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Phonological Processing, Automaticity, Auditory Processing, and Memory in Slow Learners and Children with Reading Disabilities

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Phonological Processing, Automaticity, Auditory Processing, and Memory in Slow Learners and Children with Reading Disabilities

by

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Phonological Processing, Automaticity, Auditory Processing, and Memory in Slow Learners and Children with Reading Disabilities

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The definition and classification of learning disabilities has been an ongoing debate, largely related to the use of a discrepancy between intelligence and achievement as the determining factor. Children who have a discrepancy are typically classified as learning disabled and qualify for services through the schools, while those who have difficulty reading but do not have a discrepancy due to low or below average intelligence levels ("slow learners") are frequently denied services. Many studies have revealed more similarities than differences between slow learners and children with learning disabilities, yet educational policy has not reflected these findings. In order to further the understanding of differences between the two groups and to provide additional information about the reading process, the current study examined the relationship between phonological processing, automaticity, auditory processing, and memory in slow learners and children with reading disabilities. Participants were selected from a sample of 2,361 students in the first through fifth grades who were tested as a part of the standardization for the *Woodcock-Johnson III*. Three groups were formed: Control (n = 75), Slow Learner (n = 79), and Learning Disabled (n = 32), resulting in a total sample size of 186 participants. MANOVA results revealed overall differences between the groups. Follow-up comparisons found that the Slow Learner group had significantly poorer performance as compared to the Control group on all measures; the Learning Disabled group was significantly worse than the Control group on Phonological Processing but not on any other measure; and the Slow Learner Group performed significantly worse than the Learning Disabled group on all measures. Correlational analyses revealed a series of significant correlations from small to large. Results from a multiple regression revealed that from the four factors that were investigated, Phonological Processing was the only statistically significant contributor to the variance of Basic Reading. Results appear to support the "phonological-core-variable-difference" hypothesis from the literature (Stanovich, 1988), as well as current proposals for changes to educational policy. Future research should be directed towards determining the capacity of slow learners and children with learning disabilities to respond to intervention.

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CHAPTER 1

INTRODUCTION

Learning disabilities have been found to be present in approximately five percent of the American school-age population (Gresham, MacMillan, & Bocian, 1996; Sofie & Riccio, 2002; Snow, Burns, & Griffin, 1998). It has been estimated that they account for the difficulties of approximately half of all children within special education services (Lyon, 1996). More specifically, learning disabilities in reading are thought to represent 80% of all learning disabilities (Snow et al., 1998). Because they affect such a large number of children, learning disabilities are an important area of study.

Generally, learning disabilities have been defined as unexpected underachievement in almost any academic area (Hammill, 1990; Heath & Kush, 1991; Keogh, 1990; Texas Education Agency, 1999a). A great deal of controversy, however, consistently has surrounded definitional issues in the field. For instance, many different definitions exist regarding the inclusionary criteria for this educational category (Hammill, 1990; Lyon, 1995). As a result, there is no universal formula for determining the presence of a learning disability: a child who is classified in one state as having a learning disability might not receive the same classification in another state (Fletcher, Francis, Rourke, Shaywitz, & Shaywitz, 1992; Heath & Kush, 1991; Meyer, 2000; Morrison & Siegel, 1991; O'Malley, Francis, Foorman, Fletcher, & Swank, 2002; Shaywitz, Fletcher, Holahan, & Shaywitz, 1992).

Another controversial issue is related to the theory of the existence of learning disabilities as distinct from more general academic problems (Aaron, 1997; Fletcher et al., 1992; Rutter & Yule, 1975; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992; Siegel, 1989a; Stanovich, 1988a, 1994). In the distribution of reading ability, it has historically been believed that there exists a unique group of children of at least average intelligence who have reading difficulties as measured on reading achievement tests. The reading problems of this group of children are said to be unexpected given that their reading achievement scores are lower than would be predicted by their intelligence scores (Aaron, 1997; Keogh, 1990; Meyen, 1989; Siegel, 1992; Stanovich & Siegel, 1994). These children are classified as having learning disabilities and are considered different from slow learners, who are described as children with reading difficulties accompanied by low to below average intelligence (The Center for Slower Learners; Humphries & Bone, 1993; Johns, 1990; Marshall, 1988; Siegel, 1989b, 1990; Williams, 1989).

Underachievement as a criterion for the classification of learning disabilities is usually measured by the presence of an intelligence-achievement discrepancy (Heath & Kush, 1991), which is also a controversial issue (Aaron, 1997; Merrell, 1990; O'Malley et al., 2002; Siegel, 1989a, 1989b, 1990, 1992, 2003; Swanson, Hoskyn, & Lee, 1999; Vellutino, Scanlon, Lyon, 2000). Many researchers argue against the use of a discrepancy formula in the determination of the existence of learning disabilities, suggesting that the notion of a discrepancy is based on several assumptions that have yet to be proven. For example, it is assumed that children who have a discrepancy between intelligence and achievement test scores are qualitatively and etiologically distinct from children who do not display this discrepancy (Aaron, 1997; Toth & Siegel, 1994).

Traditionally, it has been believed that slow learners, because of their lower intelligence scores, are not able to benefit from remediation (Aaron, 1997; Jiménez et al., 2003) and have different educational prognoses (Aaron, 1997; Stanovich, 1994; Swanson et al., 1999). Current educational policy for the provision of special services is based on these assumptions: children who have a discrepancy receive special services and are classified as having learning disabilities, while slow learners who lack this discrepancy are frequently denied special services (Aaron, 1997; Fletcher et al., 1992; Gresham et al., 1996; Lyon, 1996; O'Malley et al., 2002; Shaw, 1999; Siegel, 1989a, 1990; Snow et al., 1998; Stanovich, 1994). These assumptions, however, have not been proven conclusively. There have been few studies investigating differential outcomes on intervention methods between slow learners and children with learning disabilities (Aaron, 1997; Swanson et al., 1999). In addition, most studies comparing the performance of slow learners and children with learning disabilities on a variety of measures have found more similarities than differences (Aaron, 1997; Fletcher et al., 1992; Gresham et al., 1996; O'Malley et al., 2002; Share, 1996; Shaywitz, Fletcher, et al., 1992; Siegel, 1989a, 1989b, 1992; Toth & Siegel, 1994; Ysseldyke, Algozzine, Shim, & McGue, 1982).

Advocates supporting the revision of the classification criteria for learning disabilities in reading argue that phonological coding is a better predictor of reading than intelligence level (Calfee & Norman, 1998; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stanovich & Siegel, 1994; Truch, 1998). Phonological coding refers to the metalinguistic ability to consider words as units of language separate from their meaning (Alexander, Andersen, Heilman, Voeller, & Torgesen, 1991; Felton, 1993; Snow et al., 1998), and is a part of the more inclusive skill of phonological processing (Poldrack et al., 2001). Performance on phonological processing measures has been found to be similar for slow learners and children classified as learning disabled (Fletcher, Shaywitz, et al., 1994; Shaywitz, Fletcher, et al., 1992; Siegel, 1989a; Stanovich & Siegel, 1994).

Three other skills that have been found to be important to the development of efficient reading skills are rapid naming, or automaticity (Denckla & Cutting, 1999; Denckla & Rudel, 1974, 1976; Wolf, 1999; Wolf & Bowers, 2000; Wolf, Bowers, & Biddle, 2000), auditory processing (Ahissar, Protopapas, Reid, &

Merzenich, 2000; Byrne & Lester, 1983; Poldrack et al., 2000; Schulte-Korne, Deimel, Bartling, & Remschmidt, 1999; Shapiro, Nix, & Foster, 1990), and memory (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer, Knee, & Delis, 1999; Morris et al., 1998; Swanson, 2000; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner & Torgesen, 1987). Evidence is either equivocal or nonexistent regarding comparisons of the performance of slow learners and children with learning disabilities on measures of automaticity, auditory processing, and memory.

Within the field of learning disabilities, there has been much research and speculation regarding the presence of subtypes. Subtype research has been driven by a variety of different theoretical perspectives and has led to the development of models of reading ability and disability. Some of these models are integrative and multidimensional, spanning across the range of theoretical orientations of learning disabilities research (Coplin & Morgan, 1988; Spear-Swerling & Sternberg, 1994). These and other models and subtype classifications recognize the presence of reciprocal influences of a variety of skills involved in the reading process, including phonological processing, automaticity, auditory processing, and memory (Baddeley, 1999; LaBerge & Samuels, 1974; Lovett, 1984; Rack, Snowling, & Olson, 1992; Spear-Swerling & Sternberg, 1994; Wagner & Torgesen, 1987). A larger research base would add to the current understanding of the theoretical, behavioral, and neuroanatomical evidence emphasizing relationships between these skills and would extend the possibilities for identification and treatment of reading difficulties in both slow learners and children with learning disabilities.

The question remains unanswered as to how similar slow learners are to children with learning disabilities on a variety of tasks and interventions. Practice, however, continues to be based on the assumption that slow learners, given their lower intelligence levels, are qualitatively different from children with learning disabilities. As a result, slow learners often do not receive remedial services. More research needs to be done attempting to answer this question. As stated by Shaw (1999), "for this extremely large and vital population [slow learners], research is scarce and getting harder to find every year" (p. 31). The present study compared patterns of performance between slow learners and children with learning disabilities on measures of four skills that have been theoretically and empirically related to the reading process. It is believed that additional studies with sound methodologies will provide more conclusive evidence regarding the nature of learning difficulties in slow learners and children with learning disabilities. This evidence will be useful in informing current educational practices. The next section reviews existing research on slow learners and children with learning disabilities in relation to several skills that are linked to the reading process.

CHAPTER 2
REVIEW OF THE LITERATURE

This review will examine pertinent research investigating the definition of learning disabilities, differences between children included in and children excluded from the definition of learning disabilities (LD), and the relationship among four skills related to the reading process. “Slow learners” is a term that is frequently used in practice and will be used in the current study to describe children who have difficulty with academics but do not fit the LD definition due to the lack of discrepancy between ability and achievement test scores. For the purpose of this study, the main focus will be on reading disabilities since they are the most commonly found and most researched type of learning disability (Aaron, 1997; Shaywitz et al., 1992; Snow et al., 1998). Following an investigation of the construct of learning disabilities, four neuropsychological processes that are related to reading as well as their relationships will be examined. First, phonological awareness has often been found to be deficient in children who have difficulty reading (Aaron, 1997; Catts, 1986; Fletcher, Shaywitz, et al., 1994; Gough & Tunmer, 1986; Lyon, 1995, 1996; Shankweiler et al., 1995; Shaywitz, Fletcher, et al., 1992; Siegel, 1989a, 1990, 1992; Stanovich, 1994; Stanovich & Siegel, 1994; Toth & Siegel, 1994). A second component to be examined will be rapid naming skills, or automaticity, given its hypothesized influence on the developing reading process (Denckla & Cutting, 1999; Denckla & Rudel, 1974, 1976; Wolf, 1999; Wolf & Bowers, 2000; Wolf, Bowers, & Biddle, 2000). Third, research on auditory processing and its contribution to the acquisition of reading skills will be investigated (Ahissar et al., 2000; Byrne & Lester, 1983; Schulte-Körne et al., 1999; Shapiro et al., 1990). Fourth, memory deficits have been found to be significantly related to the reading difficulties of some children (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer et al., 2000;

Morris et al., 1998; Swanson, 2000; Wagner et al., 1993; Wagner & Torgesen, 1987). The relationship between these four variables will be discussed and will be linked to the reading process. Finally, a rationale for this study will be presented, integrating the main areas of research reviewed here and offering hypotheses for questions that have as of yet been unanswered or answered inconclusively.

The Learning Disabilities/ Slow Learner Debate

Defining Learning Disabilities

Learning disabilities, though their presence has been noticed for over a century (Aaron & Simurdak, 1991; Doris, 1993; Lyon, 1996; Pennington, Gilger, Olson, & DeFries, 1992; Sleeter, 1986), were not federally recognized as a handicapping condition until 1968, when they were defined by the National Advisory Committee on Handicapped Children (Lyon, 1996). In 1975, this definition was then incorporated in the Education for All Handicapped Children Act, P.L. 94-142 (Fletcher, Shaywitz, et al., 1994; Hammill, 1990; Heath & Kush, 1991). An updated version of the definition of a specific learning disability, as stated recently in the Final Regulations from the Individuals with Disabilities Education Act (IDEA, as reprinted by Texas Education Agency, 1999a), reads:

> Specific learning disability […] means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, that may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations, including conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia…The term does not include learning problems that are primarily the result of visual, hearing, or motor disabilities, of mental retardation, of

> emotional disturbance, or of environmental, cultural, or economic disadvantage. (34 CFR 300.7(10))

The criteria to determine the existence of a specific learning disability, stated more specifically in Section 300.541 (Texas Education Agency, 1999a), require that the child be achieving at a level less than expected given his or her age and ability levels, and given an opportunity for appropriate educational experiences. Most states require at least average intelligence with lower achievement levels (Aaron, 1997; Williams, 1989).

Some researchers see this current federal definition as a definition of exclusion rather than of inclusion, describing what a learning disability is not instead of what it is (Batchelor & Dean, 1991; Heath & Kush, 1991; Lyon, 1995). As a result, there is no agreement upon an accepted definition (Lyon, 1996; Merrell, 1990; Morris et al., 1998; Sleeter, 1986), and the actual criteria and classification procedures used in schools may differ largely from state to state and even within states from school district to district (Fletcher et al., 1992; Heath & Kush, 1991; Meyer, 2000; Morrison & Siegel, 1991; Shaywitz, Fletcher, et al., 1992). For example, students with similar cognitive limitations, regardless of adaptive skills, may be served in one state as learning disabled and in another as mentally retarded (Gottlieb, Alter, Gottlieb, & Wishner, 1994; Gresham et al., 1996; Siegel, 1990, 1995). To be considered as having a learning disability in the state of Texas, for example, a severe discrepancy between ability and achievement consists of intellectual ability above the mentally retarded range (70 standard score points) with achievement levels falling more than one standard deviation (more than 15 standard score points) below ability scores (Texas Education Agency, 1999b). Other states may require a discrepancy of up to two standard deviations between intelligence and achievement scores (Fletcher et al., 1992).

Donald Hammill (1990), in his article calling for a consensus on the definition of learning disabilities, reviews the 11 main definitions that are currently or have been historically employed (see Appendix A). One of the most notable findings from his review is that each definition conveys the notion of underachievement, usually through the presence of a significant discrepancy between aptitude and achievement scores. There are several methods of determining this discrepancy. It has been found that the most psychometrically defensible yet most rarely used formula for determining an IQ-achievement discrepancy is a regression approach, because it takes into account regression to the mean over time as well as the correlation between IQ and achievement (Heath & Kush, 1991). However, other formulas are used more frequently to determine whether a child is achieving at a level that is less than expected, including (1) expectancy formulas, where the child's actual achievement is compared to an expected achievement as predicted from a mental or chronological age quotient; (2) standard score differences, where the child's achievement score is subtracted from her intelligence score; (3) deviation from grade level, where the child's achievement is compared to her grade level; and (4) scatter analyses, where a profile is created from subtest scores indicating the child's strengths and weaknesses (see also Fletcher et al., 1992). Sofie and Riccio (2002) suggest some options other than those that employ some variation on the ability-achievement discrepancy, such as norm-referenced tests of achievement and curriculum-based measures of reading.

In sum, due to the exclusionary nature of most existing definitions of learning disabilities, there has not been a consensus as to the specific criteria required for this classification. Though the requirement for an aptitude-achievement discrepancy is almost universal, neither the derivation of this discrepancy nor the magnitude of the split is consistent from state to state. As suggested by Lyon (1995), a precise definition is needed in order to be able to accurately identify, treat, and research learning disabilities (see also Morris et al., 1998).

The Discrepancy Requirement

As stated above, most current definitions of learning disabilities (LD) require that children classified as LD have average to above average intelligence (Aaron, 1997; Williams, 1989). The low achievement levels of these children are said to be unexpected due to this discrepancy between their achievement and intelligence (IQ) test scores (Aaron, 1997; Fletcher et al., 1992; Fletcher, Shaywitz, et al., 1994; Gresham et al., 1996; Hammill, 1990; Keogh, 1990; Merrell, 1990; Pennington et al., 1992; Shaywitz, Fletcher, et al., 1992; Siegel, 1989, 1992; Stanovich, 1994; Stanovich & Siegel, 1994; Toth & Siegel, 1994; Williams, 1989; Wise & Olson, 1991). However, there has been much controversy surrounding the validity of the use of this discrepancy as a defining characteristic of learning disabilities (Aaron, 1997; Fletcher et al., 1992; Keogh, 1990; Merrell, 1990; Morris et al., 1998; O'Malley et al., 2002; Pennington et al., 1992; Shaywitz, Fletcher, et al., 1992; Siegel, 1989, 1990, 1992; Stanovich, 1994; Stanovich & Siegel, 1994; Swanson et al., 1999; Toth & Siegel, 1994). According to some researchers, there are certain assumptions that underlie the discrepancy definition or model of learning disabilities, assumptions that in many cases do not appear to be supported by empirical evidence (Aaron, 1997; Keogh, 1990; Siegel, 1989a, 1990; Stage, Abbott, Jenkins, & Berninger, 2003; Swanson et al., 1999; Toth & Siegel, 1994).

One assumption underlying the discrepancy model is that the presence of a learning disability will not affect IQ. Siegel (1989a, 1990), however, suggests that a lower IQ score may be a consequence of the learning disability, and that IQ scores may underestimate the true ability of those with LD. The Matthew effect, as defined by Stanovich (1986), refers to the reciprocal relationship between reading and cognitive development (see also Siegel, 1989a, and Sofie & Riccio, 2002). For example, it is thought that verbal intelligence scores of children with reading disabilities may decrease over time, possibly because they read fewer books and may fail to acquire new vocabulary (Siegel, 1990). Slow reading acquisition may lead to reduced educational opportunities, thus further lowering verbal intelligence and subsequent academic achievement (Aaron, 1997; Stanovich, 1989). In sum, low IQ scores may in fact be a consequence of reading failure rather than a cause. Therefore, according to Siegel (1989, 1990, 1992), the use of the discrepancy model to identify learning disabilities should be discontinued since it may be discriminating against those who actually are disabled: "children with low IQ scores who fail to read are genuinely reading disabled and do not fail to read because of low IQ scores" (Siegel, 1990, p. 116; see also Vellutino et al., 2000).

A second assumption is that children with learning disabilities experience unexpected reading difficulties. The difficulties are described as unexpected because the intelligence scores of these individuals fall in the average range or above, so their difficulties cannot be attributed to low IQ (Aaron, 1997). Reading problems for children with lower IQ scores but without an intelligence-achievement discrepancy (slow learners) are expected, however, because lower reading scores are consistent with these children's lower IQ levels (Aaron, 1997; Siegel, 1992). Therefore, according to Aaron (1997), intelligence cannot explain the reading difficulties of children with learning disabilities but it can explain those of slow learners. Consequently, it can be deduced that the etiologies of the learning problems of these two groups— children with learning disabilities (with a discrepancy) and slow learners (without a discrepancy)—are different (Aaron, 1997). Challenging the idea of unexpected underachievement in learning disabilities is again Stanovich's (1986) explanation of the Matthew effects (see the first assumption above), which accounts for the possibility of the existence of children with learning disabilities who also have low IQ scores, since reading and intelligence are reciprocal processes. In addition, Seigel (1989a, 1990, 2003) has questioned the validity of the discrepancy definition based on the presence of children whose profiles include high reading scores with significantly lower intelligence scores. This assumption based on the discrepancy formula is that if children have low IQ scores they are predicted to be poor readers, and if they have higher IQ scores, they are predicted to be better readers. She states that "according to the discrepancy formulation, it should *not* be possible for a child with a low IQ to be a good reader; however…a significant number of such cases exist" (1989a, p. 472; see also Vellutino et al., 2000).

Assuming differential etiologies, a third assumption is made by the discrepancy model, that slow learners and children with learning disabilities have different cognitive processes and information processing skills (Siegel, 1989a, 1990; Stanovich, 1994; Toth & Siegel, 1994). According to Toth & Siegel (1994), the use of the discrepancy definition would be validated if it could identify a unique group that is different from other poor readers who have no discrepancy. Many studies investigating the difference between slow learners and children with learning disabilities have found more similarities than differences between the groups (Aaron, 1997; Gresham et al., 1996; Siegel, 1989; Teeter & Semrud-Clikeman, 1997; Toth & Siegel, 1994), however, as will be investigated in a future section of this review.

This third assumption leads to a fourth and final assumption to be explored within the context of this review: that because etiological differences are assumed to exist between children with learning disabilities and slow learners, then the two groups respond differently to various remediation and instructional strategies

(Aaron, 1997). If there exists a unique group that can be identified using the discrepancy theory, then this finding would indicate differential educational prognosis and justify intervention and special status only for the children with a discrepancy (Stanovich, 1994; Toth & Siegel, 1994). However, very few studies have investigated differential outcomes between poor readers with and without discrepancies (children with learning disabilities and slow learners; Swanson et al., 1999). Of those that have been done, results have often been inconclusive or methodologically flawed (Aaron, 1997).

According to most of the authors surveyed above, the assumptions upon which the discrepancy theory is based are questionable. In sum, it has been argued that the presence of a learning disability may affect scores on intelligence tests, and that results comparing the performance of slow learners and children with learning disabilities on assessment measures and intervention strategies are equivocal or nonexistent. The third and fourth assumptions regarding the existence of two unique groups each with a different educational prognosis, will be investigated more extensively in a future section of this review.

Reading Difficulties: Continuous or Categorical?

Current school policies in most school systems regarding the provision of services for reading difficulties invoke the two final assumptions described above, that children with LD are etiologically distinct from slow learners, and that these two groups respond differently to remediation. In other words, present practices reflect a categorical model in which reading disabilities are thought to be a condition that is qualitatively and etiologically distinct from normal reading ability and other reading difficulties (Aaron, 1997; Fletcher et al., 1992; Fletcher, Shaywitz, et al., 1994; Fletcher, Morris, et al., 1994; Gough & Tunmer, 1986; Gresham et al., 1996; Lyon, 1996; Rutter & Yule, 1975; Shaywitz, Escobar, et al., 1992; Siegel, 1989a, 1990; Snow et al., 1998; Stanovich, 1994). This classification procedure is based on data from the London and Isle of Wight studies conducted by Rutter and Yule (1975; see also Shaywitz, Escobar, et al., 1992, and Vellutino et al., 2000). Results from their longitudinal research showed a bimodal distribution on the continuum of reading ability, as indicated by the presence of a “hump” at the lower end of the distribution of reading ability (Rutter & Yule, 1975). The researchers concluded that the hump on the lower end of the reading distribution represented a distinct group of children whose intelligence scores were significantly higher than their reading scores (Rutter & Yule, 1975; see also Aaron, 1997, and Siegel, 1989). This distinct group was described as having specific reading retardation, and their reading difficulties were considered to be different from other less specific reading problems described by Rutter and Yule as general reading backwardness, where children read significantly below their age level yet not below their intelligence level (Gresham et al., 1996; Rutter & Yule, 1975). Since Rutter and Yule’s 1975 study, children described as having specific reading retardation have been classified as having reading disabilities, while children with general reading backwardness have been considered slow learners or “garden variety poor readers” (Fletcher, Stuebing, et al., 1994; Gough & Tunmer, 1986).

Rutter and Yule’s (1975) findings have not been successfully replicated except by Stevenson (1988, as cited by Fletcher, Shaywitz, et al., 1994, and Fletcher, Stuebing, et al., 1994) who also found a bimodal reading distribution in a sample of London twins. However, there have been a number of methodological concerns raised by other researchers regarding the findings of these two studies. Shaywitz, Escobar, Shaywitz, Fletcher, and Makuch (1992) attest that Rutter and Yule’s results were based on a group test designed to select out the poorest readers (see also Fletcher, Shaywitz, et al., 1994, and Vellutino et al., 2000). In this manner, a ceiling was imposed and better readers were underrepresented (Aaron, 1997; Siegel, 1989). According to the critiques, this selection procedure could have skewed the results and produced the appearance of a bimodal distribution, with the hump at the lower end of the distribution having been caused by the test used in the study itself (Aaron, 1997; Fletcher, Shaywitz, et al., 1994; Shaywitz, Escobar, et al., 1992; Siegel, 1989).

Other than methodological concerns, empirical evidence has also been provided by several researchers that partially contradicts the findings of Rutter and Yule's (1975) Isle of Wight and London studies. In most cases, however, the possibility of the existence of a distinct, severely disabled group is acknowledged (Aaron, 1997; Fletcher et al., 1992; Lyon, 1996; Pennington et al., 1992; Stanovich, 1994; Swanson, 1999). Using data from the Connecticut Longitudinal Study, Shaywitz, Escobar, et al. (1992) found that reading disabilities (dyslexia) appear to occur along a continuum that blends imperceptibly with normal reading ability. They concluded that dyslexic children represent the lower portion of this continuum, with no distinct cutoff point distinguishing between children with dyslexia and children with normal reading ability. The researchers, however, state that they are not ruling out the possibility of the existence of dyslexic children who do possess a unique biological deficit. A twin study conducted by Pennington, Gilger, Olson, and DeFries (1992) to determine the heritability of reading disabilities found that specific reading retardation (or IQ-discrepant reading disability) was not etiologically distinct from general reading backwardness (or age-discrepant reading disability). The researchers concluded that there does seem to be support for the possibility that specific reading retardation and general reading backwardness, though not etiologically distinct from each other, may both be distinct from the etiology of a normally distributed reading ability (Pennington et al., 1992).

In sum, the findings of the Isle of Wight and London studies (Rutter & Yule, 1975), which provided evidence that dyslexia is a discrete disability, have not been fully replicated with a methodologically sound design (Aaron, 1997; Fletcher, Shaywitz, et al., 1994; Pennington et al., 1992; Shaywitz, Escobar, et al., 1992). Though the possibility for the existence of a discrete reading disability remains, most subsequent research has found a normal distribution of reading ability. This has important implications for special education policy which currently only provides services to those who meet a certain cutoff or criteria. In light of the current findings, it has been argued that dyslexia is not an all-or-none phenomenon but is instead a difficulty that presents itself in differing degrees of severity (Shaywitz, Escobar et al., 1992). Shaywitz, Escobar, et al. (1992) also state that "children who do not meet these arbitrarily imposed criteria may still require and profit from special help" (p. 149). These and similar findings have had an impact on the theoretical conception of LD but have not yet filtered down to the practical level in order to influence educational policy (O'Malley et al., 2000; Swanson et al., 1999).

Defining Slow Learners

Slow learners, though not recognized as an official educational category, are students whose achievement scores are low to below average, but who are not classified as having learning disabilities because their IQ scores, also falling in the low to below average range, are not discrepant with their achievement, (The Center for Slower Learners; Fletcher et al., 1992; Humphries & Bone, 1993; Johns, 1990; Marshall, 1988; Shaw, 1999; Siegel, 1989b, 1990; Williams, 1989). Slow learners have also been described as low achieving (Gresham et al., 1996; Merrell, 1990; Shaywitz, Fletcher, et al., 1992; Williams, 1989), borderline (MacMillan, Gresham, Bocian, & Lambros, 1998; Williams, 1989), general reading backward (Rutter & Yule, 1975), age-discrepant reading disabled

(Pennington et al., 1992), non-discrepant poor readers (Aaron, 1997), and garden variety poor readers (Gough & Tunmer, 1986; Stanovich, 1988a). For the purposes of this study, children who fit this description will be referred to as slow learners.

Although their IQ scores often fall in the below average range, slow learners are not usually classified as mentally retarded due to their self-sufficiency, the absence of central nervous system deficit, the presence of intelligence scores that are above the cutoff for classification as mentally retarded, and the primarily academic nature of their difficulties (MacMillan et al., 1998). Neither are they classified as learning disabled due to their below average ("borderline") intelligence test scores, which are often considered to fall between approximately 75 and 89 standard score points (The Center for Slower Learners; Johns, 1990; Marshall, 1988; Pennington et al., 1992; Shaw, 1999; Toth & Siegel, 1994; Wise & Olson, 1991). Because this group is not officially recognized, this standard score point span may vary slightly in different studies (Aaron, 1997; Ackerman & Dykman, 1993; Badian, 1996; Humphries & Bone, 1993; MacMillan et al., 1998; Williams, 1989). Shaw (1999) proposes that slow learners make up 14.1 percent of the population, a larger percentage than children with learning disabilities, mental retardation, and autism combined. It is important to continue to study slow learners in order to provide justification for intervention, given one researcher's hypothesis that slow learners "account for a disproportionate number of school drop outs, unwed teen mothers, illicit drug users, functionally illiterate persons, incarcerated persons, unemployed, underemployed, violent offenders, alcohol abusers, school failures, low scorers on group tests, and gang and hate group members" (Shaw, 1999, p. 31).

A historical overview of the placement of slow learners is important in understanding their current position in the educational system. Beginning in the

1960's, slow learners were classified as "borderline mentally retarded" and subsumed under the label "educable mentally retarded" (EMR; Gottlieb et al., 1994; MacMillan et al., 1998; Shaw, 1999). Classification as EMR required a deficit in adaptive behavior as well as in intelligence, and slow learners met this requirement because severe and persistent underachievement or failure to succeed in the general education classroom constituted an impairment in adaptive behavior (MacMillan et al., 1998). The inclusion of slow learners as EMR created two subgroups of individuals: students who were impaired in general, with problems stemming from neurological origins, and students who were impaired solely in school-related areas. The aptitude of this second subgroup is thought to have been underestimated by intelligence tests, given the fact that they did have good adaptive skills across settings and their intellectual inefficiencies were less evident away from the school's academic demands. Due to these characteristics, this group of children was often described as having "six hour retardation" (MacMillan et al., 1998).

A combination of the passage of two different acts made it more difficult for slow learners to receive special services. In 1973, the American Association on Mental Retardation modified its definition of mental retardation, requiring for this classification an IQ that was two standard deviations below the mean instead of one (Shaw, 1999; Sleeter, 1986). As a result, slow learners could no longer be classified as EMR (Gottlieb et al., 1994; MacMillan et al., 1998; Williams, 1989). The second act which had been passed in 1970, the Children with Specific Learning Disabilities Act (Title VI-G, the Education of the Handicapped Act, P. L. 91-230, as cited in Aaron, 1997; see also Doris, 1993; Lyon, 1996; MacMillan et al., 1998; Williams, 1989), provided special education for children of average intelligence encountering learning problems. As a result, slow learners no longer qualified under either category since their IQ scores were neither low enough to be classified as mentally retarded, nor high enough to be considered learning disabled (Gottlieb et al., 1994; MacMillan et al., 1998; Shaw, 1999; Williams, 1989).

During the 1960s and 1970s, slow learners were largely from lower social classes and were linked to the controversy that surrounded the overrepresentation of minorities in EMR classes (MacMillan et al., 1998). Williams (1989) suggests that the American Association on Mental Deficiency (AAMD) modified its definition of mental retardation in 1973 partly because of the disproportionate number of children from minority backgrounds who were labeled mentally retarded. Siegel (1990, 1989a) has argued that the use of IQ scores in the determination of learning disabilities penalizes children who are from different cultural backgrounds than the one in which the intelligence measure was formed (see also Williams, 1989, and Greenfield, 1997). Children from different backgrounds may not have acquired the specific knowledge or had the experience necessary to answer many of the intelligence test questions correctly, possibly resulting in low IQ scores (Siegel, 1989a, 1990; Williams, 1989). As a result, Siegel (1990) continues, "they may not be called reading disabled but instead labeled as slow learners and not be considered intelligent enough to benefit from remediation. The consequence is that they do not get the help that they need" (p. 123).

As reviewed by Snow, Burns, and Griffin (1998), it appears that the highest concentration of poor readers is found in certain ethnic groups and in poor urban neighborhoods. Though some individuals who have trouble reading are able to overcome these difficulties and attain high levels of academic and occupational achievement, more frequently, success is not as likely in the realm of education, leading to little success in the occupational world. Success is more likely when reading interventions are provided, but services to help children from urban or certain ethnic settings read better are not as likely to be accessible under impoverished conditions (Snow et al., 1998). In addition, poverty is "explicitly precluded from the approved list that renders a child ineligible to receive special education services. Being poor, in the absence of a demonstrable educational disability as defined by federal and/or state regulation, is insufficient for a child to be classified as disabled" (Gottlieb et al., 1994, p. 456; see also, Keogh, 1990, and Siegel, 1990).

In sum, the idea has been explored that the category of slow learners, though not officially recognized, was created when the criteria for mental retardation was modified and when an official definition for learning disabilities was accepted. The literature describes these children as usually having intelligence levels between one and two standard deviations below the mean, with achievement scores falling in the same range. It has been argued that the lack of intelligence-achievement discrepancy within this population may in some cases be due to cultural or socioeconomic factors.

Comparisons Between Slow Learners and Children with Learning Disabilities

As described above in the third assumption, the foundation for the discrepancy model of learning disabilities assumes that the nature of the problem for children with learning disabilities is different than it is for slow learners (Aaron, 1997). There have been conflicting results in studies comparing the performance of the two groups on various tasks, with some studies supporting differences between the groups and others finding more similarities than differences (see Appendix B). The Isle of Wight and London studies (Rutter & Yule, 1975) found significant differences between slow learners (children with general reading backwardness) and children with learning disabilities (children with specific reading retardation). Slow learners were found to have a significantly higher number of brain disorders and more difficulty in a range of neuro-developmental functions, including coordination and language impairment, than children with learning disabilities. Due to these observed differences, Rutter and Yule (1975) concluded that there were educational implications in the distinction of the two groups, but at the time of their study no data were available investigating this distinction (see next section for discussion regarding educational implications).

A more recent study done by Merrell (1990) found significant differences between slow learners and children with learning disabilities on nearly all variables from the Woodcock Johnson Psychoeducational Battery. Variables that best separated the groups, even better than IQ, were math skills, reading, and written language scores (Merrell, 1990). In a more recent study, Fawcett, Nicholson, and Maclagan (2001) found that both slow learners and children with learning disabilities performed worse than controls on phonological and naming speed tasks, but that slow learners performed worse than children with learning disabilities on these same tasks. In addition, children with learning disabilities were found to have specific deficits in static cerebellar functioning as related to muscle tone and stability (Fawcett et al., 2001). Some researchers, though they may have found differences between the two groups, attributed the results to an artifact of the initial group classification (Gresham et al., 1996; Shaywitz, Fletcher, et al., 1992)

Although some studies have found many differences between slow learners and children with learning disabilities, other studies have found more similarities than differences. Siegel (1992) found no significant differences between children with learning disabilities and slow learners in performance on reading, spelling, or phonological processing measures. These findings further suggested that areas in which differences were found between slow learners and individuals with learning disabilities (eg., arithmetic, visual-spatial processes) were less related to the fundamental processes involved in reading. Thus, according to Siegel (1992), "the distinction between these two groups of disabled readers does not appear to be a meaningful one in terms of the basic processes underlying reading" (p. 626). Siegel's (1992) hypothesis is therefore supported: the more related the task is to reading, the less likely IQ is to make a difference in scores. Therefore, because both groups have similar problems in reading, spelling, phonological processing, memory, and language, both deserve the label of reading disabled (Siegel, 1992). A longitudinal study by O'Malley, Francis, Foorman, Fletcher, and Swank (2002) investigated the development of eight skills related to the reading process in slow learners, children with learning disabilities, and control readers. Results indicated that both the slow learners and children with learning disabilities performed significantly worse on all skills than the control group. Children with learning disabilities had significantly greater growth over time in letter-sound knowledge, better visual-motor integration at the beginning of the study, and greater deceleration of the rapid naming of letters and numbers than slow learners. The two groups had similar performance and development, however, on tasks of phonemic awareness, rapid naming of objects, perceptual discrimination, spelling, and word reading. O'Malley and colleagues argued that their results did not support the intelligence-achievement discrepancy criteria for identifying learning disabilities.

A review by Toth and Siegel (1994) examines the differences between slow learners and children with learning disabilities in 21 recent studies. The groups were significantly different in intelligence levels since IQ was one of the classification criteria. On measures of spelling, vocabulary, math, syntactic awareness, and memory, the number of studies that reported a difference was equal to the number of studies that did not; therefore, these results were inconclusive. However, on tasks directly related to reading, including word reading and decoding, phonological awareness, reading comprehension, and orthographic processing, the performance of children with learning disabilities and slow learners did not differ. The authors argue, in light of this latter finding, that IQ should not be included in the definition of dyslexia (Toth & Siegel, 1994).

Previously discussed as the fourth assumption of the discrepancy definition for learning disabilities, if unique groups can be identified by using the intelligence/reading achievement discrepancy, then the educational prognosis and procedures for remediation for each of these groups should be distinct (Aaron, 1997; Gresham et al., 1996; Siegel, 1989a, 1990; Stanovich, 1994; Swanson et al., 1999; Toth & Siegel, 1994). There are very few studies investigating this assumption. Aaron (1997) reviews this small body of literature, noting that there is little research to support this premise because few records are kept about the degree of progress made by poor readers regardless of their educational placement. Of what is available, there is no compelling evidence of differential educational gains between the two groups, and therefore the meaningfulness and validity of current classification procedures is questioned (Aaron, 1997; Stanovich, 1994).

Two recent studies have found similar benefits following remediation for children with learning disabilities and slow learners. Jiménez and colleagues (2003) assessed the effectiveness of computer-based intervention for Spanish students with reading difficulties who either had or did not have an ability-achievement discrepancy. Results revealed that computer-assisted practice was as beneficial, if not more, for participants without a significant IQ-achievement discrepancy as it was for those with a significant discrepancy. They concluded that IQ may be irrelevant in predicting intervention outcomes. A longitudinal study conducted by Vellutino, Scanlon, and Lyon (2000) found that IQ did not distinguish between children who had reading difficulties and who were average readers, or between children who were easily remediated and those who were more difficult to remediate. They also concluded that the use of the IQ-achievement discrepancy should be abandoned, especially given their findings that language-based tasks discriminate more reliably than IQ between slow learners and children with learning disabilities. Further study is needed in this area.

In sum, due to contradictory conclusions drawn by different studies, it is not yet clear whether or not slow learners are etiologically distinct from children with learning disabilities. There is an increasing amount of evidence, however, that appears to support the hypothesis that the groups are more similar than different in patterns of performance and results from remediation. Despite the lack of consensus surrounding the classification of children as learning disabled, it is necessary to understand the nature of reading difficulty a child is experiencing.

Reading is comprised of a variety of integrated processes. It is important to investigate relationships between these processes in order to help identify children who may be at risk for developing difficulties in reading and to identify the source of their difficulties. These processes may have different relationships in children with different levels of functioning. In subsequent sections of this review, the relationships among four variables that have been found to be related to reading will be investigated. Potential differences between slow learners and children with learning disabilities will be considered during this investigation. The first variable, phonological processing, has a well-documented influence on reading (Aaron, 1997; Catts, 1986; Fletcher, Shaywitz, et al., 1994; Gough & Tunmer, 1986; Lyon, 1996; Morris et al., 1998; Rack et al., 1992; Shankweiler, et al., 1995; Siegel, 1989a, 1992; Stanovich & Siegel, 1994; Truch, 1998; Wagner et al., 1993). The second variable, automaticity, has also been shown to influence reading (Denckla & Cutting, 1999; Denckla & Rudel, 1974, 1976; LaBerge &

Samuels, 1974; Lovett, 1984; Semrud-Clikeman, Guy, Griffin, & Hynd, 2000; Wolf, 1986, 1997, 1999; Wolf, Bally, & Morris, 1986), but this influence has not been reflected in common assessment, diagnosis, or remediation practices. The third variable to be examined here is auditory processing, which has been less frequently investigated in its relationship to reading but has been hypothesized by theoretical models and found by several studies to influence reading acquisition (Ahissar et al., 2000; Byrne & Lester, 1983; Chermak & Musiek, 1997; Schulte-Körne et al., 1999; Shapiro et al., 1990). The fourth and final variable, memory, has been found to be important in the development of efficient reading skills (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer et al., 1999; Morris et al., 1998; Swanson, 2000; Wagner et al., 1993; Wagner & Torgesen, 1987). The following sections will investigate each of these four variables in their relationship to reading and to each other, and will review previous studies comparing children with learning disabilities and slow learners on each variable, where possible.

Subtype Research and Models of Reading Ability and Disability

Because reading is such a complex skill involving many factors, it seems logical to think that there are many points at which the reading process can break down. McAnally, Castles, and Stuart (2000) state that "many researchers have questioned the notion that developmental reading disorders occur in only one form. A complex and multifaceted process such as reading, it has been argued, will surely be likely to fail in an equally complex and multifaceted range of ways" (p. 150). Therefore, dyslexia may not be a unitary disorder and should be studied from a multivariate perspective (McAnally, Castles, & Stuart, 2000; Morris et al., 1998). Some of the confusion surrounding the field may in part be due to "the fact that multiple phenomena are given a single label" (Spear-Swerling & Sternberg, p. 92). If this is true, there exists a variety of expressions of reading disabilities that are symptoms of a variety of underlying causes which can be explored through subtype research (Castles & Coltheart, 1993; Coplin & Morgan, 1988; Farmer & Klein, 1995; Fletcher, Morris, et al., 1994; Fletcher, Shaywitz, et al., 1994; Morris et al., 1998). This section will focus on an exploration of a sample of subtype research as well as related theoretical models of reading in order to help provide the basis for the examination of the four experimental variables used in this study.

Subtype Research

Subtype research is generally driven by the probable existence of a variety of causes and possible treatments for learning disabilities. According to Coplin and Morgan (1988), "Subtypes would include distinctive characteristics and antecedent conditions that consistently predict specific patterns of learning difficulties. A taxonomy of subgroups of learning disabilities would provide a conceptual basis for intervention strategies and for research on the effectiveness of treatment" (p. 614). Therefore, research that identifies different conditions or characteristics that may be predictive of future reading difficulties is helpful in designing early identification and intervention strategies.

Research and the development of theoretical models related to reading disabilities have taken on many different forms and have been done from many different perspectives. As a result, the search for subtypes has at times led to increased confusion in the field of learning disabilities due to the number of different subtypes that have been hypothesized based on a variety of different methods and perspectives. In addition, the concept of "subtype" in reading disabilities is a difficult one to understand given the lack of clarity or independence between the different divisions made. For example, both when comparing children with reading disabilities to children with normal reading abilities, and children with different subtypes of reading disabilities to each other, the cutoff point becomes difficult to determine because there is not an absolute but a gradual difference in performance between the groups (Rispens, van der Stege, & Bode, 1994). Therefore, because of the low likelihood that naturally occurring subgroups will be found in dyslexia, subtypes are imposed and should be understood as "regions within a multidimensional space…constituted by the variables that are implied in the description of the disorder" (Rispens et al., 1994, p. 74). In this conceptualization of subtypes, children who have similar positions on these defined dimensions comprise a subgroup, and criteria and cut-off scores must be imposed in order to define them.

Rather than agreeing with previously cited authors who believe that reading disability can be caused by a variety of different difficulties, Stanovich (1988b) supports the "assumption of specificity": "The concept of a specific reading disability requires that the deficit displayed by the disabled reader not extend too far into other domains of cognitive functioning" (p. 155). Stanovich (1988a) proposed the phonological-core variable-difference model of reading disabilities, which in general postulates that children with reading disabilities who have an intelligence-achievement discrepancy (learning disabled) as well as children who are poor readers but have no discrepancy ("garden-variety" poor readers; see also Gough & Tunmer, 1986) can both attribute their main difficulties in reading to inefficient phonological coding. The term "variable-difference" pertains to the contrasting performance of the children with reading disabilities and garden-variety poor readers: both groups have a core difficulty related to phonological coding, but the garden-variety poor readers have a wider variety of cognitive deficits in a wider variety of domains. Stanovich (1988a) hypothesized that along the continuum of poor readers, moving from children with a discrepancy to garden-variety poor readers, difficulties range from deficits localized in the phonological core to more general, global deficits of the garden-variety poor reader who exhibits a lag in reading development. In describing this continuum, however, Stanovich (1988a) qualifies his hypothesis by invoking his Matthew effects theory (Stanovich, 1986), where children who are initially poor readers may display even more global cognitive deficits as they grow older and where "early modular deficits can grow into generalized cognitive, behavioral, and motivational problems" (Stanovich 1988a, p. 603). Through the Matthew effects, a young poor reader with a discrepancy could actually develop into a garden-variety poor reader; an early deficit in phonological processing could culminate in a series of cognitive skill deficits as the child continues in school (Stanovich, 1986, 1988b). This emphasizes the importance of early assessment and intervention of reading difficulties.

Another group of researchers has proposed the phonological limitation hypothesis, which has also found that the principal correlate of reading disability is linguistic in nature and can be represented by performance on measures of phonological awareness (Fletcher, Shaywitz, et al., 1994). However, although Stanovich (1988a) and Stanovich and Siegel (1994) found that the poor readers with an ability-achievement discrepancy had no other major weaknesses besides phonological awareness, Fletcher, Shaywitz, and colleagues (1994) found that there were a variety of cognitive weaknesses in each group in their sample, including poor readers with and without a discrepancy. The cognitive profiles of the different groups of children investigated in Fletcher, Shaywitz and colleagues' (1994) study were more similar to each other than they were different. The largest differences between the groups occurred between measures most closely related to ability, which had been part of the researchers' initial selection and classification criteria. The findings of this and many other studies challenge Stanovich's (1988b) assumption of specificity and phonological-core variable difference model of reading disabilities.

Though phonological difficulties may be the main source of reading difficulties for many children, there are also other areas where the reading process can break down. One of the main areas of more recent study is related to reading rate, or automaticity. Morris et al. (1998) found evidence for seven different subtypes of reading disability, with six of the subtypes sharing impairments in phonological processing, and short-term memory, spatial skills, and reading rate also contributing to subtypes of reading disabilities. Lovett (1984) identified rate- and accuracy-disabled subtypes of learning disabilities and proposed that reading rate be considered as a new criteria for achievement. These "rate-disabled" readers would not have been traditionally identified as having dyslexia, and according to Lovett, are increasingly and frequently referred as having reading problems as they get older given the increased amount of information they must process in higher grades and their resulting difficulties in all academic areas.

Several subtype frameworks of reading disabilities integrate phonological processing skills and automaticity. Some researchers consider automaticity to be a part of phonological processing (Wagner & Torgesen, 1987; Wagner et al., 1993), while others argue that these two skills are independent of each other (Denckla & Cutting, 1999; Wolf, 1997, 1999; Wolf & Bowers, 2000; Wolf, Bowers, & Biddle, 2000). The initial understanding of the relationship between these two variables was based on the idea that automaticity is the efficiency of retrieving phonological codes (phonemes, word segments, or common short words) from long-term memory (Wagner et al., 1993). Although this view is still held by some researchers today, other researchers have moved to a new conceptualization of reading disabilities that is captured by the double-deficit hypothesis (Denckla & Cutting, 1999; Wolf, 1997, 1999; Wolf & Bowers, 2000; Wolf et al., 2000). This hypothesis views deficits in phonological processing and automatic naming as independent sources for reading disabilities. The presence of a combination of deficits in both processes results in the deepest level of reading impairments (Wolf & Bowers, 2000).

In summarizing a sample of the available subtype literature, it is evident that there are many perspectives on how reading disabilities should be categorized. Some of the variables introduced here that are often used in determining subtypes or the nature of specific reading deficits will be investigated in more detail in future sections of this review. The next section examines some of the theories and models of reading that have driven subtype research or that have resulted from it.

Models of Reading Development

In their review of nonword reading deficits in dyslexia, Rack, Snowling, and Olson (1992) note that most of the recent models of reading development are stage models that all "emphasize an initial visual stage of reading which later gives way to a phonological stage" (p. 31). During this phonological stage, the knowledge of letter-sound relationships is developed, leading to the ability to pronounce printed words. One model of reading that follows this sequence was proposed by Frith (as cited by Castles & Coltheart, 1993, and Rack et al., 1992), who hypothesized the existence of three phases of reading development. The first phase, the logographic phase, is where children develop a small sight vocabulary of words they are able to recognize immediately. Second, children enter into the alphabetic phase after the logographic procedures become less effective. In the alphabetic phase, acquired phonic knowledge is used to read words through letter-to-sound correspondences. Third is the orthographic phase where children are able to bypass phonological conversion and read words as orthographic units. In Frith's model, this recognition of orthographic units relies on rapid recognition of internal representations (memory) of letter combinations.

Expanding upon the importance of rapid recognition, LaBerge and Samuels' (1974) model is based on the possibility that the reader has several options for processing a given word that require less attention as they become more practiced:

> When he encounters a word he does not understand, his attention may be shifted to the phonological level to read out the sound for attempts at retrieval from episodic memory. At other times he may shift his attention to the visual level and attempt to associate spelling patterns with phonological units, which are then blended into a word which makes contact with meaning. When the decoding and comprehension processes are automatic, reading appears to be "easy." When they require attention to complete their operations, reading seems to be "difficult." (p. 313)

Wagner and Torgesen (1987) describe the reading process for beginning readers as broken down into three component processes. These include decoding a string of visually presented letters, temporarily storing in memory the decoded information including the sounds of the letters, and blending together the decoded information to form words. As the reader's phonological skills are developed, specifically the efficient storage of letter sounds as phonological codes, more resources can be allocated to the next step in the process, blending sounds into words.

In contrast to the many stage models of reading development, Spear-Swerling and Sternberg's (1994) model of reading acquisition views transitions between the different phases as being gradual and smooth. They include six phases in their model of developing reading skills. The phases include visual-cue word recognition; phonetic-cue word recognition, which requires a rudimentary level of phonological awareness; controlled word recognition, which requires considerable effort; automatic word recognition, which requires less attention and effort; strategic reading, where strategies for increasing comprehension are employed; and proficient adult reading, based on highly developed comprehension abilities that depend on automatic word-recognition skills.

It could be hypothesized that phonological processing skills would be affected by the child's understanding of the alphabetic principle, or letter-sound correspondence, acquired partially through the auditory processing pathways during the first few stages of reading development. If the child experiences continued difficulty with phonological processing, he or she must continue to focus a large percentage of available attention on the decoding of individual words, instead of being able to store them in long-term memory and retrieve them automatically by visual recognition. As a result, the child will have difficulty attaining proficiency in reading. It is not clear if differences in these processes are present between slow learners and children with learning disabilities.

Just as there are a variety of models describing the development of the reading process, there are also models describing the development of reading disabilities. For the purpose of this review, integrative models of reading disabilities were chosen for examination. Two such models are described in the next section.

Integrative Models of Reading Disability

Spear-Swerling and Sternberg (1994) and Coplin and Morgan (1988) each present an integrative, multidimensional model of reading disability. The more recent model has been proposed by Spear-Swerling and Sternberg, as described above, in an attempt to move away from the strict, specific nature of classifying learning disabilities into subtypes. Their integrative theoretical model of reading disabilities focuses mainly on symptoms and deviations from normal reading development rather than on etiology and the presence of distinct subtypes. Children with reading disabilities are not conceptualized as having a distinct or specific biological disorder or as being qualitatively different from other poor readers. They instead are viewed as falling into one of four predictable patterns of reading difficulty. When the reading process breaks down for individual readers at any of the first four phases of Spear-Swerling & Sternberg's model of reading development, outlined in the above section, the reader is described as having a reading disability.

The second multidimensional perspective for conceptualizing learning disabilities was proposed by Coplin and Morgan (1988). They theorize that the use of a multidimensional view for establishing the presence of subtypes in learning disabilities would result in a less restrictive, more flexible, and more productive framework for the assessment and intervention of learning disabilities. Just as Spear-Swerling and Sternberg (1994) pose that biological and environmental factors interact, Coplin and Morgan emphasize the co-existence and reciprocal influence of neuropsychological, developmental, and environmental influences: these skills "do not exist in a vacuum, and their interdependence is critical to the attainment of academic skills" (p. 620). Their multidimensional perspective includes a continuum along which learning disabilities fall, ranging from mediational subtypes, which are highly specific and organically based, to production subtypes, which are rooted in metacognitive skills, motivation level, teaching deficiencies, and sociocultural deprivation. Integrative, multidimensional models of reading disabilities allow for the inclusion of children such as slow learners within the classification system, especially given their emphasis on the interaction of biological and environmental influences.

This review of a sample of the existing research on subtypes as well as some models of reading development and reading difficulties highlights several important skills and contributions to the reading process. Four of these skills, the focus of this study, will be discussed in detail in the following sections. They include phonological processing, automaticity, auditory processing, and memory.

Processes That Influence Reading Development

There are many component processes that influence reading. When a child has difficulty reading or learning to read, there are many possible points where the reading process could be disturbed, despite intelligence level or educational classification. Four component processes that are related in some way to reading include phonological processing, automaticity, auditory processing, and memory. These processes are described below.

Phonological Processing

Two of the most important parts of the complex reading process are word recognition and reading comprehension (Aaron, 1997; Gough & Tunmer, 1986; Lyon, 1996). Phonological processing has been the focus of recent research because phonological processing precedes word recognition, which in turn is a precursor to comprehension (Aaron, 1997; Lyon, 1996). According to Wagner, Torgesen, Laughon, Simmons, and Rashotte (1993), phonological processing "refers to the use of phonological information, especially the sound structure of one's oral language, in processing written and oral information" (p. 83). Phonological awareness, a precursor to efficient phonological processing, is the awareness of and access to the phonology of language (Wagner & Torgesen, 1987). As explained by the National Research Council's Committee on the Prevention of Reading Difficulties in Young Children (Snow et al., 1998), phonological awareness also refers to a general ability to attend to the sounds of words as separate from their meaning. It is a metalinguistic skill that involves treating language as the object of thought rather than using language for communication only, an essential skill for the understanding of the alphabetic principle that leads to phonics and spelling (Alexander et al., 1991; Felton, 1993;

Snow et al., 1998). Phonological aspects of language include prosodic elements (intonation, stress, and timing) as well as articulatory elements (words, syllables, and phonemes) (Snow et al., 1998). According to Poldrack et al. (2001), phonological processes that are important for reading include phonological segmentation, which is breaking down a spoken word into its separate phonemes; phonological coding, which is the mapping of orthographic symbols onto particular phonemes; and lexical retrieval, which is the retrieval of word forms.

A less inclusive term than phonological processing is "phonemic awareness," which refers to the understanding of every spoken word as a sequence of phonemes (Calfee & Norman, 1998; Snow et al., 1998; Shankweiler et al., 1995). Phonemes are speech sound structure units that comprise speech and make a difference in meaning (Poldrack et al., 2001; Snow et al., 1998). For example, the word "soap" consists of three phonemes, /s/, /o/, and /p/ (see also Calfee & Norman, 1998). The concept of phonics is often confused with that of phonemic awareness or phonological processing. The term "phonics" refers to instructional practices that teach systematic relationships between speech sounds and spelling (Snow et al., 1998). Phonics instruction usually assumes the presence of phonemic awareness (Snow et al., 1998).

Phonological awareness for most children develops gradually and naturally during the preschool years and is closely related to speech development (Snow et al., 1998). Some of the first signs of phonological awareness include appreciating rhymes, playing with sounds, and correcting speech errors. One of the beginning steps of phonemic awareness is being able to appreciate alliterations, which also usually takes place during the preschool years. The more complex phonemic segmentation skills are not usually developed in most children until they are five or six years old (Snow et al., 1998). Given the nature of these skills, appropriate development of initial phonological awareness requires adequate auditory processing.

Current research has revealed that though phonological processes do not appear to be the only source of a reading disability, they are the core deficit in many poor readers (Fletcher, Shaywitz, et al., 1994; Lyon, 1996; Morris et al., 1998; Rack et al., 1992; Siegel, 1989a, 1992; Stanovich, 1998; Stanovich & Siegel, 1994; Wagner et al., 1993). In addition, the relationship between reading and phonological processing has been found to be causal, possibly due to a bottleneck in the development of phonological processing skills (Aaron, 1997; Catts, 1986; Gough & Tunmer, 1986; Lyon, 1995; Morris et al., 1998; Shankweiler et al., 1995; Stanovich, 1989; Truch, 1998; Wagner & Torgesen, 1987). Reading and phonological processing have also been found to have a reciprocal relationship: "While phonological awareness is a prerequisite for normal reading, reading experience also facilitates phonological awareness" (Schulte-Korne et al., 1999, p. III/28). In addition, phonological awareness has been found to be highly correlated with general language ability (Snow et al., 1998). The relationship between phonological awareness and language ability will be explored in a future section of this review.

Even though phonological processing is not usually very well developed in most children when they begin school, it has been found to be a strong predictor of reading success (Aaron, 1997; Blachman, 1997; Snow et al., 1998). Many researchers have shown that deficits in phonological processing are similar in slow learners and children with learning disabilities (Aaron, 1997; Fletcher, Shaywitz, et al., 1994; Shaywitz, Fletcher, et al., 1992; Siegel, 1989a, 1990, 1992; Stanovich, 1994; Stanovich & Siegel, 1994; Toth & Siegel, 1994). In addition, phonological processing has been found to be a better predictor of reading than intelligence level (Aaron, 1997; Calfee & Norman, 1998; Gough & Tunmer, 1986; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stage et al., 2003; Stanovich & Siegel, 1994; Truch, 1998).

Phonological awareness can be assessed with tasks that require isolation or segmentation of phonemes, combination of phonemes into a word, or manipulation of phonemes within a word by adding, subtracting, or rearranging phonemes (Aaron, 1997; Blachman, 1997; Rack et al., 1992; Snow et al., 1998). In children who have phonologically based learning disabilities, their reading problem may be primarily evident in the processing of unfamiliar words and nonwords (Rack et al., 1992). Therefore, some researchers have suggested that the most distinctive indicator of deficits in phonological processing is difficulty reading pseudowords, which are logical letter combinations that do not form actual words (Badian, 1996; Catts, 1986; Felton, 1993; Rack et al., 1992; Siegel, 1989a, 1990, 1992; Stanovich, 1994; Stanovich & Siegel, 1994).

In sum, many researchers have argued that deficits in phonological processing are central and possibly causal to reading difficulties for many slow learners and children with learning disabilities (Aaron, 1997; Catts, 1986; Fletcher, Shaywitz, et al., 1994; Gough & Tunmer, 1986; Lyon, 1995, 1996; Morris et al., 1998; Rack et al., 1992; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stanovich, 1998a, 1989b; Stanovich & Siegel, 1994; Wagner et al., 1993; Truch, 1998; Wagner & Torgesen, 1987). Some researchers also argue that automaticity influences phonological processing (Wagner & Torgesen, 1987; Wagner et al., 1993). The construct of automaticity will be discussed in the following section.

Automaticity

Just as research on phonological processing has begun and greatly expanded in the past few decades, so has the exploration of the importance of automaticity in the language and reading processes. Automaticity as it relates to reading is frequently referred to as automatization or rapid naming but has also been called rapid retrieval (Denckla & Rudel, 1976) and efficiency of phonological code retrieval from long-term memory (Denckla & Cutting, 1999; Wagner et al., 1993). It generally refers to the process by which the many components involved in the complex activity of reading are coordinated and executed within a very short period of time (LaBerge & Samuels, 1974), after practice and without a decrease in general processing capacity (Wolf et al., 1986). Lovett (1984) has defined automaticity as "a performance which has been overlearned to the point of requiring little or no conscious attention for its enactment" (p. 69). Automaticity has been further described as the point at which processing can be completed while attention is directed elsewhere (LaBerge & Samuels, 1974) and where few mental resources are required (Spear-Swerling & Sternberg, 1994). As related to dyslexia, automaticity also refers to increases in the speed of word recognition during normal reading development (Lovett, 1984).

Automaticity has been increasingly studied recently because initial studies found that scores on measures of automaticity could predict later reading skill (Badian, 1998; Catts, 1993; Denckla & Rudel, 1974, 1976; Semrud-Clikeman et al., 2000; Wolf et al., 1986). Performance on tasks that measure automaticity has been found to differentiate between children with reading disabilities and average readers (Ackerman & Dykman, 1993; Badian, 1996; Denckla & Rudel, 1976; Wolf et al., 2000). Several different types of rapid naming tests are currently available, such as the Rapid Automatized Naming Test (Denckla & Rudel, 1974, 1976) that measures naming speed for a series of four repeating numbers, letters, colors, or objects; and tests measuring the speed of picture naming or word finding such as those found in the *Woodcock-Johnson III* (Woodcock, McGrew, & Mather, 2001).

Norman Geschwind (1965), a neurologist from the second half of the twentieth century, has been credited with initially theorizing about the connections between reading and naming (see also Wolf, 1997 and 1999, and Denckla & Cutting, 1999). Initial investigations of this reading-naming relationship focused on the difficulty of color-naming by some children with dyslexia (Denckla, 1972), which led researchers to question the possibility that naming other stimuli (letters, numbers, and pictures of objects) through visual-verbal tasks would also be difficult for poor readers (Denckla & Rudel, 1974, 1976). Though these extended studies of naming, it was discovered that the importance of naming lies not in the inability to name or in the accuracy of naming, but in the length of time required for the individual to produce the name (Wolf, 1986). Denckla (1972) described the hesitancy of children with dyslexia relative to controls on naming tasks as a "lack of automaticity" (see also Denckla & Cutting, 1999). Research on naming and reading continued with the development of a set of rapid automatized naming tasks (RAN) that differentiate between the naming speed of normal readers and children with dyslexia (Denckla & Rudel, 1974, 1976). Results from early studies using this RAN task offered an explanation for a major source of reading impairment in children with reading disabilities: when readers fail to acquire automaticity in the subprocesses of reading that overlap with naming, such basic lower-level tasks as feature recognition and name access expend extra processing time and cognitive attention, thus leaving little attention for higher level components in the reading process (Denckla & Rudel, 1974, 1976; Wolf, 1986).

Many models of reading incorporate the presence of automatized subprocesses in fluent reading (Fletcher, Shaywitz, et al., 1994; Morris et al., 1998; Wagner et al., 1993; Wolf, 1986). Bottom-up theories of reading, which stress the importance of decoding and spelling (as opposed to top-down theories, which emphasize meaning and the use of context), highlight the importance of automaticity in word decoding so that more attention is available to focus on processing the meaning of text (Laberge & Samuel, 1974; Truch, 1998). LaBerge and Samuels (1974) propose an information processing model, described previously in more detail, that stresses the importance of the development of automaticity:

> If each component process requires attention, performance of the complex skill will be impossible, because the capacity of attention will be exceeded. But if enough of the components and their coordinations can be processed automatically then the load of attention will be within tolerable limits and the skill can be successfully performed. (p. 293)

Other theories and hypotheses of reading and reading disability also include the notion of automaticity, which has generally been seen as contributing to the reading process in one of two ways: either in conjunction with and supporting phonological awareness (Catts, 1986; Farmer & Klein, 1995; Spear-Swerling & Sternberg, 1994; Truch, 1998; Wagner & Torgesen, 1987; Wagner et al., 1993), or as an autonomous cognitive process (Denckla & Cutting, 1999; Wolf, 1999; Wolf & Bowers, 2000; Wolf et al., 2000). For instance, Spear-Swerling and Sternberg's model of reading (1994) emphasizes the sequence of reading, where automaticity in decoding develops first, early, and quickly, followed by phonological awareness. On the other hand, other models of the breakdown in the reading process, most notably the recent double-deficit hypothesis mentioned above, describe automaticity and phonological processing as independently developing processes (Denckla & Cutting, 1999; Wolf, 1999; Wolf & Bowers, 2000; Wolf et al., 2000).

As research continues to reveal the nature of the link between automaticity and reading, the importance of the assessment of automaticity is being increasingly recognized. Phonologically based reading interventions have greatly improved over the years, but there remains a subgroup of children whose reading difficulties lie outside the phonological realm and who therefore fail to be remediated despite these well-developed interventions (Wolf, 1999). Thus, Wolf (1999) argues for a "dual emphasis on both phonological processes and the fluency-related processes underlying naming speed" (p. 5) in research and treatment in an attempt to catch the children who often slip through diagnosis and intervention unidentified or unremediated (see also see also Lovett, 1984; Wiig, Zureich, & Chan, 2000).

Another research question regarding automaticity is whether rapid naming skills are relatively independent from intelligence levels. Some researchers have hypothesized that IQ and naming are independent (Wolf, 1997). Recently, however, a few studies have found differential performance between poor readers with and without a discrepancy on rapid naming tasks. One unpublished study (Scarborough & Domgaard, 1998, as cited by Wolf, 1999) found no difference in letter and number naming between slow learners and children with learning disabilities but did find a difference in object naming. Ackerman and Dykman (1993) found that slow learners performed better on RAN tasks than children with reading disabilities; however, in the researchers' sample, the slow learners were more advanced readers than the children with learning disabilities, a factor that could have influenced the results of the study. Badian (1996) compared slow learners to children identified as having learning disabilities on a variety of tasks, including rapid naming, and found that although at younger ages (6 to 7 years) there was no difference in her sample between these two groups on reading-related tasks, at older ages (8 to 10 years), slow learners had average rapid naming skills while children with learning disabilities were significantly impaired. This study, however, included a very broad range of verbal ability levels for the learning disabled group (85 to 130 standard score points), and did not specify a lower cutoff verbal ability score for the slow learner group (below 92 standard score points). It is possible that the broad range of verbal abilities, overlap between the ability scores between the two groups, and lack of a minimum score for the slow learners influenced the researcher's results. Given equivocal evidence and methodological concerns of studies previously conducted in this area, it is clear that more research is necessary in order to understand the nature of the relationship between automaticity and intelligence.

In sum, the construct of automaticity has been incorporated into many theories of reading and reading disabilities (Fletcher, Shaywitz, et al., 1994; Morris et al., 1998; Wagner et al., 1993; Wolf, 1986). Empirical evidence has also demonstrated a relationship between automaticity and reading skill in children (Denckla & Rudel, 1974, 1976; Geschwind, 1965; Semrud-Clikeman et al., 2000; Wolf, 1986). Auditory processing, a third skill that has been found to be related to the reading process, will be explored in the following section.

Auditory Processing

Auditory processing is a skill that has been found to be significantly related to reading (Byrne & Lester, 1983; Shapiro et al., 1990), and deficits in auditory processing have been found to play a role in reading disabilities (Gomez & Condon, 1999; Schulte-Körne et al., 1999). While many early studies of reading disabilities implicated underlying visual impairments, recent studies have also revealed the presence of a relationship between auditory processing and some types of reading disabilities (Ahissar et al., 2000; Farmer & Klein, 1995; McAnally et al., 2000; Merzenich et al., 1996; Tallal et al., 1996). Given this emerging evidence, difficulties in auditory processing or the presence of auditory processing disorders may influence reading acquisition, possibly contributing to the development of learning disabilities in reading. In order to understand how auditory processing deficits can interfere with reading ability, it is important to understand what auditory processing is and how these processes can be disordered.

Currently in the fields of speech, hearing, and language, there exists much controversy and no consensus as to the exact definition and procedures for the identification of and intervention for central auditory processing and its related disorders (American Speech-Language-Hearing Association, 1996). In 1993, a task force was commissioned by the American Speech-Language-Hearing Association (ASHA) in order to help develop a statement of consensus in identification and practice related to central auditory processing disorders. The task force developed the following definition for central auditory processes:

> Central auditory processes are the auditory system mechanisms and processes responsible for the following behavioral phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal resolution, temporal masking, temporal integration, and temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals. (p. 43)

Early models of auditory processing hypothesized that information is processed in specific brain regions. The definition provided above, however, given its complexity and integrative nature, has led to the development of network models that have replaced older pathway models. These network models emphasize the distributed nature of the nervous system's information processing and hypothesize that many brain regions are involved in integrative responding to acoustic signals (Chermak & Musiek, 1997).

Generally, individuals with central auditory processing disorders (CAPD) have been found to have normal hearing accompanied by auditory-based receptive communication or language learning problems (Keith, 2000b). The Task Force on Central Auditory Processing Consensus Development (ASHA, 1996) defines CAPD as a deficiency in any of the processes described in the definition of central auditory processes, provided above. The Task Force also notes that CAPD may either result from a breakdown of the processes and mechanisms involved in audition, from a more general system dysfunction such as ADHD that affects performance across modalities, or from a combination of the two. Other terms that have described CAPD include auditory processing disorder, auditory perceptual problem, and central auditory dysfunction (Keith, 2000b).

The validity of the diagnosis of CAPD has been questioned since some researchers argue that this diagnosis is not based on theory, there is no standardized format for diagnosing the disorder, and there are no incidence or prevalence statistics (Cacace & McFarland, 1998). Based on clinical reports, clinical experience, and prevalence data for comorbid conditions, however, Chermak and Musiek (1997) estimate the prevalence of CAPD in children as being between two and three percent.

Although CAPD has not yet been included in the DSM-IV (American Psychiatric Association, 1994), Keith (2000a) proposes a sample entry with diagnostic criteria and differential diagnosis for CAPD, including the following behavioral symptoms: difficulty discriminating between speech sounds, remembering and manipulating phonemes, understanding rapid speech, and recognizing musical sound patterns and rhythms (Keith, 2000b). Other symptoms may include having difficulty comprehending speech in the presence of background noise or remembering and following auditory directions; having poor listening skills; and responding inconsistently to auditory stimuli as well as having scattered scores on auditory-dependent subtests included in psychoeducational batteries (Keith, 2000b). Keith also (2000a) proposes that the individual must exhibit four of these nine symptoms for at least six months in order to receive a diagnosis of CAPD. Differential diagnoses are also specified, so that CAPD is seen as a specific disorder separate from peripheral hearing loss, language impairments, learning disabilities, impaired intellectual functioning, ADHD, and normal variations in auditory processing abilities. These specific disorders are often co-morbid, however, as children with CAPD often also have significant reading problems, are poor spellers, and have poor handwriting Chermak & Musiek, 1997). Children with CAPD are also most often male (Keith 2000a). In addition, individuals with these diagnoses frequently experience difficulty with spoken language processing.

Because there continue to be disagreements between researchers about what exactly a CAPD is, there is as of yet no consensus regarding the assessment of related skills. Some cognitive assessment batteries, including the *Woodcock-Johnson III* (WJ-III, Woodcock et al., 2001), include measures of auditory processing such as tasks of auditory interference, where target words are presented in the presence of background noise; closure, where parts of words are pronounced with segments missing; and synthesis, where separately presented syllables are blended together. Non-language measures of auditory processing have also been developed in order to avoid the possibility of confounding language with auditory processing. Examples include the *Test of Variables of Attention-Auditory*(TOVA -A, Greenberg, 1999) and the Sound Patterns-Music test from the WJ-III which both involve a pair of tones that must be differentiated from each other.

In reviewing available research to date, there did not appear to be any research investigating comparative patterns of performance between slow learners and children with learning disabilities on tasks of auditory processing. Given the suggested links between reading disabilities and auditory processing difficulties that are examined here, an interesting question is raised regarding existing similarities or differences on measures of auditory processing between slow learners and children with learning disabilities, especially for identification and treatment purposes.

In sum, auditory processing skills have been linked to reading (Byrne & Lester, 1983; Shapiro et al., 1990) and to some forms of reading disabilities (Ahissar et al., 2000; Farmer & Klein, 1995; McAnally et al., 2000; Merzenich et al., 1996; Tallal et al., 1996). Disorders in auditory processing, though their diagnosis is not yet fully recognized or agreed upon, are often comorbid with reading disabilities (Chermak & Musiek, 1997; Keith, 2000b). The next section will investigate memory, a fourth skill that has been found to be related to the reading process.

Memory

Deficits in memory have been found to be significantly related to the reading difficulties of some children (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer et al., 2000; Morris et al., 1998; Swanson, 2000; Wagner et al., 1993; Wagner & Torgesen, 1987), and verbal memory has been found to be a strong predictor of preschool children's future reading achievement (Snow et al., 1998). It has been hypothesized that beginning readers have three basic tasks to perform, two of which require memory: decoding a string of visually presented letters, storing the sounds of the letters in a temporary store, and blending the contents of the temporary store to form words (Wagner & Torgesen, 1987). Previous sections of this review have described important points where memory involvement is necessary in reading. For example, words and alphabetic codes must be retrieved from long-term memory, and words and concepts must be held in and processed by working memory during the reading of a passage. An exploration of the theoretical composition of memory systems will help to clarify the proposed role of memory in reading development.

Memory researchers have largely come to an agreement regarding the presence of at least two memory systems based on evidence from research since the 1960s (Lezak, 1995). These two systems include declarative memory, which is the ability to learn and remember information, objects, and events; and procedural memory, or ability to perform habitual actions such as walking or talking. While an individual is aware of the presence of information in declarative memory, he or she is not usually aware of the presence of procedural memories. The declarative memory system has largely been the focus in the study of reading disabilities.

As described by Gazzaniga, Ivry, and Mangun (1998), declarative memory includes three stages: encoding, storage, and retrieval. During encoding, incoming information is processed through acquisition and consolidation, resulting in a stronger representation with the passage of time. Storage occurs when the permanent record of information is created and maintained. Retrieval is the process of accessing the stored information in carrying out a thought or action that has been stored in memory. Gazzaniga and colleagues provide subdivisions of memory based on the length of retention of information, including sensory memory, short-term (immediate) memory, and long-term memory. Sensory memory refers to memory that lasts no longer than a few seconds and may be represented in visual or auditory modalities. Short-term memory lasts between a few seconds and a few minutes, and long-term memory spans between days and years (see also Baddeley, 1999 & 2002; Lezak, 1995; and Tranel & Damasio, 2002, for an explanation of the stages of memory).

Working memory is related to the short-term memory system and is responsible for processing information being held in short-term memory

(Baddeley, 1999). Swanson (2000) defined working memory as “a processing resource of limited capacity involved in the preservation of information while simultaneously processing the same or other information” (p. 551). Baddeley and Hitch’s theoretical proposal of working memory in 1974 (as cited in Baddeley, 1999) includes three components: the phonological loop, visuospatial sketchpad, and central executive. The phonological (or articulatory) loop is a hypothesized mechanism that accounts for the process of rehearsal, usually by way of subvocal speech, in order to retain the memory trace. Kramer, Knee, and Delis (2000) found a specific pattern of performance for children with dyslexia that may be related to a functional deficit in the phonological loop: although children with dyslexia were able to retain information once it was learned and were aided by recognition, they had significant difficulty learning new material, rehearsing, and encoding semantic information. Baddeley (1999) notes that the process of reading often involves subvocalization, where people commonly hear what they are reading in an inner voice that he attributes to the phonological loop. He also hypothesized that this subvocalization plays a less crucial role in fluent readers. If disruption to this portion of working memory occurs in adults, no difficulty should occur; however, if a disruption of this sort occurs in children it is likely to influence their language acquisition skills (see also Gang & Siegel, 2002).

The second component of the working memory system as proposed by Baddeley (1999) is the visuospatial sketchpad. This component is used for temporarily holding visual and spatial information, “for displaying imageable words and for manipulating images in mnemonic schemes” (p. 65). Given that visual memory deficits have been reported less frequently than verbal memory deficits in children with reading disabilities (Gang & Siegel, 2002; Kramer et al., 2000), the visuospatial sketchpad may play a less important role in reading than the other components of working memory.

The third and final component of the working memory system is the central executive. The central executive is described as a “limited-capacity system that controls the phonological loop and visuospatial sketchpad, and relates them to long-term memory” (Baddeley, 1999, p. 66). Baddeley notes that although knowledge about the central executive is limited, the concept has proven valuable in understanding memory processes and relating short term memory to long-term memory (see also Gazzaniga et al., 1998, and Henry, 2001, for summaries of Baddeley and Hitch’s working memory theory.)

There are many measures available for the assessment of memory functioning, and research studies have used a variety of evaluation methods including those measuring short-term, long-term, and working memory in the verbal and visual modalities. Some examples of memory tasks incorporated in previous research studies have included short-term memory for words and/or numbers (Ackerman & Dykman, 1993; Kramer et al., 2000; Morris et al., 1998; Wagner et al., 1993); nonverbal short-term memory (Fletcher, Shaywitz, et al., 1994; Morris et al., 1998); and working memory for words, numbers (Siegel, 1992), and patterns (Henry, 2001). Several assessment measures are available to test the many different aspects of memory in children and adults. Some assessment batteries, such as the *Woodcock-Johnson III* (Woodcock et al., 2001), include tasks of memory functioning as a part of the cognitive or achievement tests.

Results from studies investigating memory in slow learners and children with learning disabilities have been ambivalent. Some studies have found differences between the groups in some areas but not in others. For example, Stanovich and Siegel (1994) found that slow learners and children with learning disabilities performed similarly on a task of memory for letter span, but that children with reading disabilities performed significantly better than slow learners on a working memory task for words and numbers. Henry (2001) investigated memory differences at different levels of intelligence and found that children in the borderline range of intelligence performed as well as children with average intelligence on tasks of visual-spatial memory and memory span, while they were performed significantly worse on memory tasks for phonological memory (see Vicari & Carlesimo, 2002, for a review of memory deficits in children with mental retardation). Other studies have found similarities between groups (Fletcher, Shaywitz, et al., 1994; Siegel, 1992). Additional research would help to provide more conclusive evidence in this area.

The Relationship Between Phonological Processing, Auditory Processing, Automaticity, and Memory

Reading is a complex process that involves many variables. As stated previously, many researchers theorize that reading disabilities are not a unitary phenomenon and that difficulty with reading may be related to a breakdown in one of the many factors involved in reading (McAnally et al., 2000; Morris et al., 1998). The present study focuses on four of these many variables and their hypothesized relationship: phonological processing, automaticity, auditory processing, and memory. Links between these skills will be examined here through an analysis of theory as well as an investigation of behavioral and neuroanatomical evidence.

Theoretical Links and Behavioral Evidence

There are several theories that emphasize the necessity of both phonological processing and automaticity in the development of the efficient reading process. In Spear-Swerling and Sternberg's (1994) integrative theoretical model of reading disability, based in part on LaBerge and Samuels' (1974) theory of automatic information processing, phonological awareness precedes the development of automaticity, both of which are crucial steps in developing normal reading skills. It is theorized that one of the initial steps of reading acquisition is phonetic-cue word recognition, where readers begin to use phonetic cues to recognize words though this recognition is inconsistent and infrequent. Phonological awareness is necessary at this stage since children must have some level of awareness of the presence of phonemes in the speech heard around them. A later phase, automatic word recognition, is described as the ability of children to "recognize most common words in a manner that is not only accurate, but also relatively effortless" (Spear-Swerling & Sternberg, p. 94). As words become more and more automatic, automatization of word recognition is established which then leads to the foundation for an increasing skill in comprehending what is read.

As described previously, some theories define automaticity as a component process of developing phonological processing skills. Other theories hypothesize that automaticity and phonological processing are independent processes, with a deficit in both areas causing the most profound reading impairments than either one alone (Denckla & Cutting, 1999; Wolf, 1997, 1999; Wolf & Bowers, 2000; Wolf et al., 2000). For the purposes of this study, automaticity and phonological processing are understood as reciprocally contributing to the development of reading.

Given the research and theory explained in previous sections of this review, the importance of memory is evident in the development of both advanced phonological processing skills and automatic processing of verbal input. In order to advance to higher levels of phonological processing, it is necessary to develop and commit to long-term memory an alphabetic code of sound-symbol correspondence. In normal readers, these codes are then automatically cued as the visual input is present. This is the process of automaticity, which has been referred to as the efficiency of retrieval of phonological codes from long-term memory (Denckla & Cutting, 1999; Wagner & Torgesen, 1987; Wagner et al., 1993). For efficient reading to take place, it is also necessary to be able to effectively utilize working memory when verbal inputs must be processed. In reviewing previous research, Wagner and colleagues (1993) proposed that during an ongoing reading task, information is coded in a sound-based representation system that results in a set of phonemes being available to the reader for blending in working memory. The pronunciations of letters as well as common words and words segments may also be retrieved from long-term memory.

Several theories and groups of researchers have hypothesized as to the relationship between auditory processing and phonological processing. Catts (1986) attributes the development of adequate phonological processing skills to learning "the complex correspondence between the sounds of words and their spellings" (p. 504), and notes that a lack of explicit awareness of sound segments could interfere with this process. In order to appropriately attribute the sounds of words to their spellings, it could be hypothesized that in the initial stages of reading development, auditory processing skills must be adequate. Some research has shown that auditory perceptual skills are significantly related to reading skill. As explained by McAnally et al. (2000), it has been hypothesized that auditory sensory deficits lead to difficulty with speech perception, which in turn leads to deficits in phonemic awareness, a component of phonological processing where speech sounds are manipulated. Research has revealed strong correlations between auditory sensory impairments and problems in phonemic awareness (Tallal et al., 1996). Some studies have also shown that deficits in temporal processing contributing to difficulty perceiving and discriminating phonemes lead to difficulty recognizing phonemes and therefore a lack of automaticity in auditory processing skills (Farmer & Klein, 1995). Language-based models of reading disabilities are founded on the idea that phonemic awareness, or the insight that words are made up of smaller units of speech (Snow et al., 1998), is deficient in children with reading disabilities (Ahissar et al., 2000; Farmer & Klein, 1995; Tallal et al., 1996). From this perspective, these deficits in phonemic awareness can be attributed to a specific deficiency within phonology, which is theorized to be the language component that processes the sounds of speech (Ahissar et al., 2000). It has been theorized that these deficits in phonology are, in turn, caused by a deficit in acoustic signal reception; for example, children who are poor readers have been found to have difficulty discriminating between speech sounds (Ahissar et al., 2000). As reviewed by Farmer and Klein (1995), there is a firmly established link between early language difficulties and later reading disabilities (see also Tallal et al., 1996).

Speech itself can be defined as "an acoustic signal comprised of multiple co-occurring frequencies, called formants" (Fitch, Miller, & Tallal, 1997, p. 332). Speech perception is characterized by translating continuous, rapidly changing acoustic signals onto phonemic representations (Poldrack et al., 2001). McAnally et al. (2000) have hypothesized that auditory sensory deficits lead to difficulty with speech perception, which in turn leads to deficits in phonemic awareness, the component of phonological processing where speech sounds are manipulated. As a result, the development of the reading process is disrupted.

The quick, brief nature of continuous speech signals where listeners must quickly recognize phonemes, syllables, and words in speech are referred to as "real-time speech" (Chermak & Musiek, 1997). If a deficit in auditory processing exists, automaticity of these language components may not be established, leading to difficulty in the development of language skills including reading. If acoustic signals are degraded by being presented very rapidly or in the presence of background noise, it is difficult to develop good real-time language processing skills. These barriers may place children with central auditory processing disorders at risk for developing learning disabilities (Chermak & Musiek, 1997).

The review undertaken in this section is designed to provide empirical evidence and theoretical underpinnings for the relationships between reading and phonological processing, automaticity, auditory processing, and memory. It is hypothesized here that phonological processing is the pathway leading to successful decoding skills. During development, phonological processing is initially influenced by auditory processing as the child is learning the associations between certain sounds and letter combinations. As the associations between these sounds and letters are continually practiced, they become automatic and are stored in long-term memory, no longer necessitating the decoding process each time they are confronted. As a result, the phonological processes become automatized and more efficient, leading to improved reading achievement. The relationships between these skills are complex, and more research is needed to understand them better. In addition, there is little conclusive research that investigates the performance of poor readers at different levels of intelligence on all four of these skills.

Research investigating the neuroanatomy of learning disabilities has offered a great deal of information about apparent brain dysfunction and structural abnormalities in children and adults with learning disabilities. Neuroanatomical evidence has also been found linking brain regions or pathways involved in learning disabilities, phonological processing, automaticity, and auditory processing, and memory. A brief examination of existing literature on these links is provided in the following section.

Neuroanatomical correlates

Not only are there behavioral findings and theoretical underpinnings that connect these three processes to each other, but some neuroanatomical connections have also been found. One of the most widely agreed upon finding is that learning disabilities are linked to the left hemisphere planum temporale, the brain region that is thought to be key in linguistic and reading processes (Hynd & Semrud-Clikeman, 1989; Teeter & Semrud-Clikeman, 1997). In children and adults with average reading ability, this left hemisphere brain region has been found to be larger than the same region in the right hemisphere; however, individuals with learning disabilities have been found to have symmetrical left and right plana. The presence of asymmetry in the planum temporale of average readers has been linked to several skills important in the reading process, including phonological processing and rapid naming skills (Teeter & Semrud-Clikeman, 1997).

Several studies have found evidence supporting neuroanatomical connections between auditory processing and learning disabilities, possibly due to the proximity of the left hemisphere planum temporale to the auditory association cortex (Teeter & Semrud-Clikeman, 1997). Some postmortem studies reviewed by Chermak and Musiek (1997) have found brain abnormalities in auditory regions of the brain in children with learning disabilities. One study found that children with learning disabilities have deficits in left hemisphere auditory processing (Obrzut, 1991; see also Teeter & Semrud-Clikeman, 1997). Galaburda, Menard, and Rosen (1994) investigated the hypothesis that anatomical abnormalities in the auditory system may be the cause of difficulties in abnormal auditory processing in children with reading disabilities. Differences were found between controls and children with reading disabilities in the medial geniculate nucleus, the region in the thalamus responsible for distributing auditory information (see also Livingstone, Rosen, Drislane, & Galaburda, 1991; and Rosenzweig, Leiman, & Breedlove, 1996): while controls had no hemispherical asymmetry in the medial geniculate nuclei, children with dyslexia displayed a pattern exhibiting more small (parvocellular) neurons and fewer large (magnocellular) neurons in the left medial geniculate nuclei than in the right. These findings are consistent with behavioral results showing a left hemisphere phonological deficit in children with reading disabilities (Galaburda et al., 1994). Another study found that in children aged five to nine years old, anatomical asymmetry of the auditory association cortex predicted phonemic awareness, a necessary part of phonological processing (Leonard et al., 1996). In their review of neuroanatomical research, Poldrack et al. (2001) noted that phonological processing in reading and phonological processing in speech perception appear to rely on common brain regions in the inferior frontal cortex.

Wolf (1999) developed a hypothesis related to automatic naming and neuroanatomical correlates drawing upon some additional findings of Galaburda et al. (1994), that not only is the magnocellular system (the cells responsible for rapid processing) abnormal in the medial geniculate nuclei, but it is also abnormal in the lateral geniculate nuclei, which is the area of the thalamus responsible for coordinating visual processing. As a result, automaticity may be compromised in visually based reading tasks. Wolf hypothesized that slower rates of processing could lead to slower letter-pattern identification, naming speed, and recognition of patterns in written language, as well as the need for multiple exposures before a letter pattern is sufficiently represented in the child's mental lexicon.

As outlined by Tranel and Damasio (2002), many structures in the brain have been found to be involved in memory. For instance, the hippocampal region has been found to be related to immediate and retrograde memory. The frontal lobes play at least a secondary role in memory through their involvement in attention, encoding, and problem-solving. They have also been implicated in aspects of working memory. The basal ganglia and the cerebellum have been implicated in procedural learning and memory, with a particular emphasis on learning movement coordination within the cerebellum. The primary association cortex for visual, auditory, and somatosensory information that is used in perception of information is also used for the recall of information. Finally, the thalamus provides support for memory capacities contributing to the acquisition of factual knowledge and the temporal sequencing of memory. Lezak (1995) reports that registration of the stimulus, short-term memory, and rehearsal of information to be stored involve electrochemical activation at the synaptic level; and that memory consolidation, long-term memory, retrieval, and forgetting are all due to semipermanent changes in cell structure or chemistry.

Like reading, memory is a complex process that involves many different brain regions. Some of these regions overlap with regions implicated in the processes described above. For example, the thalamus has been found to be an important structure involved in memory, phonological processing, automaticity, and auditory processing. Also, the auditory association cortex has been implicated in both memory and phonological processing. These similarities in neuroanatomy allow for the hypothesis that memory is not only theoretically and functionally related to phonological processing, automaticity, and auditory processing, but that it is structurally related to these processes.

In sum, neuroanatomical evidence has been found that relates these processes to each other and to localized abnormalities in brain structure. The need remains for further study in these areas. Neuroimaging studies comparing slow learners and children with learning disabilities may also be useful in helping to understand the sources of different types of reading difficulties.

Statement of the Problem

Though several definitions currently exist for learning disabilities, the inclusionary criteria for diagnosing a learning disability remain in dispute. Initially, reading disabilities were thought to exist as a discrete entity that did not fall along the normal distribution of reading ability (Rutter & Yule, 1975). The practice of using an intelligence score cutoff point in the definition of reading disabilities is based on these findings (Shaywitz, Escobar, et al., 1992). More recent research, however, has been unable to fully replicate these results that showed a bimodal reading distribution of reading ability, suggesting instead that reading disabilities represent the lower end of the normal distribution of reading (Pennington et al., 1992; Shaywitz, Escobar, et al., 1992). It has been suggested that current school practice has not been modified to fit these findings (Stage et al., 2003; Swanson et al., 1999). Therefore, there exists a population of children who fall below the intelligence score cutoff in the classification as reading disabled even though many researchers suggest that they should also receive services (O'Malley et al., 2000; Shaywitz, Escobar, et al., 1992; Siegel, 1989a, 1990, 1992; Snow et al., 1998; Stage et al., 2003; Stanovich, 1989). These children, often referred to as slow learners, have low to below average intelligence scores with commensurate achievement scores, resulting in the absence of a discrepancy which would otherwise classify them as having learning disabilities (The Center for Slower Learners; Fletcher et al., 1992; Humphries & Bone, 1993; Johns, 1990; Marshall, 1988; Siegel, 1989b, 1990; Williams, 1989).

Researchers who oppose the discrepancy model argue that its underlying assumptions have yet to be proven (Aaron, 1997; Siegel, 1989a, 1990, 1992, 1995; Stanovich, 1989, 1994; Swanson et al., 1999; Toth & Siegel, 1994). For example, the discrepancy theory assumes that because of different intelligence scores, these two groups of children have different etiologies of reading problems (Aaron, 1997; Siegel, 1989a, 1990; Stanovich, 1994; Toth & Siegel, 1994). In turn, it is assumed that educational prognosis will be differentially affected by intelligence (Aaron, 1997; Swanson et al., 1999; Toth & Siegel, 1994). Many studies, however, have found similar patterns of performance between these groups on a variety of measures, including phonological awareness tasks (Aaron, 1997; Shaywitz, Fletcher, et al., 1992; Siegel, 1992; Toth & Siegel, 1994; Vellutino et al., 2000). In addition, the existing research has not provided convincing evidence supporting different outcomes following specific interventions or teaching techniques (Aaron, 1997; Gresham et al., 1996; Swanson et al., 1999). In fact, several very recent studies have found similar outcomes following remediation for slow learners and children with reading disabilities or for children with and without a discrepancy (Jiménez et al., 2003; Vellutino et al., 2000).

Deficits in phonological processing, a metalinguistic skill in which readers are able to think about words as units separate from their meaning (Alexander et al., 1991; Felton, 1993; Snow et al., 1998), are believed to be at the core of reading difficulties for most poor readers regardless of intelligence level (Fletcher, Shaywitz, et al., 1994; Lyon, 1996; Morris et al., 1998; Siegel, 1989a, 1992; Stanovich & Siegel, 1994). A second skill that has been linked to the reading process is automaticity, or the ability to process reading information quickly and with little effort (see LaBerge & Samuels, 1974; Lovett, 1984; Spear-Swerling & Sternberg, 1994; Wolf et al., 1986). The relationship between automaticity and intelligence is unclear, given the presence of equivocal evidence (Ackerman & Dykman, 1993; Badian, 1996; Wolf, 1997, 1999). A third skill whose importance in the reading process is hypothesized but less well understood is auditory processing for both speech and non-speech stimuli, in its contributions to the initial stages of the development of phonological processing (Catts, 1986; Farmer & Klein, 1995; McAnally et al., 2000; Poldrack et al., 2001; Tallal et al., 1996). Auditory processing disorders and learning disabilities often co-exist, and it is hypothesized that deficits in auditory processing may lead to some types of learning disabilities (Keith, 2000a; Chermak & Musiek, 1997). Finally, memory deficits have been found to be significantly related to the reading difficulties of some children (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer et al., 1999; Morris et al., 1998; Swanson, 2000; Wagner et al., 1993; Wagner & Torgesen, 1987).

Study Purpose

Many studies have been done investigating patterns of performance for slow learners and children with learning disabilities, and there is increasing evidence that the performance of slow learners and children with learning disabilities on a variety of measures is more similar than different (Aaron, 1997; Ackerman & Dykman, 1993; Fawcett et al., 2001; Fletcher et al., 1992; Gresham et al., 1996; Merrell, 1990; O'Malley et al., 2002; Rutter & Yule, 1975; Share, 1996; Shaywitz, Fletcher, et al., 1992; Siegel, 1989, 1992; Toth & Siegel, 1994; Vellutino et al., 2000; Ysseldyke et al., 1982). No study has yet investigated the relationship between reading and phonological processing, automaticity, auditory processing, and memory in the two groups. A study investigating the relationship among these four skills would provide better understanding of the reading process as well as a foundation for treatment. In addition, it may help to more completely understand the nature of reading difficulties that are experienced by slow learners and children with learning disabilities. This study investigated the underlying processes of reading in order to help inform future research directions as well as intervention and prevention methods, including early identification of children who are at risk for reading difficulty.

Research questions regarding the relationship between phonological processing, automaticity, auditory processing, and memory in slow learners and children with learning disabilities were proposed in the current study. More specifically, some research questions addressed differential performance between slow learners, children with learning disabilities, and average readers, while others examined the connections between the four skills examined here.

Hypotheses

Hypothesis 1

The Slow Learner and Learning Disabled groups will have lower scores than the Control group on the phonological processing, automaticity, auditory processing, and memory composites. Additionally, the pattern of performance on these composites will be similar for the Slow Learner and Learning Disabled groups.

Rationale. Studies comparing the performance of slow learners and children with learning disabilities on various measures have been inconclusive, with some finding general differences between the groups (Ackerman & Dykman, 1993; Badian, 1996; Fawcett et al., 2001; Merrell, 1990; Rutter & Yule, 1975), and others finding more similarities than differences (Fletcher et al., 1992; Gresham et al., 1996; O'Malley et al., 2002; Share, 1996; Shaywitz, Fletcher, et al., 1992; Siegel, 1989, 1992; Toth & Siegel, 1994; Ysseldyke et al., 1982). Both groups have been found to have similar difficulties with phonological processing (Aaron, 1997; Calfee & Norman, 1998; Gough & Tunmer, 1986; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stanovich & Siegel, 1994; Truch, 1998). Equivocal evidence has been found comparing the two groups on rapid naming tasks (Ackerman & Dykman, 1993; Badian, 1996; Wolf, 1999) and memory (Fletcher, Shaywitz, et al., 1994; Henry, 2001; Siegel, 1992; Stanovich & Siegel, 1994; Vicari & Carlesimo, 2002), but no research was available investigating the relationship between auditory processing skills and reading in slow learners and children with learning disabilities.

Hypothesis 2

In all groups, phonological processing, automaticity, auditory processing, and memory will be significantly related to each other, and these four skills will be significantly related to basic reading.

Rationale. Reading has been found to be influenced by many processes, four of which were investigated here: phonological processing (Alexander et al., 1991; Felton, 1993; Snow et al., 1998), automaticity (Badian, 1998; Catts, 1998; Denckla & Rudel, 1974, 1976; Semrud-Clikeman et al., 2000; Wolf et al., 1986), auditory processing (Ahissar et al., 2000; Byrne & Lester, 1983; Schulte-Körne et al., 1999; Shapiro et al., 1990) and memory (Ackerman & Dykman, 1993; Baddeley, 1999; Bigler, 1992; Kramer et al., 1999; Morris et al., 1998; Swanson, 2000; Wagner et al., 1993; Wagner & Torgesen, 1987). Based on an integration of several models of reading and theories of reading disability (see Castles & Coltheart, 1993; Rack et al., 1992; Spear-Swerling & Sternberg, 1994; Wagner & Torgesen, 1987), it was hypothesized here that phonological processing, automaticity, auditory processing, and memory influence one another at various stages of the reading process.

Hypothesis 3

Phonological processing, automaticity, auditory processing, and memory combine to form a significant predictor of basic reading.

Rationale. Given the contribution of each of these skills to reading, as previously described, it naturally follows to hypothesize that the combination of these skills would provide strong predictive ability for children who may be at risk for reading difficulties.

CHAPTER 3

METHOD

Participants

Participants were selected from a sample of 2,361 students in the first through fifth grades who were tested as a part of the standardization for the *Woodcock-Johnson III* (WJ-III, Woodcock et al., 2001). Data for this sample were gathered continuously between September 1996 and May 1999 in a number of different communities throughout the United States. Participants were randomly selected from schools that had agreed to participate in the standardization procedure and included students with disabilities who spent at least part of the day in regular education classes. Students who had less than one year of experience in regular English-speaking classes were excluded from the norming sample (McGrew & Woodcock, 2001; see Table 1 for demographic characteristics).

Table 1

Frequencies of Demographic Characteristics for the Sample by Group and Total

Variable	Control	Slow Learner	Learning Disabled	Total
Age				
6	12	3	2	17
7	11	13	7	31
8	13	10	10	33
9	17	16	6	39
10	15	25	5	45

Table Continues

Table 1, Continued

Variable	Control	Slow Learner	Learning Disabled	Total
Age, Continued				
11	7	11	1	19
12	0	1	1	2
Total	75	79	32	186
Grade				
1	14	9	7	30
2	10	15	7	32
3	18	15	9	42
4	18	23	6	47
5	15	17	3	35
Total	75	79	32	186
Gender				
Male	37	37	15	89
Female	38	42	17	97
Total	75	79	32	186
Ethnicity				
Caucasian	52	38	25	115
African American	9	25	3	37
Hispanic	7	12	1	20
Asian	5	2	1	8
Native American	2	2	2	6
Total	75	79	32	186

Table Continues

Table 1, Continued

Variable	Control	Slow Learner	Learning Disabled	Total
Language Spoken at Home				
English	67	67	30	164
Spanish	0	4	0	4
Bilingual Eng./Span.	4	5	2	11
Bilingual Other	3	3	0	6
Native American	1	0	0	1
Total	75	79	32	186
Parent Education				
< 5th Grade	0	1	0	1
< H.S. Diploma	3	13	3	19
H.S. Graduate	17	27	9	53
1-3 Years College	24	26	15	65
Bachelors +	31	10	5	46
Total	75	77	32	184
Region				
1 Northeast	19	14	9	42
2 Midwest	18	16	6	40
3 South	25	27	5	57
4 West	13	22	12	47
Total	75	79	32	186

For the current study, the total sample was narrowed based on age. Participants were included for consideration if they were between six and 12 years old, inclusive, and in first through fifth grades. Participants were then selected based on performance on a set of selection criteria (described below) and were classified into three groups: Control, Slow Learner, and Learning Disabled (see Table 2 for a summary of classification criteria means and standard deviations).

Table 2

Means, Standard Deviations, and Ranges for Groups by Selection Criteria

Group	Mean	Standard Deviation	Range
		IQ	
Control	103.25	6.56	91 - 115
Slow Learner	81.10	5.21	71- 89
Learning Disabled	101.34	5.28	91 - 111
Overall	93.52	12.17	71 - 115
		Reading	
Control	102.19	6.29	91 - 115
Slow Learner	81.62	4.83	70 - 89
Learning Disabled	79.25	7.98	57 - 89
Overall	89.51	12.09	57 - 115

Table Continues

Table 2, Continued

Group	Mean	Standard Deviation	Range
		Discrepancy	
Control	1.07	6.30	-15 - 14
Slow Learner	-0.52	6.00	-13 - 14
Learning Disabled	22.09	6.08	16 - 40
Overall	4.01	10.30	-15 - 40

Note. IQ = GIA cluster from WJ-III Cognitive; Reading = Letter-Word Identification test from WJ-III Achievement; Discrepancy = IQ – Reading.

Total sample size for the study was 186 participants, with 75 in the Control Group, 79 in the Slow Learner Group, and 32 in the Learning Disabled Group. In selecting participants from the overall standardization sample, the Control Group included many more participants than the other two groups; therefore, a random sample was selected from the Control Group to be included in the data analysis. Discrepancy scores that were used to help determine group membership were derived for each participant by subtracting the Reading Achievement standard score from the Intelligence standard score. Several other methods of determining a discrepancy score are also available and possibly more reliable (see Heath & Kush, 1991, for a review), but this method was used in the current study based on typical practices within Texas school districts (Texas Education Agency, 1999b). Although division into these groups using imposed cutoff scores may seem arbitrary or artificial, this method reflects current educational practice (see Ackerman & Dykman, 1993). Additional criteria for inclusion in each of the groups were as follows:

Control (C) Group

Students included in the Control Group were those who had average Intelligence and Reading Achievement scores. Intelligence was operationalized as performance on the General Intellectual Ability cluster from the *Woodcock-Johnson III Tests of Cognitive Abilities* (WJ-III Cognitive, Woodcock et al., 2001b). Reading Achievement was operationalized as performance on the Letter-Word Identification test from the *Woodcock-Johnson III Tests of Achievement* (WJ-III Achievement, Woodcock et al., 2001a). For the purposes of this study, the average range was considered to be between 90 and 115 standard score points, inclusive. Students whose scores were within this range were excluded from the study if there was a significant discrepancy (16 standard score points or more) between their Intelligence and Reading Achievement scores.

Slow Learner (SL) Group

Students included in the SL group were those who had difficulty with reading and whose Intelligence, as measured on the WJ-III Cognitive, and Reading Achievement scores, as measured on the WJ-III Achievement, were in the standard score range from 70 to 89 (The Center for Slower Learners; Johns, 1990; Marshall, 1988; Shaw, 1999; Toth & Siegel, 1994; Wise & Olson, 1991). Students whose scores were within this range were excluded from the study if there was a significant discrepancy (16 standard score points or more) between their Intelligence and Reading Achievement scores.

Learning Disabled (LD) Group

Students included in the LD group were those who had difficulty with reading and were found to have a discrepancy between Intelligence as measured on the WJ-III Cognitive and Reading Achievement as measured on the WJ-III Achievement. This discrepancy meets the guidelines set by the Texas Education Agency (1999b), which require at least a 16-point discrepancy (just over one standard deviation) between intelligence test (IQ) scores and achievement test scores. Intelligence scores were within the average range (90-115 standard score points), and Reading Achievement were in the below average range (89 standard score points or below). In order to be included in the study, participants had a discrepancy between Intelligence and Reading Achievement that was more than one standard deviation below IQ (16 or more standard score points).

Materials

As described above, all data were derived from the standardization sample of the *Woodcock-Johnson III* (Woodcock et al., 2001). The *Woodcock-Johnson III Tests of Cognitive Abilities* (WJ-III Cognitive, Woodcock et al., 2001b) is an individually administered intelligence test of overall cognitive functioning composed of 20 standard and supplemental tests yielding 23 different ability clusters measuring constructs such as general intellectual ability, verbal ability, thinking ability, and cognitive efficiency. The *Woodcock-Johnson III Diagnostic Supplement to the Tests of Cognitive Abilities* (WJ-III Diagnostic Supplement, Woodcock, McGrew, Mather, & Schrank, 2003) is a collection of 11 tests that contribute additional information to clusters from the WJ-III Cognitive. The *Woodcock-Johnson III Tests of Achievement* (WJ-III Achievement, Woodcock et al., 2001a) is an individually administered achievement test that includes 22 standard and supplemental tests yielding 19 different achievement clusters measuring various aspects of reading, math, written and oral language, and academic knowledge. For the purposes of this study, measures of Intelligence and Reading Achievement were used to classify participants into the groups described previously. Although cluster scores can be calculated for a variety of skills and abilities on the WJ-III, composite scores for the dependent variables (Phonological Processing, Automaticity, Auditory Processing, and Memory) that are distinct from these cluster scores were developed for the current study by averaging scores from tests that either when combined contributed to cluster scores for the WJ-III or were acknowledged by the authors to measure the specified construct (see Table 3 for intercorrelations). Reliability scores for individual tests were provided in the examiner's manuals for the WJ-III (Mather & Woodcock, 2001). Reliability scores for the composite variables were created using the formula presented by Guilford (1954) which takes into account the standard deviations and intercorrelations of each test included in the composite.

Intelligence

Intelligence for all participants was measured using the General Intellectual Ability cluster (GIA) from the WJ-III Cognitive. The seven subtest scores from the WJ-III that are combined to form the GIA cluster include Verbal Comprehension, Visual-Auditory Learning, Spatial Relations, Sound Blending, Concept Formation, Visual Matching, and Numbers Reversed. This cluster had a median reliability of 0.98 for individuals in the standardization sample ages five through 19 years (Mather & Woodcock, 2001b).

Achievement

Reading Achievement for all participants was measured using the Letter-Word Identification test from the WJ-III Achievement. This test measures basic reading skills by presenting a series of individual letters and words to be read orally and pronounced accurately by the participant. The items become increasingly difficult during the course of the test. This test had a median reliability of 0.91 in the standardization sample for individuals ages five through 19 years (Mather & Woodcock, 2001a).

Table 3

Intercorrelations Between Tests and Basic Reading

Variable	1	2	3	4	5	6	7	8	9	10	11
Reading Achievement											
1. Letter-Word Identification (*n* = 186)	-	.66**	.68**	.59**	.23**	.22**	.23**	.26**	.44**	.33**	.54**
Phonological Processing											
2. Word Attack (*n* = 186)		-	.78**	.52**	.25**	.22**	.19*	.18*	.41**	.34**	.45**
3. Spelling of Sounds (*n* = 172)			-	.56**	.17*	.20**	.28**	.37**	.55**	.39**	.43**
4. Sound Awareness (*n* = 186)				-	.30**	.16*	.20**	.26**	.50**	.39**	.90**
Automaticity											
5. Retrieval Fluency (*n* = 182)					-	.38**	.03	.14	.11	.22**	.36**
6. Rapid Picture Naming (*n* = 176)						-	.20*	.16*	.20*	.20*	.18*
Auditory Processing											
7. Incomplete Words (*n* = 173)							-	.32**	.57**	.22**	.19*
8. Auditory Attention (*n* = 169)								-	.58**	.22**	.29**
9. Sound Patterns-Music (*n* = 155)									-	.47**	.44**
Memory											
10. Auditory Working Memory (n = 168)										-	.38**
11. Understanding Directions (n = 180)											-

*p < .05, two-tailed. **p < .01, two-tailed.

Phonological Processing

The Phonological Processing composite was created by combining three tests from the WJ-III Achievement: Word Attack, Spelling of Sounds, and Sound Awareness. The Word Attack and Spelling of Sounds tests combine to form the Phoneme/Grapheme Knowledge Cluster on the WJ-III Achievement. Although the Sound Awareness test is not included as a part of this or any cluster on the WJ-III, it is recognized by the authors to be a measure of phonological awareness (Mather & Woodcock, 2001a).

The first test, Word Attack, is a pseudoword reading task that measures the ability to apply phonic and structural analysis skills in order to pronounce nonwords or low-frequency words that follow regular English orthographical patterns. As described in previous research, pseudoword reading is a good measure of phonological processing skills (Felton, 1993; Siegel, 1989a, 1990, 1992; Stanovich, 1994; Stanovich & Siegel, 1994; Rack et al., 1992). The median reliability of this subtest for individuals ages five to 19 years old was 0.87 in the standardization sample (Mather & Woodcock, 2001a). The second test, Spelling of Sounds, is a pseudoword spelling task measuring phonological and orthographical coding. A series of nonwords or low-frequency words that follow regular English orthographical patterns is presented on an audio recording, and the individual is asked to write down the words. The median reliability of this subtest for individuals ages six to 19 years old was 0.74 in the standardization sample (Mather & Woodcock, 2001a). The third and final test that is included as a part of the Phonological Processing composite in the current study is Sound Awareness. This test measures four types of phonological awareness, including rhyming, deletion, substitution, and reversal. In the Rhyming subtest, the participant is asked to provide a word that rhymes with the orally-presented item. For the Deletion task, the participant is asked to pronounce a word without including a specified part or a sound of the word. The Substitution subtest involves substituting a letter sound or a word ending in one word and pronouncing the resulting word. The fourth and final subtest of Sound Awareness is the Reversal subtest, where either letter sounds or parts of compound words are reversed and the new word is pronounced. The median reliability of this test for individuals ages five to 19 years old was 0.81 in the standardization sample (Mather & Woodcock, 2001a). The reliability of the Phonological Processing composite score was found to be 0.97 in the current study's sample.

Automaticity

The Automaticity composite included two tests from the WJ-III Cognitive: Retrieval Fluency and Rapid Picture Naming. These two tests are two of the three tests that make up the Cognitive Fluency cluster from the WJ-III. In the Retrieval Fluency test, the individual must name as many words as possible under a time limit that fit into a specified category. The Rapid Picture Naming test is a series of 120 pictures that are to be named under a time limit. Median reliability in the standardization sample for individuals ages five through 19 years was 0.83 and 0.97, respectively, for these tasks (Mather & Woodcock, 2001b). In the current study's sample, the reliability of the Automaticity composite score was found to be 0.91. Both of these tests are believed to measure speed of retrieval from stored information, similar to rapid naming speed which has been found to be closely related to reading skill (Badian, 1998; Catts, 1986; Denckla & Cutting, 1999; Denckla & Rudel, 1974, 1976; Semrud-Clikeman et al., 2000; Wolf, 1986, 1997; Wolf et al., 2000; Woodcock et al., 2001b).

Auditory Processing

Three tests were combined to create the Auditory Processing composite: Incomplete Words and Auditory Attention from the WJ-III Cognitive, and Sound Patterns-Music from the WJ-III Diagnostic Supplement. For the Incomplete

Words test, a series of words, each missing one or more phonemes, is presented by audiotape and the participant is asked to identify the complete word. This test is included in the Phonemic Awareness cluster on the WJ-III Cognitive and is noted to provide information about auditory processing (Woodcock et al., 2001b). Median reliability for individuals between the ages of 5 and 19 years who were included in the standardization sample was 0.77. The Auditory Attention test is one of the two tests that contribute to the Auditory Processing cluster on the WJ-III Cognitive. For this test, an audio tape is used to present words accompanied by increasingly loud background noise. From a set of four pictures, participants must choose the picture representing the word that was spoken on the recording. This test had a median reliability in the standardization sample for ages five through 19 of 0.87 (Mather & Woodcock, 2001b). The Sound Patterns-Music test is part of the WJ-III Diagnostic Supplement and can be included in the Auditory Processing cluster score from the WJ-III Cognitive (Schrank, Mather, McGrew, & Woodcock, 2003). This test is also presented on an audio recording and is an auditory discrimination task where pairs of sounds produced by musical instruments are presented and the individual must decide whether the two sounds are alike or different. Items may differ in pitch, rhythm, or sound content. The median reliability in the standardization sample for ages three through 19 years was 0.90 (Schrank et al., 2003). The reliability of the Auditory Processing composite score was found to be 0.94 in the current study's sample.

Memory

The Memory composite was formed using the Auditory Working Memory test from the WJ-III Cognitive and the Understanding Directions test from the WJ-III Achievement. Auditory Working Memory is one of two tests that combine to form the Working Memory cluster from the WJ-III Cognitive. In this test, the participant is asked to repeat a series of words and numbers while separating the words and numbers and then repeating them in the order they were presented. The median reliability for this test in the standardization sample of individuals five to 19 years old was 0.88 (Mather & Woodcock, 2001b). Although the second test included here in the Memory composite (Understanding Directions) is not included as part of a memory cluster in the WJ-III, it is believed to include a strong working memory component as evidenced in recent exploratory analyses by the authors (K. McGrew, personal communication, December 2, 2002). For this test, a series of directions are presented on an audio tape and the participant responds by pointing to a variety of objects contained in the stimulus picture. The median reliability on this test for individuals ages five to 19 years in the standardization sample was 0.77 (Woodcock et al., 2001a). The reliability of the Memory composite score was found to be 0.89 in the current study's sample.

Procedure

Information included in the following description of the data collection procedure was gathered from a description of the standardization procedures of the WJ-III as outlined by McGrew and Woodcock (2001). A stratified random sample design was used, controlling for several variables. These variables included census region, community size, sex, ethnicity, type of school, and education and occupation of adults or parents. The sampling design for selection of participants took place at three levels: community, school, and participant. Communities were selected based on information from the U.S. Department of Commerce Bureau of the Census, in order to have a proportional representation in the data set based on region, size of community, and distribution of socioeconomic status. Twenty-seven states were included in the sample. Permission was requested from school systems that met selection criteria. Once permission was granted, individual schools were selected based on their demographic representation of the community; in small communities, all schools were included. Also included in the school sampling were parochial and private schools, and home-schooled students were included in the subject pool.

A list of all students in each grade at the selected schools was obtained and a table of random numbers helped to form a group of potential participants. Permission forms were then sent home to the parents of the potential participants requesting approval or non-approval for their child to participate in the project. Other questions requesting information regarding demographics were included on the permission form. All participants who received parental permission were given both the achievement and cognitive tests. The tests were administered individually by trained, closely supervised research assistants.

CHAPTER 4

STATISTICAL ANALYSES

Preliminary Procedures and Analyses

In the original WJ-III data set, each participant was coded in two separate ethnicity variables: race (Caucasian, African American, Native American, Asian/Pacific Islander) and Hispanic (Yes or No). For the purposes of the current study, the two variables were combined into one Ethnicity variable by labeling the 20 participants who had been coded as "yes" for Hispanic as Hispanic in the race variable. Nineteen of the 20 Hispanic participants had also been coded as Caucasian in the race variable, so they were subtracted from the frequency count for the Caucasian participants. The twentieth Hispanic participant had also been coded as Native American but was counted only in the Hispanic group for frequency count purposes (see Table 1 for a frequency table of demographic characteristics).

A series of chi-square analyses was conducted to determine the presence of any difference between the groups on inherent characteristics, including age, grade, gender, ethnicity, language spoken at home, parent education, and geographical region. A statistically significant difference between groups was detected on the parent education and ethnicity variables (see Table 4 for results from the chi-square analysis). A series of analyses was conducted comparing results with and without the effects of these two variables included in the model. Results showed that, in general, the effects of parent education and ethnicity did not differentially affect group performance on the composite scores. Further details of these analyses are described in the appropriate sections below.

Table 4

Chi-Square Analysis for Demographic Variables by Group

Variable	*df*	*n*	χ^2	*p*
Age	12	186	20.08	.07
Grade	8	186	7.14	.52
Gender	2	186	0.11	.95
Ethnicity	8	186	20.15	.01
Language Spoken at Home	8	186	8.45	.39
Parent Education	8	184	24.63	.002
Region	6	186	8.73	.19

Because it was important for the SL and LD groups to have similar reading achievement given the nature of the current study, a *t* test was conducted to test for significant differences between the groups on this selection variable. No significant difference was found, t (109) = 1.92, $p = .06$ (two-tailed). In order to identify any effects of age on the dependent variables, a correlation table was examined. A single significant (although weak) correlation was revealed between age and phonological processing, $r = -.21$, $p < .01$. Examination of the data indicated that two-thirds of the 11- and 12-year old participants ($n = 21$) were in the low reading achievement groups (SL and LD, $n = 14$). Given that basic reading was highly correlated with phonological processing and because a large percentage of the older age groups had lower scores on basic reading, it would also follow that the older age groups would have lower scores on phonological processing. This pattern would result in a negative relationship between age and phonological processing.

As described previously in Chapter 3, composite scores for each dependent variable were formed by averaging test scores from a combination of tests. In the case of missing data, the remaining test scores were averaged. If there were no data available for any of the tests in a specific composite, the participant was excluded from that particular analysis.

In order to test the following hypotheses, two main types of statistical analyses were used: multivariate analysis of variance (MANOVA) and multiple regression. Prior to beginning the study, tables from two sources (Hair, 1998; Stevens, 1996) were examined to determine sample size necessary for sufficient power to detect significant findings. Using the table presented by Stevens (1996), a power level of 0.80 for a three group MANOVA with four dependent variables would be achieved with a total sample size of 56 for a moderate effect size and 125 for a small effect size at an alpha level of 0.05. Using the table presented by Hair (1998) for the multiple regression analysis, a power of 0.80 with an alpha level of 0.05, a sample size of 100, and four variables will detect a minimum R^2 between .10 and .12. Effect sizes were calculated for most analyses using the Partial Eta Squared statistic, denoted as η^2 in the text.

Preliminary analyses were conducted to test for violations of assumptions for MANOVA and multiple regression. Each composite variable was found to be normally distributed and the covariance matrices were found to be homogeneous. No correlation between composite scores was above .80, reducing the possibility of multicollinearity. In addition, error variances across composites were found to be equal.

The following section addresses each hypothesis separately. First, Hypothesis 1 examined group differences on phonological processing, automaticity, auditory processing, and memory through the use of a MANOVA. Second, Hypothesis 2 explored the correlations between the dependent variables and basic reading. Finally, Hypothesis 3 utilized a multiple regression analysis to investigate the ability of a combination of the dependent variables to predict basic reading achievement.

Hypotheses

Hypothesis 1

It was hypothesized that the Slow Learner and Learning Disabled groups would have lower scores than the Control group on all composites (phonological processing, automaticity, auditory processing, and memory). Additionally, it was expected that the pattern of performance on these composites would be similar for the Slow Learner and Learning Disabled groups. A multivariate analysis of variance (MANOVA) was conducted to examine Hypothesis 1. Using Wilks' Λ, overall results were significant, $F\ (8, 348) = 33.17$, $p < .001$, $\eta^2 = .43$. Follow-up ANOVAs and pairwise comparisons indicated several significant relationships (see Table 5). (Pairwise comparisons were corrected using the Bonferroni statistic in order to decrease the probability of a Type I error.) On the phonological processing composite, the performance of each group was significantly different from the others, $F\ (2, 177) = 146.05$, $p < .001$, $\eta^2 = .62$. Pairwise comparisons revealed that the SL group performed more poorly than the LD group ($p < .001$), and the LD group performed more poorly than the C group ($p < .001$). On the automaticity composite, an overall difference between the groups was found, $F\ (2, 177) = 10.78$, $p < .001$, $\eta^2 = .11$. A series of pairwise comparisons indicated that scores for the C group were not significantly different from scores for the LD group ($p > .10$), although the SL group performed significantly worse than both the C group ($p < .001$), and LD group ($p < .05$). A similar pattern of performance was found on the auditory processing composite, F

(2, 177) = 11.02, $p < .001$, $\eta^{2} =$ .11, and the memory composite, F (2, 177) = 64.96, $p < .001$, $\eta^{2} =$ .42. In sum, the Slow Learner group had significantly poorer performance as compared to the Control group on all measures; the Learning Disabled group was significantly worse than the Control group on phonological processing but not on any other composite; and the Slow Learner Group performed significantly worse than the Learning Disabled group on all composites.

Table 5

Group Means and Standard Deviations for Dependent Variables

Variable	Control (n = 73)	Slow Learner (n = 76)	Learning Disabled (n = 31)	Overall (n = 180)
Phonological Processing	101.34 (6.45)	83.67 (5.95)	93.17 (6.98)	92.43 (10.23)
Automaticity	101.46_a (11.59)	93.25 (9.24)	99.41_a (12.38)	97.67 (11.42)
Auditory Processing	101.97_b (11.28)	94.21 (9.91)	100.85_b (10.84)	98.48 (11.21)
Memory	101.34_c (8.31)	88.04 (7.39)	100.10_c (5.74)	95.39 (9.87)

Note. Means having the same subscript are not significantly different at $p < .05$ in the Bonferroni adjustment. Standard deviations are presented in parentheses.

Given significant chi-square results for the demographic variables of parent education and ethnicity (see Table 4), the MANOVA was rerun with these two variables entered in as covariates. Results of the analysis with and without the covariate were similar and revealed the same pattern of significance as described above.

Hypothesis 2

Hypothesis 2 predicted that in all groups, phonological processing, automaticity, auditory processing, and memory would be significantly related to each other and to basic reading. This hypothesis was tested using a correlational analysis (see Table 6).

Table 6

Intercorrelations Between Composite Scores and Basic Reading

Composite	1	2	3	4	5
1. Basic Reading	-	.74**	.27**	.33**	.50**
2. Phonological Processing		-	.29**	.39**	.63**
3. Automaticity			-	.18*	.32**
4. Auditory Processing				-	.37**
5. Memory					-

Note. Phonological Processing = (Word Attack + Spelling of Sounds + Sound Awareness) / 3, all from WJ-III Achievement; Automaticity = (Retrieval Fluency + Rapid Picture Naming) / 2, both from WJ-III Cognitive; Auditory Processing = (Incomplete Words + Auditory Attention + Sound Patterns-Music) / 3, from WJ-III Cognitive and Diagnostic Supplement; Memory = (Auditory Working Memory + Understanding Directions) / 2, from WJ-III Cognitive and Achievement.

*$p < .05$, two-tailed. **$p < .01$, two-tailed.

All correlations were statistically significant at the .05 or .01 level of significance, although some correlations were fairly small. The largest correlation was found to be between basic reading and phonological processing ($r = .74$), with the next largest correlation being between phonological processing and memory ($r = .63$). Moderate correlations were found between phonological processing and auditory processing (*r* = .55), and basic reading and memory (*r* = .50). Remaining correlations were small, with the weakest correlation being between automaticity and auditory processing (*r* = .18). Although all correlations were significant, their practical value varied depending on the strength of the relationship.

Hypothesis 3

It was hypothesized that phonological processing, automaticity, auditory processing, and memory composites would, in combination, statistically significantly predict basic reading. A multiple regression analysis was conducted to address this hypothesis and to determine how much of the variance in basic reading could be explained by a combination of the four composite variables (phonological processing, automaticity, auditory processing, and memory). Simultaneous regression method was employed, where all predictor variables were entered into the analysis at the same time. Results indicated that these variables explain a statistically significant amount of the variance of basic reading, $R^2 = .55$ (F [4, 175] = 53.57, $p < .001$). An examination of individual composites revealed that phonological processing was the most useful and only significant predictor of basic reading, when the other composites were controlled (see Table 7). The remaining three composites did not contribute significantly to the prediction of basic reading beyond the prediction by phonological processing.

Table 7

Simultaneous Regression Analysis for Variables Predicting Basic Reading Achievement (N = 180)

Variable	*B*	*SE B*	β
Phonological Processing	.81**	.08	.68**
Automaticity	.05	.06	.05
Auditory Processing	.04	.06	.04
Memory	.05	.08	.04

Note. $R^2 = .55$

**p < .01

Given the statistically significant chi-square results for the demographic variables of parent education and ethnicity (see Table 4), results from the multiple regression were further examined with additional analyses. Each participant was assigned additional codes of high (some college or college degree and beyond) or low (high school diploma and below) parent education, and Caucasian or other (African American, Hispanic, Asian, Native American) ethnicity. The multiple regression analysis was then rerun separately for the high and low parent education groups and the Caucasian or other ethnicity groups. Results were compared between the groups based on demographic variables. There did not appear to be a substantial different between the groups, and relationships between the variables when broken down by group were found to be similar to overall results (see Table 8).

Table 8

Simultaneous Regression Analysis for Variables Predicting Basic Reading Achievement by Parent Education and Ethnicity (N = 180)

Variable	*B*	*SE B*	β
High Parent Education (n = 111; R^2 = .52)			
Phonological Processing	.82**	.11	.67**
Automaticity	.00	.08	.00
Auditory Processing	.04	.08	.04
Memory	.07	.11	.05
Low Parent Education (n = 73; R^2 = .52)			
Phonological Processing	.82**	.13	.68**
Automaticity	.13	.08	.14
Auditory Processing	.02	.10	.02
Memory	.00	.14	.00
Caucasian (n = 115; R^2 = .53)			
Phonological Processing	.92**	.12	.69**
Automaticity	.09	.08	.08
Auditory Processing	.05	.08	.05
Memory	-.01	.12	-.01

Table Continues

Table 8, Continued

Variable	*B*	*SE B*	β
	Other (n = 71; R^2 = .62)		
Phonological Processing	.65**	.09	.68**
Automaticity	.00	.07	-.01
Auditory Processing	.02	.09	.02
Memory	.17	.10	.16

**p < .01

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Before reviewing the results, it is important to note that no group's mean scores were in the below average range on any of the four dependent variables. Other than the Slow Learner group, whose scores on phonological processing and memory were in the low average range, mean group scores for all groups on all composites were in the average range. This is partially due to the design of the study, where participants were classified into groups and some degree of individual variability was lost. The original data set includes many participants who have average composite scores but specific weaknesses within the composite. For example, a participant may have an average score on one of the tests included in a composite but borderline to below average scores on the remaining tests included in the same composite, resulting in an average overall composite score. This pattern illuminates the importance of addressing a student's specific strengths and weaknesses for intervention, to be discussed further below.

Hypothesis 1 predicted that differences would be found on phonological processing, automaticity, auditory processing, and memory between the Control group and the Slow Learner and Learning Disabled groups, while no differences would be found on any of these measures between the Slow Learner and Learning Disabled groups. Results, however, revealed significant differences among the Slow Learner group and the other two groups (Control and Learning Disabled) on all measures. This pattern indicates that slow learners have a wider range of deficits than children with an intelligence-achievement discrepancy and, as expected, Controls. Results from Hypothesis 1 also revealed a significant difference between the Learning Disabled and Control groups only on phonological processing, with no significant difference between these two groups on automaticity, auditory processing, or memory. This finding suggests that while the latter three skills are not implicated in the reading difficulties of children with an intelligence-achievement discrepancy, phonological processing is a central deficit for both clinical groups.

Results from Hypothesis 1 support Stanovich's (1988a) "phonological-core variable-difference" model of reading disabilities. In this model, slow learners and children with reading disabilities show their main difficulties in phonological processing. He proposed that the differences between the two groups are of degree, not type: "As we move in multidimensional space from the dyslexic to the garden-variety poor reader [slow learner], we move from a processing deficit localized in the phonological core to the global deficits of the developmentally lagging garden-variety poor reader" (Stanovich, 1991, p. 14). In other words, slow learners have a wider variety of cognitive difficulties in a wider variety of domains.

Stanovich (1991) attributed results from studies finding deficits in addition to phonological processing for children with learning disabilities to the presence of less strict inclusionary criteria and therefore the incorporation of more slow learners in the study's sample. For the current study, clearly defined groups were formed that differentiated between slow learners and children with an intelligence-achievement discrepancy (learning disabled); the only statistically significant finding between the Learning Disabled and Control groups was on phonological processing. Therefore, Stanovich's hypothesis regarding inclusionary criteria in research is supported by results from this study given the specific nature of the Learning Disabled group's deficits and the more generalized weaknesses of Slow Learners. One explanation for the presence of a broader range of deficits in slow learners is that the difficulties experienced by children who are initially poor readers may generalize to negatively affect a wider range of skills and abilities through their development (Stanovich, 1986). In addition, it becomes increasingly difficult to differentiate aptitude from achievement as a child gets older (Stanovich, 1991). As a result, Stanovich (1986, 1991) argues against the use of an IQ-achievement discrepancy in the determination of a learning disability, an argument that the current study supports.

Hypothesis 2 predicted that the skills measured by overall composite scores would be related. A correlational analysis that combined participants from all three groups revealed that all variables were significantly correlated in the positive direction at either the .05 or the .01 level of significance. Strong relationships were found between phonological processing and both basic reading and memory. Moderate correlations were found between phonological processing and auditory processing, as well as between basic reading and memory. All other correlations, though significant, were small.

The presence of a strong positive overall correlation between phonological processing and basic reading has been supported by much research (Aaron, 1997; Blachman, 1997; Catts, 1986; Fletcher, Shaywitz, et al., 1994; Gough & Tunmer, 1986; Lyon, 1995, 1996; Siegel, 1989a, 1992; Snow et al., 1998; Truch, 1998). Some even argue that phonological processing is a better predictor of reading than intelligence (Calfee & Norman, 1998; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stanovich & Siegel, 1994; Truch, 1998). In the current study, phonological processing was also found to be strongly correlated to memory. This is a logical relationship, given that phonological codes must be assigned to letters and stored in long-term memory in order to progress in reading development (Castles & Coltheart, 1993; Rack et al., 1992).

A moderate overall correlation was found between memory and basic reading. The importance of memory in reading development has been proposed by many researchers. For example, during an ongoing reading task, letters may either be decoded and stored in a temporary store (Wagner & Torgesen, 1987), or the pronunciations of letters and words may be retrieved from long-term memory (Wagner et al., 1993). In addition, the model of reading presented by Rack and colleagues (1992) allows for an understanding of how memory is involved in the development of reading skills. Initially, reading is a visual process where letters are processed and sight words are retrieved from memory. Then reading becomes a phonological process, and letter-sound relationships are developed as these correspondences begin to be encoded in long-term memory.

A moderate overall relationship was also found between phonological processing and auditory processing. The importance of this relationship has also been described by previous researchers. For example, Catts (1986) notes that the development of adequate phonological processing skills has been attributed to learning the correspondence between letters and their sounds, a process that necessitates adequate auditory processing skills. Additionally, the development of phonological processing may be compromised if auditory sensory deficits or speech perception deficits are present (McAnally et al., 2000). Therefore, correlational results from the current study support the hypothesized relationship between auditory processing and the development of phonological processing.

Although not a part of the current study, a follow-up question to this overall correlational analysis would be whether or not the correlations explored here differ in significance or magnitude depending on group membership. This question was not investigated in the current study given that all of the overall means for the groups were in the average range, with the exception of low average scores on phonological processing and memory for Slow Learners. This may be an interesting area for further investigation with a similarly grouped population that shows more severe impairments on the constructs measured here.

The third and final hypothesis predicted that all four composites (phonological processing, automaticity, auditory processing, and memory) would combine to form a statistically significant predictor of basic reading. Results from the multiple regression revealed that of the four composites, phonological processing was the only statistically significant predictor of basic reading. Separate regressions by group were not conducted given that there would be a smaller number of participants per analysis and a resultant reduction in power. Results from Hypothesis 3 are congruent with several previous studies finding that phonological processing is the best predictor of reading available (Calfee & Norman, 1998; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stanovich & Siegel, 1994; Truch, 1998), and again with Stanovich's (1988a) phonological-core-variable-difference model of reading disabilities, described above.

Limitations

Several limitations of the current study must be considered in the interpretation of results. First, the nature of placing participants into groups based on test scores can be seen as artificial, given that much of the natural variability between the participants is lost using this design. Had intelligence been treated as a continuous variable, a different pattern of results may have been found; however, the classification of "slow learner" and "learning disabled" could not have been used. The purpose of this study was to reflect the current practice in many school districts, where students are typically classified into groups based on test scores.

Second, there are multiple methods available to measure the constructs investigated here. Were a modification made to the combination of tests used in the constructs, results from group comparisons as well as composite correlations and contributions to reading may have been different. For example, Vellutino and colleagues (2000) found that the magnitude of intelligence-achievement discrepancy present for each participant depended on the measure of reading that they used. Therefore, had a different measure been used for basic reading in the current study, participants may have been grouped differently. Similarly, there are many measures available that test different aspects of phonological processing, automaticity, auditory processing, and memory. For example, were the *Rapid Automatized Naming Test* (RAN, Denckla & Rudel, 1974, 1976) used to measure automaticity instead of Retrieval Fluency and Rapid Picture Naming from the WJ-III, a different pattern of results may have been found. There are also many different aspects to memory that may be important in reading development including long-term, short-term, and working memory, but working memory was targeted in the current study. The composites created specifically for this study do not purport to measure every aspect of and skill involved in the constructs being investigated. In sum, as Boring stated in 1923, "Intelligence is what the tests test" (p. 35). One could modify that statement to read, "Automaticity is what the tests test," and the like for all variables investigated here. Therefore, it is extremely important for clinicians and practitioners to describe specific skills and abilities that are strengths and weaknesses for an individual, rather than use a single test or composite score to determine overall performance on a particular construct.

Third, the process of reading is very complex and is not captured simply through the examination of basic reading, which was chosen for this study given that it precedes the higher levels of reading development such as reading comprehension (Aaron, 1997; Lyon, 1996) and reading rate (Castles & Coltheart, 1993; LaBerge & Samuels, 1974; Rack et al., 1992). Many individuals who have average basic reading skills, however, may have below average reading rate or comprehension. Therefore, any generalization of these results to overall reading skills must be done cautiously.

Fourth, the investigation of demographic variables that were significantly different between groups may not have been specific enough to reveal inherent differences between the groups on the constructs measured in the current study. Given the small number of participants who were of certain ethnic groups or levels of parent education, in some analyses it was necessary to combine ethnic groups or education levels to conduct comparisons. In the process, subtle possibly significant differences between groups on demographic variables may not have been detected. A larger, more ethnically and culturally diverse sample would allow for a more thorough investigation into the effects of parent education and ethnicity.

Implications for Research and Practice

In examining the total data set available from the standardization of the WJ-III, there are many cases in which a participant's reading score is more than one standard deviation *above* his or her intelligence score. This trend raises questions regarding the assumption that individuals with a significantly higher intelligence level than reading level respond differently to remediation and instructional strategies than individuals with low intelligence and low reading levels (Aaron, 1997; Siegel, 1989a; Stanovich, 1994; Swanson et al., 1999). The widely used intelligence-achievement discrepancy formula for determining the presence of a learning disability is based on this assumption. Siegel (1989a) states that:

> According to this discrepancy formulation, it should not be possible for a child with a low IQ to be a good reader; however…a significant number of such cases exist…Existence of such children means that children with low IQ scores can learn to read, often as well as children with higher IQ scores and no reading disabilities. (p. 472)

A future study regarding comparisons between groups with IQ-achievement discrepancies in both directions would be an interesting follow-up to the present study. For example, discrepancies can exist in children with low to below average intelligence and significantly higher reading, children with average or above average intelligence and below average reading, and even children with superior intelligence and significantly lower but still average reading. An understanding of the cognitive factors involved in these different patterns would provide additional information for the field. Again, an assessment of individual differences in cognitive abilities and academic skills is crucial to treatment planning in targeting specific skill deficits or cognitive processing weaknesses.

In addition, given the increasing linguistic diversity of America's student body, it is important to consider language differences and their influences on factors involved in the reading process. Although some constructs explored in the current study may be generalizable across language (such as Memory and Automaticity), others may be language-specific (such as Phonological and Auditory Processing). In order to recognize and properly evaluate a bilingual or other-than-English-speaking student's area of difficulty, knowledge of the typical development and necessary skills in the student's primary language should be applied. Therefore, it would be interesting and informative to investigate differences in performance on the variables explored here between children who are bilingual and those who are either fluent English or Spanish speakers, for example. The current sample included only students who had more than one year of experience in regular English-speaking classes (McGrew & Woodcock, 2001). Demographic variables in the WJ-III standardization sample are available for first language spoken and language spoken at home. An examination of the influence of these and other factors in language and reading development would be important.

Beyond the study of linguistic diversity, an interesting expansion of the study of reading is the investigation of the influence of non-language-based skills on reading and reading development. For instance, a recent body of research has found evidence for an association between reading disabilities and sensory processing deficits (McAnally et al., 2000). In addition, some recent research is focused on investigating temporal processing, the timing aspect of auditory processing (Farmer & Klein, 1995; Poldrack et al., 2001; Tallal et al., 1996). The WJ-III *Diagnostic Supplement* (Schrank et al., 2003) includes two similar auditory discrimination tasks, one that uses human speech sounds as the stimulus, and the other that uses musical sounds. Preliminary analyses for the current study indicated that the speech-related test was much less strongly correlated with basic reading (r = .25, p < .01) than the non-speech-related test (r = .45, p <.001). This is an interesting area of research that offers many possibilities for remediation of reading difficulties.

Especially recently, researchers and policymakers have noted the importance of early identification of reading disabilities. Because there is evidence that poor readers differ from normal readers at very early ages despite intelligence scores, early identification for these students is possible and should be encouraged (O'Malley et al., 2002). Additional longitudinal studies would provide evidence of any damaging effects of time on students who do not receive early preventive services or intervention to ameliorate their reading difficulties. Stage and colleagues (2003) argue that if policies were redirected towards identifying poor readers in the initial stages of reading development, there would be fewer students with pervasive difficulties that have developed over time as a result of a lack of treatment. Current policy proposals and recommendations eliminate reliance on this "wait to fail" approach by eliminating the IQ-achievement discrepancy requirement in the identification of learning disabilities (Nealis, 2003).

Results from the current study support recent proposals for changes to educational policy. An amendment to IDEA that is currently being debated in Congress (H.R. 1350) proposes three main changes in the current procedures (see Nealis, 2003). First, the requirement of the discrepancy model is eliminated. Second, the determination of learning disabilities may be aided by evidence from the child's "response to intervention" (Nealis, 2003, p. 14): if appropriate efforts have been made with research-based interventions and the child shows inadequate response to the intervention, the child may be considered as having a learning disability. Third, pre-referral interventions will be provided for students who have not yet been identified as needing special education.

As a response to these proposed amendments to IDEA, the National Association of School Psychologists (NASP, 2003) offers a solution that would involve a three-tiered system for the treatment and identification of students experiencing academic difficulty. In the first tier, all students in general education should receive "high-quality, research-based instruction and behavioral supports" (NASP, p. 3). Curriculum-based assessment should be ongoing, and remedial instruction and group interventions within the general education environment must be provided. Tier 2 provides research-based, intensive prevention or remediation services and/or individually designed interventions for students who continue to have difficulty despite efforts at Tier 1. The student's progress should be reviewed every six to eight weeks for up to one year in order to determine his or her response to treatment. Should the student fail to respond to at least two strategies over a period of at least six weeks, he or she is referred to Tier 3 for a comprehensive, multidisciplinary evaluation. At this point only is special education considered, and if the student is found eligible for additional Tier 3 services, an IEP is developed.

A similar three-level system is proposed by the International Dyslexia Association (IDA; Dickman, Hennessy, Moats, Rooney, & Tomey, 2002). Both the NASP and the IDA recommendations would provide workable solutions to the debate surrounding the use of the discrepancy theory. Neither group focuses on changing the legal definition of learning disabilities presented in the Individuals with Disabilities Education Act of 1997; instead, both target regulations illuminating eligibility criteria.

If accepted, how would these proposals influence the role of school psychologists? Many have expressed concern that with the elimination of the IQ-achievement discrepancy, the lack of a requirement for IQ testing would reduce the use of and need for school psychologists. However, with the proposed changes, a school psychologist may instead play a more important, integrated role as he or she becomes involved at all levels of the process. For example, as proposed by NASP (2003), the school psychologist would play a more important role in pre-referral interventions at Tier 2, would continue to design appropriate assessments at Tier 3, and would help provide training activities and develop evaluation procedures at all levels of the model. Additionally, amendments to IDEA being considered in Congress seem to be moving toward data-driven assessments, an area of proficiency for school psychologists (Nealis, 2003).

Should the discrepancy requirement be eliminated, the inclusion of intelligence tests in school-based assessments may no longer be a requirement. Some researchers and practitioners have argued for the discontinuation of the use of intelligence tests in the assessment and identification of learning disabilities (Benson, 2003; O'Malley et al., 2002; Stage et al., 2003; Vellutino et al., 2003), while others argue that the problem lies not in the use of intelligence tests but in the misuse of a single number to represent a child's intellectual capacity (Benson, 2003).

Intelligence tests, when interpreted appropriately, can provide a wealth of valuable information about an individual child's processing abilities that can be helpful in treatment planning by linking the child's individual strengths and weaknesses to strategies used in general and special education classrooms. Some researchers, however, have argued for the use of tests that measure specific deficit areas rather than intelligence tests in order to identify a learning disability (Calfee & Norman, 1998; Shankweiler et al., 1995; Siegel, 1989a, 1992; Stage et al., 2003; Stanovich & Siegel, 1994; Truch, 1998). Both intelligence tests and measures that target specific skill areas should continue to be used in assessing children with learning disabilities in order to provide a comprehensive evaluation that will lead to an understanding of individual strengths and weaknesses to aid in the development of a treatment plan or individualized education program (IEP). Because the practices of special education vary so significantly from region to region, it will be important to continue to research how different identification and assessment methods affect the students and the educational system as policies and procedures begin to change.

Conclusion

The debate about how similar or different slow learners are to children with learning disabilities resists an easy answer, given the large amounts of research supporting both sides of the argument. From this perspective, it may be useful to shift the focus of related research to the more practical question, "Can both slow learners and children with learning disabilities benefit from intervention?" By seeking to answer this question, if even a handful of studies find that slow learners make some degree of improvement, an argument will be made for providing intervention to this group of students. Recently, studies of this type have been more visible and have found positive outcomes from children with and without an intelligence-achievement discrepancy (Jiménez et al., 2003; Vellutino et al., 2000). The inherent complexity and longer-term nature of this area of research no doubt contribute to the lack of research in this particular area. An investment in this type of research, however, is an investment in the future.

Given findings from their review of studies comparing slow learners and children with learning disabilities on skills related to reading, O'Malley and colleagues (2002) conclude the following:

> The message sent to students and teachers is that the educational system has hope only for students with at least average intelligence…The perceived message for students who have below-average intelligence scores and low achievement scores is that the educational system has little to offer them. (p. 33)

It is hoped that recently proposed amendments and recommendations for change that eliminate the discrepancy requirement, allow for earlier identification, and provide opportunities for intervention prior to entering the special education system will eventually be implemented and will reverse the effects of this "message" described by O'Malley and colleagues (2002). A shift in the understanding of the term "disabled" may be necessary in order to successfully adopt these amendments and to provide much needed intervention to slow learners, given that children who could be classified as slow learners may actually be at more of a disadvantage than children classified as learning disabled.

Results from the current study support proposals for change as presented by NASP (2003) and IDA (Dickman et al., 2002). Rather than examining discrepancies between intelligence and achievement, which do not appear to provide adequate information about a child's functioning, this study emphasizes the importance of investigating individual patterns of performance and determining specific areas of weakness for all children. As identification procedures for learning disabilities begin to change, comprehensive assessments that include intelligence and achievement tests should continue to be conducted for students suspected of having learning disabilities, in order to provide adequate information for treatment planning. Should these new regulations be employed, the role of school psychologists should, if anything, become more crucial to decisions about prevention, intervention, and placement. It is hoped that with any upcoming changes, the value and importance of school psychologists' specialized training will be recognized, and that in conjunction with an understanding of the individual student's strengths and weaknesses, results from studies like the present one be taken into consideration in the design of interventions.

As Nealis (2003) states:

> What is required of school psychologists now is that we continue to advocate for the children we intend to serve so that school leaders and policymakers understand the value of our services. We must continue to monitor and collect data on educational and behavioral outcomes for students based on the delivery of services to maintain support for and justify their continued use. And we must advocate for the profession by marketing our unique skills and training, emphasizing the many roles we can play in schools and the community. The strength and value of the school psychologist goes far beyond any requirement to conduct IQ tests. If this needs to be restated to your school leaders, then now is the time to make that statement. (p. 18)

Whether the proposed regulatory changes are supported or opposed by researchers or practitioners, the above statement provides a plan of action for every dedicated school psychologist. After all, part of the future is in their hands.

APPENDIX A

Historical and Current Definitions of Learning Disabilities

Appendix A

Historical and Current Definitions of Learning Disabilities

ORIGIN AND DATE	IMPORTANT ELEMENTS IN DEFINITION
Kirk (1962)	• Refer to retardation, delay, or disorder in speech, language, reading, writing, arithmetic, or other school subjects • Result from psychological handicap caused by possible cerebral dysfunction or emotional/behavioral disturbances • Do NOT result from mental retardation, sensory deprivation, or cultural and instructional factors
Bateman (1965)	• Refer to basic disorders in the learning process that present as a significant discrepancy between ability and achievement • May or may not be accompanied by demonstrable central nervous dysfunction • Are NOT secondary to generalized mental retardation, educational or cultural deprivation, severe emotional disturbance, or sensory loss
The National Advisory Committee on Handicapped Children (NACHC, 1968)	• Refer to a disorder in one or more of the basic psychological processes involved in understanding or using spoken and written language, manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic • Include conditions of perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. • Do NOT result primarily from visual, hearing, or motor handicaps, mental retardation, emotional disturbance, or environmental disadvantage
Northwestern University (Kass & Myklebust, 1969)	• Refer to significant deficits in essential learning processes (perception, integration, and verbal/nonverbal expression) as demonstrated by a discrepancy between ability and achievement in the areas of spoken, read, or written language, mathematics, and spatial orientation • Do NOT result primarily from sensory, motor, intellectual, or emotional handicap, or lack of opportunity to learn
Council for Exceptional Children, Division for Children with Learning Disabilities (CEC/DCLD, 1971)	• Refer to specific deficits in perceptual, integrative, or expressive processes which impair learning efficiency • Include conditions of central nervous system dysfunction • Do NOT result from inadequate mental ability, deficient sensory processes, or emotional instability

Continued

ORIGIN AND DATE	IMPORTANT ELEMENTS IN DEFINITION
Wepman, Cruickshank, Deutsch, Morency, and Strother (1975)	• Refer to a substantial deficiency in a particular aspect of academic achievement • Caused by deficits in perceptual or perceptual-motor skills (mental processes through which the child acquires basic alphabets of sounds and forms)
U.S. Office of Education (USOE, 1976)	• Manifested as a severe discrepancy between ability and achievement in oral or written expression, listening or reading comprehension, basic reading skills, mathematics calculation or reasoning, or spelling • Must be a discrepancy that is 50% or below of the child's expected achievement level, when age and educational experiences are considered
U.S. Office of Education (USOE, 1977, included in the Education for All Handicapped Children Act of 1975, PL 94-142)	• Refer to a disorder in the basic psychological processes involved in understanding or using spoken or written language, manifested in an imperfect ability to listen, speak, read, write, spell, or do mathematical calculations • Include conditions such as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia • Do NOT result primarily from visual, hearing, or motor handicaps; mental retardation or emotional disturbance; or environmental, cultural, or economic disadvantage
National Joint Committee on Learning Disabilities (NJCLD, 1981)	• Refer to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities • Result from intrinsic disorders due to central nervous system dysfunction • May occur across the life span • Do NOT include by themselves problems in self-regulatory behaviors or social perception or interaction; and do NOT result primarily from sensory impairment, mental retardation, serious emotional disturbance, cultural differences, or insufficient/inappropriate education
Learning Disabilities Association of America (Association for Children with Learning Disabilities, ACLD,1986)	• Refer to a chronic condition that interferes with the development, integration, or demonstration of verbal/nonverbal abilities • May result from neurological origin • May occur across the life span, differ in degree of severity, and affect self-esteem, education, vocation, socialization, and daily living activities

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ORIGIN AND DATE	IMPORTANT ELEMENTS IN DEFINITION
Interagency Committee on Learning Disabilities (ICLD, 1987)	• Refer to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, mathematical abilities, or social skills • Result from intrinsic disorder due to central nervous system dysfunction • Do NOT result primarily from sensory impairment, mental retardation, social/emotional disturbance, cultural differences, or insufficient/ inappropriate instruction
Classification of Mental and Behavioural Disorders (ICD-10, World Health Organization, 1993)	• Refer to a discrepancy between ability and achievement of at least two standard errors of prediction • Do NOT result primarily from intelligence levels below 70 standard score points, deficits in visual or hearing acuity, neurological disorder, or inadequate educational experience
Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV, APA, 1994)	• Refer to a discrepancy between ability and achievement • Do NOT result primarily from sensory deficits or inappropriate educational experience
International Dyslexia Association (IDA, Dickman, Hennessy, Moats, Rooney, & Tomey 2002)	• Refer to a class of specific disorders due to cognitive deficits intrinsic to the individual • Are often unexpected in relation to other cognitive abilities • Result in performance deficits in spite of quality instruction • Can co-exist with other disabilities and in individuals who have experienced “atypical environments” • Predict difficulty in the development of adaptive functioning, with lifelong consequences

Adapted from Hammill, D. D. (1990). On defining learning disabilities: An emerging consensus. *Journal of Learning Disabilities, 23,* 74-84.

APPENDIX B

Comparative Patterns of Performance Between Slow Learners and Children with Learning Disabilities

Appendix B

Comparative Patterns of Performance Between Slow Learners and Children with Learning Disabilities

STUDY	SAMPLE	RESULTS	CONCLUSIONS
Rutter & Yule (1975)	**SL** mean IQ (WISC)**:** 80; 2 yr. 4 mo. below age on rdg. test (Neale) (n = 79) **LD** mean IQ (WISC)**:** 102.5; 2 yr. 4 mo. below age on rdg. test (Neale) (n = 86)	-SL is ass'd w/ overt neuro. disorder: worse perf. than LD on motor coord. & lang. impairmt.; fathers have low social status jobs -LD more common in boys, not found w/ neuro. disorder; less progress in spelling & rdg. than SL but more in math	-Differential educational implications are inferred for the two groups, SL (general reading backward) and LD (specific reading retarded)
Ysseldyke, Algozzine, Shinn, & McGue (1982)	**SL:** Ach.+ 1.5 sd ≥ IQ (n = 49) **LD:** Ach.+ 1.5 sd ≤ IQ (n = 50)	-96% of scores on psychoed. measures in common range for LD & SL	-LD & SL are essentially identical constructs -Diagnostic value of the term "learning disabilities" is questioned
Siegel (1989)	**LD:** WRAT Rdg. ≤ 25th %ile 4 groups: (1) IQ (WISC-R) < 80; (2) 80 < IQ < 90; (3) 91 < IQ < 109; (4) IQ > 109 **C:** WRAT Rdg. ≥ 30th %ile	-Children class. as LD, regardless of IQ, had similar word & pseudoword rdg., spelling, orthographic/phonological knowledge of English lang., short-term memory, spelling, and rdg. comp.	-Regardless of IQ, children with reading disabilities have similar patterns of performance; therefore, the use of IQ should be abandoned in determining the presence of LD; instead, scores on pseudoword rdg. tests should be used.
Merrell (1990)	**SL:** referred for but found ineligible for special ed. (n = 93) **LD:** Ach.+1.5sd ≤ IQ (WJ); prev. class. as LD (n = 152)	-Sig. dif.s found on all variables between LD & SL on WJ academic variables, esp. Skills, Reading, & Written Lang.	-Need more consistent classification procedures; -Use academic ach. info more in instructional planning

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STUDY	SAMPLE	RESULTS	CONCLUSIONS
Fletcher, Francis, Rourke, Shaywitz, & Shaywitz (1992)	**SL:** IQ (WISC) ≥ 79, Ach (WRAT Rdg.) ≤ 93 **LD:** Ach.+ 1sd ≤ IQ N = 1069	-No dif's b/t LD & SL on tests of speech-sound perception, auditory closure, sentence memory, or verbal fluency	-Dif's b/t LD & SL are either nonexistent or small & of questionable significance
Shaywitz, Fletcher, et al. (1992)	**SL:** WJ-Rdg. ≤ 25%ile (n = 38) **LD:** WJ-Rdg.+1.5sd ≤ IQ (WISC) (n = 32) **C:** WJ-Rdg. ≥ 40^{th} %ile	-No dif's b/t LD & SL on motor, visual perception, language -LD better than SL on IQ, rdg., rdg. improvemt.; BUT IQ counted for nearly all the variance between the groups	-There are few dif's b/t LD & SL that can't be accounted for by IQ; therefore, LD & SL have similar patterns of performance -It may be more reasonable to consider both groups as eligible for special ed.
Siegel (1992)	**LD:** WRAT Rdg. ≤ 25^{th} %ile (SL: Ach. +1sd ≥ IQ (WISC-R); LD: Ach.+1sd < IQ) (n = 465) **C:** WRAT Rdg. ≥ 30^{th} %ile (n = 1192)	-LD & SL performed similarly on reading, spelling, phon. processing, & short-term memory tasks -LD did better on math tests than SL	-The closer the cognitive process is to rdg., the less likely IQ is to make a diff.; -Both groups (LD & SL) should be labeled LD due to their similar deficits
Ackerman & Dykman (1993)	Poor readers: ≤ 90 (WRAT-R) **SL:** Ach. = IQ +/- 17 (n = 21) **LD:** Ach. + 17 ≤ IQ (n = 42)	-LD performed worse than children with only AD/HD on RAN tasks, while SL had similar perf. to children with AD/HD on RAN tasks	-SL have a different cognitive profile than LD

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STUDY	SAMPLE	RESULTS	CONCLUSIONS
Kavale, Fuchs, & Scruggs (1994)	(same sample as Ysseldyke et al., 1982) **SL:** Ach.+ 1.5 sd ≥ IQ (n = 49) **LD:** Ach.+ 1.5 sd ≤ IQ (n = 50)	-Re-analyzed Ysseldyke et al.'s data in order to account better for group variability -Only 37% overlap between LD & SL was present when re-analyzed -80% of LD group could be differentiated from SL group, with LD scoring lower than SL	-LD & SL are in fact distinct -Data provided by Ysseldyke et al.'s (1982) study has been misinterpreted and misused to support policies from the Regular Education Initiative
Badian (1996)	Poor readers (<85 on word id. task): **SL:** IQ < 92 *(n = 20)* **LD:** 85 < IQ < 130 (n = 58)	-SL had better nonword reading than LD -At younger ages (6-7), LD & SL look more similar -A smaller LD discrepancy had fewer pervasive deficits	-In children 8 years and older, a discrepancy may be an important marker of underlying deficits -The term "reading disability" should not be applied to poor readers in their first 2 years of reading
Gresham, MacMillan, & Bocian (1996)	**SL:** Ach.+ 1.5sd ≥ IQ ≥ 76 (n = 40) **LD:** Ach. (WRAT-R) + 1.5 sd ≤ IQ (WISC-III) ≥ 82 (n = 67)	-Differences almost exclusively in cog. ability & academic tasks, esp. rdg.: -LD performed more poorly in academic ach. than SL -Avg. level of differentiation is 63%	-These groups could be reliably differentiated, but… -This diff. is probably an artifact of how groups were defined -No well-controlled studies exist showing diff. performance on different interventions
Share (1996)	Poor readers: **SL** mean IQ: 81.4 (n = 11) **LD** mean IQ: 105.5 (n = 11)	-SL & LD differed only on word substitution tasks -Performed similarly on 25 other measures, including word & pseudoword rdg., spelling, symbol-word learning	-There are no qualitative diff.'s between SL & LD

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STUDY	SAMPLE	RESULTS	CONCLUSIONS
Fawcett, Nicholson, & Maclagan (2001)	Poor readers: **SL:** 67 < IQ < 87 (WISC-R) (n = 29) **LD:** 90 < IQ < 133 (n = 38)	-SL had poorer perf. than LD on speed tasks, phonological tasks, and dynamic cerebellar tasks -LD had poorer perf. than SL on static cerebellar tasks	-Discrepancy increases with age -Both groups have general phonological and speed deficits as compared to controls -Tests of cerebellar functioning may differentiate b/t SL & LD
O'Malley, Francis, Foorman, Fletcher, & Swank (2002)	**SL:** IQ (WISC-R), Ach. (WJ-R) ⦸ 90 (n = 29) **LD:** Ach. > 1.5 sd below predicted ach. (n = 25) **C:** IQ, Ach. > 90 (n = 325)	-SL=LD on all skills at beginning of study (1st grade) -SL, LD < C on all 8 skills -Rates of development of SL and LD similar on phonemic awareness, RAN letters & #'s, perceptual discrim., spelling, & word reading -LD had better initial visual-motor integration, greater growth in letter-sound knowledge, and greater deceleration of rapid naming of objects	-Results do not support IQ-Ach. discrepancy criteria -Schools have lower expectations for students who do not receive services (SL), exacerbating the impact of reading disabilities on SL -Early identification and intervention for both groups is important

Note. **SL** = Slow learners; **LD** = Learning disabled; **C** = Control.

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