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The grooved pegboard test with LD and Non-LD children

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The Grooved Pegboard Test
with
LD and Non-LD Children

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Abstract

This study evaluated the effectiveness of the Grooved Pegboard Test (GPT) at identifying learning disabled (LD) children between the ages of 9 and 16. Fifty-six children were involved in the study: 27 in the LD group and 29 in the non-LD group. All subjects had a full scale IQ that fell in the 80 to 120 range. A battery of neurological tests was administered to all subjects and the data gleaned from each test was individually analyzed. Findings showed that the administration of the Grooved Pegboard Test produced statistically significant results in determining LD when subjects used their dominant hand in completing the task. Further research considerations suggest that the outliers should be investigated to see if they have neurological deficits.

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Table of Contents

List of Tables

The Grooved Pegboard Test with LD and Non-LD Children

Although learning disabilities were once thought to be rare, they are now believed to affect at least 5 percent of the population. Many experts feel that the number of individuals affected is actually much higher and that many students are not doing as well as they could in school because of disabilities that have been undiagnosed (Smith & Strick, 1997). These children are falsely labeled as slow, dumb or just plain lazy. Many parents pin their hopes on a son or daughter who simply lacks the ability to perform as well academically as his or her classmates. "If you would just try harder" seems to be the mantra that resounds from the lips of these frustrated, yet well-intentioned parents and teachers. However, no one is more frustrated than the students themselves. "What's wrong with me?" is a question that has no easy or clear-cut answers.

In the past, learning disabilities (LDs) have been presumed to be due to central nervous system dysfunction. It has been more than 100 years since learning problems were described in children that resembled deficits typically found in adults with known brain damage (Hynd, Marshall, and Gonzalez, 1991). It was thought that some developmental anomaly existed in the brains of these children in the region of the left parietal-occipital cortex and was believed to disrupt the functioning of the cortical pathways important in learning, particularly learning to read fluently. It was believed that there was some sort of familial link in what was then termed congenital word blindness. Therefore, by the early 1900's the foundation for the study of learning disabilities was firmly established. By the 1920's, dyslexia was first brought to the attention of American educators and doctors and by the 1940's researchers began to identify an explanation for learning difficulties as having a neurobiological basis (Connelly, 1999). Along the way, these children have been labeled as having "minimal brain damage" and in later years "minimal brain dysfunction."

Although definitions for learning disabilities have continued to evolve, it is difficult to come up with a set of clear, operational criteria. One of the first formal definitions of learning disabilities was proposed by the National Advisory Committee on the Handicapped (NACH) and later incorporated into the Children with Specific Learning Disability Act of 1975 (P.L. 94-142). This law defines a learning disability as a disorder in written or spoken language that results in an imperfect ability to listen, think, read, write, spell, or do math. Children who have learning problems as a result of visual problems, hearing problems, mental retardation, motor problems, or environmental deprivation cannot be classified as LD under this law (Kronenberger & Meyer, 1996).

Although learning disabilities have become the focus of more intense research in recent years, the fact is that the term learning disability refers not to a single disorder but to a broad range of afflictions that can affect any area of academic performance. Only rarely can they be traced to a simple cause (Smith & Strick, 1997). Many different problems can impair brain function, and these children's physiological problems are often complicated to some degree by their home and school environments. Learning disabilities can be divided into general types, but since they often occur in combinations and with a tremendous variance in severity, it can be very hard to see what students grouped under this label have in common. However, the one marker of this problem is that there is a discrepancy between what it seems the child ought to be able to do and what he or she actually can do. What they do have in common is simply unexpected underachievement (1997). Most of the time these children function in a way that is consistent with what would be expected from their intellectual ability and their educational and family backgrounds, but when given certain types of tasks, they find themselves at an impasse. As a result, their performance in school is inconsistent. They may be on target or even ahead of the class in some areas, but fall behind in others. To be able to pinpoint a workable definition, let alone a cause or proposed treatment, is a Herculean task.

For the purposes of this study the definition of learning disability is as follows: Learning disabilities is a general term that refers to a heterogeneous group of disorders manifest by significant difficulties in the acquisition and the use of listening, speaking, reading, writing, reasoning, or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the life span. Problems in self-regulatory behaviors, social perception, and social interaction may exist with learning disabilities but do not by themselves constitute a learning disability. Although learning disabilities may occur concomitantly with other handicapping conditions (e.g. sensory impairment, mental retardation, serious emotional disturbance) or with extrinsic influences (e.g. cultural differences, insufficient or inappropriate instruction), they are not the result of those conditions or influences.

Even though students with learning disabilities are by far the largest and the fastest-growing special-needs group in the American school population, questions concerning the causes of LD can be difficult to answer because multiple factors can contribute to this condition. In recent years, the relative importance of these causes has become a matter of increasing research and debate. Speculation about the etiology of LD has focused on one psychological and three biological theories (Kronenberger & Meyer, 1996). When focusing on a psychological theory, LDs are thought to be affected by environmental factors that influence behavior, motivation, and thought processes of the child in a way that interferes with learning. Sattler (1992) proposes that family size, parental education, family conflict, teaching techniques or other behavioral problems may be home and school environmental factors that can affect LD children. Other extraneous factors, such as severe anxiety or depression, may also be disruptive in the learning process.

The three biological theories for the cause of LDs include developmental lag, genetic factors, and neurological impairment (Kronenberger & Meyer, 1996). Developmental lag theories suggest that some children with LD have learning problems because their neurological development is progressing more slowly than that of other students of the same age. It could be that neurological development is one of those normally distributed traits, and LD children could be those children in the lower tail of the distribution. However, while this may be a possibility, it is not to suggest that the child will catch up with other children and become relatively normal.

Research conducted since the mid-1980's indicates that heredity plays a far greater role in determining the development of learning disabilities than previously believed

(Smith & Strick, 1997). Studies of the families of children with LD consistently find a higher than average incidence of similar learning problems among parents, siblings, and other related individuals. A new research focus in learning disabilities is attempting to locate a specific gene for learning disabilities by determining if learning problems regularly occur with some other trait whose genetic origin is already known (1997). This research also suggests that there are probably many ways that learning disabilities can be inherited such as unusual brain anatomy, uneven patterns of brain maturation, and susceptibility to diseases that affect brain function. However, although genetic predisposition may be associated with the development of learning disabilities, the presence of such conditions does not invariably predict an eventual learning disability, and there are many individuals with LD who have no such history (American Psychiatric Association, 1994).

Neurological theories state that LD is a reflection of structural damage or improper development of the nervous system (Kronenberger & Meyer, 1996). Development of the human brain begins at conception and continues through young adulthood. The nervous system of a fetus grows in stages, with different brain regions forming at different times throughout pregnancy. A particularly critical developmental period is the fifth to seventh months of gestation, when cells move into their proper positions in the cerebral cortex. This part of the brain is involved in virtually all aspects of conscious activity. Proper functioning of the cerebral cortex is essential for higher-level thinking and learning (Smith & Strick, 1997). During infancy and childhood, regions of the brain become increasingly specialized. If this ongoing process of neural development is disturbed at any point, parts of the brain may not develop normally.

The types of problems produced by errors in brain development depend in part on which regions of the brain have been affected. Since learning and other complex behaviors depend on the activation of circuits involving several brain areas, impairment in one brain region can affect growth and performance elsewhere in the system. For this reason, it is unusual for a student with learning disabilities to have a single, isolated weakness (Smith & Strick, 1997). Different patterns of related problems are far more common.

Early investigations attempting to explain irregularities or abnormalities of brain morphology in individuals with learning disability used computerized tomography (CT) (Bigler, Lajiness-O"Neill & Howes, 1998). The human brain is known to possess a number of functional and structural asymmetries. The left cerebral hemisphere generally specializes in language functions, and in most right-handed individuals the left parietoccipital region is wider than the right. Students showing a possible reversal of the usual cerebral asymmetry have trouble with reading, writing, and sometimes speech. Difficulties with language are also associated with poor comprehension and memory for verbal material. Such students often have difficulty with tasks involving logic and analysis. They take a global approach to learning and do not easily understand that specific sequences of activities or events are necessary to arrive at a final solution. Overactivitiy in the right cerebral hemisphere can produce delays in learning to read, as the right side of the brain is poorly adapted to the task of decoding words by breaking them into individual sounds and syllables.

The right side of the brain usually organizes and processes nonverbal information. Individuals with deficiencies in the right cerebral cortex can have problems with time sense, body awareness, spatial orientation, visual perception, and visual memory. Nonverbal communication begins at birth and contributes to the bonding between mother and infant. The right cerebral hemisphere is more developed than the left at birth, presumably because of the importance of right hemisphere-mediated visual-spatial and emotional interactions with the mother as part of the bonding process (Brumback, Harper, & Weinbert, 1996). Mothers (even left-handed women) tend to cradle infants with the left arm against the left breast, apparently to allow the infant's left visual field to see and left ear to hear the mother better, since such inputs go more directly to the right hemisphere. Even very young children at the end of the first year of life normally check their mother's facial expression to see if an activity is safe or not, and a mother can effectively regulate a young baby's behavior through a series of glances and affective expressions (Voeller, 1995). As these children continue to grow they often have difficulty understanding the perspectives of others and cannot conduct interactive conversations, often focusing on topics that are of little interest to their social group.

In attempting to evaluate and diagnose children with learning disabilities, four elements are essential: the clinical history, the neuropsychological testing, the evaluation of social emotional functioning, and the assessment of achievement (Fennell, 1995). The clinical history, obtained by review of medical records and clinical interview of the parents, should focus on previous or current medical or psychosocial factors that could contribute to neurobehavioral problems. A family history of learning disabilities is obtained along with a thorough review of preschool and school experiences, including information on any prior remediation efforts.

In assessing children for neuropsychological function, experts agree that the assessment of a potential learning disability requires a multifaceted approach (Gregory, 1997). There is little consensus as to the best instruments and techniques, however, the most essential tools in the assessment of learning-disabled children are reliable and valid achievement and intelligence tests. Most LD test batteries include instruments in both areas, for example the Stanford-Binet:Fourth Edition (SB:FE), Weschler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R), or the Weschler Intelligence Scale for Children-III (WISC-III) for intellectual assessment. For measurement of achievement, the Weschler Individual Achievement Test (WIAT) or the Woodcock-Johnson Psycho-Educational Battery (WJ-R) are frequently utilized. However, the choice of additional measures differs widely from one practitioner to another. The choice of measures will depend upon the age of the subject and the nature of the referral question. Some additional tests that may be employed would assess brain-behavior relationships to measure sensory output, attention and concentration, learning and memory, language skills, visuo-spatial and manipulatory skills, and motor output (1997).

Social-emotional functioning is another assessment domain that is typically addressed in the neuropsychological examination. Information is gathered from parent interview, teacher reports of classroom problems, and child interview. An important concern is to assess the degree to which social-emotional symptoms and behavior problems are a reaction to other cognitive deficits or are a primary manifestation of brain disorder (Fennell, 1995).

Most research and clinical work in LD is conducted with the assumption that a specific learning disability is considered to exist when there is a significant discrepancy between an individual's intellectual/cognitive ability and academic achievement that is manifested in one or more receptive or expressive skills. Although the assessment of a learning disorder is based on various psychometric tests, the underlying assumption is that neurologic irregularities or abnormalities are the basis of the disorder (Bigler, Lajiness-O'Neill & Howes, 1998). The human brain is known to possess a number of functional and structural asymmetries. A possible reversal of the usual cerebral asymmetry or an increased ratio of symmetry has been reported in some children with LD with the use of magnetic resonance imaging (MRI). The electroencephalogram (EEG), which is a graphic record of the electrical currents developed by the cerebral cortex, has also been used to identify a number of brain irregularities in individuals with learning disabilities, but no consistent patterns have been shown. Likewise, Positron Emission Tomography (PET) and Single Photon Emission Computerized Tomography (SPECT) allow observation of metabolic activity and/or cerebral blood flow over time in the brain. These techniques have demonstrated a number of abnormalities and inconsistencies in individuals with learning disabilities, but once more no systematic research has demonstrated specific diagnostic abnormalities. Though progress has been made and some consistent patterns have begun to emerge in the assessment of learning disability with these technologies, a number of challenges still remain (1998).

In an ideal world, identification of a child with LD along with follow-up treatment or education, would be an exact science. Standardized assessment techniques would promise a definitive diagnosis and, in turn, a positive outcome. However, in the real world, the many facets of learning disorders, from the lack of a clear and concise definition to the myriad of causal factors, often give rise to more questions than they do answers. Therefore, the main focus of this study will include only one aspect of LD, the assessment of manual dexterity and motor output using the Grooved Pegboard Test.

The purpose of this study is to determine whether the Grooved Pegboard Test can discriminate between LD students and non-LD students. A secondary purpose is to determine if the Grooved Pegboard Test can discriminate between neuro-based LD and non-neuro based LD. The hypotheses for this study are as follows:

NULL HYPOTHESIS: There will be no statistically significant difference in scores between the LD sample and non-LD sample on the Grooved Pegboard Test.

ALTERNATIVE HYPOTHESIS: There will be a statistically significant difference in scores between the LD sample and non-LD sample on the Grooved Pegboard Test.

Method

Subjects

For the purpose of this study, sixty male and female subjects ranging in age from 9 to 16 years were selected randomly from a stratified sample of learning-disabled (LD) children and non-LD children in West Virginia. All subjects obtained full scale IQs of at least 80, but no more than 120 on the WISC-III. The children selected for the LD group were initially chosen because of a previous diagnosis of LD, although some were later screened out and replaced with other subjects because of their failure to meet the criteria of this study's operational definition of LD. IQ scores were obtained by administration of the WISC-III. Reading and Math Composite Scores were obtained by the administration of the Basic Reading, Reading Comprehension, Math Reasoning and Numerical Operations subtests of the WIAT. LD children were confirmed as having a learning disability by using criteria set forth by West Virginia Policy 2419. Policy 2419 defines LD children as being those children who have a "severe discrepancy" (in this case, a minimum of 1.75 standard deviations) between individual standardized achievement and IQ scores, taking regression and 1.0 standard error of measurement into account. Calculations to determine potential discrepancies between achievement and IQ scores were performed using the West Virginia Learning Discrepancy Program, Version 2.0. Each of the subject's Verbal, Performance, and Full Scale IQ scores were compared with their WIAT Reading Composite Score and WIAT Math Composite Score. If any of the comparisons resulted in the subject's achievement score being a minimum of 1.75 standard deviations lower than their IQ score, then that subject was placed in the LD group. The lower limit was within a 68% confidence band. Other subjects' scores whose IQ/Achievement discrepancies were found to be less that 1.75 deviations were placed into the control group. All subjects were determined to have had no previous diagnosis of any mental disorder. Informed consent was obtained for each subject by parental signatures prior to any test administration.

Instruments

A battery of eleven tests was utilized in this study. The WISC-III was used as a measure of intelligence in conjunction with the WIAT, which measures educational achievement, to determine LD or non-LD status. The remaining nine tests were chosen to be utilized in determining their usefulness in identifying neurologically based LD. The following is a list of the tests and what they measure:

1. Trail Making Test (Parts A and B) – measures appreciation of symbolic significance of numbers and letters, scanning ability, flexibility and speed.
2. Children's Auditory Verbal Learning Test – 2 (CAVLT-2) – measures auditory verbal learning and memory abilities.
3. Beery Developmental Test of Visual-Motor Integration, 4th Ed. (Beery VMI) – measures the extent to which individuals can integrate their visual and motor abilities.
4. Children's Memory Scale (CMS) – used to evaluate visual and verbal learning and memory.
5. DCS – A Visual Learning and Memory Test for Neuropsychological Assessment – designed as a learning and memory test for detecting memory deficit.
6. Children's Category Test (CCT) – measures non-verbal learning and memory, concept formation, and problem-solving abilities.
7. Benton Visual Retention Test, Fifth Edition (BVRT) – measures visual perception, visual memory, and visuoconstructive abilities.
8. Stroop Color and Word Test – used to investigate personality, cognition, stress response and brain damage.
9. Grooved Pegboard Test – used as a measure of manipulative dexterity and visual-motor coordination.

The Grooved Pegboard Test was developed in 1973 by H. Clove. It consists of a 5 x 5 inch metal surface with a 5 by 5 array of slotted holes, each angled at various directions (Ruff, 1993). The metal test surface is mounted on a base with a hollow depression, which serves as a reservoir for the pegs. Each peg is constructed of metal and has a ridge running along the entirety of its one-inch length. The pegs are identical and must be rotated to match each hole before it can be inserted. The test requires 25 pegs to complete. The subjects are instructed to place the pegs in the holes as quickly as they can. The dominant hand is used in the first trial followed by the non-dominant hand.

The length of time required to perform each trial is recorded beginning when the subject starts the task until the last peg is put in. The second score is the number of "drops" made during each trial. A "drop" is any unintentional drop of a peg from the time the subject attempts to pick up the peg from the tray until it is placed correctly in the hole. The third score is the number of pegs correctly placed in the holes for each trial. For each hand, the three scores are summed (the total time, total number of drops and the total number of pegs correctly placed in the board) to get the complete score.

The Grooved Pegboard is a test of manual dexterity to evaluate lateralized brain damage in adults, adolescents, and children aged 5 years and older. Scores on such a test are of diagnostic utility in neuropsychological practice only within the context of an extensive sampling of medical, cognitive, motor, sensory and personality factors (Grooved Pegboard Test Instruction/Owner's Manual, 1989). When the Grooved Pegboard Test is to be used for personnel selection, the ideal procedure is to establish its validity locally, by testing all newly hired employees and correlating scores with their subsequent performance. This test should correlate most highly with those jobs that require speed, finger dexterity and manual dexterity.

Procedure

The entire battery of tests was administered individually to each subject. Each of ten graduate students located six subjects, 3 of whom were considered normal and served as a part of the control group, and 3 of whom were diagnosed with LD. Each subject was administered the WISC-III and the WIAT to determine into which group, if any, they would be placed. The subjects were numbered randomly. Odd-numbered subjects were administered the neurological tests in the following order: Trails A & B, CAVLT-2, VMI, Grooved Pegboard, Children's Memory Scale, DCS, Children's Category Test, BVRT, and Stroop Color and Word Test. The even-numbered subjects were tested in the reverse order. The subjects were tested at a table with no other persons present in the room and minimal distractions.

Results

When the GPT was administered, all subjects were required to insert the pegs in the pegboard using each hand individually. Subjects were questioned as to which hand they preferred to write with. For the purposes of this study, the hand used to write with was designated as the dominant hand and the hand not used for writing was designated as the non-dominant hand. The dominant hand was used in the first trial followed by the non-dominant hand.

Scores for each subject were recorded. The length of time required to perform each trial, the number of drops, and the number of pegs correctly placed in the holes were totaled individually for each hand. The method used for selecting variables was a stepwise discriminant analysis in which the dominant hand was determined to be the best predictor of variance.

Following the stepwise discriminant analysis, an analysis of variance (ANOVA) was used to examine the GPT dependent variable referred to as the dominant hand. Obtained ANOVA results for the dominant hand variable were statistically significant at the p <

.05 level and suggest that the GPT is able to discriminate between LD and non-LD groups using this particular measure. A second ANOVA was conducted examining the GPT variable referred to as the non-dominant hand. Results for this variable were not found to be statistically significant at the $p < .05$ level and suggest that the GPT is not able to discriminate between LD and non-LD using the non-dominant hand. The mean of the scores used and the standard deviation can be viewed in Table 3.

In order to achieve the objective of this study, two hypotheses were used. Based on the data analyses in this study, the null hypothesis was rejected in that there was a statistically significant difference in scores obtained between the LD sample and the non-LD sample. It follows, then, that the alternate hypothesis is accepted as true in that a statistically significant difference in the scores was found between the LD and the non-LD sample on the GPT.

Table 1

Stepwise Discriminant Analysis

56 Observations   2 Variables in the analysis
2 Class Levels   0 Variables will be included

The Method for Selecting Variables will be: STEPWISE

Significant Level to Enter = 0.0500
Significant Level to Stay = 0.0500

Class Level Information

GROUP	Frequency	Weight	Proportion
LD	27	27.00	0.48
Non LD	29	29.00	0.52

Stepwise Selection: Summary

Step	Variable Entered	Variable Removed	No. In	Partial R**2	F Statistic	Prob> F	Average Squared Canonical Correlation	Prob> ASCC
1	DOM		1	0.162	10.437	0.0021	0.162	0.0021

Table 2

Analysis of Variance Procedure

Dependent Variable: Dominant Hand

Source	df	Sum of Squares	Mean Square	F Value	Pr > F
Group	1	1569.60	1569.60	10.44	0.0021
Error	54	8121.26	150.39		
Corrected Total	55	9690.86			

Dependent Variable: Non-Dominant Hand

Source	df	Sum of Squares	Mean Square	F Value	Pr > F
Group	1	2843.96	2843.96	5.45	0.0234
Error	54	28196.60	522.16		
Corrected Total	55	31040.56			

Table 3

Mean and Standard Deviation of LD and Non-LD Groups

Level of Group	N	--------Dominant------- Mean	SD	---Non-Dominant--- Mean	SD
LD	27	110.63	13.91	122.30	29.93
Non-LD	29	100.03	10.51	108.03	13.23

Discussion

The GPT is a brief, portable measure of finger dexterity. Uses of the GPT may be subdivided into two broad categories: (a) measurement of finger dexterity, and (b) inference of brain dysfunction from test performance. The first use is more applicable to occupational or rehabilitation settings where fine-motor coordination is important as a predictor of job performance or as an indicator of everyday functional abilities (Mahurin & McClure, 1995). The second application is more frequently encountered in clinical evaluations, in which discrepancies from age-adjusted normative scores are hypothesized to relate to lateralized cerebral dysfunction.

There are, however, important factors that must be acknowledged in this study. A secondary purpose of this study was to determine if the GPT can discriminate between neuro based LD and non-neuro based LD. Although an analysis is hypothesized to be related to lateralized cerebral dysfunction, no analysis can be made for determining the basis of the LD type per se within the context of this study. Further research should investigate the outliers to check for neurological deficits. Scores on such a test are of diagnostic utility in neuropsychological practice only within the context of an extensive sampling of medical, cognitive, motor, sensory and personality factors (Grooved Pegboard Test Instruction/Owner's Manual, 1989).

Some other factors may be taken into consideration and should be contemplated in a discussion of the outcome of this study. The instructions for administration for the GPT are generally well written and contain sufficiently detailed descriptions of the administration and scoring procedures with one exception. This test requires that the "dominant/non-dominant" hands be used but it does not suggest how this dominance be established. One subject in our study made it known to the test administrator that he was ambidextrous, and was instructed to use the hand he preferred to write with in his first trial, the one for the dominant hand. Such ambiguity needs to be addressed.

Little information is available concerning the reliability of the GPT and no data are provided in the manual. Also, several studies have been performed that address the validity of the GPT in children and two of these are mentioned in the manual. However, they are not listed as sources of validation for the instrument. The scoring system and norms reported in the manual are not consistent and also problematic (Stratton, 1995). The norms for the Kiddie and the Adolescents are based on time only with no penalty added for drops. The Adult norms use a scoring formula that adds together time, drops, and number of pegs inserted. This formula penalizes subjects who place the most pegs in the board during the test. It would make more sense to add together time, drop, and holes *not* filled to attain a total score. The manual offers no explanation as to why different scoring formulas are used for different age groups.

When taking into account what other variables might be considered for further research, gender and age would both seem likely to produce interesting results. In a study by Ruff and Parker (1993) gender was an important predictor of performance. Females' times were substantially faster than males' for both the non-dominant and dominant hand.

A post-hoc analysis in the current research study suggested a statistically significant difference between males and females for the dominant hand. The analysis for the dominant hand suggested no significant difference between males and females.

Another fascinating consideration for future study could involve a larger number of subjects who considered their left hand as the dominant hand. Too few left-handed subjects were included in the current study to warrant any analysis.

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Appendix A:
Literature Review

The world of learning disabilities (LD)s is one that is fraught with specific questions that have no specific answers. These questions are posed by sincere people who have genuine problems. However, even in today's world with all of its technological advances, learning disabilities remain an unexplained perplexity of indistinct symptoms with no one key to understanding and success. The nature of these problems in and of itself makes it difficult for researchers to study LD and provide those troubled by it a precise remedy for their daily struggles.

Recognition that LDs are a distinct diagnostic category is relatively recent (Mpofu, Watson & Chan, 1999). The recognition is commonly associated with the passage of the United States Learning Disabilities Act of 1969. The Act adopted the National Advisory Committee on Handicapped Children's (NACHC) definition of LDs as referring to children with average or above-average ability who have significant deficits in basic psychological processes involved in understanding or using written or spoken language in the absence of sensory, emotional, or environmental disadvantage (1999). However, legally the most widely accepted definition occurs in Public Law 94-142 (Education for All Handicapped Children). This law defines LD as a disorder in written or spoken language that results in an imperfect ability to listen, think, read, write, spell, or do math. Children who have learning problems as a result of visual problems, hearing problems, mental retardation, motor problems, or environmental deprivation cannot be classified LD under this law (Kronenberger & Meyer, 1996). Although newer definitions acknowledge the neurological basis of learning disorders and recognize their diversity, as well as their constant and pervasive nature, no clear-cut operational definition has been universally accepted (Hynd, 1991).

The issue of identification will become even more critical in the future as there continues to be an increase in the demand for special education services (Shaw, Cullen, McGuire & & Brinckerhoff, 1995). These demands are expected to increase the pressure on educators to more clearly distinguish those who are truly disabled from those who are not. In addition, there are a growing number of adults with LD seeking support services or accommodations in postsecondary education, adult education, and employment. With the passage of the Americans with Disabilities Act of 1990, which extends protection in employment and public services that was available to adults with LD in programs and activities that receive federal assistance under Section 504 of the Rehabilitation Act of 1973, there is an even greater need to develop an operational definition of a learning disability (1995).

The Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition (1994) recognizes three specific learning disorders, and it allows for a "Not Otherwise Specified" designation for other disorders of learning. Reading Disorder, Mathematics Disorder and Disorder of Written Expression are given their own diagnostic categories. The skill in question in each case must be tested by an individually administered, standardized test of achievement in that area. The score obtained on that test must be substantially lower than the score that would be expected given the person's age, education, and intelligence. This intelligence score is usually obtained from an IQ test. The IQ-achievement discrepancy is commonly used as the deciding factor in the diagnosis of a learning disorder

(Kronenberger & Meyer, 1996). In a survey compiling the results of 51 state departments of education, 50 of the 51 states included discrepancies in their definition on criteria (Mercer, Jordan, Allsopp & Mercer, 1996). A majority of states also use standardized measures to define this discrepancy, such as 1.75 standard deviations between achievement test and IQ.

Problems with discrepancy formulas have reflected confusion as to the nature of the condition of LD. Shaw, Cullen, McGuire, and Brinckerhoff (1995) suggest that the symptom is confused with the problem. Low achievement relative to overall ability is confused with a specific cognitive deficit. In addition, concerns about discrepancy formulas have also been expressed by clinicians, who argue that they leave little room for professional judgment. One major drawback is that in some cases, a learning disability adversely affects performance on both the aptitude and achievement measures used to diagnose it, resulting in a profile that does not meet discrepancy criteria but nonetheless is LD.

Most discrepancy formulas have been criticized for failing to address the full scope of accepted conceptual definitions of LD. Nearly all definitions delineate some difficulty with some aspect of information processing as the cause of academic difficulties. Also, many practitioners use the discrepancy between achievement and intellectual potential as the only criterion in the identification process (Shaw et al., 1995). As a result, many underachieving students have been inappropriately identified as having LD.

Others also feel that the discrepancy between IQ and achievement scores is not a necessary part of the definition of a learning disability and furthermore, that it is not even necessary to administer an IQ test to determine whether or not there is a learning disability (Siegel, 1999). One assumption behind the use of IQ tests is that the scores predict and set limits on academic performance, so that if a person has a low IQ score, we should not expect much from him or her in the way of academic skills. They measure for the most part, what a person has learned, not what he or she is capable of doing in the future. It has been considered to be a paradox that IQ scores are required of individuals with LD because most of these people have deficiencies in one or more of the component skills that are part of theses IQ tests. Therefore, their scores on IQ tests would be an underestimate of their competence.

When a physician is asked to make a proper diagnosis of LD, it is suggested that a thorough history be taken by interviewing the parent as well as the child and a confirmation be made using neuropsychometric testing (Capin, 1996). It is also noted, though, that a systematic approach to the diagnosis and management of learning disorders is complicated by the lack of a clear classification of the disease as physicians tend to encompass all disorders that cause a persistent deficit in function of the brain as some type of a learning disorder. Some of these diagnoses include mental retardation, dysgraphia, dyspraxia, traumatic brain injury, and disorders of executive functioning. It is also apparent that within the context of taking a history, physicians would include questions pertaining to the child's birth weight, length of gestational period or any complications of delivery. The answers to these questions are a consistently predictive factor in determining LD (Cherkes-Julkowski, 1998).

Aside from the medical history and neurologic examination, child neurologists rank psychological reports as important sources of information in diagnosing children's learning disabilities (Fennell, 1995). Results from a neuropsychological assessment of a child with a suspected learning disability should meet two major goals. First, the examination should provide a clear and accurate picture of the child's current cognitive, academic, neuropsychological, and social functioning. A second goal is to provide a treatment plan to remediate the child's academic problems.

An initial purpose in conducting a child neuropsychological assessment is to provide information about the functional integrity of the child's central nervous system (Fennell, 1995). Tests that assess attention, memory, visuomotor skills, sensorimotor . functions, and language are designed to determine whether the child's behavior deviates from age-appropriate brain functions.

The correlation between higher brain functions and specific brain areas is well accepted in clinical neuroscience, but the exact underlying anatomic conditions are still not fully defined (Weinberg, Harper, & Brumback, 1995). Recent use of computerized brain imaging has allowed investigators to localize cerebral cortical lesions accurately in adults and correlate these with specific behavioral-communication dysfunction and cerebral cortical architectural areas. For example, malfunctioning of the left angular gyrus results in poor reading characterized by difficulty decoding written words.

Other studies have suggested that children with LD have exhibited early compromises to their neurodevelopment. In a survey completed by the subjects' primary caregiver, questions were posed concerning the child's development from infancy to 8 years of age. Gross motor, speech/language, fine motor, attention, social behavior, and academic skills were surveyed (Blumsack, Lawandowski & Waterman, 1997). These researchers found the skills in the areas of academics, attention, and social behavior were the most frequently reported as early difficulties. These findings suggest that children showing difficulties before 9 years of age and usually prior to the diagnosis of LD are those most likely to be diagnosed as LD. These difficulties are being observed by a large number of parents not trained to detect such difficulties. It appears, then, that learning disabilities seem to have developmental precursors.

Many contend that LD refers to a learning disorder that can result from a number of etiologies, all of which have some basis in altered or abnormal central nervous system dysfunction. Most research and clinical work in LD is conducted with the assumption that a specific learning disability is considered to exist when there is a significant discrepancy between an individual's intellectual or cognitive ability and academic achievement that is manifested in one or more receptive or expressive skills (Bigler, Lajiness-O'Neill & Howes, 1998). Although the assessment of a learning disorder is based on various psychometric tests, the underlying assumption is that neurologic irregularities or abnormalities are at the basis of the disorder. A possible reversal of the usual cerebral asymmetry or an increased ratio of symmetry has been reported in some children with LD. The use of magnetic resonance imaging (MRI) has revealed such differences in brain symmetry. However, rather than focusing exclusively on linear measurements, such as length and width obtained from brain surface area, volumetric estimates or cerebral regions and individual gray matter structures have also been analyzed.

The electroencephalogram (EEG) is a graphic record of the electrical currents developed by the cerebral cortex. The EEG and metabolic imaging techniques offer methods by which human brain activity can be studied during cognitive processes. In a study of adolescent poor readers, the subjects were shown a series of letters and words on a screen and were asked to read them silently (Ackerman, McPherson & Oglesby, 1998). An EEG was performed on all subjects while they viewed the words. The results found that in the adolescent poor readers, no significant correlation was found between beta levels and measures of phonological skill. However, the differences that did emerge came from the level of automaticity of phonological decoding and symbol naming. Also, the results of the EEG study provide evidence that both the phonological impairment and slow naming may stem from atypical brain functioning.

In another study of brain functioning, the regional cerebral blood flow during the reading of narrative text among nondyslexics and developmental dyslexics was measured (Hynd & Semrud-Clikeman, 1989). In this way, the topography of brain metabolic activity can be correlated directly to the level and kind of reading performed by dyslexic persons and their matched controls. In any case, the precise impact of these anomalies in neural maturation of developing morphological-behavioral systems remains unclear. However, there appears to be a growing body of evidence that attests to the neurodevelopmental irregularities with developmental dyslexia (1989).

The question of whether or not learning disabilities have a cerebellar-vestibular dysfunctional origin has also been examined. In a study involving 4000 individuals between the ages of 7 and 50, a diagnosis of learning ability was made using neurological and optokinetic diagnostic parameters (Levinson, 1988). The purpose of the study was to determine whether or not adults with learning disability improve with age or do not significantly improve and maintain the same symptoms until adulthood. All subjects were of normal or superior IQ and had significant deficits in one or more academic areas of memory, speech, concentration, activity level, time and direction as well as motor difficulties involving balance, coordination and rhythm. All adults in the study indicated that they had learning related symptoms that dated back into their childhood. Results of the study indicated that 99.5% of the learning disabled subjects displayed greater or equal to 1 neurological or optokinetic parameters. In addition, cerebral-vestibular neurological signs appeared to be less detected from childhood to adolescence and to increase from adolescence to adulthood. On the basis of the study, the cerebral-vestibular basis of learning disabilities was shown to be clinically and statistically supported. Also it can be suggested that various symptoms of academic, speech, and concentration activity appear to be shaped by a diverse group of cerebral –vestibular determinant mechanisms instead of distinct neurophysiological disorders. The cerebral cortex appears to play a vital role in shaping the final symptoms and whether or not they result in a learning disability.

Some tests related to the assessment of the functioning of the central nervous system have been studied in regard to neurological validity as well as their psychological validity. In a study that included post meningitis children, neurological tests were employed to measure a wide range of cognitive functions involving procedures which have demonstrated sensitivity to brain disorders (Taylor, 1992). The WISC-R was included in determining IQ as well as the parents and teachers reporting of behaviors and home and at school. Information regarding the child's socioeconomic status and home environment were also obtained. The results showed that social factors and neuropsychological performance varied widely depending on the type of skill assessment, but generally confirmed the assumption that neuropsychological measures can be useful in their sensitivity to assess neurological result. Findings did not provide any conclusions as to the best neuropsychological predictor of IQ. However, results did show that neuropsychological skills are generally a better predictor of behavior than the WISC-R Verbal IQ and Performance IQ.

It seems though, that researchers in the field of learning disabilities have been subjected to criticism because of the misidentification of any child who has learning problems as being learning disabled. Therefore, some researchers are advocating that the learning disability diagnosis be reserved for learning problems of a neurological origin only, that is, those caused initially by a minor central nervous system dysfunction. Because treatments obviously differ according to the nature of the disability, it is important that the child neurologist not accept as fact a differential diagnosis of a learning disability unless the qualifications of the diagnostician are known (Cordoni, 1995). Ideally, the child should be evaluated by a child study team or by a psychologist specifically trained in learning disabilities.

The value of the neurological examination in the study of children with mild cognitive dysfunction or with specific learning disabilities has long been a matter of discussion. Screening tests proposed for the early identification of children suspected of having learning difficulties have often contained a mixture of motor, sensory, language and other cognitive items. This makes it very difficult to assess how simple motor and sensory functions, as tested by neurological examination, are related to cognitive function, as seen in standardized intelligence tests or school performance (Huttenlocher et al., 1990). Establishment of correlations between simple motor and sensory tests and later cognitive functions is vital to the understanding of central nervous system maturation. It is particularly interesting to know whether, and to what extent, maturational lags are scattered, affecting simple motor and sensory functions, as well as more complex cognitive abilities, including language. Such information also has practical importance, especially in the preschool years, since there is a persistent need for simple diagnostic tools to aid early identification of at-risk children. In the Huttenlocher study, neurological tasks were given to children identified as at-risk for cognitive impairments and to age-matched control groups of three-year-olds and of five-year-olds. Very simple, easily scored tasks such as touch localization, walking on toes, and walking on heels were useful between the ages of three and five years. Follow-up of the five-year-olds at age seven showed a significant relation between scores on neurological tasks and the Weschsler Intelligence Test for Children. The neurological examination at age five also had predictive value regarding class placement at age seven. The findings suggest that a simple neurological test may be helpful for the early identification of preschool children who are at risk for learning difficulties.

There has been a growing trend toward the identification of a neurodevelopmental basis for learning disabilities because of two main factors. First, the survival rates have increased significantly for children who experience early neurological trauma, such as low-birthweight infants. As a result, it is highly probable that these children will exhibit a learning disability during the school years. The second factor is the reality of PL 99-457 and the specific need to identify, evaluate, and develop programs for preschool children who are at educational risk (Finlayson & Obrzut, 1993). Comprehensive neuropsychological assessment batteries such as the Halstead-Reitan Neuropsychological Test Battery for Children and other batteries have been utilized to aid in the identification of specific neuropsychological deficits in LD populations. Unfortunately, the length of time required for administration and interpretation of these neuropsychological batteries frequently prevents their usefulness as screening measures.

In the study by Finlayson and Obrzut (1993), the Quick Neurological Screening Test-Revised was used to determine its usefulness as a screener for this population. The QNST-R is an individually administered screening instrument developed for children between the ages of 5 and 15 years in order to assess the development aspects of children's neurological abilities. It is meant to tap neurological integration (sensory and motor functions) as it relates to learning and was designed for early identification of children with learning disabilities. It appeared that the QNST-R demonstrates validity for a subtest of neuropsychological functions. The significant age differences regarding performance on the QNST-R indicate that the instrument is sensitive to a general maturity factor. Younger children with learning disability had more difficulty with QNST-R tasks than did older children with LD. Therefore, poor performances on the QNST-R by older children may be a more significant indicator of neuropsychological deficit than poor performance by younger children.

In a study by Rourke et al. (1973) an analysis was used to determine if the performance of older children with learning disabilities, some of whom do and some of whom do not exhibit patterns of lateralized motor deficits, is similar to that of adults with known cerebral lesions. It was thought that if the patterns of performance of these two groups of subjects were shown to be similar, this would lend support to the view that cerebral dysfunction is a significant factor in the etiology of learning disabilities.

The subjects received an extensive battery of neuropsychological tests and had been referred for neuropsychological assessment because of a learning or perceptual problem to which it was thought that cerebral dysfunction might be a contributing factor. All subjects exhibited poor performance in a particular school subject of general academic underachievement. The subjects were divided into groups on the basis of the relationship between their right-hand and left-hand performance on the Grooved Pegboard Test, to measure speed and accuracy of hand-eye coordination. The results indicated that when such children are separated into groups solely on the basis of patterns of lateralized deficits on a complex psychomotor task, their performances are, in many respects, similar to those exhibited by adult subjects with well-documented cerebral lesions. Furthermore, it would seem reasonable to assume that were the criteria for group composition to include other measures of motor behavior in addition to that derived from the Grooved Pegboard Test, the similarity between the two populations would have been even more striking.

Another aspect of learning disabilities concerns the use of nonverbal tests to screen for writing dysfluency in school-age children. It has been suggested that writing dysfluency may be present in the absence of other academic difficulties and is generally diagnosed less frequently than other types of learning disabilities (Williams et al., 1993). Writing fluency is defined as the ability to write rapidly and easily and is determined to be critical for the timely completion of written assignment in the classroom. Children with normal ability to communicate ideas and basic writing skills are often penalized by slowness to complete written tasks. In the Williams et al. study (1993), instruments that were chosen measured quick information processing of visual material, visuomotor integration, and psychomotor speed. The Coding subtest from the WISC-R was selected as a measure of processing speed involving visual symbols. In addition, measurement of Performance IQ from the WISC-R was included. The Developmental Test of Visual Motor Integration (VMI) was administered to measure development of visual motor integration. The Grooved Pegboard Test (GPT) was used as a measure of complex motor skill. The criterion variable of writing fluency was measured by the Writing Fluency subtest of the Woodcock-Johnson Test of Achievement –Revised. Results suggested that a combination of low scores on Coding, Beery's visuomotor test, and the Grooved Pegboard Test can be effective in screening children for possible writing dysfluency during clinical evaluations. Boys appear to be more likely than girls to have difficulties with speeded written tasks. Examination of test predictability by gender indicated that the GPT appears to be particularly sensitive to problems with writing fluency for girls. Lower scores on Coding and Beery's visuomotor test are more likely to be associated with slowness on writing tasks for boys. It was suggested that further research should examine whether specific subgroups of children with learning and behavioral problems are more vulnerable to writing dysfluency. The researchers found that this screening is an effective tool in ruling out writing dysfluency or suggesting the need for further evaluation.

Harnadek and Rourke (1994) conducted a study whose purpose was to derive a pattern of the features that would be most useful for identifying children who exhibit nonverbal learning disabilities (NLD). Children who experience their major academic learning difficulties in mechanical arithmetic, visual-spatial organization, tactile-perceptual, psychomotor, and nonverbal problem-solving skills exhibit the principal features of this type of learning disability. Their strengths lie in the areas of work recognition and spelling. It is also seen in persons suffering from a wide variety of neurological diseases and disorders. The subjects were individually administered a battery of neuropsychological tests which included the use of part or all of the following tests: The Category Test, Wide Range Achievement Test, Tactual Performance Test, Grooved Pegboard Test, The Target Test, Trail Making Test Part B, Peabody Picture Vocabulary Test, Speech, Sounds Perception Test, and the Sentence Memory Test. The principal finding of this study was that a subset of four neuropsychological tests (The

Target Test, the Trail Making Test Part B, the Tactual Performance Test, and the Grooved Pegboard Test) served to discriminate the NLD subjects from those with a reading/spelling disability profile and the nonclinical comparison group with a high degree of accuracy (> 95%). It is of note to mention, though, that these four tests may not be the best neuropsychological predictors of NLD in children. Other combinations of tests or other individual tests may have enough predictive utility to be considered.

Another developmental index was originally developed as an indicator of cognitive impairment in adults but has also been applied to children because neuropsychological deficits have often been believed to account for learning difficulties during the development period. The Wechsler Deterioration Index (WDI) was composed of two groups of Weschler subtest scores: hold subtests, which were considered to be insensitive to deterioration in brain injury (Vocabulary, Information, Object Assembly, and Picture Completion), and don't hold subtests, which were judged vulnerable to intellectual decline (Digit Span, Similarities, Coding, and Block Design). These groups of subtests were later renamed the Weschler Development Index because children's cognitive skills are not deteriorating but rather, are assumed to be developing unevenly (Watkins, 1996). Therefore, this measure has been used to discriminate among groups of children with and without learning disabilities. The ability of the WDI to serve as a distinctive measure of neurocognitive impairment in children with learning disabilities was investigated in this study. The researchers found that a large group of children with learning disabilities exhibited average WDI scores that were significantly higher than those of children with diagnoses of mental retardation. However, this study indicated that the WDI is, in effect, incapable of assisting in the diagnostic decision-making process when students with learning disabilities are to be distinguished from students with other disabilities and students without disabilities. Other researchers concur that progress in the entire field will be aided by definition and identification of validated subgroups of the heterogeneous mixture of learning disabled children (Hinshaw, 1986).

Although clinical application of neuropsychological test procedures such as the Halstead-Reitan Neuropsychological Test Battery continues to grow, it still remains true that many of these widely used tests are poorly developed and documented from a psychometric point of view (Bornstein, 1985). Many of the measures that comprise the Halstead-Reitan Battery were developed as standardized experiments and not as a test for detection of some particular component of behavior. The lack of data has, to some extent, been related to the overwhelming logistic problems associated with the implementation of these studies. However, of perhaps greater importance is the fact that proper clinical interpretation involves many levels of judgment. In particular, interpretation of such test results relies on level of test performance, pattern of performance across a variety of tests, examination of emotional signs, and comparisons of performance of the two sides of the body on motor and sensory-perceptual measures. It is thought that large-scale collaborative studies that make use of more extensive test batteries and sophisticated sampling techniques are necessary to develop the type of normative data bases such as those obtained with the Wechsler Intelligence Scales (1985). In a similar manner, neuropsychologists who use comparable test batteries in different geographic locations could collaborate to obtain large scale cross-sectional samples that are sensitive to a variety of demographic variables, such as age, sex, and education, as well as examining other potential influences, such as race, ethnic background, or socioeconomic status. Development of such large-scale normative data bases will enhance clinical application of neuropsychological test procedures and also will facilitate neuropsychological research.

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Appendix B:
Subject Data Sheet

Appendix B
Subject Data Sheet

Subject ID	Group	Gender	Age	Race	DomHand	Non-DHand
1	LD					
2	Non-LD	f	10;0	white	97	122
3	Non-LD	f	9;0	white	103	109
4	Non-LD	m	9;7	white	101	120
5	LD	m	10;3	white	107	96
6	LD	m	9;9	white	119	119
7	Non-LD					
8	Non-LD	f	10;5	white	89	103
9	LD	m	11;8	white	100	140
10	Non-LD	m	12;1	white	96	123
11	LD	f	9;1	white	130	137
12	LD	m	12;6	white	103	105
13	LD	f	15;1	white	99	96
14	Non-LD	f	10;9	white	98	98
15	Non-LD	f	12;5	white	91	96
16	Non-LD	m	15;11	white	93	92
17	LD	m	16;0	white	102	109
18	LD	m	9;7	other	108	97
19	LD	m	15;0	white	98	104
20	Non-LD	m	15;1	white	96	104
21	Non-LD	f	15;3	white	87	101
22	LD	m	10;0	white	91	125
23	Non-LD	m	10;9	white	114	103
24	LD	f	13;9	white	106	138
25	Non-LD	m	12	white	101	127
26	Non-LD	f	15	white	91	93
27	LD	m	11	white	126	120
28	Non-LD	m	9	white	105	86
29	Non-LD	m	11	white	109	88
30	LD	m	9	white	113	133
31	Non-LD	f	12;3	white	94	116
32	Non-LD	m	13;11	white	82	114
33	Non-LD	f	12;4	white	90	99
34	LD	m	14;11	white	100	113
35	LD	m	13;3	white	136	158
36	LD					
37	Non-LD	f	10;3	white	96	97
38	Non-LD	f	10;1	white	99	141
39	Non-LD	f	10;9	white	94	121
40	LD	m	10;6	white	124	106
41	LD	m	9;0	white	126	117
42	LD					
43	LD	m	9;1	white	144	136
44	LD	m	9;8	white	127	239
45	Non-LD	m	9;4	white	106	112
46	LD	m	9;4	white	98	113
47	LD	f	11;0	white	94	98
48	Non-LD	m	10;4	white	121	121
49	LD	m	9;8	white	113	162
50	Non-LD	m	11;6	white	103	95
51	Non-LD	m	9;7	white	124	118
52	LD	f	12;2	black	108	131
53	LD	m	12;8	white	92	100
54	Non-LD	f	9;7	white	116	102
55	LD	m	14;6	white	107	100
56	LD	m	9;0	white	108	96
57	Non-LD	f	11;5	white	88	111
58	Non-LD	m	10;4	white	116	120
59	Non-LD	m	11;0	white	101	101
60	LD	m	14;7	white	108	114

Appendix C:
Post –Hoc Test for the
Analysis of Variance

Post-hoc Test for the Analysis of Variance

Dependent Variable: Dominant Hand

Source	df	Sum of Squares	Mean Square	F Value	Pr > F
Group	1	942.79525129	942.79525129	6.60	0.0131
Gender	1	459.99163955	459.99163955	3.22	0.0786
Group*Gender	1	74.77628966	74.77628966		
Error	52	7428.38138528	142.85348818		
Corrected Total	55	9690.85714286			

Dependent Variable: Non-Dominant Hand

Source	df	Sum of Squares	Mean Square	F Value	Pr > F
Group	1	1867.83600647	1867.83600647	3.45	0.0690
Gender	1	28.37776719	28.37776719	0.05	0.8198
Group*Gender	1	14.24232701	14.24232701	0.03	0.8718
Error	52	28162.56320346	541.58775391		
Corrected Total	55	31040.55357143			

Mean and Standard Deviation of LD and Non-LD Groups by Gender

Level of Group	N	Dominant Mean	Dominant SD	Non-Dominant Mean	Non-Dominant SD
LD	27	110.629630	13.9094549	122.296296	29.9317362
Non-LD	29	100.034483	10.5067419	108.034483	13.2327590

Level of Gender	N	Dominant Mean	Dominant SD	Non-Dominant Mean	Non-Dominant SD
Female	19	98.421053	10.6787213	111.000000	16.0762074
Male	37	108.594595	13.2695547	116.918919	26.8476963

Level of Group	Level of Gender	N	Dominant Mean	Dominant SD	Non-Dominant Mean	Non-Dominant SD
LD	Female	5	107.400000	13.8130373	120.000000	21.1778186
LD	Male	22	111.363636	14.1473385	122.818182	31.9726615
Non-LD	Female	14	95.214286	7.5567450	107.785714	13.3253868
Non-LD	Male	15	104.533333	11.0832349	108.266667	13.6091997