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Using Processing Speed Tests to Predict the Benefit of Extended Test Time for University Students with Learning Disabilities

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Abstract

The present study examined the relationship between processing speed and the accommodation of extended test time for university students with learning disabilities (LD). At present most accommodation decisions are based on the student's LD documentation, though there has been little research which supports the relationship between specific tests and accommodations. In order to evaluate the predictive capability of three processing speed tests frequently included in the psychoeducational reports of students with LD, a logistic regression analysis was used to predict the probability of benefit from the accommodation of extended test time. In keeping with previous research, the Nelson Denny Reading Test (NDRT) was used as a measure of test performance for the controlled time and extended time test conditions. Participants were 30 university students with LD and 30 university students without learning disabilities (NLD) from a large research university in the East. Results showed that students with LD perform significantly lower on processing speed tests than NLD students, and when compared to NLD students, derived greater benefit from the extended time test condition on the NDRT. The Visual Matching and Cross Out processing speed tests from the Woodcock-Johnson Tests of Cognitive Ability-Revised were significantly correlated with the benefit of the extended time condition, and the Digit Symbol subtest from the Wechsler Adult Intelligence Scale-Revised was not. Of those students in the LD sample who benefited, 90% were correctly classified as likely to benefit.

Students with learning disabilities (LD) are the fastest growing group of individuals with disabilities receiving services in postsecondary settings (Gajar, Murphy, & Hunt, 1982; Henderson, 1995). This growth, in addition to the impact of disabilities legislation (e.g., American with Disabilities Act [ADA], 1990), has placed greater demands on disability support services in higher education (Brinckerhoff, Shaw, & McGuire, 1993; Vogel & Adelman, 1993).

The most frequently requested and provided services that students with LD receive through disability support offices are test accommodations (Bursuck, Rose, Cowen, & Yahaya, 1989; Nelson & Lignugaris-Kraft, 1989; Yost, Shaw, Cullen, & Bigaj, 1994). The right to test accommodations stems primarily from regulations accompanying statutory law (e.g., ADA, 1990; Section 504 of the Rehabilitation Act of 1973). Examples of test modifications may include (a) having a proctor read the test to the student; (b) having a proctor act as writer for the student; or (c) taking the test in an alternate format (e.g., open-ended questions versus multiple choice questions). However, the most commonly requested test accommodation allows a student more time to take a classroom exam (Bursuck et al., 1989; Nelson & Lignugaris-Kraft, 1989; Yost et al., 1994).

"More time" is typically defined as one and a half to two times longer than a non-LD (NLD) peer is permitted to take the test (Brinckerhoff, 1991). While each student with a LD does not need the same accommodation(s), most are permitted to request extended test time. If time can be deemed a critical component in the competency of a skill or ability, the faculty or institution is not required to make the accommodation.

In a recent survey, 100% (n = 91) of the postsecondary service providers for students with LD indicated they determine a student's accommodations based largely on tests from the psychoeducational documentation used for the diagnosis of the LD (Ofiesh & McAfee, in press). The analysis of test scores from documentation is a common practice and may be helpful in individual cases for predicting college success (Vogel, 1986). However, Adelman (see McGuire et al., 1991) stated there is no standard formula or equation to guide the process of using documentation to grant test accommodations, and research is needed not only to document when a request is valid, but also when it is not. One way to validate an accommodation request is to base the decision, in part, on research which supports the relationship between specific tests and specific accommodations. For example, information on the relationship between specific tests that measure processing speed and the accommodation of extended test time, could help service providers to formulate their clinical judgment on the appropriateness of extended test time for an individual.

Most psychoeducational evaluations and documentation include tests of processing speed as part of the intelligence or ability testing. Processing speed tests were developed to measure how a student performs with respect to correct responses and time constraints (Anastasi, 1988; Runyun, 1991). College students must perform in a similar manner on classroom tests. Based on the idea that processing speed tests and classroom tests require correct responses in a certain timeframe, this study examined the relationship between three processing speed tests and the likelihood of benefit from the accommodation of extended test time.

Theoretical Rationale for Examining the Relationship Between Processing Speed and Test Time

The accommodation of extended test time was built on a growing body of literature which supports the contention that some individuals with LD characteristically take longer than do NLD individuals to complete a variety of timed tasks (e.g. reading passages, math calculations) (Bell & Perfetti, 1994; Geary & Brown, 1990; Hayes, Hynd & Wisenbaker, 1986; Wolff, Michel, Ovrut, & Drake, 1990), and more specifically, times tests (Alster, 1997; Jarvis, 1996; Runyun, 1991; Weaver, 1993). Extended test time most often does not significantly benefit NLD students (Alster, 1997; Runyun, 1991; Weaver, 1993). Scores on timed academically-based tests (standardized or classroom) and scores on processing speed tests have one major similarity: both scores depend on the number of correct responses completed in a designated time frame. If processing speed test scores could determine the probability of those students who might benefit from the accommodation of extended test time, service providers may be able to improve their professional decisions regarding which students are most likely to benefit from extended test time on classroom tests.

Definitions of Speed and Processing Speed

Speed. The construct of speed as a cognitive ability has been measured by researchers for years (Eysenck, 1986; Lorsbach & Gray, 1986; Reed & Jenson, 1993; Tomar & Cunningham, 1993; Vernon, 1983). One problem evaluating processing speed is that a variety of speeded tasks may be used depending on the nature of the study, and the type of speeded task appears to influence the results. In this regard one consistent

finding is that both individuals with and without LD exhibit a range of responses on a variety of speeded tasks, and the intercorrelations between different speeded tasks are often very different for both groups. Research on the relationship between speed and IQ is less consistent.

The relationship between speed and intelligence is not simple (Neisser et al., 1996). Neisser et al. (1996) explained that high- and low-IQ individuals differ in other ways that affect speeded performance, and that researchers still have not answered the question which underlies the direction of relationship: Do high levels of "neural efficiency" promote the development of intelligence, or do more intelligent people simply find faster ways to carry out perceptual tasks? Or are both of the above stated conditions true?

Because students with LD have normal to above normal intelligence with some measured variation in cognitive or intelligence test performance, the application of these findings to them is even more complex. Even when intelligence is comparable between both students with and without LD, most students with LD characteristically perform lower and more variably than NLD students on many speeded tasks (Cordoni, O'Donnell, Ramaniah, Kurtz, & Rosenshine, 1981; Faas & D'Alonzo, 1990; Hayes et al., 1986; Spring & Capps, 1974; Spring, 1976). Researchers have suggested these findings may demonstrate that deficits in higher order cognitive processing found in children with LD persist into adulthood, and that the failure to automatize very basic subskills may relate to central nervous system dysfunction among individuals with LD.

Processing speed. Sattler (1992) has defined processing speed as the hypothesized ability underlying item content (perceptual processing) and mental process (speed) (p. 1044). Anastasi (1988) has explained that a pure speed test is one in which individual differences depend entirely on speed of performance and usually contains items of relatively low difficulty, while pure power tests are made up of increasingly difficult items so that virtually no one individual can get a perfect score, but scores reflect the number correct. Most tests are simply a combination of both speed and power to a varying degree. The scores from processing speed tests reflect more speed than power because the items often do not increase with difficulty, are relatively low in difficulty to most individuals, and are based on the number correct (Anastasi, p. 127). Anastasi (1988) has stated the objective of cognitive tests which measure certain constructs [processing speed] is to identify 'specific information processing components' (pp. 159-161).

Both the Woodcock-Johnson Tests of Cognitive Ability-Revised (WJ-R) (Woodcock & Mather, 1989) and the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981) were developed within cognitive paradigms which include the measurement of the construct processing speed. The processing speed tests of the WJ-R (i.e., Visual Matching and Cross-Out) and the WAIS-R (i.e., Digit Symbol) measure how a student performs with respect to correct responses and time constraints (Anastasi, 1988; Runyun, 1991). The Visual Matching and Cross-Out tests were devised initially to assess the processing speed factor in the theory of fluid and crystallized intelligence (Cattell, 1963; Compton, 1996; Horn, 1985). The Digit Symbol test of the WAIS-R was devised to assess psychomotor speed in the measurement of g (Wechsler, 1975; Swiercinsky, 1988). Using different theoretical bases, researchers have employed these tests as standardized measures of processing speed in order to evaluate the relationship between processing speed and other variables (Kail, 1992; Kail & Hall, 1994).

Studies involving Processing Speed Tests and College Students with Learning Disabilities

No study was located which compared the scores of college students with and without LD using the WJ-R tests. Several studies have found that children and adolescents with LD score significantly lower than subjects without LD on the processing speed test called Coding (Coding is the child normed version of the adult Digit Symbol test on the Wechsler scale) (Ackerman, Dykman, & Peters, 1977; Huelsman, 1970; Johnson & Wollersheim, 1997; Rugel, 1974; Vance, Wallbrown, & Blaha, 1978). Furthermore, researchers have found that this lower performance persists into adulthood (Cordoni et al., 1981; Slate, Frost, & Cross, 1991). In one study, the WAIS-R profiles of 57 college students with LD aged 17 to 25 were compared to a control group of 17 students without LD (Cordoni et al., 1981). The mean score for the NLD group on the Digit Symbol test was 12.1, while for the LD group it was 10.0. The mean score on the Digit Symbol test from the Cordoni et al. study approximated findings by Slate et al. (1991) who examined the WAIS-R stability for college students with learning disabilities and found the WAIS-R Digit Symbol scores to be highly stable over time.

Studies Investigating Extended Test Time for Students with Learning Disabilities

Four studies have been conducted to investigate the effectiveness of extended test time for college students with LD. Two used the Nelson Denny Reading Test (NDRT) (Brown, Bennett, & Hanna, 1981; Brown et al. 1993) under timed and extended time conditions (Runyun, 1991; Weaver, 1993); one used actual classroom tests under timed and extended time conditions (Jarvis, 1996), and one used the Asset Elementary Algebra Test (American College Testing Program [ACT], 1989) (Alster, 1997). The results of all four studies indicated that under time constraints, students with LD scored significantly lower than their normally achieving peers. When provided with extra time, significant score differences were not found between students with LD who received extended time, and their normally achieving peers who received no extra time.

In keeping with the studies on the effectiveness of extended test time by Runyun (1991) and Weaver (1993), the present study used the NDRT (Brown, Friscoe, & Hanna, 1993) to measure test performance under controlled time and extended time conditions. The processing speed tests used in this study were selected because they are a part of the two most widely administered tests to college students with LD (Ofiesh & McAfee, in press).

Students without learning disabilities were included in the study, in part, to compare the findings to previous research on extended test time. To examine the relationship between processing speed and extended test time, the following questions were developed:

1. Are the processing speed test scores significantly different among students with and without LD?

2. Are the gain scores between controlled time and extended time test conditions on the NDRT significantly greater for students with LD when compared to NLD students?

3. Using a logistic regression equation, can processing speed test scores predict the probability that an individual will benefit from extended time conditions?

Method

Design

A quasi-experimental design was used in the study, and a logistic regression analysis was employed to model the probability that a student's reading test score would increase under the extended test time condition. The model was based on the use of the WJ-R Visual Matching and Cross Out tests, and the WAIS-R Digit Symbol test as predictors of the probability of benefit (e.g., score increase) under extended test time.

Participants

A total of 60 undergraduate students (30 with LD and 30 without LD) were recruited for the study. There were 15 males and 15 females in both the LD and NLD groups. The average age was 22 for the LD group and 20 for the NLD group. Among the LD group, there were 3 freshmen, 9 sophomores, 9 juniors, and 9 seniors. Among the NLD group there were 17 sophomores, 6 juniors, and 7 seniors. Based on scores from the Kaufman Brief Intelligence Test (K-BIT) , (Kaufman & Kaufman, 1990), the mean IQ of the LD group was 101, SD = 8, and the mean IQ for the NLD group was 110, SD = 8. The mean reading rate score based on the NDRT was 195, SD = 21 for the LD group and 211, SD = 23 for the NLD group. English was the primary language for all of the participants. The sample included 3 Asian-Americans and 2 Hispanic-Americans. All others were Caucasian.

Each of the participants with LD met the following criteria: (a) 18-30 years of age; (b) full-time undergraduate; and (c) a diagnostic evaluation, which met the Office for Disability Services guidelines, including a statement in the diagnostic report indicating the diagnosis of a LD. All of the NLD participants met the same criteria with the exception of the LD diagnosis.

Instrumentation

Kaufman Brief Intelligence Test (K-BIT). To acquire descriptive data on the intelligence levels of the participants, the K-BIT was administered. This test is a brief, individually administered screener of verbal and nonverbal intelligence. The test consists of a Vocabulary section which measures crystallized thinking, the knowledge of words, and their meanings. The Matrices section measures fluid thinking, the ability to solve new problems through perceiving relationships and completing analogies. An IQ composite was scored. The administration time was 15-30 minutes. The K-BIT scores were used to report subject characteristics and evaluate the relationship of specific variables within LD and NLD groups using correlational statistics.

Nelson-Denny Reading Test (NDRT). To measure a change in test performance under controlled time and extended time conditions, the NDRT was administered. The NDRT has two statistically equated forms, G and H. The test contains a vocabulary section and a silent reading comprehension section. The first minute of the reading comprehension section is used for obtaining a reading rate. The Reading Comprehension section, the Vocabulary section, and the Reading Rate section were used. The Vocabulary section contains a total of 80 questions with multiple choice answers. The section is

designed to be completed in 15 minutes. The Reading Comprehension section contains eight reading passages and a total of 38 questions. This section is designed to be completed in 20 minutes.

In the NDRT manual it is stated that one of the uses for the alternate form is to evaluate an extended test time administration. All of the extended test time data in the manual and in this study were based on the use of an alternate form, and a time increase on the Vocabulary test from 15 to 24 minutes and on the Comprehension test from 20 to 32 minutes. These time extensions equated to 60% additional time under the extended time administration. The Reading Rate scores were reported as subject characteristics. Only the total NDRT scores (i.e., the combination of the Vocabulary and Comprehension Tests) were used in this study. Furthermore, these total scores were used as a gain score by subtracting the controlled time test score from the extended time test score. The gain score was used to (a) calculate score differences between the LD and NLD groups under extended time test conditions, and (b) calculate score differences within the LD and NLD groups on the NDRT, based on those participants who showed score increases and decreases. For use in the logistic regression analysis this score was recoded into a binary variable called the benefit/no benefit variable, where "1" represented an increase of 1 or more points (i.e., benefit) and "0" represented a decrease of 1 or more points, or no change in score (i.e., no benefit).

Processing speed tests. To measure processing speed, the Digit Symbol test of the WAIS-R and the Cross Out and Visual Matching tests of the WJ-R were selected. These scales were selected for the following reasons: (a) the tests were developed based on cognitive paradigms which include the construct of processing speed as a factor (Salvia & Ysseldyke, 1995; Sattler, 1992; Sweircinsky, 1988); (b) in two studies, the WAIS-R and WJ-R were found to be the most frequently used tests to measure intelligence and ability in university students with learning disabilities (Carlton & Walkenshaw, 1991; Ofiesh & McAfee, in press; and (c) previous researchers have used these three tests as measures of processing speed (Kail, 1992; Kail & Hall, 1994). The data from these tests were used to determine significant differences in processing speed between the LD and NLD groups. Additionally, the processing speed test data were the predictor variables used in the regression analyses. These tests are described below.

In the WAIS-R Digit-Symbol test, 93 numbers in a boxed, grid-like array are presented along with a "key" of nine numbers (1-9), each with an associated "symbol," a simple geometric design. The examinee must simply code each number, in the empty square beneath it, with its proper symbol, according to the key. The test requires passive associative learning of lexically based symbols, visual speed, attention, and intense, but brief (90 seconds), effort. The task is essentially one of new and unfamiliar learning under some pressure of time (Sattler, 1992).

The WJ-R Visual Matching test measures the ability to locate and circle the two identical numbers in a row of six numbers. In the Visual Matching task, each of 60 rows includes six digits, two of which are identical (e.g., 8 9 5 2 7 9). The task proceeds in difficulty from single-digit numbers to triple-digit numbers and has a 3-minute time limit (Woodcock & Mather, 1992). The performance measure is the number of rows completed correctly in 3 minutes.

In the Cross-Out test of the WJ-R, each of 30 rows consists of a geometric figure at the left end of a row and 19 similar figures to the right. One row, for example, consists of a triangle enclosing a single dot; the 19 figures are triangles with various objects inside (e.g., three dots, a plus and a square). The examinee places a line through the 5 figures of the 19 that are the same as the one at the left. Performance is measured by the number of rows completed in 3 minutes.

Procedure

The purpose of this study was to evaluate the use of processing speed tests from the WAIS-R and WJ-R to predict the probability that students would benefit under the accommodation of extended test time. To begin the study, students received a letter requesting their participation in research which examined learning abilities among university students. The letter did not disclose the exact nature of the study.

The participants with LD were a self-selected sample of students who had disclosed their disability and who, at the time of the study, were receiving services from the university's Office for Disability Services (ODS). No diagnostic testing was conducted through the ODS, and the content of students' documentation varied. All students' documentation met the LD eligibility guidelines at the university. These guidelines included, but were not limited to: (a) a diagnostic evaluation with intelligence and academic testing; (b) a diagnosis of specific learning disability made by a licensed psychologist or other appropriate diagnostician; and (c) evidence that the disability had significantly impacted the individual's academic achievement. During the recruitment period there were approximately 252 students with LD enrolled at the university. A total of 45 students with LD responded to the mailing.

The NLD participants were recruited from several undergraduate courses at the university. Approximately 250 informed consent forms were distributed to individuals who expressed interest in participating. A total of 49 NLD students volunteered to participate. Participants were selected by gender and LD/NLD status in the order the responses were received. Each person selected to be in the study was paid $25. All of the participants with and without LD who were selected for the study were administered the three processing speed tests from the WAIS-R and WJ-R, and the K-BIT during a 40 minute session. The NDRT was administered to all participants during one of five test sessions.

The five test sessions were conducted in a standardized manner. All participants were administered two alternate forms of the same reading exam: the NDRT (Form G and Form H). Form H was administered according to the standardization procedure of non-extended time described in the manual. This was the "controlled time" condition. After each participant completed the exam under the controlled time condition, participants were administered Form G with the directions, "This test is similar to the first only the questions are different and the timing is different. Please begin the Vocabulary section. You will have 24 minutes to complete this section." When the 24 minutes had passed, they were told to "Please begin the Comprehension section. You will have 32 minutes to complete this section." This was the "extended time" condition.

Data Analysis

All data were analyzed using the computer software package MYSTAT 2.1.1 (Hale, 1992) and SPSS Advanced Statistics for Windows 6.1 (Norusis, 1993). The data were analyzed using t-tests to determine significant differences between LD and NLD groups on processing speed and gain scores. The scores used from the WJ-R tests were the observed raw scores. The scores used for the Digit Symbol test from the WAIS-R were the converted standard scores. The WAIS-R scores were converted so that they could be directly compared to previous research which had also used the converted standard scores. Since no previous research was located on the WJ-R processing speed tests and the WJ-R raw scores are not directly converted to standard scores (see Woodcock & Mather, 1990), the raw scores were used. Pearson and point biserial correlation coefficients were used to evaluate the independent contribution of IQ to the benefit from extended test time.

Logistic regression analysis (Agresti, 1996), a non-linear, non-parametric statistical procedure was used to predict the probability that a student would benefit from extended test time based on processing speed. In the SPSS program the parameters for this analysis that make the observed results most "likely" were automatically established where the probability of the observed results were decreased less than .01 (Norusis, 1996). There are various ways to assess whether or not the model fits the data. This study used a classification table to compare predictions to the observed outcomes.

Results

The primary question addressed by this study was whether a predictive relationship could be established between processing speed and the probability of benefit on a reading test under extended test time conditions. The results of three specific questions are reported below.

Question One: Are the Processing Speed Test Scores Significantly Different Between Students with and without LD?

The results of a t-test for independent means indicated there was a significant difference between LD and NLD students for all three processing speed tests. The means of the groups for each test are listed in Table 1. When compared to the NLD group, the LD group performed significantly lower on each processing speed test: Digit Symbol ($t = 3.269$, $df = 58$, $p < .005$, two-tailed), Visual Matching ($t = 4.980$, $df = 58$, $p < .001$), and Cross Out ($t = 3.201$, $df = 58$, $p < .005$, two-tailed).

Question Two: Are the Gain Scores between Controlled Time and Extended Time Test Conditions on the NDRT Significantly Greater for Students with LD When Compared to NLD Students?

A reading gain score was calculated for each subject by subtracting the controlled time total reading score from the extended time total reading score. The mean scores for both groups under controlled time and extended time, and the mean gain scores are presented in Table 2. There was a significant difference between the gain scores for the LD and NLD groups ($t = -2.965$, $df = 58$, $p = < .005$). As a group, the students with LD increased, while the NLD students showed almost no increase.

To compare the gain scores of LD students who had score increases under extended test time, with the gain scores from NLD subjects who had score increases under extended test time, a supplemental analysis was conducted. The LD and NLD groups were subdivided by the benefit/no benefit variable. Scores used in this analysis are

listed in Table 3. The gain scores of the students with LD who benefited under extended test time (M=14.95) were approximately double the gain scores of the NLD students who benefited under extended test time (M=7.69). Within each group the gain score difference between those who benefited and those who did not was significant (LD: t = -4.497, df = 28, p = < 0.00; NLD: t = -6.227, df = 28, p = < 0.00).

To investigate the independent contribution of intelligence to the extended test time outcome, the intelligence scores between those who benefited and those who did not benefit, within each group of students (LD and NLD), were separately compared using a t-test. Within each group, there were no significant differences in the intelligence scores of those who benefited and those who did not benefit. The intelligence scores of those who benefited from extended test time in both groups were approximately 2 points higher than those who did not benefit (Table 3).

Question Three: Using A Logistic Regression Equation, Can the Probability of Benefit from Extended Test Time Be Predicted from Processing Speed Test Scores?

The third hypothesis was tested using logistic regression analysis, a procedure which models the probability that a person belongs to group A or group B. To begin the analysis, the Pearson and point biserial correlation coefficients between the three processing speed tests, the benefit/no benefit variable, the gain score, and the K-BIT total composite score were analyzed for significance. These correlations are listed in Table 4. The Visual Matching and Cross Out tests were significantly negatively correlated with the benefit/no benefit variable, indicating as the processing speed scores decreased, the association with benefit from extended test time increased. These two tests were included in the model. While Digit Symbol was significantly correlated with gain score, it was eliminated due to its nonsignificant correlation with the benefit/no benefit variable.

The K-BIT and gain scores were included in the correlation matrix to further evaluate the relationship between intelligence and performance under extended test time for the entire group. While intelligence was significantly correlated with two measures of processing speed (Visual Matching and Digit Symbol), it was not significantly correlated with the gain score or the benefit/no benefit variable.

The statistical analysis indicated that both the Visual Matching and Cross Out tests could significantly predict the probability that a student would benefit, as opposed to not benefit, under the extended time condition, when modeled independently of each other (p = < .005). The use of both predictors in the model did not increase the predicted odds of improvement. The log odds, standard error, and predicted odds of improvement are listed in Table 5. These scores suggest for every one unit of decrease on the Visual Matching and Cross Out tests, the predicted odds of benefiting from extended time, as opposed to not benefiting, are .89/.13 based on the Visual matching score and .74/.26 based on the Cross Out score. Practically speaking, as Visual Matching increases by one unit, a student is .8936 times as likely to improve as not to improve; or taking the inverse of .8936, as Visual Matching lowers by one unit, a student is 1.12 times as likely to improve as not to improve. As the Cross Out score lowers by one unit, a student is 1.33 times as likely to improve as not to improve.

For both groups a classification table was used to compare the predicted probability of a subject benefiting or not benefiting with the actual outcomes of the study. The results were exactly the same for both the Visual Matching and Cross Out tests.

Predictors for the probability of benefit or no benefit were correct for over 60% of the group; however the model correctly predicted 90% of the students with LD who benefited from extended test time. The percents in Table 6 show whether the estimated probability is greater or less than one-half, for each predicted group. The table does not indicate whether the 10 people who had false negative results had predicted probabilities near 50%, or lower probabilities.

A case analysis indicated that 19 of the 21 students with LD (90%) who benefited from extended time were correctly classified based on their Visual Matching and Processing Speed scores. Of the 9 students with LD who did not benefit 2 were correctly classified as not likely to benefit. Of the 13 students without LD who benefited from extended time, 5 were correctly classified as likely to benefit. Of the 17 NLD students who did not benefit, 12 were correctly classified as not likely to benefit.

Discussion

Differences in Processing Speed

The students with LD in this sample performed significantly lower than NLD students on all three processing speed tests. While the different processing speed tests produced different levels of significance between the LD and NLD groups, the 2-point discrepancy between the LD and NLD groups on the Digit Symbol tests was consistent with previous literature (Cordoni et al., 1981). This suggests Digit Symbol's use as a processing speed test appears to reliably measure processing speed differences in LD and NLD populations.

The largest significant difference between the groups was seen on the WJ-R Visual Matching test, followed by the WJ-R Cross Out test and lastly, the WAIS-R Digit Symbol test. Because the correlation between Digit Symbol and Visual Matching was the highest of all three processing speed tests, the difference in significance between the groups suggests these tasks place different demands on the "information processing components" of students with and without LD.

There are three main characteristics which set Visual Matching apart from Cross Out and Digit Symbol. The most obvious is that Visual Matching is the only one of the three tests based on purely numerical stimuli. The stimuli in Cross Out are abstract symbols, and the stimuli in Digit Symbol are abstract symbols and numbers, but Digit Symbol emphasizes copying. Secondly, the Visual Matching test demands a great deal of attention to the sequencing of numbers. Neither Cross Out nor Digit Symbol require the level of sequencing which Visual Matching does. Hessler (1993) stated that while both Visual Matching and Cross Out require concentration, the Visual Matching test requires sustained concentration.

Thirdly, contrary to Cross Out and Digit Symbol, the Visual Matching Test increases in difficulty; the task proceeds from single-digit numbers to triple digit numbers. This increase in difficulty means that of the three processing speed tests, Visual Matching incorporates the most power as compared to speed (Sattler, 1992). It may be these aspects of the Visual Matching test which made the task much more challenging to students with LD than to NLD students, especially more so than the Digit Symbol test. It is possible the Visual Matching test addresses the higher order cognitive deficits of adults with LD which Hayes et al. (1986) noted in the performance of these

adults on a speeded classification task. The performance differences on the Visual Matching test as compared to Cross Out and Digit Symbol support previous research which has found that despite intercorrelations among speeded tasks, the nature of these tasks can produce different results among both the LD and NLD populations (Cordoni et al., 1981; Faas & D'Alonzo, 1990; Hayes et al., 1986).

Group Differences in Reading Gain Score on NDRT Under Controlled and Extended Time

Students with LD increased an average of nine points on the extended test time administration of the NDRT, while the average increase of NLD students was only a fraction of one point. This finding does not apply to each student with and without LD. In actuality, 13 of 30 NLD students benefited from the extended time condition, and 9 of 30 students with LD did not benefit. As in previous research, students with LD in this study benefited to a greater extent than their NLD peers (i.e., 9 points vs. 10 point) (Runyun, 1991; Weaver; 1993). This finding diverges from the Jarvis (1996) study which found no statistically significant benefit for students with LD under extended test time when all the gain scores from a series of authentic classroom tests were averaged together. In that study there were gains for some students with LD on individual tests.

Similar to previous studies by Runyun (1991), Weaver (1993) and Jarvis (1996), not every one of the NLD students completed tests in the standard time frame, but their gains under extended time were not statistically significant. When the group means were evaluated, students with LD benefited to a significantly greater extent and more frequently, than NLD students. As Weaver noted, some NLD students perform similarly to students with LD (Weaver, 1993), but this finding does not warrant the accommodation of extended test time for NLD students. To warrant an accommodation under the ADA, an individual must provide documentation of a disability that significantly limits the ability to perform a major life activity [learning] (italics added) at an unequal level to NLD peers, as well as a pattern of substantial academic difficulties (ADA, 1990).

The finding that close to 50% of NLD students benefited from more time, although to a lesser degree than students with LD, is important for two reasons. First, it supports research that many of the information processing characteristics of college students with LD are similar to the normal variance in cognitive functioning of NLD college students, yet these characteristics become disabilities in the population with LD due to their severity and frequency (Vogel, 1996). Thus the accommodation of extended test time allows some students with LD the opportunity to perform at par with their NLD peers; the normal variance in cognitive functioning will still exist for both groups even when the accommodation is granted to students with LD.

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time, rather than "just enough" time, should be allotted to satisfy the needs of most students in the classroom. Yet this recommendation should be considered in light of the data which indicated that too much time may result in lower test performance and other unintended outcomes. Some students decreased by more than 10 points under the extended time condition, despite statistically equal alternate forms of the NDRT. Furthermore, some of the students who ran out of time in the first condition and did not complete the test, still did not improve with the accommodation of extended test time and the completion of all items on the test. Conversely, students who completed the test within the controlled time condition improved under extended test time. These inconsistencies may be test artifacts, a result of fatigue during the second test, and/or lack of motivation to perform on the NDRTs as one would perform where the consequences were more personal (e.g., earned grade or course credit). It is also possible that some participants in the group of students without LD may have undiagnosed learning disabilities.

Processing Speed as a Predictor

Once it was established that processing speeds were significantly different between students with and without LD, and that these groups perform significantly differently under extended test time, the extent to which a predictive relationship exists between processing speed and extended test time was examined. When the regression model was applied to both students with and without LD, both Visual Matching and Cross Out were found to predict the probability that a student would improve under extended test time with 70% accuracy. However, the accuracy with which a student was predicted as likely not to improve was slightly over 50%. A case analysis of this 70% revealed that 19 of the 21 students with LD were correctly identified.

This indicates the probability of predicting a successful accommodation for a student with a LD based on processing speed tests was reasonably good. Ninety percent of the students with LD who benefited from extended test time were correctly classified as likely to do so, based on their Visual Matching and Cross Out test scores. These findings suggest processing speed is correlated with performance under timed and extended time conditions for students with LD. Specifically, the lower an individual scores on processing speed tests, the more the probability increases that the person will benefit from extended test time. Furthermore, this finding suggests that for students without LD who benefit, the benefit is not as highly related to their processing speed scores as for students with LD. In general, this logistic analysis provides useful information regarding the relationship of certain processing speed tests and the accommodation of extended test time.

General Implications of Findings

Theoretical implications. Many learning disabilities theorists support an information processing model as an approach to understanding LD (Cattell, 1963; Horn, 1985; Woodcock & Mather, 1989). Within this model constructs such as short- and long-term memory, auditory processing, visual processing, and processing speed provide information on how an individual learns. It has been suggested that students with LD process certain types of information differently than NLD students. In the context of an information processing model, the findings of this study demonstrate that students with LD do seem to process information differently than their NLD peers despite average to above average intelligence.

Because the cognitive constructs which underlie many processing speed tests are not the same and result in different performance levels between students with and without LD, Anastasi's discussion regarding the use of tests to identify specific information processing components seems appropriate (Anastasi, 1988). The nature of a speeded task is an important determinant in how an individual performs under speed. There do seem to be specific 'information processing components' which distinguish the performance of students with and without LD, however, the interaction of these processes is not clearly understood.

One main theoretical implication that can be derived from this study is that students with LD are as much like NLD students as unlike. There seems to be a normal distribution of performance characteristics within the LD and NLD populations. In both groups scores under extended time decreased, did not change, and increased.

Applied implications. The findings on the performance difference of students with and without LD on processing speed tests has practical implications for college LD service providers. If normative data are accumulated on a specific university population, service providers can begin to better evaluate the processing speed test data provided in psychoeducational evaluations in the context of the setting demands of that specific university. Additionally, while NLD students are not entitled to the accommodation of extended time, educating faculty about adequate timing on course tests might provide all students with a better opportunity to demonstrate their knowledge.

While not all students with LD need or use the accommodation of extended test time, the results of this study imply that processing speed test scores from the Visual Matching and Cross Out tests, especially Visual Matching, may be good predictors of the probability of improvement under extended test time conditions. The significant relationship between processing speed and extended test time could be useful to service providers who use psychoeducational evaluations as part of their decision making process to determine reasonable accommodations for students with LD. To continue to use tests from LD documentation as a basis for service delivery without appropriate research is essentially an invalid technique. Messick (1988) stated

A variety of inferences may be made from scores produced by a given test, and there are many ways of accumulating evidence to support any particular inference. Validity, however, is a unitary concept. Although evidence may be accumulated in many ways, validity always refers to the degree to which evidence supports the inferences that are made from the scores. (p. 34)

General Limitations

The findings are limited by the fact that the test order was the same for all students in both groups and by the self selection of the participants to join the study. If similar research is conducted, it is recommended that the test order of the timed and extended time exams be counterbalanced to reduce the threat to internal validity. This was not feasible in this study, and some scores may reflect the statistical concept of regression to the mean. Additionally, while the participants did not know they were participating in a study on extended test time, they self-selected to participate in this study. There may be characteristics of this self-selected population such as self-motivation, which affected their performance on all of the tests in this study. This limitation could be evaluated by comparing the results from the present study to archival test data on students with LD who did not participate in the study.

It should also be remembered that university students with LD are not representative of all students with LD. The heterogeneity of the population limits the generalization of these findings to students with LD in other types of postsecondary education (e.g., vocational/technical schools, community colleges, universities with higher/lower admissions criteria). Clearly the sample in this study is underrepresentative of non-white participants.

Lastly, the practical application of this study to postsecondary students is limited by the nature of the logistic regression equation. It is not suggested that LD specialists use a statistical procedure as a "gatekeeper" tool to determine who is allowed extended time. This study does, however, provide evidence that the processing speed tests typically included in psychoeducational evaluations are related to the need and benefit of extended test time.

Future Directions

The findings of this study have raised further research questions. It is not clear if processing speed as a predictor of the probability of benefit of extended test time would replicate using actual classroom tests. Unfortunately, the use of actual classroom tests in a study such as this increases the number of confounding variables such as study skills and familiarity with test material.

Additional research needs to be conducted using a different test than the NDRT and with a larger sample size. It has been stated that the NDRT is a tightly timed test (Cummins, 1981). A more liberally timed test with a greater ceiling may be able to distinguish the timing differences between LD and NLD students to a more accurate degree. Further research also needs to address different test formats in relation to processing speed. For example, this study does not answer how processing speed predicts the probability of benefit from extended test time for essay or short answer tests.

Applying this regression model to a larger sample of students with LD may establish more information on the relationship between processing speed and benefit from extended test time. Subsequently, a better understanding of certain types of students with LD who benefit from extended time may result in identification of other characteristics that could be used to enter additional variables into a new regression model. It is possible that other tests from the WJ-R Tests of Cognitive Ability may exhibit stronger correlation with performance under extended test time. For example,

tests which measure analysis and synthesis in problem solving may account for some of the other 'specific information processes' involved in test taking performance.

A factor analytic study of the tasks in the processing speed tests could provide very useful information when compared to the essential tasks involved in reading. If the relationship between these factors and performance on a test like the NDRT could be better understood, this may provide useful information in the development of a speeded test more directly related to classroom tests. Also, it is important to recognize that processing speed can be impacted by other qualities such as motivation, field dependence/independence, depression, and attention (Hessler, 1993; McGrew, 1994). Weaver (1993) found significant differences between students with and without LD on anxiety and concentration scales. A regression model incorporating these characteristics which are often aspects of an LD and different from the typical performance of NLD students, may increase the probability of predicting which students will benefit from extended test time.

The results of future research would provide researchers and service providers with a better understanding of the test taking performance of students with LD. It cannot be overemphasized that the understanding of an individual's performance under controlled and extended test time involves a full understanding of the area of cognitive processing and learning. This study was intended to contribute some information to both of these areas so that students with LD can be better informed about their strengths and weaknesses, and service providers can feel competent in determining appropriate accommodations.

References

Ackerman, P. T., Dykman, R. A., & Peters, J. E. (1977). Hierarchical factor patterns on the WISC as related to areas of learning deficit. Perceptual and Motor Skills, 42, 583-615.

Adelman in McGuire et al. (1991), Journal of Postsecondary Education and Disability, 9, 232-240.

Agresti, A. (1996). An introduction to categorical data analysis. New York: John Wiley & Sons.

Alster, E. H. (1997). The effects of extended time on the algebra test scores for college students with and without learning disabilities. Journal of Learning Disabilities,30 (2), 222-227.

American College Testing Program. (1989). ASSET technical manual. Iowa City, IA.

Americans with Disabilities Act of 1990, 42 U.S.C.A. § 12101 et seq. (West 1993).

Anastasi, A. (1988). Psychological testing (6th ed.). New York: MacMillan.

Bell, L. C., & Perfetti, C. A. (1994). Reading skill: some adult comparisons. Journal of Educational Psychology, (86) 2, 244-255.

Brinckerhoff, L. C. (1991). Developing LD support services with minimal resources. Journal of Postsecondary Education and Disability, 9, 184-196.

Brinckerhoff, L. C., Shaw, S. F., & McGuire, J. M. (1993). Promoting postsecondary education for college students with learning disabilities: A handbook for practitioners. Austin, TX: PRO-ED.

Brown, J. I., Bennett, J. M., & Hanna, G. (1981). Nelson-Denny Reading Test. Boston, MA: Riverside.

Brown, J. I., Friscoe, V. V., & Hanna, G. (1993). Nelson-Denny Reading Test. Chicago, IL: Riverside.

Bursuck, W. D., Rose, E., Cowen, S., & Yahaya, M. A. (1989). Nationwide survey of postsecondary education services for college students with learning disabilities. Exceptional Children, 56 (3), 236-245.

Carlton, C. M., & Walkenshaw, D. (1991). Diagnosis of learning disabilities in postsecondary institutions. Journal of Postsecondary Education and Disability, 9, 197-206.

Cattell, R. B. (1963). Theory for fluid and crystallized intelligence: A critical experiment. Journal of Educational Psychology, 54, 1-22.

Compton, C. (1996). A guide to 100 tests for special education. Upper Saddle River, NJ: Globe-Fearon..

Cordoni, B. K., O'Donnell, J. P., Ramaniah, N., Kurtz, J., & Rosenshein, K. (1981). Wechsler adult intelligence score patterns for learning disabled young adults. Journal of Learning Disabilities, 14 (7), 404-407.

Cummins, R. P. (1981). Test review: The Nelson-Denny Reading Test (Forms E and F). Journal of Reading, 25, 54-59.

Deary, I. J. (1995). Auditory inspection time and intelligence: What is the causal direction? Developmental Psychology, 31, 237-250.

Eysenck, H. J. (1986). Inspection time and intelligence: A historical introduction. Personality and Individual Differences, 7, 603-607.

Faas, L. A., & D'Alonzo, B. J. (1990). WAIS-R scores as predictors of employment success and failure among adults with learning disabilities. Journal of Learning Disabilities, 23 (5), 311-316.

Gajar, A. H., Murphy, J. P., & Hunt, F. M. (1982). A university program for learning disabled students. Reading Improvement, 19, 282-288.

Geary, D. C., & Brown, S. C. (1990). Cognitive addition: Strategy choice and speed-of-processing differences in gifted, normal, and mathematically disabled children. Developmental Psychology, 27 (3), 398-406.

Hale, R. L. (1992). Mystat statistical applications (Version 2.1.1) [Computer programming]. Cambridge, MA: Course Technology, Inc.

Hayes, F. B., Hynd, G. W., & Wisenbaker, J. (1986). Learning disabled and normal college students' performance on reaction time and speeded classification tasks. Journal of Educational Psychology, 78 (1), 39-43.

Henderson, C. (1995). College freshmen with disabilities: A statistical profile. Washington, D C: HEATH.

Hessler, G. L. (1993). Use and interpretation of the WJ-R. Itasca, IL: Riverside.

Horn, J. L. (1985). Remodeling old models of intelligence. In B. B. Wolman (Ed.), Handbook of development psychology (pp. 267-300). New York: Wiley.

Huelsman, C. B. (1970). The WISC subtest syndrome for disabled readers. Perceptual and Motor Skills, 30, 535-550.

Jarvis, K. A. (1996). Leveling the playing field: A comparison of scores of college students with and without learning disabilities on classroom tests. Unpublished doctoral dissertation, The Florida State University.

Johnson, D. A., & Wollersheim, J. P. (1997). WISC patterns and other characteristics of reading disabled children, Perceptual and Motor Skills, 45, 729-730.

Kail, R., & Hall, L. K. (1994). Processing speed, naming speed, and reading. Developmental Psychology, 30 (6), 949-954.

Kail, R. (1992). Processing speed, speech rate, and memory. Developmental Psychology, 25 (8), 899-904.

Kaufman, A. S., & Kaufman, N. L. (1990). Kaufman Brief Intelligence Test. Circle Pines, MN: American Guidance Service.

Kaufman, A. S., & Kaufman, N. L. (1990). Kaufman Brief Intelligence Test: Examiner's manual. In A. S. Kaufman and N. L. Kaufman: Kaufman Brief Intelligence Test: Circle Pines: American Guidance Service.

Lorsbach, T. C., & Gray, J. W. (1986). Item identification speed and memory span performance in learning disabled children. Contemporary Educational Psychology, 11, 68-78.

McCue, P. M., Shelley, C., & Goldstein, G. (1982). Intellectual, academic, and neuropsychological performance levels in learning disabled adults. Journal of Learning Disabilities, 15 (1), 39-43.

McGrew, K. S. (1994). Clinical interpretation of the Woodcock-Johnson Tests of Cognitive Ability-Revised. Boston: Allyn and Bacon.

Messick, S. (1988). The once and future issues of validity: Assessing the meaning and consequences of measurement. In H. Wainer & H. I. Braun (Eds.), Test validity (pp. 33-45). New Jersey: Lawrence Erlbaum.

Neisser, U., Boodoo, G., Bouchard, T. J., Boykin, A. W., Brody, N., Ceci, S. J., Halpern, D. F., Loehlin, J. C., Perloff, R., Sternberg, R. J., & Urbina, S. (1996). Intelligence: Knowns and unknowns. American Psychologist, 51 (2), 77-101.

Nelson, R. & Lignugaris-Kraft, B. (1989). Postsecondary education for students with learning disabilities. Exceptional Children, 56 (3), 246-265.

Norusis, M. (1993). SPSS for windows base system users guide release 6.0. Chicago, IL: SPSS Inc.

Ofiesh, N. S., & McAfee, J. (in press). Using psychoeducational evaluations for service delivery among college students with learning disabilities. Journal of Learning Disabilities.

Palmer, J., McLeod, C. M., Hunt, E. & Davidson, J. E. (1985) Information processing correlates of reading. Journal of Memory and Language, 24, 59-88.

Reed, T. E., & Jenson, A. R. (1993). Choice reaction time and visual pathway nerve conduction velocity both correlate with intelligence but appear not to correlate with each other: Implications for information processing. Intelligence, 17, 191-203.

Rehabilitation Act of 1973, 29 U.S.C. § 794 et seq.

Rugel, R. P. (1974). WISC subtest scores of disabled readers: A review with respect to Bannatyne's recategorization. Journal of Learning Disabilities, 7, 48-55.

Runyun, M. K. (1991). The effect of extra time on reading comprehension scores for university students with and without learning disabilities Journal of Learning Disabilities, 24, 104-108.

Salvia, J., & Ysseldyke, J. (1995). Assessment (6th ed.). Boston: Houghton Mifflin.

Sattler, J. (1992). Assessment of children (3rd ed.). San Diego: J. M. Sattler.

Slate, J. R., Frost, J., & Cross, B. (1991). WAIS-R stability for college students with learning disabilities. Learning Disability Quarterly, 14, 2-6.

Spring, C. (1976). Encoding speed and memory span in dyslexic children. Journal of Special Education, 10, 35-40.

Spring, C. & Capps, C. (1974). Encoding speed, rehearsal, and probed recall of dyslexic boys. Journal of Special Education, 66, 780-786.

SPSS Advanced Statistics for Windows 6.1 (1993) [Computer programming]. Chicago, IL: SPSS Inc.

Swiercinsky, D. P. (1988). WAIS-R tutorial workbook. Austin, TX: PRO-ED.
Tomar, A., & Cunningham, W. R. (1993). The structure of cognitive speed measures in old and young adults. Multivariate Behavioral Research, 28 (1), 1-24.

Vance, H. B., Wallbrown, F. H., & Blaha, J. (1978). Determining WISC-R profiles for reading disabled children. Journal of Learning Disabilities, 11, 657-661.

Vernon, P. A. (1983). Speed of information processing and general intelligence. Intelligence, 7, 53-70.

Vernon, P. A. (1987). Speed of information processing and intelligence. Norwood, NJ: Ablex.

Vogel, S. A., & Adelman, P. B. (1993). Success for college students with learning disabilities. New York: Springer-Verlag.

Vogel, S. A. (1986). Levels and patterns of intellectual functioning among LD college students: Clinical and educational implications. Journal of Learning Disabilities, 19, 71-79.

Weaver, S. M. (1993). The validity of the use of extended and untimed testing for postsecondary students with learning disabilities. Unpublished doctoral dissertation, University of Toronto, Toronto, Canada.

Wechsler, D. (1975). Intelligence defined and undefined: A relativistic appraisal. American Psychologist, 30, (2). 135-139.

Wechsler, D. (1981). Wechsler Adult Intelligence Scale-Revised. San Antonio, TX: Psychological Corp.

Whyte, J., Curry, C., & Hale, D. (1985). Inspection time and intelligence in dyslexic children. Journal of Psychology and Psychiatry, 26, 423-428.

Wolff, P. H., Michel, G. F., Ovrut, M., & Drake, C. (1990). Rate and timing precision of motor coordination in developmental dyslexia. Developmental Psychology, 26 (3), 349-359.

Woodcock, R. W., & Johnson, M. B. (1989). Woodcock-Johnson Psycho-Educational Battery-Revised. Allen, TX: DLM Teaching Resources.

Woodcock, R. W., & Mather, N. (1989). WJ-R Tests of Cognitive Ability-Standard and Supplemental Batteries: Examiner's Manual. In R. W. Woodcock & M. B. Johnson, Woodcock-Johnson Psychoeducational Battery-Revised. Allen, TX: DLM Teaching Resources. (1992)

Yost, D. S., Shaw, S. F., Cullen, J. P., & Bigaj, S. J. (1994). Practices and attitudes of postsecondary LD service providers in North America. Journal of Learning Disabilities, 27, 631-640.

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