures of schizotypy (total PAS score, three SPQ factor scores, and total SPQ score) ($|\gamma|$ ranging from 0.0 to 0.06, $p > 0.1$), although the Categories Achieved index correlated weakly with factor 2 (interpersonal factor) of the SPQ ($\gamma = 0.07$, $p = 0.04$). Similarly, no significant differences on any WCST performance index and factor were noted between psychometrically-defined schizotypic (high PAS) and control (low PAS) subjects (Table 3).

DISCUSSION

Developmental Trends and Comparability

While the lack of a gender effect on WCST performance among our adolescent sample is consistent with the results of previous studies (Chelune & Baer, 1986; Paniak et al., 1996), the effect of age is not. Unlike the normative data reported in the WCST manual (Heaton et al., 1993), which indicated that all WCST indexes are quadratically associated with age and that performance on each index improves with age among adolescents 13-15 years of age, the developmental trends of the WCST indexes in this study were less prominent. Among the WCST indexes examined in this study, only Categories Achieved and Failure to Maintain Set were associated with age; the other indexes were stable across the age interval of 13-15 years. Two sampling-related reasons might have contributed to the differences in the developmental trends of the two studies. First, subjects with a history of neurological dysfunction, learning disability, emotional disorder, or attentional disorder were screened out in Heaton et al.'s study, while we

Table 1. Means and Standard Deviations of Wisconsin Card Sorting Test Indexes among Adolescents 13-15 Years of Age and Adults 30-39 Years of Age.

WCST index	This study						Heaton et al. (1993)							
	13 years (N = 240)		14 years (N = 320)		15 years (N = 257)		13 years (N = 29)		14 years (N = 27)		15 years (N = 32)		30-39 years (N = 63)	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Total Errors	42.5	(19.4)	41.1	(19.8)	40.1	(19.6)	42.5	(19.2)	34.6	(22.7)	27.0	(18.1)	16.2	(13.3)
Percent Total Errors (%)	33.2	(15.1)	32.1	(15.4)	31.4	(15.3)***	35.0	(13.0)	29.9	(15.6)	26.0	(12.4)	17.6	(10.7)
Nonperseverative Errors	19.6	(10.8)	20.5	(12.8)	19.2	(10.6)	21.1	(13.6)	17.6	(17.4)	14.8	(13.3)	7.9	(7.4)
Percent Nonperseverative Errors (%)	15.3	(8.4)	16.0	(10.0)	15.0	(8.3)	17.5	(10.1)	15.1	(13.0)	13.9	(9.8)	8.7	(7.8)
Perseverative Errors	23.0	(15.5)	20.6	(12.8)	21.0	(13.5)	21.3	(10.5)	16.9	(10.7)	12.3	(6.4)	8.3	(7.0)
Percent Perseverative Errors (%)	17.9	(12.1)	16.1	(10.0)	16.3	(10.5)****	17.5	(7.3)	14.8	(7.2)	12.1	(4.2)	8.9	(4.8)
Perseverative Responses	26.2	(20.5)	23.2	(16.4)	23.5	(17.3)	25.3	(14.1)	18.7	(12.7)	13.3	(7.1)	8.9	(8.3)
Percent Perseverative Response (%)	20.5	(16.0)	18.1	(12.8)	18.8	(14.7)***	20.7	(10.1)	16.3	(8.8)	13.1	(4.9)	9.4	(5.8)
Categories Achieved	5.0	(2.5)*	5.5	(2.7)	5.7	(2.7)	4.3	(1.5)	5.0	(1.5)	5.5	(1.2)	5.6	(1.1)
Conceptual Level Responses (%)	57.5	(20.3)	59.2	(20.6)	60.1	(20.8)****	55.2	(17.5)	63.7	(19.4)	68.7	(15.7)	78.8	(14.3)
Trials to Complete First Category	28.3	(31.8)	25.3	(27.9)	23.8	(23.8)****	18.7	(17.1)	19.1	(23.4)	12.9	(5.1)	12.2	(4.8)
Learning to Learn ^a	-2.0	(7.0)****	-2.1	(7.6)	-0.9	(6.3)	-5.7	(7.5)	-2.3	(5.0)	-0.9	(3.0)	-1.5	(3.4)
Failure to Maintain Set	2.0	(1.6)**	1.5	(1.4)	1.5	(1.3)	1.3	(1.0)	0.9	(1.1)	0.7	(1.2)	0.6	(1.1)

Note. Effects of age in this study were assessed with two-way ANOVA; * $p < 0.05$; ** $p < 0.01$. Differences of index scores between this study and Heaton et al. (1993) in each age group were tested with t -test; *** $p < 0.05$; **** $p < 0.01$. Differences of comparable index scores between each age group of this study and the 30-39 year-old group of Heaton et al. (1993) were tested with t -test; statistics for all t tests among all three age groups, except for Learning to Learn, were all significant and were not displayed in the table.

^a Numbers of subjects for whom "Learning to learn" could be calculated in this study are 209, 286, and 229 for the age group 13, 14, and 15 years, respectively.

Table 2. Factor Loadings from a Varimax Rotation Analysis of the 9 Wisconsin Card Sorting Test (WCST) Indexes among 817 Adolescents Aged 13-15 Years.

WCST index	Factors		
	Conceptualization/ Problem solving	Learning	Inefficient sorting
Total Errors	0.95	-0.28	-0.01
Nonperseverative Errors	0.67	-0.52	0.08
Perseverative Errors	0.93	0.04	-0.10
Perseverative Responses	0.92	0.13	-0.01
Categories Achieved	-0.82	0.26	-0.45
Conceptual Level Responses	-0.94	0.28	0.00
Trials to Complete First Category	0.57	0.61	0.23
Learning to Learn	-0.26	0.84	-0.06
Failure to Maintain Set	-0.08	0.03	0.97
Variance explained	56%	18%	14%

Factor loadings larger than 0.5 are in boldface.

did not screen for these features in our study. Second, the adolescent subjects in Heaton et al.'s were volunteers and the number in each age group was relatively small, while the subjects in the present study were selected randomly and the number was much larger. However, both Heaton et al.'s and this study were based on cross-sectional data only. A prospective follow-

up of an adequate cohort might be warranted to evaluate developmental changes in WCST performance more rigorously.

Despite the differences in developmental trends between our study and that of Heaton et al. (1993), evidence supporting comparability of the results of the two studies comes from the fact that the age-specific mean scores of most

Table 3. Wisconsin Card Sorting Test (WCST) Performance among Schizotypic and Control Subjects.

WCST index and factor	Schizotypic subjects (<i>N</i> = 45)		Control subjects (<i>N</i> = 157)		<i>t</i>	<i>p</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)		
Index						
Total Errors	40.1	(20.6)	43.9	(20.5)	1.09	0.28
Nonperseverative Errors	19.0	(10.7)	21.4	(11.8)	1.19	0.24
Perseverative Errors	21.1	(14.3)	22.5	(13.8)	0.62	0.54
Perseverative Responses	24.2	(18.4)	25.4	(17.6)	0.40	0.69
Categories Achieved	5.8	(2.8)	5.0	(2.6)	-1.71	0.09
Conceptual Level Responses (%)	60.8	(21.5)	56.2	(21.3)	-1.26	0.21
Trials to Complete First Category	24.1	(25.7)	27.8	(28.0)	0.66	0.51
Learning to Learn ^a	-2.6	(6.4)	-2.0	(8.1)	0.43	0.67
Failure to Maintain Set	1.5	(1.2)	1.7	(1.4)	1.03	0.31
Factor						
Conceptualization/Problem solving	-0.42	(6.31)	0.77	(6.04)	1.15	0.25
Learning	-0.38	(1.00)	-0.33	(1.05)	0.30	0.78
Inefficient sorting	-0.13	(0.81)	0.03	(0.95)	1.12	0.26

^aNumbers of subjects for whom "Learning to Learn" and "Learning factor" could be calculated are 41 for schizotypic and 137 for control.

WCST performance indexes in our study were not significantly different from those reported by Heaton et al. except for in the 15-year-old age group. The differences between the 15-year-old age groups in the two studies were in the Percent Total Errors, Percent Perseverative Errors, Percent Perseverative Responses, Trials to Complete First Category, and Conceptual Level Responses indexes, which are all components of the “conceptualization / problem solving” factor. In contrast, the Learning to Learn scores, which reflect changes in conceptual efficiency during the test, were not significantly different between these two studies among those aged 14 or 15 years. The difference in the Learning to Learn scores of the 13-year-old subjects in the two studies might reflect the lower mean index reported by Heaton et al. (1993).

Compared with the performance of adults aged 30-39 years of age reported in Heaton et al. (1993), the scores on Learning to Learn by the adolescents in this study did not show any developmental trends and had achieved the adult level. The scores on Categories Achieved and Failure to Maintain Set in this study showed developmental trends, but could not be compared directly to those of adults in Heaton et al.’s study because the number of total trials varied in that study. The scores on the other WCST indexes by the adolescents in this study neither showed any developmental trends nor had achieved the adult level, which is consistent with the findings of Paniak et al.’s (1996). Taken together, these findings suggest that different components of the WCST performance might end their developmental changes at different ages. A tentative sequence might be as follows: Learning to Learn, Categories Achieved and Failure to Maintain Set, and then the other indexes. However, this proposition warrants further validation by comparing the adolescents’ data to the performance of Taiwanese adults on the computerized version of the WCST.

Factor Structure

In contrast to the inconsistent results in terms of developmental trends on the WCST indexes, the results of factor analyses were more consistent with the findings of other studies. The 3-factor

structure and the components of the factors for WCST performance derived from the factor analysis in this study were almost identical to those from Paolo et al.’s study of normal adult subjects (1995). The only difference was that, in the current study, Trials to Complete the First Category loaded on both the “overall conceptualization / problem solving” factor and the “learning” factor, while it loaded only on “learning” in the study by Paolo et al. (1995). If Trials to Complete the First Category represents the “initial conceptualization”, it is reasonable that it would be part of the factor represented as “overall conceptualization”, though it loaded mainly on the “learning” factor along with the Learning to Learn index. Failure to Maintain Set, in both this study and Paolo et al.’s (1995), formed a factor by itself. Categories Achieved and Failure to Maintain Set loaded on different factors, consistent with their differences in association with age.

We found more variations in factor constituents in comparing our results with the findings of previous factor analysis studies of WCST indexes. This variation most likely reflects differences in the indexes included in various studies. The Learning to Learn index was not included for factor analysis in previous studies (Bell et al., 1997; Greve et al., 1997; Guesta et al., 1995; Koren et al., 1998; Sullivan et al., 1993) and hence the “learning” factor was not obtained. The “overall conceptualization” factor noted in our and Paolo et al.’s studies was similar to what was defined by other researchers as the “perseveration” factor (Bell et al., 1997; Guesta et al., 1995; Koren et al., 1998; Sullivan et al., 1993) or the “undifferentiated executive function” factor (Greve et al., 1997). An important finding is that the Nonperseverative Error index, which was a component of the “overall conceptualization” factor in our study, formed another factor labeled as “nonperseverative errors” in previous reports, either by itself (Bell et al., 1997) or along with the Unique Responses index (Guesta et al., 1995; Sullivan et al., 1993). The most invariant aspect of the factor analyses across these studies was that the “Failure to Maintain Set” index formed a factor named “inefficient sorting”, either by itself (Koren et

al., 1998; Paolo et al., 1995) or with the Total Correct Minus 10 Per Category Achieved index (an additional measure of failure to maintain set) (Greve et al., 1997; Guesta et al., 1995; Sullivan et al., 1993).

The finding of a two-factor solution by Greve et al. (1997) might have been due to the absence of Trials to Complete the First Category, Learning to Learn, Nonperseverative Errors, and Unique Response indexes in their study. Koren et al. (1998) included Unique Responses but not Nonperseverative Errors in their factor analyses. This resulted in a factor named "idiosyncratic sorting", which was solely composed of Unique Responses, rather than the "nonperseverative errors" factor reported by others (Bell et al., 1997; Guesta et al., 1995; Sullivan et al., 1993).

Relation of WCST index Scores to Schizotypy

Both the PAS and SPQ are psychometric indicators used to detect the latent schizotypy taxon, which Meehl (1990) suggested to be present in about 10 percent of the general population. However, the majority of previous studies of either PAS or SPQ were limited to college students or adults. Our previous study is the first to apply both scales in adolescents (Chen et al., 1998). In some contrast to a previous finding that higher PAS scores were associated with poorer CPT performance in adolescents, there were no correlations between the WCST performance indexes and the PAS or SPQ scores in the present study.

When psychometrically-defined schizotypic (high PAS) subjects were compared to control (low PAS) subjects, there were still no differences in WCST performance indexes and factors between the two groups. In contrast, Lenzenweger and Korfine (1994) found that similarly defined adult schizotypic (high PAS) subjects showed deficits on the Failure to Maintain Set and Categories Achieved indexes. Their results are consistent with those of other studies that used different definitions of schizotypy in adults (Lyons et al., 1991; Spaulding, Garbin, & Dras, 1989). It is intriguing to note that the two indexes reported to be poorly performed by schizotypic adults, Categories Achieved and Failure to Maintain Set, were the only ones

found to undergo developmental changes in this study. Thus, the lack of association between these two WCST indexes and schizotypy in the present study might indicate that such deficits in WCST performance do not manifest before the respective WCST index scores reach a mature level. Follow-up study of the adolescent cohort in the present study would help to clarify this issue.

Although higher scores on the Perseverative Errors and Perseverative Responses indexes are common findings in studies of WCST scores in schizophrenics (Bornstein et al., 1990; Green, Satz, Ganzell, & Vaclav, 1992; Koren et al., 1998; Wagman, Heinrichs, & Carpenter, 1987; Weinberger, Berman, & Zec, 1986), this study, and previous studies of schizotypic subjects, did not find this association (Lenzenweger & Korfine, 1994; Lyons et al., 1991; Spaulding et al., 1989). Lenzenweger and Korfine (1994) explained this discrepancy with the notion that Perseverative Errors scores increase only once the schizophrenia per se begins to unfold, and strengthened this explanation with the finding that patients with multiple-episode schizophrenia had significantly more Perseverative Errors than first-episode patients (Sweeney, Haas, & Li, 1992). Thus, the association between deficits in WCST performance and schizophrenia-spectrum psychopathology may vary depending on subjects' age, type of WCST indexes, and severity of the underlying psychopathology.

In conclusion, using a computerized version of the WCST in a large representative adolescent sample, most WCST performance indexes were observed to be stable during adolescence and did not reach adult levels by age 15, although scores on the Category Achieved and Failure to Maintain Set indexes did change with age during adolescence, and scores on the Learning to Learn reached adult levels by age 15 years. Despite possible cultural and ethnic differences, most of the WCST indexes scores by Taiwanese adolescents were similar to those by their Caucasian counterparts. The agreement between the 3-factor structure of the WCST performance found in Taiwanese adolescents and that in Caucasian adults indicates that the same cognitive processes are involved in WCST per-

formance across a range of ages and ethnic groups. Psychometrically defined schizotypic subjects did not perform significantly worse than control subjects on any WCST indexes. The results indicate that deficits on WCST performance might not be sensitive indicators of vulnerability to schizophrenia in adolescence.

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