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**Defining the early indicators of dyslexia: providing the signposts to intervention**

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Defining the early indicators of dyslexia: providing the signposts  
to intervention  
*Volume 1 of 1*

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A thesis submitted for the degree of Doctor of Philosophy  
University of Bath  
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March 2009

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## Abstract

The general aim of this thesis was to identify the indicators of reading disability and to analyze the effect of these factors in preschool age children in order to determine which factors play a principal role in the development of dyslexia. Various theories of developmental dyslexia have been investigated and the key components of major theories are presented in this paper. It is a generally held view that dyslexia is caused by a deficit in phonological processing which is an inability to understand the sound structure of language. This thesis aims to unite current research findings in order to better classify dyslexia as well as to determine approaches to intervention which are critical to a preschool child's development of literacy. Three studies were conducted. The goal of study 1 was to determine the discrepancies in performance between non-dyslexic readers and dyslexic readers. Study 2 investigated phonological awareness abilities in preschool age children and their relationship with intelligence. An intervention study was then carried out on the preschool participants to determine the effects of instruction in the alphabetic principle on elements related to intelligence and phonological awareness. The results of this thesis and the studies conducted herein found a wide range of domains that were causal to reading disability. These include visuo-spatial discrimination skills, phonological knowledge and working memory. These studies also indicate that early identification of weaknesses in these areas can be mediated by well informed instruction in letter-sound correspondence and can be a critical determinant of future reading ability.



## 1. *Introduction to Developmental Dyslexia*

Dyslexia has probably been part of culture since the beginnings of mankind (Guardiola, 2001). Manifestations of dyslexia can affect the cognitive and emotional development of an individual and have an impact on society (Coltheart and Jackson, 1998). However, despite its clear importance, there is no single established definition of dyslexia upon which all researchers agree. The scope of past and present research is broad. In order to begin to understand the ramifications of the disorder, it is crucial to present the various definitions of dyslexia so to begin to delineate its characteristics. The process of defining and researching the disorder is complex and still greatly debated. Stein (2007) describes how those who initially recognised dyslexia as a condition believed its basis derived from purely psychological rather than biological causes. Duane (1981) believed the reason dyslexia is not utilized more frequently as a term was because it is regarded as a medical term.

Historically, dyslexia extends back to 1877 when researchers such as the German neurologist, Adolf Kussmaul initially described the disorder. Kussmaul described the disorder word blindness or text blindness as those with “good intellect who used words in the wrong places and often distorted them, leaving 'on the minds of the observers the impression that they are crazed” (Stein, 2007). Subsequently, Pringle Morgan additionally wrote of “word blindness” in the British medical Journal, *The Lancet* in 1896. During this period, researchers reported cases of adults with tumour or brain injury and resulting loss of ability to read; the condition being termed, acquired alexia (Shaywitz, 2003). A subsequent form, later termed developmental dyslexia, was described when in the late 1800’s, an ophthalmologist, James Hinshelwood wrote of a patient who was of above average intelligence but was unable to read. He believed that his patient’s difficulty was somehow involved with his visual memory. At the same time, Samuel Orton, a neuropathologist and psychiatrist described “twisted symbols” or strephosymbolia as the difficulty with words his patients had with reversals and mirror

writing. Orton was also one of the first researchers to link dyslexia with language—a concept that is agreed upon by most researchers today (Orton, 1929). Over the last several years there has been a shift with researchers moving from exclusionary definitions of dyslexia to more inclusive definitions. There is widespread agreement among researchers today that dyslexia is a language disorder (Hurford, 1998; Myers and Hammill 1976). What is today referred to as developmental dyslexia, has become a complex diagnosis with sociological, medical and educational researchers sometimes at odds over causal factors, interventions and treatments. It must also be clarified that the dyslexia described within this paper is developmental dyslexia which is characterized as an inability to acquire reading skills. Alternatively, *acquired dyslexia* is described as being caused by brain trauma which may occur prenatally or later and which leads to the inability to understand printed or written language. This thesis will employ the term dyslexia throughout to describe developmental dyslexia and its characteristics unless otherwise specified.

## 1.1 Varying Definitions

Identification and treatment of dyslexia is affected by a trove of interdisciplinary research on identification, classification and instruction (Moats 2008). The literal translation of the term dyslexia is: “difficulty with words” - difficulty with reading words, writing words, remembering words and pronouncing words. G. Emerson Dickson (2008) president of the International Dyslexia Association believes that the term “dyslexia” is best understood, in a precisely measured sense, when it is used as an operational research definition. Discrepancy among researchers as to the precise meaning behind the term is indicated by the following definitions and classifications for dyslexia.

- **Dyslexia** has been defined by the British Dyslexia Association as "a combination of abilities and difficulties that affect the learning process in one or more of reading, spelling, and writing. Accompanying weaknesses may be identified in areas of speed of processing, short-term memory, sequencing and organization, auditory and/or visual perception, spoken language and motor skills. It is particularly related to mastering and using written language, which may include

- alphabetic, numeric and musical notation." (British Dyslexia Association, The Dyslexia Handbook 2002, p67).
- **Dyslexia** is defined by the British Psychological Society as a disorder with difficulties in accuracy and fluency of reading and spelling at the word level. The BPS definition does not rely on a discrepancy between aptitude and performance and does not refer to intelligence scores. The BPS (1999) recommends the following working definition of dyslexia: Dyslexia is evident when accurate fluent word reading and/or spelling develops very incompletely or with great difficulty. This focuses on literacy learning at the “word level” and implies that the problem is severe and persistent despite appropriate learning opportunities. It provides the basis for a staged approach to assessment through reading.
  - **Dyslexia** is described by the United States Department of Health and Human Services (1998) as a specific learning disability characterized by difficulty in learning to read. Some dyslexics have difficulty learning to write, spell and in some cases speaking and reading numbers.
  - **Dyslexia** is also known as reading disorder, and is marked by reading achievement (e.g., reading accuracy, speed and comprehension as measured by standardized tests) that falls substantially below that expected given the individuals chronological age, measured intelligence, and age appropriate education (DSM-IV, **Dyslexia**)
  - **Dyslexia** is a disorder manifested by difficulties in learning to read, despite conventional instruction, adequate intelligence and socio-cultural opportunity (World Federation of Neurology, 1968).
  - **Dyslexia** is a specific type of learning difficulty where a person of normal intelligence has persistent and significant problems with reading, writing, spelling and, sometimes, mathematics and musical notation. The person may not have difficulties in other areas: many dyslexic people are extremely creative, think laterally and have excellent problem-solving skills. It may be helpful to think of dyslexia as an information processing difficulty. (International Dyslexia Association; Board of Dyslexia, 2002)

Since the term dyslexia was coined by the German Ophthalmologist in 1877, there have been significant criteria established to make it an identifiable syndrome (King, 2008). Scientific research is divided in agreement as to what the primary factors are in defining and measuring dyslexia (Stanovich and Siegel, 1994). Researchers continue to discuss the neuro-physiological, genetic and environmental influences of reading disabilities. King argues that the contemporary terms currently being used, such as visual, auditory, and fine motor processing disorder serve only to “skirt” around the problem an individual is having and lead to delays setting up intervention strategies. Additional terms, such as learning disability, or specific language disorder are too vague to be helpful (King, 2008). Stanovich and Siegal (1994) present research models that analyze and compare the cognitive profiles of children at beginning stages of reading development and employs a logistical regression analysis as a method of analyzing such factors and their substantive influence on reading disability. They conclude their results support the phonological-core variable difference model of reading disability. This model postulates that phonological processing is at the core of all word level reading disabilities.

Shaywitz (1995) also argues that developmental dyslexia must be described as an unexpected difficulty in reading in children and adults who otherwise possess the intelligence, motivation and schooling considered necessary for accurate reading. It is more likely that an amalgamation of factors which contribute to and help explain the disorder. Whether in combination, or alone, it is hypothesized that phonological factors (Snowling, 1995; Seigel, 1990; Stanovich, 1996), working memory (Baddeley, 1993; Rack, 1994), visual processing (Wilkins, 2003; Stein, 1989) and processing speed of information (Rack, 1994) play vital roles in explaining dyslexia.

Fletcher and Lyon (2008) contend that the need for “greater definitional precision” is clear and non-negotiable if researchers and practitioners are to fully understand dyslexia. They argue that the difficulty in establishing a definition that is precise and inclusionary and which provides specific criteria for identifying dyslexia is invaluable.

## 1.2 Prevalence Rates

One consequence of varying definitions is the varying rates of prevalence reported by researchers. A multitude of study conclusions differ on the precise rate of prevalence rate for dyslexia. Yule, Rutter, Berger and Thompson (1973) argue the incidence rate of significant specific reading problems was at 5% in the Isle of White and over 10% in London. A study of 400 primary school children in Oxford found 9.4% reading 2 standard deviations or more behind what was expected from their IQ measurements (Thompson, 1982; Stein, 2001) Stein (2001) notes that 5-10% of children “notably boys” are dyslexic. Wyke (1982) reports on studies that claim there is evidence that more males are dyslexic than females.

The manifestation of dyslexia changes over time, varies with the individual, and evolves along with the life factors of the individual. Simpson (2000) asserts that research in the field of dyslexia has been more concerned with investigating signs and symptoms versus looking for explanations or causes. Dyslexia has been estimated to occur in 4% of the UK population, and 10% show some of the symptoms of dyslexia (British Psychological Association, 1999) Developmental Dyslexia persists throughout an individual’s lifetime, manifesting in reading, spelling, semantics and verbal memory deficits.

Anthony and Francis (2005) report the cause of dyslexia as related to a difficulty in phonological processing with prevalence rates for dyslexia at 5-10%. Wilkins (2003) argues that the visual factors associated with dyslexia are experienced by 5 to 20% of otherwise typically developing children. Shaywitz and Shaywitz (2001) contend the prevalence of dyslexia is estimated to range from 5 to 17 percent of primary age children, and can also be measured with as many as 40 percent of the total population reading below grade level. They argue that dyslexia is the most common and most carefully studied of the learning disabilities, affecting 80 percent of all individuals identified as learning disabled. In addition, they maintain that dyslexia is not a transient condition but rather is persistent chronic condition. The prevalence rate of developmental dyslexia is variant and dependent on various definitions presented. In summary, the prevalence rate for dyslexia between 5 and 20 percent seems to be a figure most commonly reported by researchers.

### 1.3 Intelligence and Dyslexia

Differences in prevalence rates are related to definitions differences, such as the relationship with intelligence Brown, Sherbenou, and Johnson (1997) describe intelligence as a hypothetical construct. Intelligence is a concept in which researchers study its components but that has no directly observable physical properties or characteristics. Typically, researchers seek to define intelligence through their specific theoretical models. Through these models it is possible to define intelligence by the particular components that make it up. Brown, Sherbenou, and Johnson present a chronological view of widely used definitions of intelligence:

Thorndike (1903) described intelligence as being comprised of three abilities: abstract (the ability to manipulate symbols and ideas), mechanical (sensory motor) and social (the ability to deal effectively with others). In contrast, Binet (1910) defined intelligence as the compilation of comprehension, invention, direction and censorship. Soon after, Binet and Simon (1916) further defined intelligence as “good sense, initiative, and the faculty to adapt to circumstances, judge well and comprehend well”. Soon after, David Wechsler (1939) explained intelligence as the “aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with the environment”. In 1952, Piaget portrayed intelligence as a form of biological development that allows an individual to act on and interact effectively with the environment. There is a similarity or common factor in most definitions of intelligence. Researchers agree that, universally, intelligence is comprised of the ability to reason, to think abstractly, to perceive relationships to solve problems, to act with purpose and to adapt and cope effectively with the environment (Brown et al). Many of those who theorize about defining intelligence have done so with the idea of being able to measure it. After constructing theories and refining their definitions, many researchers continued on to develop norm-referenced tests of intelligence.

Galton (1869) published *Hereditary Genius* in which he studied hereditary traits in families. He proposed that families with talents (such as musical talents) tended to produce members with similar abilities. In 1884 Galton developed an intelligence

assessment that measured “questionable” skills (Andrews, 2003). His research was flawed, according to Hawley, Hawley, and Pendarvis (1986) in that he failed to take into account environmental conditions as well as to use random sampling.

In 1890, Cattrell developed a series of mental tests which he published research on in his article *Mental Tests and Measurement*. He proposed in this series of ten tests that an individual’s intelligence could be measured by response time. His ten tests included; strength of a hand squeeze, rate of movement of the hand when started from a resting position, sensation areas (the two point threshold, pressure causing pain and weight differential), reaction time for sound and for naming colours, bisection of a 50 centimetre line, the ability to judge seconds of time, and number of letters the individual could repeat in one naming (Fancher, 1985). Fancher argues that Cattell was relatively influential in his theory and that he created an acceptance for Binet’s later intellect measurements.

Alfred Binet, in 1905, was solicited by the French Education Department to develop a means of identifying children who were behind in their academic performance in order to implement remediation programming. Binet and Simon (1916) produced an intelligence test that was designed to predict which children would succeed in a school setting and which children would not succeed. The Binet-Simon test was developed by Binet and Simon as a series of subtests designed to measure the intellectual capacity of an individual. The Binet-Simon calculates the quotient of mental age and chronological age to derive the intelligence quotient (IQ). Binet defined intelligence as the “general mental ability of individuals in intelligent behaviours” and as having several components including, reasoning, judgement, memory and the power of abstraction. Binet and Simon’s test was the first intelligence test that compared one child’s score to the score of other children. This test was also the first to measure mental age. This is the age at which a certain level of mental ability is reached. Lewis Terman, from Stanford University, revised the Binet-Simon Intelligence test in 1916. Originally, as part of his doctoral thesis, Terman developed an intelligence test with eight parts. These parts consisted of invention and creative imagination, Terman’s test of intelligence was renamed the Stanford-Binet Intelligence Test. In his revision, Terman attempted to reconceptualise the relationship between mental age and chronological age. Terman

proposed that a person's mental age be divided by his or her age in years and subsequently multiplied by 100. Terman believed that the ratio between mental age and chronological age was a better measure of intelligence. The drawback to measuring intelligence in this manner was mental age does not increase steadily throughout an individual's lifespan. Mental age levels off at adolescence but chronological age continues to increase, meaning an individual's IQ appears to decrease as they age. The drawback to measuring intelligence in this way was that created a problem with validity, as scores did not fall equally along the bell curve—there were more extreme results at each end. Shaywitz, Escobar, Shaywitz, Fletcher and Makuch (1992) maintain that the variability which is innate in the diagnosis of dyslexia can be measured and predicted using a normal distribution model. Shaywitz et al. hold opposing views to some researchers who believe reading ability follows a bimodal distribution with dyslexia at the low end of the continuum. In their research they conclude that reading ability follows the normal distribution with dyslexia at the lower end and which occurs in degrees. In Terman's review of the Stanford-Binet he proposed that it was also difficult to convert IQ scores from other achievement and ability tests. Subsequently, deviation IQ is currently used rather than mental age to calculate intelligence. Deviation IQ uses a scale based on the rarity with which the ratio scores occur. Rather than actual scores, individuals are given a percentage score which smoothes out the bell curve and increases reliability and validity. Binet believed that intelligence was not static and subject to substantial change in an individual. Binet postulated that intelligence did have a mental "ceiling" but that rarely did individuals ever approach that ceiling. Binet argued in his theory that intelligence consisted of two major processes: perceiving the external world and then reinstating those perceptions into memory by reworking and rethinking. Charles Spearman performed research for his doctorate studies at the University of Leipzig in 1902 (Fancher, 1985). Spearman had studied William Wundt's theory of "voluntaristic psychology". In Wundt's theory, an individual's intentions and motivations played a large role beyond association. Spearman believed that when full conscious attention is focused, that new ideas could be combined and focused on in numerous ways. Spearman introduced a correlation matrix of academic ranking and test scores. Spearman's research was quite similar to Cattell's work. Spearman also



analyzed Binet's test scores in order to analyze correlations. He developed a correlation formula that accounted for the variability in test scores. This formula was called the tetrad equation. Spearman, in 1904, published his research looking at children's scores in various subject areas. His results found that children who obtained higher scores in one particular subject area also obtained higher scores in other subject areas. Those children who performed poorly in one subject area tended to also perform poorly in other subject areas. Spearman hypothesized that these results indicated a general factor in intelligence which he called "g". In Spearman's theory, the g factor is seen as a large, broader mental capacity encompassing a number of narrower abilities. This notion of the g factor continues to be an accepted theory with researchers (Andrews, 2003). In 1993, John Carroll reviewed several hundred research studies that had occurred over the last century, related to g factor. Carroll produced a three level model of intelligence. In this theory, the top level was "g". The second level contained eight groups of mental abilities including; the ability to understand and use new information, an individual's fund of general knowledge, the ability to learn and remember new information, the ability to deal with information that is seen, the ability to deal with information that is heard, the ability to call up information from memory, the ability to perform mental tasks quickly and the ability to react to information quickly (Andrews, 2003). The third and final level in this model consisted of more specific abilities within the group of eight in level 2. In 1919, Jean Piaget conducted research and development of an intelligence test for the French. His work was based upon a version of a British intelligence test. During his research, Piaget noted that children tended to provide the same types of incorrect responses at certain ages. This finding let him to explore the development of children's thinking styles as they grew (Andrews, 2003).

Wechsler's intelligence scale is currently the most widely used IQ test (Andrews, 2003). Wechsler began to consider the theory that intelligence was not fixed. He proposed in a paper written in 1932 that his testing was superior to the Stanford-Binet because it accommodated special needs and disabilities. When Wechsler was appointed head of Psychology at the New York Bellevue Hospital he began to develop testing that viewed intelligence as multi-factored. This measure was, in the beginning, designed for adults. Wechsler developed the Wechsler-Bellevue scale in 1939 which was designed to base

test scores on the normal bell curve. In the Wechsler-Bellevue scale, David Wechsler compared the mean score for a suitable age group to a value of 100 and subsequently developed tests that would result in a standard deviation of 15. Wechsler defined intelligence as “the aggregate or global capacity of the individual to act purposely, to think rationally, and to deal effectively with his environment” (Wechsler, 1944). Wechsler had deduced that Spearman’s analysis of the g factor was too constricted. In 1955, Wechsler’s test was revised and renamed the Wechsler Adult Intelligence Scale. Wechsler’s test of intelligence is composed of 11 subtests with each subtest producing a composite score. Six of the subtests measure verbal ability. These include information, comprehension, arithmetic, digit span, similarities and vocabulary skills. Five of the subtests measure performance ability. These include picture arrangement, block design, picture completion, digit symbol substitution and block design. In 1949 the scale for children was developed. This Wechsler Intelligence Scale for Children (WISC-IV) was published in 2003. The test has been considered the standard for children ages 6 years to 6 years 16 months. The Wechsler Intelligence Scale for Children, like the WISC, is a two part assessment. The first subtests measure verbal skills and like the Stanford-Binet depends heavily on word skills. The second part and its subtests measure performance skills. The Verbal subscales elicit a VIQ (verbal intelligence). These subtests rely heavily on word skills and include: Information, Comprehension, Arithmetic, Vocabulary, Similarities, and Digit Span. The PIQ (performance intelligence) is comprised of performance subtests that rely heavily on performance skills. The WISC elicits several subtests in which a full scale IQ is obtained as well as four index scores. These include Verbal Comprehension (similarities, vocabulary and comprehension activities), Perceptual Reasoning (matrix reasoning, block design, and picture concepts), Working Memory (letter number sequencing and digit span) and Processing Speed (symbol search and coding). In 1963 the Wechsler Preschool and Primary Scale (WPPSI-III) was introduced. The WPPSI-II is used to measure verbal IQ, performance IQ and obtain a full-scale IQ in children ages 3 to 7 years. Intelligence testing was primarily designed as a means to measure an individual’s potential to perform. The goal is to predict how an individual will perform in the future (Andrews, 2003). Agreement between researchers on precisely what potential can be

predicted is still debated. Presently, intelligence testing is used to measure and predict how well an individual will fare in school. Much research has been conducted as well to predict how an individual's IQ will impact their ability outside of the classroom environment.

In conclusion, IQ is not an indication of the value a person holds cognitively. IQ reflects a level of performance on a group of tasks and should occur in the context of broader assessments. Although not a perfect measurement of cognitive and processing abilities, IQ is considered a consistent and reliable measurement.

#### **1.4 Impact of Intelligence on Dyslexia**

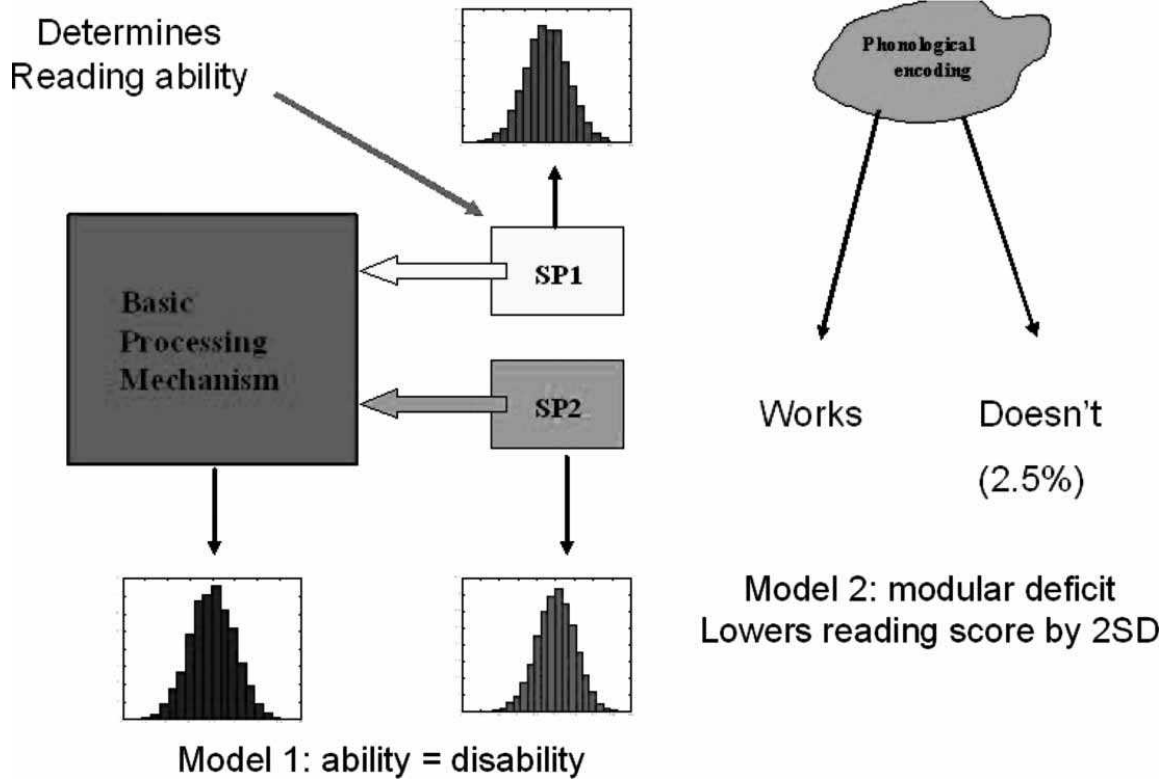
It is fairly straightforward to see how reading ability and intelligence can be correlated. Tests of vocabulary and comprehension are common in the compilation of tests for intelligence. On the other hand, children with high intelligence can be found to have difficulties with reading. Researchers tend to agree that the developmental disorder of dyslexia is impacted by the effect of intelligence on reading performance (Shaywitz, 2003, Anderson, 2008). Research in dyslexia has developed historically to appreciate the disorder for its own sake and for the examination of general intelligence in relationship to reading development. Researchers tend to support either a modular deficit theory of dyslexia or an ability=disability discrepancy model. A modular deficit theory explains dyslexia as caused by a deficit in a specific phonological processing module. Supporters of this theory suppose that the role of intelligence is irrelevant to the disorder because modular functions are independent of skills measured by intelligence. The ability=disability model can be described as considering dyslexia to represent the lower tail of a continuum of reading disability in which dyslexia blends imperceptibly with normal reading ability. The ability=disability model proposes that reading ability is established by a "manifest variation" in the verbal processor and the speed of processing of this mechanism (Anderson, 2008). Dyslexia results when an individual is at the low end of functioning of this continuum and lacks speed of processing and verbal ability. Stanovich and Siegel (1994) argue that dyslexia is defined as a deficit in phonology related to poor reading performance and irrespective of intelligence scores. Phonological

processing tasks are relatively independent of IQ (Snowling, 1998). Arguably some phonological processing tasks might be require more complex metalinguistic tasks which tap phonological awareness and are more highly correlated to IQ (Snowling, 1998). Anderson (2008) explains the fields of dyslexia and autism as related to intelligence. He describes the significant contribution that Uta Frith has made in this area. He reasons that research in developmental disorders had evolved towards an understanding of the disorder for its own sake as well as for its relationship to typical development and the role it plays in general intelligence. Anderson argues that researchers have become stale in the single-cause hypothesis for disorders. He believes that researchers must take into account an association rather than a dissociation approach when defining developmental disorders. Anderson proposes the research of association between disorders and intelligence. He describes a reciprocal relationship in his theory of intelligence and development in order to describe how specifically representing IQ within a disorder's model can illuminate our understanding of the of the cause underlying developmental dyslexia. He theorizes that, historically, with the rise of cognitive psychology, there appeared a view that one could specify the means from which an individual's thought processes were generated. This idea revealed that the specific area of cognitive function could vary with the task involved. The outcome and historical gains of intelligence research have led us to the development of more sophisticated data analytic techniques and have research focused on models that conceive a general factor rather than not (Plomiin & Kovas, 2005). Anderson, (2008) and Anderson and Nelson, (2005) argue that research has concurred on the concept of a concept of speed of information processing and that basic cognitive tasks with little or no knowledge content are correlated with intelligence test performance. These process tasks can include reaction time and inspection time.

Anderson (2008) explores the relationship between intelligence and dyslexia and describes theoretical disputes regarding intelligence and reading deficits. His purpose is to understand developmental disorders in relationship to damage of one or more specific cognitive mechanisms. He postulates that the theories of reading disorder must take into account that it is an association rather than a dissociation which is the norm in developmental disorders. Anderson argues that one must acknowledge the effect of

intelligence and its role in the cause of reading disorders. He presents two alternative models. Model 1 determines that reading ability is determined by a manifest variation in one of the specific processors, SP1 or the verbal processor. Therefore an individual with a reading deficit can be determined to be at the low end of functioning of this mechanism and an individual with no reading disability would be defined as being at the high functioning end. This “ability=disability” model uses this to account for this SP1 to determine reading ability and that there are two independent sources of the variance. The first source is the latent ability of the SP1 processor and the latter being the speed of processing. Anderson argues that for the theory of dyslexia it is pertinent whether a child’s low reading score is the result of poor latent functioning of the SP1 or whether it is caused by poor speed of processing. Model 2 is described as the “module deficit” theory. This theory argues that a mechanism that functions normally in the general population does not play a role in variation of normal reading. Nonetheless, it plays a crucial role, though, in determining a reading deficit.

Figure 1.4 Two alternative models of the relationship between intelligence and reading disorder (Anderson, 2008).



Anderson gives the example that one particular mechanism would be the requirement for accurate phonological representations. Damage to this mechanism would then seriously impact reading performance whereas lack of damage to this mechanism, with reading ability variation, would be attributed to the variation in speed of processing and the latent control of the verbal processor (SP1). A considerable number of co-morbidities that are established between developmental disorders can be directly attributed to the outcome of general intelligence. He concludes that intelligence plays a vital role in the cause of reading disorders, regardless of the theoretical model presented. Wagner and Torgeson (1987) reinforce this position by maintaining that the acquisition of reading skills and many cognitive processes “go hand in hand”.

Dyck, Hay, Anderson, Smith, Piek and Hallmayer (2004) examined the discrepancy criterion for defining developmental disorders. Their purpose was to estimate the distribution of discrepancy scores for abilities in representative individuals aged 3 to 12. Dyck et al. (2004) observed that distribution of discrepancy scores varied as a function of the correlation between two abilities as well as a function of position on the index ability dimension. Their second goal was to examine whether there was a correlation between achievement discrepancies and behavioural disturbances. No such correlation was found but it was observed that underachievement related to age peers on ability was associated with behavioural disturbance and individuals with behavioural disturbances were found to underachieve on several ability measures. Dyck et al. posit that discrepancies in achievement are not a necessary condition for defining a disorder. Rather, the discrepancy in achievement between two or more abilities was more of a function of the correlation between the abilities, the shape of the distribution and the position on the index distribution. They consider that developmental disorders should be redefined along the same avenue as disorders such as mental retardation which includes; under achievements, defined magnitude, using standardized measures, known relation to normal development and concurrent deficits on standardized measures of impaired function or behavioural disturbance.

Stanovich (1991) argues that one major problem with the use of IQ scores in the discrepancy definition of dyslexia is the belief of most psychometricians, developmental psychologists and educational psychologists that IQ scores do not measure potential with any validity. Stanovich states that IQ test scores are gross measures of current cognitive functioning. In addition, Stanovich (1986) proposes that the assessment of IQ in poor readers whose verbal skills could decrease as a consequence to their limited reading experiences. Gough and Turner (1986) describe the vast majority of poor readers as “garden variety” poor readers with little discrepancy between their reading ability and assessed intelligence. Therefore developmental dyslexia is defined by the degree of discrepancy between intelligence and reading ability and this classifies this disorder differently than typical poor reading. Stanovich (1991) maintains that the dyslexic individual’s degree of discrepancy from IQ is so significant and either stems from problems different than that of the poor reader or is so much more severe for the dyslexic that they constitute a qualitative difference. He presents a phonological-core variable difference model that describes the specific assumptions in current definitions of dyslexia. In this model, a child with dyslexia has a brain/cognitive deficit that is specific to the reading task. The deficits of a dyslexic do not extend too far into other domains of cognitive functioning as, if this were to be the case, the abilities that constitute intelligence would be impaired. The key deficit in dyslexia must be domain specific and not a central cognitive mechanism with widely distributed effects.

In her research, Uta Frith contends that there are specific systems designated to exact forms of information processing. These systems may function independently of any general information processing systems and may be processed by distinct anatomical regions in the brain.

## **1.5 Development of Reading Skills**

### **Theories of cognitive, oral, and written language development.**

Jean Piaget made immense contributions to the theories of intelligence testing. He was one of the most influential researchers in the process of “coming to know” and the



attainment of the abilities inherent to intelligence. Piaget began research on elementary age children in 1921. Piaget defined his study of the development of knowledge as “genetic epistemology”. He hypothesized that as children develop they pass through four distinct stages (Boiree, 1999, Andrews, 2003). The first stage is defined as the sensorimotor period and occurs from birth to approximately two years of age. During this stage, children learn through physical interaction activities and through their senses. In this theory, if something is not within an infant’s sight, there no cognitive attention of that person or item. As infants progress from the sensorimotor period they begin to realize that something does exist even when not in view. The second phase of this theory is the preoperational period and occurs from age two to age seven. During this stage young children are capable of thinking concepts without doing them. They are capable of the use of language, simple problem solving and using make-believe in their play. Thoughts are primarily from only the child’s view at this stage of development. In the next stage, called the concrete operations stage, children begin to think logically. This stage occurs from age seven to age twelve. Finally, during the formal operations stage a young person is able to consider about the world from a perspective that is outside their own experience. The child’s thoughts become more abstract and they begin to process information about more abstract concepts. Researchers have challenged Piaget’s theory of cognitive development (Vygotsky ,1986, Vuyk, 1981). Vygotsky considered that learning came before development. Whereas, once a child learned they were prepared to move into the next stage of development. Stuart (2005) proposes that in order to have phonemic awareness (the ability to hear, identify and manipulate the individual sounds in spoken words), the child must be able to decentre from the meaning of the word to focus on its structure. Stuart interprets this decentration within the Piagetian framework to postulate that children will need to have progressed to the concrete operational stage in order to perform phonemic awareness tasks. The implications of this are that reading development is transpiring during this stage and young children are beginning to reason to specific or concrete examples of language development such as letter-sound correspondences, combining and segmenting sounds and other phonemic awareness skills.

Goldsworthy (2003) contends that the development of language awareness is vital to emerging literacy activities including phoneme isolation, segmentation, rhyming and creating grammatically correct sentences. These can be classified as meta linguistic skills. Meta linguistic skills are those skills underlying language and which influence reading development. Metalinguistic skill are classified by Goldsworthy into five broad categories which include word awareness, syntactic awareness, phonological awareness, pragmatic awareness and connected discourse awareness. Metalinguistic awareness is argued to be continuous changing process in language development (Menyuk, 1991). Van Kleeck offers a two-stage cognitive model of metalinguistic language development based on Piaget's framework.

Stage 1: This stage begins with language and lasts 6 years. During this stage, a child's thought is distinguished by "centration" and "irreversibility". Centration is the ability to concentrate on just one aspect of a situation at a time. Irreversibility is characterized by an inability to shift back and forth easily between varying aspects in a situation.

Therefore, children in stage 1 focus thought primarily on meaning rather than linguistic form. Stage two of this model occurs between ages 7 and 11. In this stage the reasoning ability of children is characterized by "decentration" and "reversibility". Decentration is the ability to hold and relate more than one aspect of a situation at a time. With decentration children are able to consider language as a means for conveying meaning as well as an object on its own. Therefore, children are able to compare two meanings of one linguistic form at one time. In this stage children are able to determine whether the syntactic form of language used is correct.

Locke (1997) in his theory of neuro linguistic development proposed the development of language in four unchanging, overlapping, sequential phases. During each phase, exclusive functions are accomplished.

Phase 1: During this phase an infant is orienting to speech. The infant is learning the vocal characteristics of those in their environment. Locke describes the infant's preference for listening to individuals speak as resulting from having cognitive and neural supports that enable specialization in social cognition. Locke also reports the infant's exposure to prenatal prosody as impacting these preferences. In Phase two, Locke theorizes that the cerebral hemisphere is quite active in processing and storing single

words and two to three word pseudo phrases in prosodic memory, which is the rhythm, intonation, stress at related attributes to speech. This phase begins at approximately 5-6 months of age and continues for 20 months. Locke argues that this phase is critical to the development of the semantic domain of language. Phase three occurs between 18 and 36 months of age. During this phase, the child notices regularities of language, syntax, morphology, phonology and pragmatics. Locke maintains that in phase three, the forms stored in phase two begin to be decomposed into parts. The child in this phase begins to learn about grammatical rules. Locke asserts that the left cerebral hemisphere becomes involved during phase three that allows for grammatical interpretation. If a child's language is developing normally in phase three, they will acquire approximately 400 expressive words by 28-30 months. They then begin to discover and apply morphological rules to their language. During phase three this analysis leads the child to discover the phoneme. The child is capable of comparing pairs of words to analyze the differing initial phonemes. This understanding of phonemes develops into knowledge of morphological endings such as plural endings and change of word tenses (Kamhi and Catts, 1999). Goldsworthy (2003) contends that the language domain of phonology is a critical area of research for underlying language-based aspects of developmental reading disabilities. She argues that because of the alphabetic phonological relationship, it is important to study the differences between good and poor readers on many aspects of phonology. In phase four Locke proposes that the child's word storage (lexicon) increases significantly. Phase four involves integration and elaboration as the child's vocabulary increases. Locke suggests that the structural analysis that occurred in phase three "takes the pressure off a holistic type of memory" and "enables the creation of larger and larger vocabularies". During these four phases, stability in normal language development is acquired in semantic, syntactic-morphological, pragmatic and metalinguistic skills. Most children have acquired these continuous skills when entering school and beginning the function of written language.

Shaywitz maintains that in the developmental stages of reading a young child first discovers that words can be separated into smaller pieces of sound. When the child makes this discovery, they subsequently begin to develop the ability to notice, identify, and manipulate individual sounds in spoken words (phonemic awareness). Shaywitz

(2003) contends that this transition and awareness of segments in words is not an ability specific to human biology as spoken language is. Thus, when a child becomes aware of the segments of spoken language, phonemes and their sounds, then the elements of written language can be learned. She argues that all readers, including dyslexic readers, must follow the same steps in order to learn to read. Locke's theory of language development concurs with the ideas of Shaywitz. Locke maintains that the sensitive period for language development is between infancy and 6-8 years. He states that the four phases of his theory are fixed and overlapping. Therefore they must occur and one phase must occur before the next. Locke's theory can be linked to Piaget's studies in that both models require a child to sequentially progress through the phases and each phase must be complete before beginning another. According to Locke, during normal language development, adequate lexical information is stored during phase two to allow the analytic mechanism in phase three to activate. When this occurs, vocabulary is expanded and the developing language system becomes integrated and elaborated.

### **1.5.1 Relationship between spoken and written language**

Though somewhat contrary to Shaywitz's premise regarding oral language and written language being contradictory, Vallutino, Scanlon, Small and Tanzman (1991), Vellutino (1993) argue a reciprocity between oral and written language. Vellutino questioned what factors or combination of factors were the best predictors of reading performance. Additionally, the concept of reading and visual abilities, and the affect they had on reading ability, was measured. Finally, Vellutino measured the cognitive and linguistic abilities of poor and normal readers to determine whether there were any significant areas of difference. Their research indicated a strong relationship between oral and written language. This reciprocity specifies that ability in processing and comprehending the written language depends directly on factors that allow one to "acquire competency in the different domains of oral language" (page 125). Vellutino maintains that in the process of reading development, oral and written language are not parallel systems, but increasingly "interactive and convergent systems". Vellutino describes this concept as one where the child is not learning or acquiring a new language but recoding the

language he has already acquired. Vellutino asserts that within this model the various subskills for reading are dependent on adequate development in other language domains. The weight assigned to a particular domain depends on the specific unique processes involved in acquiring that particular subskill as well as to what level the individual child has developed the subskill. This is particularly crucial for children at the beginning stages of reading acquisition. Vellutino (1993), Harm and Seidenberg (1999), and Barr, Pearson, Kamil and Rosenthal (2002) concur that phoneme segmentation and alphabetic mapping ability are the two essential determinants of later reading ability. In acquiring reading skills, the child must analyze the orthographic form of the alphabetic letters and begin to understand the relationship that occurs between these orthographic symbols and the linguistic elements they represent. When learning to read, the child must associate orthographic with phonological patterns in memory (Stanovich, 1991). The alphabetic orthography used in English spelling utilizes a set of 26 printed symbols that allow decoding of the English language. A good reader of the alphabetic system can read words they have not seen before without having to memorize associations between symbol patterns and corresponding words (Liberman, 1983). Bear, Invernizzi, Templeton, and Johnson (1996) convey that the concept of word and the concept of a phoneme need to be learned and taught. These two concepts will emerge and the child begins to acquire the alphabetic principle and to manage the units of speech with the printed units of orthography. Barr et al. (2002) describe the evolution of research regarding the two methods of acquiring reading skills. Prior to the 1970's it was accepted that there were two distinct ways that children learned to read--by sight and by phonological recoding. Researchers accepted that these two methods arose from two distinct forms of reading instruction. After 1970, research began to focus on the process of word reading and the established view was questioned. Researchers began to take the view that as a reader develops skill he begins to be able to read words by sight, regardless of the teaching method used. Skilled readers also utilized the letter sound relationship to read words. Findings also indicate that sight word reading is not a rote memorization process that ignores letter sound relationships. The attitude evolved to consider that there are multiple approaches to reading words by sight as well as multiple methods of reading besides decoding. The concept of analyzing words through orthographic structure and of

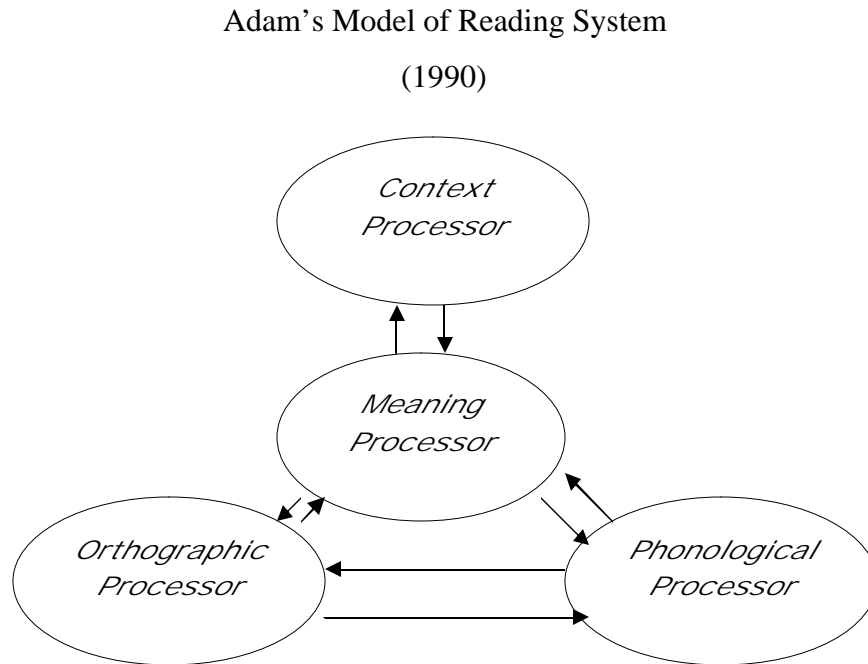
deducing words through context was studied. Goldsberry (2003) describes the process of reading as interactive and one that requires multiple cognitive abilities involving perceptual, cognitive and linguistic domains. During this process, information obtained from print, whether it is decoded or recognized as sight word, is analyzed and compared with the individual's previously acquired information. Goldsberry describes the process involved in reading acquisition as more complex than a simple transfer of meaning from oral to written language.

In summary, this section describes several theories which outline the process for development of learning and subsequently of reading skills. Whereas some of the theories presented maintain that development is fixed and overlapping, others maintain that one particular phase of development must occur before the next. Regardless of the philosophies presented in the theories, one must take from this research the evidence which indicates that development of intelligence and reading ability are progressive. When particular gaps occur during the process, an individual's abilities can be crucially impacted. The next section illustrates Adam's model of reading systems. This system differs from those described above in that it acknowledges mechanisms for the evolution of cooperation between mechanisms involved in reading development.

### **1.5.2 Adam's Model of Reading Systems**

Adams (1990) describes the process of reading development as involving four processors. These four processors work together continuously to receive information and to return this information back to each other.

**Figure 1.5 Adams Model of Reading Systems (1990)**



Adam's describes the orthographic processor as receiving information directly from the printed page. While reading, an individual uses visual, orthographic information initially. Orthographic processing is described by Stanovich, West and Cunningham, 1991) as the ability to form, store and access orthographic representations. Orthographic processing involves the visual processing of letters as well as with sublexical word parts (such as "ing") and letter patterns. This visual system is very efficient at extracting the information necessary to identify letters. Alternatively, according to Stahl, Osborn and Lehr (1990) the orthographic processor is not as efficient in processing letter order. The reader will attempt to process nonwords utilizing their familiarity with letter patterns. For example, familiar words such as "the" are strongly associated with the reader's orthographic memory and therefore a nonword such as "tge" could be processed in the orthographic memory as "the". Nonwords are vital for evaluating an individual's ability to perform phonological analysis (Margolin, 1992). Adams describes the learned associations between individual letters as responsible for the simple process in which the reader responds to familiar words.

The context processor is portrayed by Adams as the processor responsible for constructing a coherent interpretation of the printed word. As this occurs, the context processor sends “excitation” to the meaning processor. Adams explains that the amount of excitation contributed by the context processor is dependent upon how predictable the context is. Adam states that if the context is weakly predictive of the next printed word, the meaning processor will receive a strong, concentrated boost in excitation.

The meaning processor works in a similar manner to the orthographic processor. The meaning processor stores familiar word meanings as interrelated sets of primitive meaning components. Adams describes the reader’s understanding of a word as representative of an associated group of properties that collectively represent the individual’s schema and experiences with that particular word.

The phonological processor is also similar to the orthographic and meaning processors in that it contains a “complexly associated array of primitive units”. As the visual image of letters and letter strings are being processed in the orthographic processor, stimulation is made in corresponding units in the phonological processor. The stimulation is sent from the orthographic to the phonological processor if the letter string is pronounceable. The two way interaction of the orthographic and phonological processor are caused by activation of a word’s meaning resulting in excitation of phonological units underlying its pronunciation. Therefore, the activation of a letter string’s pronunciation automatically excites its meaning. The phonological processor receives its information in the form of speech. The phonological processor can be activated through outside speech or through sub vocalization. This sub vocal rehearsal then allows phonological representations to be stored by the individual. Adam’s model is an interactive theory of the reading process. Her theory emphasizes the role of letter and word recognition over comprehension. Her theory synthesizes a large amount of research and emphasizes the importance of letter-to-sound decoding in reading. Adam’s theory is a response to previous researchers (Smith, 1978; Goodman, 1994) who proposed that readers do not decode every letter from left to right during reading. Rather, they argue that readers process whole words and skip words, parts of words or whole text without impacting comprehension.



### **1.5.3 Uta Frith's theory of reading development**

Uta Frith (1985) devised a three stage theory of reading development. These stages are comprised of (1) logographic, (2) alphabetic, and (3) orthographic. Frith acknowledges that development is related to change and that the change is not arbitrary, but “biologically and culturally pre-programmed”. According to Frith, stepwise progression occurs when a new skill is introduced and the input process of reading or the output process of writing takes place. Frith believes that at any critical point of this process, certain breakdowns can occur. Where the breakdown occurs will influence the particular type of reading disorder. In her theory, Frith illustrates the differing outcomes that can occur depending on the stage in development at which the damage occurs. Frith also postulates that the reading disorder is also impacted by the type of compensation skills that occur. In her model, the reader must master three basic strategies before mastering the skill of reading. In the logographic stage a child recognizes words based on “salient graphic features”. Frith contends that the first letter of a word typically becomes the salient feature, but that a young child in this phase recognizes the symbol associated with a word such as the arched M for McDonalds. This phase of her step-wise model of literacy acquisition would be considered pre-literate where it is assumed that a child has only a symbolic understanding of the written word and occurs before the early logographic stage. Once the child understands that a specific printed word has a specific meaning they begin the logographic phase of reading development. The logographic stage is divided into two parts. The first part of the logographic phase coexists with the child's symbolic scribbling. In this function for the child, any scribbling can mean any word. In the next phase of logographic development, the child associates the relationship between particular scribbles and meaning. A delay in development prior to the logographic stage could interfere with emerging symbolic skills and therefore affects a child's recognition of printed words as symbols for objects or concepts. In the next phase of the model, the alphabetic stage, the child performs analysis of letter sound relationships. The child is sequentially putting together a string of sounds to create a word. In this stage, each letter is important as is the order in which the letter is in the word. Frith contends that during the development of the alphabetic principle, teaching is

crucial. She argues that with practice this strategy will be improved and utilized for reading. In her model, Frith postulates that the alphabetic principle is displaced when the orthographic phase is adopted. In the orthographic phase of this model there is instant recognition of morphemic parts of words when considering letter order but not letter sounds. Frith states, "... child might recognize in the word 'signatures' the morphemes 'sign' and 'ture' and plural 's'. A morpheme can be defined as the smallest meaningful unit of a word which can be grouped with other morphemes to create a word. Citing earlier research on literacy development (Frith and Frith 1980; Frith 1982) she contends that whereas the alphabetic principle is particularly suited to output function because of its sequential nature and logographic and orthographic principles are suited to input function because of their potential for instant recognition. This model also implies that acquisition of literacy is not gradual but qualitative. The child is building on and enhancing each of the three stages of the model as they build on to the skills they have already acquired. In addition, the model suggests that each separate strategy develops across multiple areas of competence with a specific level of competence required to be reached before the strategy is transferred from input to output processes or output to input processes.

#### **1.5.4 Jeanne Chall's Stages of Reading Development**

As outlined in the preceding descriptions of reading theories, many researchers maintain that the reading process is a systematic, organized process occurring from the "bottom up". Reading skill must be built upon through stages and is an ongoing process. Harvard professor Jeanne Chall has outlined the stages of reading development that begin at preschool age and continue until university age. Chall's proposed "scheme" for reading stages includes six stages with the purpose of understanding the path of reading development from pseudo-reading to extremely imaginative reading in advanced forms. Chall considers that her proposed stages of reading development resemble Piaget's stages of cognitive and language development (Chall 1983). Each reading stage has a definite structure and varies from the other stages in characteristic qualitative ways. Each stage follows a hierarchical progression. Chall believes that individuals progress through the

reading stages by interacting with their environments and that this interaction impacts the individual's reading development as much as the progression of the distinct stages themselves.

**Stage 0 - Pre-reading.** This stage covers birth to age six. Of all six stages in this model, Stage 0 includes the greatest period of time in an individual's development and covers more changes. Children in this stage accumulate a breadth of knowledge about letters, words and books. As they develop through this stage, individuals gain control over many aspects of language structure and vocabulary. Individuals in this stage also begin to recognize that rhyme and alliteration in words, that words can be detached into separate parts and that these parts can be blended into whole words. During this stage, children are capable of begin discriminating and name some letters of the alphabet. Children begin to utilize the features of writing and to write forms that resemble symbols or letters. Preschoolers at this stage begin to understand the essential concepts of reading, which include holding a book properly, pointing to words on a page, turning the pages and using the book's pictures for elaboration of the story.

**Stage 1 – Initial Reading.** Stage 1 occurs during ages 6 and 7 and is associated with learning the arbitrary set of letters and associating those letters with their corresponding parts of spoken words. During stage 1 an individual begins to internalize their knowledge of reading by appreciating what letters represent to recognize differing sounds in similar words (cat, cap) and to recognize mistakes in reading. Chall believes that the qualitative change occurring at the end of stage 1 is the insight the individual achieves about the nature of our alphabetic spelling system.

**Stage 2 – Confirmation and Fluency.** Reading in this stage consolidates what was learned during stage 1. Practice of reading increases fluency during stage 2. Chall proposes that Stage 2 is not for gaining new information, but rather for confirming the information already known by the individual. The individual is able to concentrate on the reading content as it is already familiar to them. A reading in stage 2 is able to utilize their schema to appreciate the knowledge and language and to gain confidence in their abilities.

### **Stage 3 – Reading for Learning the “New”**

Transition to Stage 3 involves the reader beginning to learn new knowledge, information, thoughts and experiences. Reading at Stage 3 is first and foremost for facts and for concepts. The individual’s schema of knowledge and vocabulary are more limited at this stage and become developed with the reading of various materials and viewpoints. Stage 3, according to Chall, involves relating of print to ideas. It becomes reading to learn more than learning to read. Chall proposes that in Stage 3 other means of knowing begin to “compete” with reading, although learning from listening and watching in this stage continues to be primarily more efficient than learning from print. It is in this stage that the reader needs to learn from the background knowledge they bring to the reading experience. Additionally, during Stage 3 the individual discovers processes of reading including the knowledge of how to search for particular information within a book.

### **Stage 4 – Multiple Viewpoints**

This stage occurs during ages 14-18 and involves management of multiple points of view. Instructional text at this stage presents the reader with various points of view on an individual topic. The individual is capable of dealing with layers of facts and concepts and complements those concepts acquired by the individual earlier. Chall argues that Stage 4 is acquired through formal education and the curriculum presented therein. This instruction gives the reader more practice in acquiring difficult concepts through reading.

### **Stage 5 – Construction and Reconstruction**

Stage 5 takes place at ages 18 and above. This is the most mature stage and Chall describes the relationship to Perry’s (1970) study of intellectual development of the university years. According to Chall, Perry describes a transition from the conception of knowledge as a quantitative “accretion of discrete rightness” to the “concept that knowledge is a qualitative assessment of contextual observations and relationships” (Perry, 1970). Within Stage 5, a reader is capable of understanding what not to read as well as what is to be read. In Stage 5 the reader is able to construct knowledge for himself by reading what others say. A reader can make judgements as to what material to read, how much to read and in what detail. An individual in this stage is able to think abstractly about the material read. Chall describes the reader being capable of adjusting

reading rate to the appropriate speed level based on past knowledge of the subject and the ability to synthesize.

The models described in the above sections outline some of the major broad theories of cognitive, language and reading development. Although theories are merely explanations of a particular phenomenon—such as language and reading development—all have major implications for understanding deficits which occur during growth. Piaget's stages of development can be described as a bottom's up approach, whereas emphasis is placed on progressing through development from the lowest realm to the highest. Chall's Stages of Reading Development resemble Piaget's stages of cognitive and language development in that both take a bottom up methodology. Frith and Adams both speak to an interactive approach to reading development. In an interactive approach to theory, both a bottom-up and a top-down process are acknowledged. An interactive model acknowledges the justifiable points of both approaches while attempting to avoid the criticisms of each. In an interactive reading model, print is input and meaning is output. Both Adams and Frith are able to support their methodologies with research that reflects simultaneous use of many levels of processing even as only one source of meaning can be used at any given time. These four theories substantially represent the variance in approaches to development and give broad understanding of the concepts which impact cognitive and reading development.

## **1.6 Cultural influences on reading ability**

Literacy throughout the world is a recent phenomenon (Chall, 1983). The effect of one's culture on reading ability is varied. With literacy being defined as one's ability to read, write and speak in their language the literacy rate can be quite varied (Agency for Healthcare Research and Quality, 2008). Research in cross-linguistic studies are beginning to reveal that the manifestations of dyslexia are dependent upon the orthography in which an individual is learning to read. In many cultures, literacy is affected by several factors related to that culture. Raman and Weekes (2005) present a case study describing an individual with bilingual Turkish and English language. They

argue that this individual's reading disability—specifically dyslexia—is rooted in a chronic under-activation of phonological representations in both Turkish and English. Ramus and Weeks (2005) describe this case study as meriting further investigation into developmental dyslexia in the Turkish language. They suggest that lexical reading problems in Turkish follow phonological impairments.

Johansson (2006) argues that the study of cultural influence on reading disability is important to the understanding of the disorder. Johansson claims that proficiency, exposure, and age of acquisition all affect an individual's cerebral representation of language. This is especially true when comparing alphabetic and non-alphabetic languages. Much research has been looked at with the agreement that cultural implications on brain organization of language have implications for dyslexia (Leong, 2006). Johansson, (2006) concludes reading and writing affect the functional organization of the brain. Primary language acquisition utilizes the same neural mechanisms as with secondary language. Individual acquisition of native language is a predictor of second language acquisition. Johansson reports that neonatal infants are capable of listening to certain sounds outside the womb and are capable of distinguishing between patterns and rhythms of certain sounds. The pattern and rhythm of native language is distinctly different in varying languages. English is characterized by strong stress and an irregular rhythm, whereas the Japanese language is characterized by few changes in pitch and a regular rhythm with little stress. In her study, Johansson found that French infants were able to distinguish between English and Japanese but not English and Dutch (whereas both have stress). Languages have universally extreme vowel sounds that an infant is able to distinguish (where consonant sounds are less distinguishable). By six months of age an infant is attuned to the more extreme vowel sounds of its language and by ten months of age is able to attune to a language's consonant sounds. But, languages with a strong stress engage in a more important role. This is important in that it relates to some reading disabilities. Certain researchers consider severe reading disabilities a manifestation of an innate language disability (Høien & Lundberg, 2000). Saffron and Wilson (2003) found that when statistical and stress cues do not agree, an infant at 7 months of age will concentrate more on the statistical cues and 9 month old infants utilized stress cues more as a means of

segmentation of language. Research into the manifestation of dyslexia with Chinese and English readers has been explored. In a review of research on Chinese and English reading development, Johansson (2006) reports that researchers have primarily found it difficult to determine whether Chinese writing can be classified as a language of logographic, morphemic or morphosyllabic. She discusses research by Perfutti, Liu and Tan (2002) in which the Chinese writing system is classified as a unique writing system with a direct expression of morphemes, each having a distinct unit of meaning and form. As reported by Johansson, Tan et al (2005) determined that the ability to read Chinese is directly related to the individual's writing skills and the relationship between phonological awareness and Chinese reading is weaker than in alphabetical languages. They propose that the role of logographic writing in the development of reading is influenced by two overlapping mechanisms. These are; orthographic awareness which makes possible the development of links between visual symbols, phonology and semantics and the establishment of motor programs which create the long term memory of Chinese characters. Ultimately, Johansson concludes finally the neuroscience of language is a rapidly progressing field, but that researchers are still at premature stages of understanding to what extent linguistic and cultural factors affect the brain's organization of language. The low incidence of dyslexia in China led to the hypothesis that reading in a logographic language is easier for those individuals who have phonological deficits such as with dyslexia (Dietz, 2002).

Uta Frith, (2007), introduced general questions of reading and reading problems with relation to orthography. Frith defines orthography as spelling words correctly, recognizing words correctly when reading and mapping speech sound with written words. In her definition, she introduces two models of speech. In a straightforward model the sound of speech is encoded in letters and small segments of words. Decoding is possible by going from small concepts to big words.

In a more complex model of orthography what the reader sees is what they know. A reader cannot pronounce previously unknown words. Frith asked of her research the following: Does the model of orthography used by a particular language affect reading strategy and efficiency. Does this affect dyslexia? From her 1960 model of reading

development Frith explores the differences in the learning of reading skills in various cultures.

According to Frith, Italians learn through a straightforward orthography. The English, French, and Danish utilize a complex orthography. An orthography where what you see is what you know. This includes much ambiguous print, including sound mappings.

Examples in the French language are: Louis – Lewis – Looie's ; ses – c'est – ces – sais

Example of ambiguous print to sound mappings in English include; *rough*, *though*, *through*, and *journal*, *ourselves*, and *thought*.

Frith (2007) studied reading in English and Italian individuals. Non words can be created in English that obey the simple model of orthography. They can be decoded in a straightforward way as in the Italian language. Frith questions whether reading strategies are shaped by different orthographies. Do English readers abandon their reading strategy, which is adapted to a complex orthography, when reading non words? Are Italian readers fazed by having to read international words?

Frith engaged in a cross language study with 72 participants. Of these 72 university students, 36 were from London, 36 from Milan and a French group was included later. Students matched on course of study, (arts, science, and engineering) and on age.

Results showed reaction times for words and nonwords based on English and nonwords based on Italian. The English group performed slower than Italians in all three areas. Italians were faster reading non words based on English words and on nonwords based on Italian words. Frith concludes that Italians were not simply faster at reading , as both Italians and English students performed equally at picture naming.

Reading of international words was also studied. Italians performed faster at reading Italian words than English students, but Italian students slowed when reading words of an English root and both groups performed equally in this task. In conclusion, it was established that Italian readers read faster. They take advantage of unambiguous print-sound relationships. In Italian, a straightforward orthography allows an efficient strategy. English readers read more slowly. They habitually need to disambiguate print sound mappings. They use this strategy also with non-words even when they do not have to do this. They read non words from different linguistic roots equally well.



In Frith's model, Italians rely on grapheme phoneme correspondence rules and English readers rely on an orthographic lexicon more. It is evident that reading strategy is shaped by orthography, language and culture. In her study, Frith investigates what occurs in the brain when we see print in comparing cultures? Her study involved 12 Italian normal readers and 12 English normal readers, both groups of whom were university students. Explicit reading (read aloud) and implicit reading (participants were presented with the words and told not to read them but to look for specific ascenders that were present (b,t,l,h)).

Areas of activation during implicit and explicit reading was found in left hemisphere of the brain. Greater activation for English readers in the word naming area at the rear of the brain (the orthographic lexicon) was found. Greater activation in Italian readers in the letter sound decoding area was found—the grapheme and phoneme conversion map. Findings indicate that there is a common area of the brain for reading but that particular areas showed more activation separately for Italian and for English readers.

How do these differences in orthography affect dyslexia?

Estimates of prevalence for dyslexia in Italy are lower than in English speaking countries. Dyslexic readers were compared in UK, France and Italy. There was some difficulty in obtaining subjects in Italy as there was no previous diagnosis for the majority of subjects. Wide screening of students at university was done and it was necessary to select slowest readers and those who performed worst on phonological tests. In UK and France adult volunteers were chosen who were previously diagnosed with known difficulties in reading and writing acquisition, slow reading and poor spelling and performance was impaired on phonological tasks.

Results show English dyslexics were impaired for performance in digit span, arithmetic and digit symbol. All tasks involved short term memory. English dyslexics had normal or above normal performance on all other subtests. Similar stimuli were used in all three languages for both words and non-words. UK dyslexics performed slower than French dyslexics and even slower than Italian dyslexics. Italians performed slowest on digit naming – but this was due to the fact that Italian number words include more syllables. For spoonerisms – Italian performed faster than both French and English who performed

the same. Word span analysis showed that dyslexics performed significantly different than the control group.

Neuroimaging PET scans were completed for tasks of explicit and implicit reading Frith expected to see difference in the grapheme phoneme mapping area or in the orthographic lexicon area. Three areas in left hemisphere were found to be active in normal readers. The dyslexic reader brain shows a reduced activation in this same area. The most stringent level of significance showed least activation in the back of the brain called the orthographic lexicon. The lexicon is the repository of word specific information stored in long term memory. Mere exposure to print versus baseline in normal and dyslexic readers reveals reduced activation in a bottleneck of the reading system. Access to the orthographic lexicon shows difficulties at the neural level. This is not surprising, claims Frith, because access to orthographic lexicon is downstream in the reading process. Also, English dyslexics are more disadvantaged relative to Italian as they rely more on an orthographic lexicon. In contrast, it was surprising because Frith hypothesized that dyslexics use more grapheme-phoneme areas. Italian normal and dyslexic readers make fewer errors and perform faster than English and French which seemed equally difficult.

Using the same data collected, the question was asked if there were subtle differences anatomically in the brains of dyslexics. This included investigating whole brain voxel by voxel to look for relative decreases and increases in grey matter. When looking at structural/anatomical differences an area shows increase in grey matter in dyslexics and a decrease in some area of gray matter. Her research found that it was the increase that correlated with reading performance in dyslexic readers. This was the same in all three languages. This increase can be explained by cell migration failure. During infant development particular cells wander to the surface of the area and are called ectopias. (Galaburda, 1997). The areas of the brain where this occurs seem to be related to all areas of language. Their speculation is that perhaps in dyslexic brains, neurons could be in the wrong place. This looks like increased grey matter in the critical brain region (orthographic lexicon).

Both areas that show increase and decrease are part of the speech processing system and are active when items are named and also active when words are named. They are

associated with rapid access to representations of words by sound, by meaning, by orthography. The skilled reader can access simultaneously a word's sound spelling and meaning. A dyslexic reader lacks this rapid access.

The study of different orthographies explains dyslexia as a disorder within the cognitive basis of the brain and is the same in different languages. The study also showed cultural differences that occurred in normal readers and dyslexic readers. Regardless of the better performance in Italian readers, they are still dyslexic. The conclusion is that dyslexia is less of a handicap when acquiring a straightforward orthography. Hidden cases manifest in relatively slower reading and speech processing difficulties. Dyslexia's problems are magnified when acquiring a complex orthography. Consequently, Italian dyslexics find it extremely difficult to learn the English language.

## **1.7 Summary**

This chapter addresses the multitude of research underlying the definition of dyslexia as well as exploring the varying prevalence rates, relationship with intelligence and cultural factors. The evidence posited herein draws attention to the variation within these factors and the caution in which researchers seek to describe and define the condition.

Complicating the approaches to characterization of dyslexia are the associations with biological, cognitive, environmental and neurological systems. This chapter additionally presents four major theories of cognitive and reading development. The rationale behind the four theories illustrated is to lay groundwork for the typical development expected during language and literacy development with the aim of exploring the deficits causal to reading disabilities in the next chapter. Coltheart and Jackson (1998) reason that dyslexia ought not to be defined by a required definition nor by relation to exclusion criteria.

They maintain that assessment of reading problems must include individual profiling of reading systems and comparisons with typical development models.

Even with the large number of definition available currently, researchers aim cautiously to seek a more conclusive means of defining and/or redefining dyslexia. A more refined definition will have implications for theory as well as practice in this field. According to Reid (2003) dyslexia must be "realigned" with contemporary movements in education

including inclusion, literacy and the development of learning skills. Chapter 2 outlines the various theories of developmental dyslexia. With an examination of the various theories of developmental dyslexia we will begin to grasp the complex nature of the disorder and the divergence in possible explanations for it.

## 2. Theories of Developmental Dyslexia

This chapter will focus on an analysis of the range of theories of current research on developmental dyslexia. The difficulty in a lack of concise definition of dyslexia has contributed to the varying research and theories that have resulted from the fields of science. There are many different theories of dyslexia. Individual researchers pursue particular avenues of exploration. It is important to remember that research is ongoing and that our knowledge is still partial.

It may be understood that dyslexia theories have led to the development of associated teaching and learning approaches, but this is not always so. Teaching and learning approaches have often been developed from observation and experimentation by practitioners themselves; the links between theory and practice are not straightforward.

The focus of this chapter will be on the issue of developmental dyslexia, in which case reading skills have not matured appropriately as opposed to acquired dyslexia which results as a consequence of brain injury and causes disruption of established reading skills. The organization of research into a useful model should be a guide to explaining the components of the reading process and how each component works together in the model (Goldsberry, 2003). Subsequently, a model allows researchers to trace reading difficulties to breakdowns in one or more of the sub processes. The study of reading is convoluted by differing models, labels and teaching approaches (Goldsberry, 2003). Numerous reading tests and reading related materials therefore frustrate practitioners with definitions, subtypes, approaches to remediation and program types. Theories of dyslexia take a progression in tandem with the emergence of institutionalized public education and the abilities of educators to observe a large number of children, identifying those with various reading disabilities (Guardiola, 2001). The models focused on here in this chapter represents just a selection of the many theories that have been presented in this field. Frith (1997) presents a causal modelling framework which outlines the focus of the

varying theories chosen as representative for the field of dyslexia: biological (genetics and neurobiology), cognitive (for information processing) and behavioural (reading and spelling).

The foundation of scientific research in dyslexia is related to the first findings of language problems which were associated with acquired aphasia. As discussed in the previous chapter, there is a historical perspective which begins to define the timeline for varying theories of models. In 1810, Franz J. Gall introduced the idea that each specific part of the brain had a function. Between 1861 and 1865 Broca began to describe the specific area of the brain where language functions were located and in 1872 physician R. Berlin of Germany attributed the loss of reading to a brain lesion. Dejerine, during that same year, localized the lesion causing reading problems to the parietal lobe area and middle and inferior regions of the left occipital lobe. It was during this period of research that the anatomically based theories of dyslexia began to develop and recognize another form of dyslexia not related to brain injury but rather one that developed during the growth of the child (Guardiola, 2001).

Over 100 years ago in Great Britain, the focus of research was primarily physicians and ophthalmologists and described as a disease of the visual system. The visual theories of this time were directed by researchers such as W. Pringle Morgan (1895), C.J. Thomas (1905), J. Herbert Fischer (1905) and Robert Walter Doyne (1907). In the United States around 1920, neurologist Samuel Torrey Orton began to research dyslexia as he studied language problems of mentally retarded individuals at the Greene County Clinic in Iowa. His research on over three thousand individuals focused on language disabilities. It was Orton who described the correlation between reading delays and factors such as left-handedness and left eyedness. He additionally suggested a genetic nature of dyslexia and showed reading deficits to run in families. Until Orton's research the study of dyslexia was primarily held by physicians. In the late 1920's and early 1930's psychologists, sociologists and educators began to study the disorder. The occurrence of this newly competitive field of research contributed to the proliferation of many new theories regarding the causes and symptoms of dyslexia (Guardiola, 2001). Multiple psychological theories depicted a range of related symptoms of dyslexia including, reading, writing, spelling and speech development difficulties which can occur in

isolation or with differing degrees of intensity. The concept of dyslexia evolved to include continuity in reading ability with dyslexics in the low tail of the distribution (Monroe and Backus, 1937, Robison, 1947, Tordrup, 1953 and Gates, 1955). Herman (1959), Smith and Stomgren, (1938) and Roberts (1945) disagreed with this continuity, believing this low tail area in the distribution of reading ability suggests a different pathological cause. Shaywitz, Escobar, Shaywitz, Fletcher and Makuch (1992) continue to research the debate of the continuity of reading disability.

Ramus, Rosen, Dakin, Day, Castellote, White and Frith (2003) outlined the several major theories of developmental dyslexia. Their research is fitting to review as it is current and oft-cited by researchers. Ramus et al outlined three “leading” theories of developmental dyslexia: (1) the phonological theory, (2) the magnocellular (which includes auditory and visual theories), and (3) the cerebellar theory.

These varying theories have been developed by researchers to describe the source of developmental dyslexia. The theories, in some instances, combine genetic influence factors as well as environmental issues. In studies, which include the Colorado Twin Study, the use of twins to separate genetic and environmental factors is widespread in research (Byrne, Samuelsson, Wadsworth, Hulslander, Corley, DeFries, Quain, Willcutt and Olson, 2006). Monozygotic twins share genes while dizygotic twin would share half their genes. In addition, both types of twins often share the same or similar environments. Byrne, et al. describes several common genes that influence phonological awareness as well as print knowledge, verbal ability and rapid naming. The theories outlined below are designed to provide a generous overview of the most current and commonly recognized theories

Several subtypes of developmental dyslexia have been described in recent literature:

#### *Surface/Phonetic Subtypes*

Surface- can read words phonetically but has problems with whole word recognition

Phonological- person can read familiar words by using whole word method but has difficulty "sounding out" words that are new or letter-to-sound decoding problems.

Mixed- Having symptoms of both Surface and Phonetic Dyslexia.

(Cestnick and Coltheart, 1999)

### *Boser's Dysphonetic/Dyseidetic Subtypes*

Dyseidetic- This Subtype is as a disability in visual processing of language, with no trouble in auditory processing. They are characterized by an over reliance on auditory decoding and slow rate of reading.

Dysphonetic- This is the largest of the three divisions. This is viewed as a disability in associating symbols with sounds. The misspellings typical of this disorder are phonetically inaccurate. The misreadings are substitutions based on small clues, and are also semantic.

Alexic or Mixed- This subtype combines the deficit of the first two groups. This person may have disability in both sight vocabulary and phonetic skills.

(Boder, 1973)

### *Visual/Auditory Subtypes :*

Visual Dyslexia- Those with visual dyslexia usually cannot learn words as a whole component. The person has problems with visual discrimination, memory synthesis and sequencing of words. Reversal of words or letters when reading, writing and spelling is common.

Auditory Dyslexia- Auditory dyslexics cannot link the auditory equivalent of a word to the visual component.

Mixed- Having symptoms of both Visual and Auditory Dyslexia.

(Johnson and Myklebust, 1967)

### *Bakker Subtypes :*

Linguistic dyslexia (L-dyslexia)- In this group, reading is characterized by relatively fast reading speed and numerous errors, such as the addition, omission, or substitution of letters, syllables, or words.

Perceptual dyslexia (P-dyslexia)- Reading is sufficiently accurate but too slow; it is frequently disrupted by hesitations and repetitions.



Mixed dyslexia (M-dyslexia)- reading presents characteristics of both L- and P-type dyslexia. (Bakker, 1979)

## **2.1 Neurological/Sensory**

### **2.1.1 The Visual Theory**

There are a variety of researchers who describe developmental dyslexia as a visual disorder that presents difficulties with the processing of letters and words (Lovegrove, Garcia & Nicholson, 1990; Lovegrove, Martin & Slaghuis, 1986; Livingstone, Rosen, Drislane & Galaburda, 1991; Stein & Walsh, 1997; Ramus, 2003). According to the visual theory, individuals may experience erratic binocular fixations, weak vergence, or increased visual crowding. Individuals with reading disability show a deficit in visual perception as the major factor in their reading difficulties. Visual perception is the ability to correctly interpret what the brain sees. The typical layperson associates dyslexia with frequent reversals of letters or the reading of words backwards. Dyslexics have a deficient visual perception of letters, most likely due to a brain malfunction in the cerebral hemisphere (Orton, 1925, 1930, 1937).

Orton suggested from his observations the term ‘strephosymbolia’ or twisted symbols, a theory which focused on errors of reversal. He also described the deficit as one that ran in families. This deficiency in visual perception of letters was suggested to be causal to a brain malfunction in the cerebral hemisphere dominance of one occipital lobe over the other (Guardiola, 2001). Theories on “Congenital Word Blindness” (Hinshelwood, 1917) proposed a defect involving the acquisition and storage in the brain of the visual memories of letters and words. Hinshelwood described this defect as hereditary and more common in males.

Fischer, Liberman and Shankweiler (1978) have examined the dyslexic’s tendency to reverse letters and words and found that dyslexic readers do not make numerous errors in reversals and that the reversal errors they do make are not related to visual perception problems. Scarborough (1998) reports a difference in visual discrimination during the preschool years is not a valid predictor of reading achievement in the primary school years. A study by Lovegrove, Garzia, and Nicholson, (1990) identified a relationship

between visual processing and dyslexia. Lovegrove et al. examined the relationship between visual processing and dyslexia as challenges have been identified with an individual's ability to process visual information. Lovegrove et al found that children with dyslexia presented a particular sensitivity for detecting "flicker". Researchers recently have studied the role of deficits in the transient visual system and the correlation with reading disorders. The transient visual system, also identified as the magnocellular visual pathway, is a visual processing system essential for many visual tasks related to reading. Lovegrove (1986) reports that deficits in the visual system cause confusion while reading. Stein (1989) also presents findings that show adults with dyslexia displaying difficulties associated with eye movement during reading. Stein (2001) additionally argues that transient system deficits are related to aspects of sensory processing and cerebellar functioning found in dyslexic readers. These visual difficulties have also been described by Stein who reveals that adults with dyslexia show difficulties with eye movement during reading. In Stein's study, adults showed difficulties with fixating their eyes on words for as long as required. Subsequently, visual theories argue that dyslexics have difficulties with processing visual information such as letters, numbers and symbols and are likely to have difficulties with reading and writing. This is more likely in young children who rely more on the visual properties of letters and numbers to identify them. Not all studies have established visual deficits as the cause for poor reading (Catts and Hogan, 2003). Share and Stanovich (1995) believe it would be beneficial to support this theory by locating a group of poor readers who display a history of visual deficits but who do not display deficits in language. Supporters of the visual theory do not exclude other theories of dyslexia, but place an emphasis on the visual contributions to reading problems in some dyslexic individuals.

Visual stress is experienced by between 5 and 20 percent of typically developing children (Wilkins, 2003). According to Wilkins, children experience this stress in terms of the movement of print causing words to appear broken up, letters appearing to move across the page and the spaces between words appearing and disappearing arbitrarily. Words appear blurred, letters tend to change size for the reader and various letters appear darker and/or fading on the paper. This visual stress causes headaches, nausea and dizziness in the reader. As a result, children who experience this visual stress attempt to look away

from the text, blink excessively and finger track during reading. Wilkins presents several simple questions that can be asked of the reader to detect the possibility of visual stress:

- Do the letters stay still or move on the page?
- Do the letters appear fuzzy or are they clear?
- Are the words too close together or far enough apart?
- Does the colour of the print change with letters appearing darker or less dark?
- Do you have to use your finger when you read?
- Does it hurt your eyes looking at letters/words?
- Do you have a headache after looking at letters or words?

Research in visual deficits relating to dyslexia can be categorized into more succinct groups. Visual perception deficit theory which included research by Morgan, Hinshelwood, and Orton initially used the term word blindness to describe the disorder and had a visual basis. Dyslexia was identified as a visual perception deficit and this discovery was one of the primary driving forces into the establishment of dyslexia research. The concept of intersensory deficit was studied by Herbert Birch (1963) and offered the concept that dyslexics were unable to integrate information from two or more sensory systems. This particular theory has been criticised by others for its lack of evidence and experimental results that do not reveal differences between normal readers and disabled readers. Study of erratic eye movements and eye convergence deficits have been done to investigate any relationship with reading difficulties. Results of studies are inconsistent and have not been proven in subsequent research (Wilsher, 1985; Bishop, 1989). Helen Irlen introduced the notion of coloured lenses to ease reading difficulties in children. Her experiments have been criticized by researchers (Irlen, 1983; Martin, Mackenzie, Lovegrove and Menicol, 1993).

Nicholson and Fawcett (1990, 2001) present a cerebellar theory of developmental dyslexia. According to their research, dyslexic children are faced with more than reading and spelling deficits. They propose that children with dyslexia also exhibit difficulties

with certain motor functions. These difficulties include gross and fine motor skills such as balance, handwriting, copying from a blackboard and serial tasks such as learning the alphabet and the multiplication facts. Children are unable to engage in visual analysis tasks such as the ability to recognize basic shapes being traced upon their skin while blindfolded (Hartas, 2006) and to discriminate a letter from a word from a sentence. These visual deficits also make it difficult for children to find their place when reading. Hartas argues that many of these characteristics of dyslexia appear during the early stages of children's development. She maintains that researchers agree the complexity of these symptoms suggest a sole approach to understanding dyslexia is not adequate.

The foundation of the cerebellar theory argues for a general impairment in the ability to perform skills automatically is related to the cerebellum in the brain. Automaticity is the process by which new skills acquired become automatic after practice. Therefore, no conscious control of the skill is required. These researchers claim that individuals with dyslexia have a dysfunctional cerebellum. The cerebellum affects motor control and Nicholson and Fawcett maintain its impact on speech articulation leads to deficient phonological representation. A hypothetical, causal chain indicating dysfunction in the cerebellum influences balance and motor skills, which subsequently affect writing skills. Additionally this same cerebellar dysfunction, through the passage of time, relates to articulatory skill, then an impaired phonological loop as well as with phonological awareness. The result is a deficit in reading. Finally, this cerebellar dysfunction is associated with problems automatising skill and knowledge which, in turn, impacts the word recognition module and spelling skills. In addition, the cerebellum is important in automatization of learned tasks. Therefore, if there is a weakness in the cerebellum it impedes the transfer of newly learned phonological tasks and words to automatized motor tasks. Nicholson, Fawcett and Dean (2001) reason a high percentage of diagnosed dyslexic individuals present behavioural evidence of abnormal cerebellar function, including balance, skill automatization and signs of dystonia. The difficulties in skill automatization are directly related to the traditional role of the cerebellum which with articulation-related cognitive skills corresponds to a role with speech related cognitive abilities.

The cerebellar theory ignores the sensory disorders of dyslexia. It is proposed that the pattern of difficulties in cognitive, information processing and motor skills is predicted by a cerebellar deficit hypothesis (Nicholson, Fawcett and Dean, 2001). A difficulty with this theory is the causal link postulated between articulation and phonology relies on a much outdated view of the motor theory of speech, whereas the development of phonological representations rely on speech articulation (Ramus et al., 2003). Even Nicholson, Fawcett and Dean concede that the cerebellar deficit hypothesis should be considered merely speculative as studies conducted were primarily small scale. They consider that it is essential to define subtypes of dyslexia as well as establish the extent to which dyslexic individuals display cerebellar signs of deficit.

Zeffiro and Eden (2001) propose that the cerebellum is merely an “innocent bystander” and the primary pathology is located elsewhere in the brain and impacting through a modulatory influence on cerebellar processing. Zeffiro and Eden (2001) maintain that the neuroanatomical location of the deficit may actually be in the area of the persylvian neocortical region. Finally, motor problems are found in only a subgroup of dyslexics causing researchers to disagree as to whether it can be classified as part of the disorder.

### **2.1.2 Rapid Auditory Processing Theory**

Rapid automatized naming originates from a simple measure performed to test brain injury recovery. The ability to respond verbally and swiftly to a visual stimulus was derived from a test of rapid naming of colours developed over 50 years ago (Denkla and Cutting, 1999). Rapid automatized naming became useful in assessing and predicting reading competence. Rapid automatized naming draws on both visual and verbal language skills and processing speed as correlated to the development of reading skills.

Geschwind & Fusillo (1966) presented a case study of an individual with stroke who was unable to name colours even with the ability to match colours and no apparent evidence of colour blindness. This study led to the development of a neurological connection model that was the foundation of rapid automatized naming (RAN). This finding of colour naming deficits led to the study of first grade children with an unexpected reading disability and the assessment of their naming of colours. Findings were significant in that

it was not so much their lack of ability to name colours that was significant but their “long latencies” and a hesitancy described by Denckla (1972) as a lack of automaticity. Denckla and Rudel (1972;1974;1976) established rapid automatized naming as a predictor of reading success. This led to substantial research in this area that further confirmed Denckla and Rudel’s findings (Blachman, 1984; Stanovich, 1981; Vellutino et al., 1996). Researchers debate whether RAN is a skill independent of other predictors of reading ability like phonological awareness and memory (Denckla and Cutting, 1999). Others propose RAN to be a component of phonological processing and memory and describe it as competence in phonological code retrieval (Wagner, Torgeson, Loughon, Simmons & Rashotte , 1993; Vellutino , Scanlon, Sipay, Small, Pratt, Chen & Denckla, 1996). Phonological processing, memory and code retrieval will be discussed in more detail in chapter 3.

Denckla and Cutting (1999) describe the differences in performance of rapid automatized naming in those identified as reading disabled, and individuals with ADHD. They propose that certain RAN tasks are better discriminators of reading disabled individuals whereas other RAN tasks are better indicators of reading disability. Specifically, Meyer , Wood, Hart & Felton (1998) purport that colours and objects (presymbolic) and numbers and letters (symbolic) when compared with each other in individuals in grades three through eight, colours and objects are better predictors of successive reading ability and vocabulary than numbers and letters. Therefore, Meyer et al. argue that presymbolic tasks of rapid automatized naming are more stable for naming speed whereas symbolic tasks are more representative of one’s experience with symbols. Denckla and Cutting append these findings with the presentation of research arguments that find a correlation between RAN and the relationship to slowness in processing, inefficiency and lack of automaticity and fluency in reading could be an argument for common co morbidity between ADHD and reading disability. Contrary to these findings presented, Denckla and Cutting reveal their own findings (Cutting, Denckla, Schuerholz, Reader, Mazzocco, and Singer 1998) which show symbolic tasks of RAN utilized as a key factor in determining good readers versus poor readers and that phonological skills (knowledge of symbols) did not differentiate between groups with ADHD and groups with reading disability.

Alfred Tomatis presented a theory of auditory transcription deficit in 1960. He argued that individuals with dyslexia demonstrate difficulty in transcribing written words into phonological representation. Tomatis emphasized the auditory sensory deficit which impairs the development of language and speech and consequently causes reading delay. According to the rapid auditory processing theory, the phonological difficulties in dyslexia are triggered by an underlying general impairment in the ability to process sequences of rapidly presented, brief sounds. Proponents of this theory postulate that the phonological theory is secondary to a basic auditory deficit. They argue that the deficit originates in the misperception of short or rapidly varying sounds such as “ba” and “da” (Tallal, 1980).

Studies show that dyslexics perform poorly on auditory tasks. This theory suggests that the auditory deficit comes before the phonological deficit—one causing the other—and therefore the outcome being a difficulty in learning to read. The primary belief of the rapid auditory processing theory is that neural temporal mechanisms play a crucial role in aspects of information processing and production which are critical for normal development and maintenance of sensory motor integration systems and phonological systems (Tallal, 1993). Tallal hypothesized that individuals with developmental language and reading problems possess a severe deficit in processing of brief components of information which enters the nervous system in rapid succession as well as a concomitant motor deficit in organizing rapid sequential motor output (Tallal, Miller & Fitch, 1993). Tallal et al. explains the deficit as “highly specific, impinging primarily on neural mechanisms underlying the organization of information within the tens of millisecond range”. Their studies report findings of significant deficits in both nonsense word reading as well as nonverbal temporal processing in individuals with dyslexia and concomitant oral language disabilities ( $r=0.81$ ,  $p<0.001$ ). Those individuals with dyslexia but no concomitant oral language problems did not display deficits in phonological decoding or temporal processing. Tallal et al. suggest that these results demonstrate an auditory processing deficit which causes “a cascade of effects, starting with disruption of the normal development of an otherwise effective and efficient phonological system” and that these deficits in phonological processing can result in failure to develop normal reading ability.

In subsequent research by Tallal (1996) she hypothesizes that the basic deficit in neural processing of brief transient sensory information causes decreased ability during infancy for distinct phonological representations of sounds in the infant's native language. This then leads to delayed overall language acquisition. Because of the child's inability to understand the more precise structures of language such as syllables, phonemes and morphological endings, the result is a "top down" processing strategy rather than a "bottom up processing ability. Merzinich (1996) explains that dyslexia is a nervous system function and must be explained at a more straightforward level than the behaviours ascribed to it. He contends that dyslexia must be reducible to a realm of neuronal or synaptic malfunction and that the dyschronicity of dyslexia interferes with rapid processing which interferes with the ability to learn associatively and therefore with phonologically learned skills.

The auditory processing theory lacks support from researchers due to the lack of specificity.

Theories which claim this auditory perception deficit as related to phonological representation of language tend to garner more support (Brady, Shankweiler, & Mann, 1983).

### **2.1.3 The Magnocellular Theory**

A prevailing, but controversial theory in recent years is the magnocellular deficit hypothesis. This theory combines the visual and auditory theories and adds a third component, tactile. Supporters of this theory suggest that the magnocellular dysfunction is generalized to all modalities (visual, auditory, tactile). Stein (2001) presents a discrepancy approach to the definition of dyslexia for the purpose of this theory. He argues dyslexics are different as they exhibit an array of symptoms and their reading skills are more than 2 standard deviations behind what would be expected based upon their IQ score. In addition, dyslexics exhibit features such as lack of coordination, left-right confusions, problems with sequencing, physical deficits, psychiatric and educational deficits.

This theory, through the single biological cause, is able to account for all manifestations or symptoms of dyslexia, including visual, auditory, motor, tactile and as a consequence,



phonological deficits. The magnocellular deficit hypothesis declares reading problems as derived from impaired sensory processing which is caused by abnormal auditory and/or visual magnocellular pathways (Nicholson, et al., 2001). Approximately 10 per cent of ganglion cells which provide the signals delivered from the eye to the brain are larger than the remainder of the ganglion cells. These cells gather light from a larger area and are more sensitive and react more quickly over a larger area. The “magno” cells are not sensitive to fine detail or colour (Maunsell, Nealey and DePriest, 1990). Binocular instability and visual perceptual instability may cause unsteady binocular fixation which is related to poor visual localization primarily on the left side (Stein, 2001). The magnocellular pathway originates in the retina. The pathway then projects to the primary visual cortex through the magnocellular layers of the lateral geniculate nucleus (Amitay, Ben Yehudah, Banai and Ahissar, 2002). These cells then project to the primary visual area in the occipital cortex through magnocellular layers in the main relay nucleus, which is the lateral geniculate nucleus (LGN). There is evidence that a slow or irregular functioning of the magnocellular pathway of the visual system could cause reading deficits (Lovegrove, Martin and Slaghuis, 1986).

According to Stein (2001) developmental dyslexia affects 5 to 10% of children, particularly boys. It is characterized by a significant deviation between reading ability and the intelligence quotient and includes other symptoms which include directional confusion and poor sequencing. This is consistent with the discrepancy definition of dyslexia as described in chapter 1. Stein proposes that there are atypical ectopias found on the brain of a dyslexic which are usually clustered near the temporoparietal language areas. The magnocellular theory of developmental dyslexia accepts the magnocellular system as being the system responsible for visual events with regard to reading. The magnocellular system is responsible for bringing the visual system “in sync” when the image drifts from the fovea area. The Magnocellular system and its sensitivity to visual motions helps establish the development of orthographic skill in both strong readers and poor readers. The magnocellular systems in thalamic regions of the brain are responsible for vision and audition (Galaburda, Menard, and Rosen (1984). These magnocellular systems play vital roles in rapid processing and inhibition of previous information. Ojemann (1990) believes there is a precise timing mechanism that operates for both

production and decoding within the cortical areas that are responsible for sequential motor movements and speech sound identification. This mechanism is critical for phonological ability. A deficit in this timing mechanism would explain the combination of naming speed and motor deficits found in dyslexics. Researchers believe that deficits found in dyslexic readers are more noticeable during rapid processing tasks and can involve processes where functions are located in cortical parietal areas accepting strong projections from the magnocellular system.

Stein (2001) suggests the visual magnocellular system does not develop normally in dyslexics. Between the 16<sup>th</sup> and 20<sup>th</sup> week of gestation differences occur while the brain is undergoing rapid neuronal growth and migration (Stein, 2001). Stein proposes that the magnocellular system is impaired along the magnocellular layers within the lateral geniculate nucleus (LGN) of a dyslexic and this creates an abnormality in motion sensitivity as well as in binocular fixation (which is unsteady in a dyslexic reader). Galaburda and Livingstone (1993) examined post mortem brains and found that the magnocellular layers of the LGN of the thalamus were out of order and the neurons of the brain in dyslexics were 30% smaller than in nondyslexics. In addition, Stein argues that many dyslexics have weaknesses in distinguishing letter sounds as they have poorly developed auditory phonological systems. This underdevelopment of the magnocellular system, according to Stein, has a clear genetic basis for impaired development of magnocells throughout the brain. A linkage found in genetic study is the area of the “Major Histocompatibility Complex” on chromosome 6 which facilitates development of the production of antibodies. The development of magnocells can be impaired by auto antibodies which influence the developing brain. Stein argues that all areas of weakness in dyslexics have “counterparts” in the cognitive domains. Typically, according to the magnocellular theory of developmental dyslexia, an individual diagnosed with the reading disorder will also have a poor sense of time and an inability to follow a logical flow of argument. Stein and Walsh (1997) assert that an important function of the magnocellular system is the control of eye movements. An impaired magnocellular system in dyslexics can destabilize binocular function, causing the individual to perceive text as moving and to cause visual confusion. Stein and Walsh

consider that within the magnocellular layers of the brain magnocells have been found to be 20% smaller in size for dyslexics than in a normal reader's brain. This finding supports the proposition that many dyslexics have an impairment of their visual processing systems. They describe the anatomical connections within the posterior parietal cortex within which abnormalities can cause sensitivity to direction of movement, direction of gaze and insensitivity to colour and visual form. The posterior parietal cortex has been found to be crucial to normal eye movement control, visuospatial attention and peripheral vision. These abilities all impact and are important components of the reading process that if damaged can result in a reading disorder.

Stanovich, Siegel and Gottardo, (1977) stress that there is no dominant trait to distinguish between poor readers and dyslexics and that the intelligence quotient (IQ) is too variable to associate directly with dyslexia. Stein believes that this position ignores the additional characteristics of dyslexic individuals and argues that IQ plays a significant role in reading disorders and explains the reading variance in 25% of the population. Stein describes the myriad of symptoms that a dyslexic experiences and argues that their reading ability is significantly lower than should be expected from their intelligence quotient.

In all sensory and motor systems magno (large) cells exist for specialized temporal processing. A distinctly separate structure in the visual system exists and is responsible for timing visual events and tracking moving targets. The neurons were found to be 30% smaller than in control brains. These particular abnormalities are known to occur during foetal development of the brain at the time of "rapid neuronal growth and migration" which occurs at the 4<sup>th</sup> and 5<sup>th</sup> month of foetal development. Their study provides evidence for supporters of the magnocellular hypothesis of dyslexia that the visual magnocellular system fails to develop normally and is the root of dyslexia.

Supporters of the visual theory and auditory processing theory have been able to come together to support the magnocellular theory in the context that visual and auditory disorders in developmental dyslexia stem from magnocellular abnormalities.

Though it is commonly agreed (Snowling, 1981; Bradley & Bryant, 1983) that dyslexics fail to develop adequate phonological skills (discussed in depth in the following chapter), supporters of the magnocellular theory argue that only about one-third of dyslexics suffer

mainly from a phonological disability. Consequently, one-third of dyslexic readers have visual/orthographic symptoms and one-third display both phonological and visual/orthographic deficits (Stein, 2001). Castles and Coltheart (1993) describe orthography as the capacity to process the visual form of words, including the shape of letters and their order in words into meaning. Orthography permits the reader to rapidly process the meaning of familiar words without having to sound them out. Phonological processing is the method of translating the letters into sounds, the phonemes that they stand for and then into the words that have meaning. This process takes more time than the direct visual route. Davis (2001) examined visual processing and described how individuals attend to pairs of visual features. Davis found that transient processes in the magnocellular stream of human vision were responsible for increased attention skills when features from neighbouring objects were directly bound together. As the visual magnocellular system is most time visual events when the individual is reading this can be related to the orthographic skills required to read visual words.

Amitray, Ben-Yehudah, Banai & Ahissar (2002) studied the theory of magnocellular deficit by testing its two basic predictions. The first was a belief that a subpopulation of reading disabled individuals would demonstrate impairments across a broad range of psychophysical tasks that rely on magnocellular functions. The second tested hypothesis was that this subpopulation would not be consistently impaired across tasks that did not rely on magnocellular functions (2002). They found that just six of thirty reading disabled subjects studied had impairments related to magnocellular function. But, these same reading disabled subjects also had impairments in a broad range of other perceptual tasks as well. The second subgroup of reading disabled subjects did not differ from controls on magnocellular tasks. This group did show impairments in performance of visual and auditory non-magnocellular tasks that required fine frequency discriminations. Amitray, Ben-Yehudah, Banai, & Ahissar (2002) concluded that some reading disabled subjects have generally impaired perceptual skills. Many reading disabled subjects have more specific perceptual deficits, though the magnocellular deficit was not uniquely related to the perceptual difficulties in those assessed by the researchers.

Critics of this theory point out that it fails to explain the absence of sensory and motor disorders in a significant proportion of dyslexics. Researchers criticize its failure to replicate findings of auditory disorders in dyslexia (Heath, et al, 1999). In addition, inconsistencies have been found with studies that show deficits in rapid auditory processing (magnocellular) and some showing deficits in slow auditory processing (Reed, 1989, Witton et al, 1998). Martin and Lovegrove (1987) found that the sensitivity to “flicker” is lower in a dyslexic reader than in a typical reader. Studies by Stein and Walsh had similar findings. This suggests that dyslexics have a specific impairment in the “visual magnocellular” system. Stein points out that these findings have been intensely disputed by Skottun (2000); Stein, Talcott and Walsh (2000) as this impairment was not found in all dyslexics studied. Skottun (2000) argues that available empirical evidence is at odds with the predictions of the magnocellular theory. He concludes that these studies failed to use larger numbers of subjects and that those studies containing larger numbers of subjects would be more likely to replicate Lovegrove’s findings. Stein recommends this large scale mode of study to identify and confirm the peripheral magnocellular impairment and to pre-screen for those dyslexics who have visual symptoms and therefore would be likely to have a magnocellular abnormality. Even Stein acknowledges that the abnormalities found in the magnocellular system can “with certainty” prove the magnocellular theory. Hulme (1988) believes it is possible that the theory could be part of the dyslexic phenotype but play no significant role in the reading difficulties of dyslexics.

## **2.2 Neurological and Brain Structure Theories**

### **2.2.1 Cerebral Lateralization**

It is commonly established by researchers that acquisition of many linguistic abilities depend on the functions of the left cerebral hemisphere whereas aspects of spatial ability and creative skills are more dependent on the right hemisphere (Galaburda 1985).

Samuel Orton (1937) proposed the existence of instability in the cerebral dominance of linguistic functions, hand, and eye preference. The concept of cerebral dominance, with the left hemisphere being more dominant for language has been explored by researchers

of dyslexia (Brosnan, 2008). It has been suggested that if the brain areas involved in language are poised between both hemispheres of the brain, then dyslexics may need more interhemispheric communication which may make their language processing more sluggish (Guardiola, 2001). Frank and Levinson (1976) and Levinson (1994) suggest a theory of deficit in the inner ear. The cerebellar-vestibular system tunes outgoing motor signals and incoming sensory signals. Frank and Levinson argue that a deficit in this system would impair the tuning of the signals which could cause symptoms of dyslexia.

### **2.2.2 Study of the neuroanatomy of the brain**

Geschwind and Galaburda (1987) introduced a theory of the temporal plane. Researchers have analyzed post-mortem brain tissue as well as living dyslexic brains (through Magnetic Resonance Imaging). This analysis allows researchers to identify the neurologic characteristics of reading ability and disability. The brain is studied in detail to discover the areas of the brain involved in language. These areas include the left parietal and temporal lobes, the temporal plane and angular gyrus. Geschwind, Behan and Galaburda (1984) propose a “testosterone hypothesis” which links certain characteristics of dyslexia which are not readily explained by other theories or models. This includes the apparent sex difference in the reported incidence of developmental dyslexia. Their theory maintains that excess levels of testosterone can cause dysfunction if the left cerebral cortex and be linked to a range of disorders. Geschwind et al propose that learning difficulties may result from development lesions within the left hemisphere and found evidence of unusual levels of hormone testosterone with the causes of asymmetrical lesions on the cortex. Geschwind et al propose that during foetal development, testosterone slows the growth of the left hemisphere. With a higher level of testosterone there is a significant correlation with left-handedness. In more severe cases, high levels of testosterone can be causally related to dyslexia. There has been some support for the testosterone theory presented by Geschwind et al, although contrasting research indicates that causal links can be difficult to justify.

## **2.3 Cognitive Theories**

### **2.3.1 Memory deficits**

Several researchers have proposed theories involving a memory deficit. Alan Baddeley (2003) and his theory of working memory, Denckla and Rudel (1976) described coding and naming deficits and Shankweiler and Liberman (1979) indicate that a dyslexic only memory deficit exists for language information (Guardiola, 2001). Thompson (1984) proposes that dyslexics have a smaller memory storage capacity than non-dyslexics. This could be related to coding deficits. Memory defined by the field of psychology is one's ability to store, retain and then recall information. Three key stages in the formation and retrieval of memory are defined. These are (1) Encoding; the method of processing and combining received information, (2) Storage; the creation of a permanent record of the coded information, (3) Retrieval; recalling back the stored information in response to some activity or process.

Memory is composed into three parts according to the processes involved. These are sensory memory, short term memory and long term memory. Short term memory allows an individual to recall something from several seconds to as long as one minute without rehearsal (Baddeley, 2003).

Baddeley and Hitch (1974) presented a model of working memory that subdivides short term memory into a set of processes and sub stores. The three-part working memory model (Baddeley, 1996) comprises a central executive system which manages the encoding and retrieval of stimuli input and manages attention changes. The central executive manages information stored in the sub-systems for the phonological loop (sound based input) and visuo-spatial sketchpad (for spatial and visual information). Research by Jeffries and Everatt (2004) found that when comparing performance between children with special education needs (SEN) and control children those with SEN performed significantly worse than controls on measures of working memory phonological loop measures (further description of working memory will be described in chapter 3). Dyslexics suffer from difficulties in learning and remembering information in

short term memory. Research has implicated deficits in the components of working memory which impact the patterns of cognitive functioning (Jeffries & Everatt, 2004). Jeffries and Everatt make a case that support a battery of measures which assess a range of cognitive functioning skill and include working memory measures are necessary to dyslexics from other SEN populations. Swanson (1999) found that children with reading difficulties had poor reading comprehension which could be attributed to deficits in the phonological loop. Subsequently, researchers have argued that there exists a link between the working memory subsystems and the cognitive profiles of dyslexics.

### **2.3.2 The Phonological Theory**

There is contention among researchers whether phonological deficits are causally related to developmental dyslexia or coexisting with the disorder. Research by Snowling (2001) and Jeffries & Everatt (2004) present support for the belief that difficulties with dyslexia are characterized primarily by phonological deficits. Theories asserting language deficits which are primarily phonological and impair reading ability are popular in cognitive psychology and linguistic research. The phonological deficit hypothesis explains dyslexia through its focus on an individual's difficulties with phonological processing (Shaywitz, 2003). With the phonological deficit, an individual displays weaknesses in their ability to make links between phonemes and graphemes and therefore displays weak phoneme awareness (Hartas, 2006). Researchers have been able to identify the specific location of a deficit within the language system. The language system is defined using a hierarchical model. Language is processed in the brain through a series of modules which are each dedicated to a particular aspect of language. Each of these systems is automatic, rapid and uses no conscious thought. The systems are also mandatory (Shaywitz, 2003). Shaywitz defines the phonological model of dyslexia as involving the lowest module on the hierarchy of language processing—phonology. Whereas semantics, syntax and discourse are considered the upper hierarchy of the language system, the fundamental element of the language system is phonology and thus the critical element for spoken and written word. According to Shaywitz, forty four phonemes are able to produce tens of thousands of words in the English language. Before words can be identified, understood, stored or retrieved from memory they must



be divided into their individual phonemes by the neural aspects of the brain. Shaywitz describes language as a code which only functions within the machinery of its phonological system. Reading is a process where one begins with an intact printed word on a page. A typical reader is able to recognize that each individual block of print on the page represents a phoneme. The reader must convert the letters into their respective phoneme sounds. Individuals with dyslexia are unable to develop the awareness that spoken and written words are comprised of these individual phonemes. Dyslexic individuals see words as an “amorphous blur” and cannot appreciate the formal segmental sound structure of words. Therefore the phonological deficit theory suggests that dyslexics have a specific impairment in the way they are able to represent, store and retrieve speech sounds. Dyslexics thus, are impaired in learning the grapheme-phoneme association of the alphabetic system. Thus, if the correspondence between sounds and letters; and the component sounds of speech are not correctly represented or stored in the brain, the basic function of reading is affected. Seigal (1990) and Snowling (1995) suggest that phonological difficulties constitute the core deficits of dyslexia. Snowling (1988) contends that a phonological deficit is the core factor in defining and understanding dyslexia. She maintains that phonological deficits are common and measurable in children with reading deficits. Tijms (2004) finds that an explicit phonological deficit is indicated in children with dyslexia. He indicates that the relationship between phonological awareness and literacy skills is bi-directional. Therefore, the development of phoneme awareness is a precursor *and* a consequence of reading. While this theory is supported by much of the current research, others reason that even as the core phonological deficit is appropriate, it cannot always be utilized for all children who experience struggles with reading. Coltheart and Jackson (1998) consider whether the core phonological deficit should be used to identify an individual with dyslexia or whether that individual’s subskills should be assessed in order to determine causal factors.

### 2.3.3 Small and Large Unit Theories of Reading Acquisition

Research by Duncan, Seymour and Hill (1997) describe two opposing theories that attempt to explain the relationship between phonological development and acquisition of literacy. They describe two differing theoretical positions, called “small-unit theories” and “large-unit theories”. The basic premise of small-unit theory is the belief that orthographic ability is dependent on the specific phonemic skill to segment speech. The authors describe Mattingly’s (1972) argument that reading ability depended on linguistic awareness. In linguistic awareness, the phonemes of language become conscious in consideration. The attainment of conscious awareness, though, is not related to development but rather to specific environmental factors. These factors might include various metalinguistic games. The largest factor in developing this conscious awareness is the experience of learning to read itself (Morais, Carey, Alegria & Bertelson (1979). The principle of small-unit theories is that reading ability is predominantly a matter of understanding the relationship between letters and sound. While there is an early stage when letters are linked to their corresponding sounds for pronunciation, an “orthographic cipher” was required to understand the complex relationships between graphemes and phonemes (Gough and Hillinger, 1972). This orthographic cipher then supports the decoding of print into speech and meaning. In this theory, the ability to read orthographical non-words was believed to be the true measure of possession of the cipher. Gough (1993) rationalizes that young children recognize first words differently than they later decode. He conducted an experiment to test two differing hypothesis regarding reading of sight words—(1) recognizing the sight word as a whole or (2) recognizing sight words by parts. In his experiment, one group of subjects was taught a set of sight words along with a salient extraneous “cue”, then tested on these words. The second group of subjects was taught a group of sight words and then tested for each half of the word. Results found that the first group was able to recognize the cue but not the word, the second group able to recognize just one half of the word (but not the other). They summarized that word learning of first words was related to selective association. In small-unit theories the encounter with literacy, specifically the learning of letters, shapes phonological awareness.

In the large-unit theory, researchers propose that phonemic segments of speech are not available to children who are at a pre-reading stage. With the phoneme being a linguistic abstract concept, pre-readers do not utilize this task. In the typical flow of speech, phonemes are not typically segmented. In many cases the sounds associated with a word focus on the vowel. The acoustic information associated with CVC type word focuses just 60% on the beginning and ending vowel, whereas the acoustic information associated with the vowel pervades the entire speech act (Duncan, Seymour and Hill, 1997). They further conclude that at the early stages of reading development phonological contributions cannot be made at a phonemic level but must exist at some higher, more naturally accessible level. Because a child's early awareness of the phonological knowledge is limited to discrimination of words and syllables, they believe that orthographic presentation should be focused on this level. In the large-unit theory, the conviction is that children will make use of pre-literate rhyming skills when encountering their first experiences with writing.

## **2.4 Summary**

The range of theories represented by current research in developmental dyslexia is vast. Clearly the varieties of theories are interrelated with the incongruity in establishing a concise definition of dyslexia. The theories described in this chapter represent the currently most prominent versions existing in literature. Certainly differing versions of each theory have been described in research and in more detail as well. It is apparent that dyslexia has an inherent factor. Both the neurological/sensory theories as well as the cognitive theories of research acknowledge the genetic link. However, numerous studies document the sequence of phonological awareness development and the evidence that a phonological deficit is sufficient cause for dyslexia (Ramus et al, 2003). Phonological awareness develops as a consequence of normal language acquisition. Preschool children as young as age three have been found to recognize syllables, onsets, and rimes prior to learning about orthography. Researchers concur that dyslexic children have a deficit that interferes with phonological development. Goswami (2002) maintains that this deficit interferes with the development of phonological awareness at the syllable,

onset, and rime levels prior to literacy acquisition as well as interferes with the representation of phonemic information once literacy is taught. Therefore as phonological development is crucial in literacy acquisition we will examine the theory in more depth in the following chapter.

### ***3. Phonological Theory of Language Development***

The ability to read involves a multitude of facets that perform together like a master orchestra. Although there are various theories of language development it is widely agreed by researchers that the ability to decode words is crucial if a reader is to make sense of the text. Phonological knowledge is an essential skill to the learning of reading, writing and spelling and therefore reading fluency and comprehension.

#### **3.1 What is phonological knowledge and how does it develop?**

The International Dyslexia Association (1995) reports that phonological knowledge is vitally important in learning to read. The role of phonological awareness in reading has been a valuable discovery for researchers (Torgenson, 1995). Studies consistently support findings that show deficits in phonological knowledge being the basis for dyslexia (Baddeley and Wilson, 1993; Coltheart and Jackson, 1998, Gathercole, Willis, Emslie and Baddeley, VanGelder, Tijms and Hoeks, 2005). Though not all researchers agree that phonological knowledge is the sole causal factor in developmental dyslexia, a meta-analysis of research shows a substantial influence. Phonological knowledge, phonology, is concerned not only with the meaningful contrasts and the way in which phonemes are understood, but also with the possible combinations of phonemes. The word *phoneme* derives from the Greek word which translates to “sound”. The components of *phones*, *phonemes* and *phonetics* have been explained by Wagner and Torgeson (1987) in current research. Phones are a complete set of speech sounds represented by letters (e.g., “c” in the word “cat”). The sounds represented by the letters vary according to the words in which they are used. These distinctions in sound are called phonemes. A phoneme is the smallest component in language that can express a distinction in the meaning- for example “s” in “sat” and “b” in “bat”. The individual phones that make up a phoneme are characterized as allophones. The English language is made up of 45 phonemes which include 16 vowel phonemes and 29 consonant phonemes (Denes and Pinson, 1963).

Phonemes represent language at the phonological level (Wagner and Torgeson, 1987). Syllables are a unit of speech segmentation and are considered the smallest independent segment of speech that can be articulated. Phonological awareness is defined as the facility to segment explicit sound units smaller than the syllable (Stanovich, 1994). Moreover, Stanovich also remarks that current researchers "argue intensely" about the meaning of phonological awareness as well as about the criterion used to measure it. Harris and Hodges (1995) present a brief essay on phonemic awareness. The term "phonemic awareness" is utilized almost exclusively by Adams (1990) in his papers. Phonological awareness is meant to denote an awareness that words consist of syllables, "onsets and rimes," and phonemes, and so can be considered as a broader notion than phonemic awareness (Sensenbaugh, 1996). Goswami and Bryant (1990) describe differing levels of analysis for spoken words and a varying rate of awareness that develops for these levels. They emphasize the importance of the syllable and two subsyllabic units; the onset and the rime—the onset being the consonant or consonant cluster preceding the vowel and the rime being the vowel and succeeding consonants. Goswami and Bryant (1990) propose that the linguistic units of onset and rime are essential in the association between rhyming and reading ability. This theory by Goswami and Bryant is rooted in the findings that pre-readers can make analogies between spelling patterns in words in order to assist them in reading new words. Therefore this process aids in the development of reading. Both phonological awareness and phonemic awareness need to be widely used and in many cases interchanged by investigators.

Phonological Knowledge/Phonological Processing can be broken down into three types of processing abilities:

1. Phonological Memory
2. Phonological access to lexical storage
3. Phonological Awareness

Phonemic awareness is the ability to hear and manipulate the sounds in spoken words and the understanding that spoken words and syllables are made up of sequences of sounds

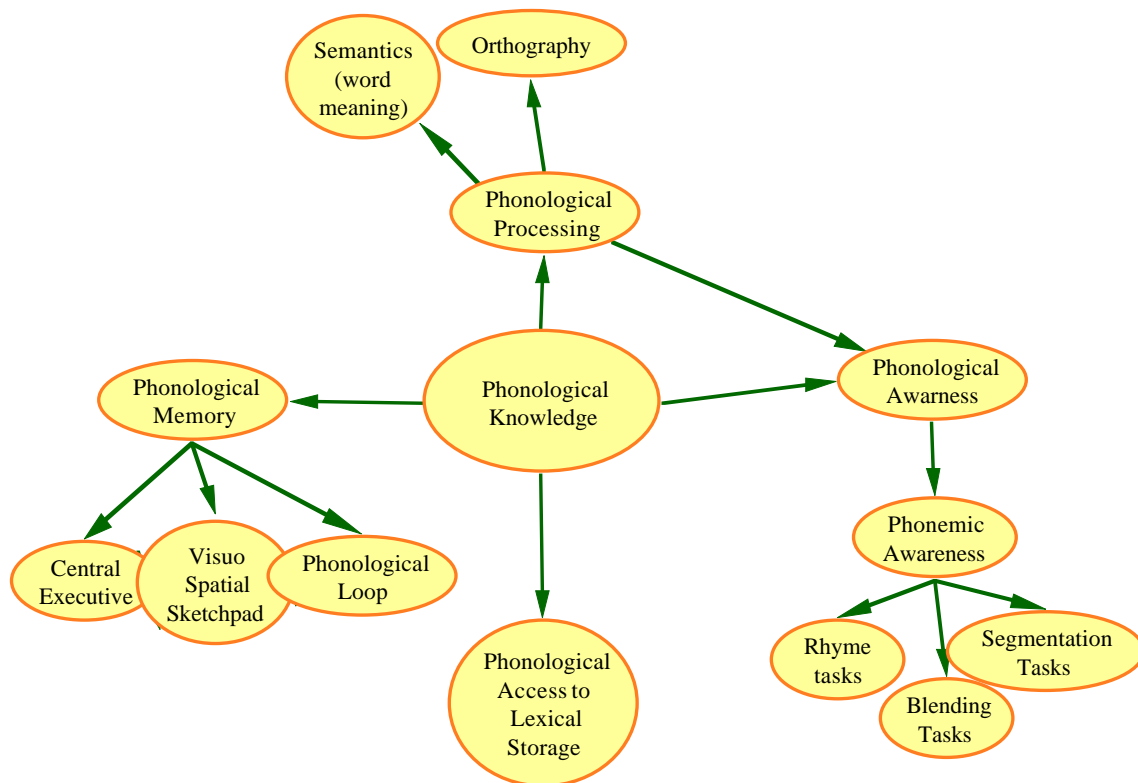
(Yopp, 1992). Phonemic awareness requires hearing of language at the phoneme level. Five levels of phonemic awareness have been described by Adams (1990):

- to hear rhymes and alliteration as measured by knowledge of nursery rhymes
- to do oddity tasks (comparing and contrasting the sounds of words for rhyme and alliteration)
- to blend and split syllables
- to perform phonemic segmentation (such as counting out the number of phonemes in a word)
- to perform phoneme manipulation tasks (such as adding, deleting a particular phoneme and regenerating a word from the remainder)

Spoken language is instinctive. Human beings need only be exposed to their native language to acquire it. In describing this innate ability Shaywitz (2003) explains:

Through neural circuitry deep within our brains, a genetically determined phonological module *automatically* assembles the phonemes into words for the speaker and disassembles the spoken word back into its underlying phonemes for the listener. Thus spoken language, which takes place at a preconscious level, is effortless.

**Figure 3.1 Mapping Phonological Knowledge**



Phonological awareness entails a number of tasks (Anthony and Davis, 2005). These tasks include blending sounds, segmenting words into separate sounds, recombining sounds and rhyme. Young children initially become aware of and sensitive to rhyme. In doing so they must attend to the way two words sound rather than their meaning (Torgeson, 1995). Additionally, phonological awareness is a continuous process—beginning in the preschool years and continuing through development. Phonological awareness develops into sensitivity to individual phonemes and a child is able to evaluate whether two words have the same first or last sounds. Continued growth in phonological awareness allows a child to isolate individual sounds in words. They would then be competent in distinguishing how many sounds are in a word. Longitudinal research can demonstrate the influence of these factors in reading development (Byrne, Samuelsson,



Wadsworth, Hulslander, Corley, DeFries, Quain, Willcutt and Wilson, 2006). Scarborough (1989, 1998) performed a longitudinal study with subjects beginning at grade 2 and continuing until grade 8. His findings indicate that those factors impacting reading development were different for normally achieving second grade children than for those with identified reading disabilities. Scarborough found that for normally achieving second graders the best predictor of future reading achievement were their grade two literacy scores. However for those children identified with reading disability, the addition of cognitive linguistic measures to the battery of assessments allowed for better prediction of future reading. In support of this theory, Anthony and Francis state that phonological awareness is heterotypically continuous. Phonological awareness is an ability that each individual utilizes from preschool through the upper elementary school years. It manifests itself in differing literacy skills throughout the person's development. Between 70 and 80% of American children master the ability to transform printed symbols into phonetic code. Those children who are unable to master the phonetic code become dyslexic (Shaywitz, 2003). In order for a child to become a reader he/she must be capable of understanding that spoken words are comprised of smaller units of speech sounds. These phonemes, which the letters of the alphabet "attach" to, drive our language system. In order to become a reader, children must take these same steps. The difference between a dyslexic reader and a normal reader is the effort involved in taking these steps (Shaywitz, 2003).

Phonological Awareness is a continuous skill. Phonological awareness plays the pivotal role in literacy development (Anthony and Francis, 2005). The tasks required by phonological awareness includes phonemic awareness and the ability to judge rhymes. Typically phonological awareness begins at preschool age and is utilized throughout the child's primary and secondary school years in many skill set areas. Researchers continue to debate the specific role each component of phonological awareness plays in the elements of reading development (Anthony and Francis, 2005). Phonological memory is the coding of information in a system represented by sounds and for short-term storage purposes. Phonological memory is used throughout all cognitive tasks that require the processing of sound information. Phonological memory is operationalized by auditory

span tasks (e.g. digit span)(Anthony, Williams, McDonald & Francis, 2007). Phonological access to lexical storage is the retrieval of phonological codes from memory. Phonological access to lexical storage is also referred to as rapid automatic naming (RAN) and involves tasks in which the child must verbally identify objects, numbers and/or letters in a rapid fashion (Anthony et al., 2007). These three phonological processing abilities (PPA) were further studied by several researchers and found to be predictive of reading (Bryant, Bradley, MacLean & Crossland, 1989; Bryant, MacLean, Bradley & Crossland, 1990; Rapala & Brady, 1990; Wagner, Torgeson & Rashotte, 1994). These studies have distinctly established phonological awareness, phonological memory and/or phonological access to lexical storage as the primary predictor of reading. Anthony et al., (2007) propose a “latent variable approach” as a true estimate of the association between the three abilities. Similar studies by Wagner & Torgeson (1987) and Wagner et al., (1994) address the relationship between phonological processing abilities and dormant literacy aptitude. In the Wagner studies, phonological awareness, phonological memory and phonological access to lexical storage were distinguished as separate, but correlated, abilities. Phonological awareness and phonological access to lexical storage were shown to possess unique predictive relationships with word reading (Anthony et al., 2007). In a similar study, Sprughevica and Hoiem (2004) explored phonological processing ability with 55 Latvian children in first and second grade. Spughevica and Hoiem found phonological awareness, phonological memory and phonological access to lexical storage to be plainly distinguishable abilities. Additionally, they found phonological awareness and phonological access to lexical storage to be predictive of word reading and phonological access to lexical storage to be predictive of reading comprehension. Therefore, these three phonological processing abilities are clearly distinguishable from each other and from general cognitive ability (Anthony et al., 2007).

### **3.2 Rhyme and Onset-Rime**

A sign of beginning development in phonological awareness is sensitivity to rhyme (Torgeson, 1995). A child must be able to attend to the sound of words rather than the

meaning in order to begin to understand rhyme. Attending to rhyme in words sensitizes pre-readers to the fact that words can be broken into parts. Rhyme detection has been found to represent a pre-reader's sensitivity to rimes (Muter, Hulme, Snowling and Taylor, 1991). Bradley and Bryant (1978) contend that requiring children to distinguish between rhyming words and non-rhyming words can be performed as early as 4 years of age. Bryant, Bradley, Maclean and Crossland (1989) argue that a child's early knowledge of nursery rhymes predict their later success in reading development but there are many critics of this theory (Macmillan, 2002). Muter, Hulme, Snowling and Taylor (1998) studied children in their first two years of reading instruction. They identified two distinct factors impacting later reading skills. These were rhyme, which includes rhyme detection and rhyme production, and segmentation. They also found that letter name knowledge was directly related to prediction of reading and spelling skills and correlated with segmentation skills. This ability is related to onset-rime and is causally related to a child's ability to read (Goswami and Bryant, 1990). It is argued that a preliterate sensitivity to onset-rime—specifically rime—influences early orthographic development (Duncan et al., 1997). There is evidence that early rime awareness affects reading development both directly and indirectly (Goswami and Bryant, 1990). Reading ability is affected directly through the early use of rime analogies and indirectly with promotion of phoneme awareness.

Onset is any consonant sound that occurs before the vowel in a spoken syllable. Rimes are the vowel and any consonants that follow it in spoken syllables. Substantial research on the role of onset and rime segments and the connection to phonological awareness and subsequent development of reading skills has been conducted (Tremain, 1983;1985). In support of Treiman's research, three approaches to teaching poor readers were evaluated (Savage, Carless and Stuart, 2003). Rime-based, phoneme-based, and a mixed rime and phoneme based program of teaching were studied. One significant finding was reported. The rime-based approach led to significant improvement in phoneme blending skills. Treiman and Zukowski (1996) present results that suggest there are many factors involved in phonological tasks. They suggest that the syllables of a word are more easily distinguished than rimes and that onsets are more accessible than single consonants. They report that phonological awareness is a variable and diverse skill and that this

heterogeneity has implications for the relationship between phonological awareness and alphabetic literacy. Therefore, for pre-reading children, learning about letter-sound correspondences is important to the development of phonemic sensitivity. This has implications the development of awareness of and sensitivity to syllables, onsets and rimes.

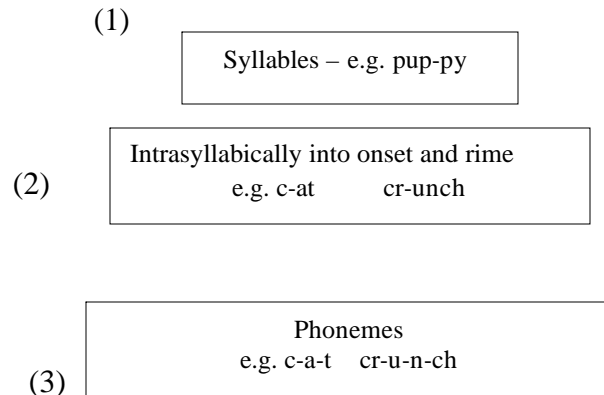
Dyslexic children have a specific deficit in phonemic awareness—more specifically the ability to detect, segment and manipulate individual speech sounds in words (Tijms, 2004). Segmentation is strongly correlated with reading and spelling attainment. Muter, Hulme, Snowling and Taylor (1998) propose that letter name knowledge predicts reading and spelling skills, and is interrelated with segmentation. Phonemic segmentation involves separating a word into its constituent phonemic sounds. Phonemic segmentation distinguishes itself from onset rime segmentation in that the individual phonemes of each word are separated. The developmental progression of the ability to perform segmentation tasks has been found to move from the ability to segment onset-rime units to segmentation into phonemes (Savage and Carless, 2004). Phonemic segmentation is one element of several different sorts of phonological skills in the framework of phonological knowledge and has been found to be interrelated with other phonological tasks (Savage and Carless, Stuart and Coltheart, 1988). Phonemic segmentation progresses from awareness of onset-rimes to awareness of phonological segments. Savage and Carless describe research by Seymour and Evans (1994) that illustrates how first year readers were able to segment, orally, into onset-rime units but had difficulty with segmentation into individual phonemes. Additionally, these first year readers performed significantly better when asked to smaller phonemic units, such as ending sounds in common words. Still, in later years of reading instruction, subjects had more difficulty with common rime unit identification than beginning and final consonant sounds. The study conducted by Savage and Carless analyzed the relationship between letter sound knowledge, phonemic manipulation, onset-rime skills and reading development. Their findings report that phoneme manipulation was a significant predictor of growth in non-word reading and letter sound knowledge. The authors found no evidence of contribution from onset-rime awareness to decoding skills. Savage and

Carless suggest that phoneme manipulation skills were the sole predictor of outcomes when a range of interventions were tested. This contrasts other philosophies where onset-rime manipulation was indicated for predicting reading ability. However, there were some indications, in their research, that onset-rime was an additional predictor of reading ability when impact of phonemic manipulation was controlled for.

### ***3.3 Phonological Processing***

Expanding on the premise of phonological knowledge is the notion of phonological processing. Phonological processing can be defined as the ability to use sound structure of language to process information. Phonological processing skill encompasses a set of skills that include phonological awareness-the relationship between the sound and the structure of the words, semantics-the meaning of the words, and (syntax), which is grammar or spelling of the words (orthography).

A progressive theory in which words can be segmented into their component linguistic units has been presented by Tremain (1983). She proposes three distinctive levels in which a child progresses:



Children proceed from the ability to segment spoken words into syllables (1), to segment syllables into onsets and rimes (2) and to segment onsets and rimes into phonemes (3). A pre-literate child shows some awareness of syllables and onset and rime while phonemic awareness develops as a result of environment and learning (Morais 1991). Tremain's view is that the rime is the major structure and that the syllable conforms to an onset-rime division.

In a summary of Schreuder and van Bon's (1989) paper on phonological awareness, Moray Stuart (2005) discusses findings of the child's ability to "decentre" from the meaning of a word and focus attention on its structure. This decentralization is key to successful performance of phonemic awareness tasks. Stuart contends this premise is similar to Tremain's (1983) description of the structural properties of words and that the way in which they are segmented affects phonemic performance.

A compromise must exist between philosophies as there may be different levels of phonological awareness which precede and influence reading development and other factors (e.g., awareness of phonemes) These varying levels are dependent on each other for learning to read in an alphabetic world.

A theory of lexical restructuring with regards to phonemic awareness is presented by Stuart (2005). A young child's phonological representations are holistic and, for the most part, undifferentiated (Wally, 1993). Wally maintains that as the child develops, their vocabulary grows and these holistic phonological representations require lexical restructuring into more detailed segmental representations in order to allow an accurate discrimination within the child's ever growing, ever changing representations.

Other researchers have supported this theory of lexical restructuring as well as built upon the notion (Metsula, 1999; Decara and Goswami, 2003). Metsula (1999) proposes the concept of phonological awareness as a function of vocabulary development and reports effects of early acquisition and neighbourhood density on performance in phoneme segmentation tasks. In addition, Decara and Goswami (2003) found links between vocabulary acquisition, neighbourhood density and performance on phonological awareness tasks.

In a Triangle Model of reading development (Harm and Seidenberg, 1999) a framework is offered wherein the developing reader forms connections between the orthographic input (graphemes) and phonological output (phonemes). They theorize that a dyslexic reader has somewhat "grainy" connections within the triangle.

In a case against Wally's lexical structuring theory, Stuart (2005) and Hart (2004) describe a case study of developmental phonological dyslexia not caused from an underlying phonological processing problem.

### **3.4 Deficits in phonological knowledge lead to reading disability**

Inadequate development of phonological knowledge is a crucial factor in the diagnosis of dyslexia (Torgeson, 1995). Fletcher, Shaywitz, Shankweiler, Katz, Liberman, Stuebing, Francis, Fowler, & Shaywitz (1994) compared dyslexic readers to normal readers on several non verbal tasks. The dyslexic readers performed significantly worse on skills for phonological awareness than any other skill tested. These dyslexic children were also compared to younger children who were determined to have similar reading skills and were found to perform more poorly on all phonological awareness skills. Phonological awareness in preschool and kindergarten age children is a strong predictor of early reading skill than verbal intelligence (Scarborough, 1998). It is clear that even while preliterate children are able to comprehend words, what they must learn in order to be literate is decoding skills (Simpson, 2000). The children with unexpected difficulty in acquiring accurate and fluent decoding skills, along with a persistent difficulty with encoding are those categorically argued as dyslexic. Though reading is a meaning driven pursuit it is critical that readers are able to immediately and accurately recognize a single written word (Adams, 1990). Decoding and reading single words with fluency is fundamental to reading and the major deficits of children with dyslexia are rooted in this skill (Beck and Juel, 1995; Stanovich, 1986). Possessing actual deficits in phonological knowledge leads to poor reading achievement. A good deal of research in dyslexia has focused on phonological deficits. Dyslexics are impaired in a number of phonological awareness tasks (Castles and Coltheart, 2004). These include phonemic blending, phonemic counting, phonemic segmentation and phonemic deletion. Most contemporary views are in favour of the hypothesis that a more specific deficit in phonological and, even more so, with metaphonological skill being the more likely proximal cause of poor reading achievement (Scarborough, 1990). Scarborough considers that skills beyond those defined as phonological need to be considered when defining the cause of reading disabilities. Recent research indicates merely a weak relation between phonemic awareness and verbal memory in students identified as reading disabled (Scarborough, 1998). He concludes that these two factors play a minor role in the subsequent reading

progress for the group that participated in the longitudinal study. Scarborough cites research demonstrating individuals with reading disabilities continue to struggle with language and reading (Badian, 1988; Butler, Marsh, Sheppard & Sheppard 1985; Fergusson, Horwood, Caspi, Moffitt & Silva, 1996; Juel 1988; McGee, Williams, & Silva, 1988; Satz, Fletcher, Clark & Morris, 1981;<sup>1</sup> Shaywitz, Escobar, Shaywitz, Fletcher & Makuch, 1992).

Phonological Knowledge has been reported to play a significant role in dyslexia. Phonological knowledge is related to the written and spoken modes of language and plays a critical role in the ability to read (Harm and Seidenberg, 1999). Bradley and Bryant (1983) additionally outline the role of a child's early knowledge of phonological structure as a predictor of reading ability. Snowling (1998) supports this premise with her contention that poor phonological knowledge is related to poor reading ability. She believes that the role of phonological knowledge in dyslexia explains the development of normal acquisition of reading. Additionally, she draws a line of reasoning that the phonological deficit theory accounts for the different manifestations of dyslexia seen across development. Even while reading difficulties are the foremost indication of dyslexia in early years, adults with dyslexia may become proficient readers but still suffer from difficulties in spelling. Research has established the causal role of phonological awareness in reading acquisition. It is the foundation underlying the learning of spelling-sound correspondences and the necessary skill for learning to read.

Phonological awareness is both a prerequisite for and a condition of learning to read. So considerable is the evidence in this realm, that developmental dyslexia can be conceptualized as a phonological core deficit (Stanovich, 1988,1991).

Simpson (2000) contends that so robust is the research on phonological awareness as the skill critical to the translation of print to sound and sound to print in an alphabetic script, that the evidence suggests a deficit in this grapheme phoneme correspondence is associated with reading difficulty. In addition, Simpson argues that it is evident phonological skills play a fundamental part in reading development and any processing deficit in this area will have serious implications for the development of fluent and automatic literacy skills.



Measuring phonological awareness in preschool children is a predictor of ensuing reading achievement. Phonemic awareness and its effect are critical to the development of the alphabetic principle and the ability to decode unfamiliar words (Byrne & Fielding-Barnsley, 1989). As it is evident phonological skills play a fundamental part in reading development, any processing deficit in this area will have serious implications for the development of fluent and automatic literacy skills (Simpson, 2000). He asserts that the earlier in which reading related cognitive difficulties can be identified and subsequent intervention offered, the better the prognosis. By 3 years of age, children with a familial risk of dyslexia may demonstrate difficulty in several tasks related to phonological knowledge. These include recall of nursery rhymes, vocabulary development, novel word repetition and knowledge of letter names, (Gallagher, Frith and Snowling, 1996). Research has supported the premise that a positive family history of language difficulties is a strong indicator for the at-risk child (Fielding-Barnsley, 2000; Gallagher, Frith & Snowling, 2000). Identification of dyslexia based on the discrepancy between intelligence and achievement is no longer a valid approach as it fails to measure the diagnostically significant phonological deficit (Stanovich & Siegal 1994). As related in chapter 1, the predicament with the discrepancy definition of dyslexia does not account for the melange of intelligence and reading skills. The reciprocal relationship between developmental dyslexia and intelligence must be further investigated in order to better understand the role each plays in the disorder.

The implications of developmental dyslexia can evolve with each individual's unique biological and environmental experiences. The focal point of this premise is the close relationship between written and spoken language. Any breakdown in phonemic knowledge or related speech/language deficits causes significant risk in reading achievement. Each case is individual to the child with individual strengths and weaknesses (Simpson 2000). Simpson professes that a good number of professionals concerned with the care and development of children are in a place to identify and monitor preschool children at risk for dyslexia. However, the nature of understanding by practitioners is less than adequate. Early intervention needs to be planned with this focus on remediating the underlying core deficit, not the symptoms.

### **3.5 Pseudo word Reading**

The reader must take a diagnostic approach to reading when decoding words. Decoding involves the translation of symbols into meaningful sounds. The various irregularities found in letter patterns and sequences in the English language mean the reader must understand these irregularities in order to be proficient in decoding to read. A graphophonic cue is information based on letter sound relationships used by readers while decoding texts. Graphophonic cueing is effective for words that encompass phonetically regular patterns or in which the phonemic letter patterns are utilized within a word that is already recognized by the reader. Consequently the reader must understand how to analyze the word by phoneme, syllable, onset and rhyme and/or morpheme within. If the reader has not yet mastered the ability to employ graphophonic cueing he must rely on using aspects of the context to recognize the unknown word. This may then involve semantic and/or syntactic cueing. For semantic cueing a reader uses the meaning of the context to approximate a guess about the unknown word. Generally, the written meaning, the illustrations and prior knowledge of the topic and genre all help to provide semantic cues to the reader. At times, recognition of the word is also confirmed by some graphophonic cueing—typically the initial or final phoneme or known letter strings within the word. Syntactic cueing involves the use of grammatical significance of a word to assist in identification of the word. The reader’s implicit knowledge of spoken and written language support this skill. Either or both of the other cueing strategies will also be used to support the reader as they decode the word. These cueing strategies are relevant to becoming a skilled reader and a deficit in one or more of these strategies can impact fluency and comprehension.

Nonword repetition tasks are important to the study of dyslexia in that they were found to be associated with reading acquisition, vocabulary acquisition, speech production ability and second-language learning ( Masterson, Laxon, Carnegie, Wright & Horslen, 2005). Nonword reading eliminates the ability to utilize context and semantic cueing therefore placing sole emphasis on graphophonic cueing.

Masterson, et al. explores the role of encoding, storage and output in the task of non-word repetition. Their experiments look at the input processes involved in the task of nonword repetition –specifically whether there is an effect when the task does not involve a spoken component.

In their first experiment, Masterson, et al. eliminated past criticisms regarding ratings of word-likeness by creating a system for defining word-likeness. These were phonological overlap with words in the lexicon, using phonological neighbourhood size, or the number of familiar words differing from a target nonword by a single phoneme. In addition, the authors chose CVC monosyllabic nonwords for their study because of the age range of those participating as well as acknowledged criticism by researchers (Snowling, Chiat, and Hulme, 1991) with regard to the use of adult ratings of word likeness for the use of children's words. Results showed that those tested performed better with nonwords of a shorter list length and those with many neighbours (list length 3). Masterson, et al. concluded from this experiment that a “significant effect of word likeness in children aged five to six using the probed recall paradigm”. In addition, they suggested that “the strongest conclusion that can be drawn is that the word likeness effect is unlikely to be solely attributable to facilitation at a late state of production of the verbal response in nonword repetition”.

A longitudinal study undertaken by Gathercole, Willis, Emslie & Baddeley (1992) showed 4-5 year olds' phonological memory skills impacting directly on vocabulary acquisition. Subsequently at a later age vocabulary knowledge became the major impact in the developmental relationship and the earlier phonological memory influence being insignificant. Their research investigates whether one factor that may constrain children's acquisition of new words is their ability to represent an unfamiliar word in the phonological component of the working memory.

Comprehension has been established to be one of the most important skills in reading development (Goodman, 1986). Comprehension depends on an individual's ability to decode and recognize printed words (Stanovich, 1993). Researchers agree that even as comprehension is the purpose of reading, decoding of distinctly word in the text is a

prerequisite to understanding what is read (Lyons,1995). Stanovich describes this dependence of comprehension on decoding skills:

Reading for meaning [comprehension] is greatly hindered when children are having too much trouble with word recognition. When word recognition processes demand too much cognitive capacity, fewer cognitive resources are left to allocate to higher-level process of text integration and comprehension.

### **3.6 Working Memory**

Working memory is a cognitive structure that allows individuals to keep active limited sums of information for a brief few seconds. Originally working memory was known as “short-term memory” but given the cognitive role it has been proven to encompass has evolved to be termed “working memory”. There are two models of working memory that have been presented by researchers (Just and Carpenter, 1992; Baddeley, 1986). Baddeley’s model is described as the phonological loop model and the capacity theory of comprehension is identified by Just and Carpenter.

Working memory is a system with multiple components that is limited in scope. The working memory includes a central executive system and an articulatory loop system (Baddeley, 1986). Word finding difficulties are described by a child’s inability to produce a target word when presented with a picture or in conversation (Dockrell, Messer, George and Wilson, 1998). Children with word finding difficulties are able to select the correct word with a referent but unable to produce a target word independently. The inability to produce the target word leads to subsequent secondary behaviours which include repetitions, reformulations, substitutions, delays, insertions, and time fillers. Word finding difficulties include long delays in word retrieval, word substitutions and a large occurrence of circumlocution. Dockrell et al. indicate that word finding difficulties were related to difficulties in grammatical production, word meaning and grammatical comprehension. There is evidence of a strong association between performance on naming and literacy tasks (Messer, Dockrell and Murphy, 2004). This association has led to deliberation on the cognitive abilities that effect naming and literacy abilities. Messer et al. studied the relationship between naming difficulties and performance on literacy

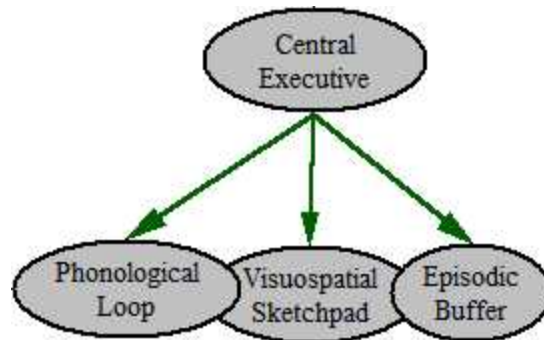
assessments. They found that those children studied had mean scores in the average range for literacy and phonological awareness tasks. Subjects studied had lower mean performance on assessments of comprehension—including lexical, syntactic, and reading comprehension. The weakest area of performance in the study involved areas of various forms of naming. They concluded that the areas in which subjects performed less well involved aspects of the semantic system and naming. Correlations were found between standardized scores for phonological awareness and literacy abilities. Correlations were also found between scores for naming and literacy abilities. When analyzing these results using multiple regression, Messer et al. found that both naming speed and phonological awareness made independent contributions in predicting literacy abilities. These findings are related to Wolf and Bowers' (1999) contention that dyslexia involves slower naming skills and low levels of reading comprehension but average performance in phonological and decoding abilities. They suggest that there are two separate deficits contributing to reading disabilities. In this double deficit model, they suggest that there are two separate causes for dyslexia. Children with dyslexia, in this hypothesis, suffer from phonological processing deficits as well as rapid naming deficits. Wolf and Bowers found that children with dyslexia can have problems with just phonological processing deficits or rapid naming deficits. They can additionally have difficulties with both. This indicates that the two processes are mutually exclusive.

Memory defined by the field of psychology is one's ability to store, retain and then recall information. There are three key stages in the formation and retrieval of memory. These are (1) Encoding; the method of processing and combining received information, (2) Storage; the creation of a permanent record of the coded information, (3) Retrieval; recalling back the stored information in response to some activity or process.

Memory is composed into three parts by the processes involved. These are sensory memory, short term memory and long term memory. Short term memory allows an individual to recall something from several seconds to as long as one minute without rehearsal.

Baddeley and Hitch (1974) presented a model of working memory that subdivides short term memory into a set of processes and substores. In Alan Baddeley's model of the working memory this short – term memory processing system consists of three parts:

**Figure 3.6 Model of Working Memory**



### **The Central Executive**

The Central Executive controls attentional systems and has limited processing capacities. The central executive manages the retrieval and encoding of inputting stimuli and the monitoring of changes in attention. The central executive is largely impacted by the frontal lobe portion of the brain. The CE also controls two subsystems, acting in a supervisory nature to these components:

### **The Phonological Loop**

The phonological loop stores sound information by rehearsing silently sounds or words in a continuous loop. The phonological loop is accountable for encoding, maintenance and manipulation of speech based information and also holds information in a phonological short term store in theorized code that decays with time but can be refreshed with sub vocal rehearsal. The phonological loop has been found to be responsible for vocabulary acquisition (Gathercole and Baddeley, 1989). The phonological loop functions by storing verbal input temporarily while cognitive process such as auditory comprehension occur. This includes novel phonological input (Baddeley, Gathercole & Papagno, 1998). This facility to store new material allows an individual to create long-term phonological representations of this new material (Montgomery, 2003).

Gathercole and Baddeley also report that phonological memory skills at age 4 are specifically linked with vocabulary knowledge and that phonological memory contributes directly to learning new vocabulary long term.

A developmental association between phonological memory skills and vocabulary knowledge can also be affected by an environmental variation in exposure to vocabulary (Gathercole et al., 1992).

The amount of material that can be held in the short term store with rehearsal increases with age (Baddeley, 2003). Essentially the phonological processes sound based input. The phonological loop has been found to be responsible for vocabulary acquisition. Gathercole and Baddeley (1989). The phonological loop can then be divided into two subgroups. The first component is a temporary phonological memory storage that holds acoustic or speech based information. The second component, which supports the first, is sub vocal rehearsal. Information is held for approximately two seconds unless it is reinforced with articulatory sub vocal rehearsal. This system additionally registers visual information within its store. Therefore when a subject is provided with a sequence of phonological information for instantaneous recall, they rely on the acoustic information rather than the visual presentation (Baddeley, 2003). Baddeley also reports that it is more difficult to recall letters with similar sounds than those with unlike sounds. This also occurs with sets of words with similar phonemes being more difficult to recall than those with dissimilar phonemes. This does not occur with the lexicality of words. Phonological memory skills at age 4 are specifically linked with vocabulary knowledge and phonological memory contributes directly to learning new vocabulary long term (Gathercole and Baddeley, 1989). Pickering and Gathercole (2001) found that dyslexic students performed worse than non-dyslexic children on tests of working memory. Baddeley contends that the phonological loop serves as an aid in learning new words. Two variables impacting performance in the phonological loop were the similarity of the item to be learned and the relevance to native language learning. Children with good verbal memory performed better at foreign language learning (Service, 1992).

Gathercole et al., acknowledge that a developmental association between phonological memory skills and vocabulary knowledge can also be affected by an environmental variation in exposure to vocabulary. Typical studies of preschool and elementary age school children assess the phonological loop of working memory by requiring children to repeat nonwords which vary in length from one to five syllables. As this type of task utilizes nonwords it is an unbiased measure of language processing for

the phonological loop (Montgomery, 2003). Most results of measures performed in this manner show that children of this age group have little trouble repeating one or two syllable nonwords. When asked to repeat three or more syllable nonwords, children with greater phonological processing memory perform with higher accuracy than those with lesser phonological processing memory. Researchers make a case that this poor phonological processing performance reflects a basic language-related processing ability that is key to the acquisition of language (Montgomery, 2003).

The phonological loop theory is challenged by Snowling, Chiat and Hulme (1991) who claim that the phonological memory actually reflects our knowledge of the structure of words in the repetition of nonwords and is not a contribution of short term phonological storage to name learning.

### **The Visuospatial Sketchpad**

The visuospatial sketchpad stores visual and spatial information. This component of working memory holds information as it is gathered during the initial processing stage and then if retrieved later from memory is used to create a recollection of an image. It is involved with visual and spatial tasks. The visuospatial sketch pad is divided into two subcomponents: a visual component that deals with visual features and a spatial component that deals with movement and location. This system is primarily affected by the right hemisphere of the brain. Baddeley (2003) reports that the visuospatial sketchpad affects reading tasks in that it maintains representation of print within the page and allows the individual to track text by moving the eyes from left to right and from line to line.

### **The Episodic Buffer**

A fourth component of working memory, the episodic buffer, is defined by Baddeley (2000). The episodic buffer links information across domains to form individual visual, spatial and verbal information as well as ordering information chronologically. It is linked to long-term memory and semantical meaning. Baddeley describes this component as capable of providing temporary storage—in a multimodal code—that unites information from the subsidiary systems of working memory and long term memory into a single episodic representation. An individual's conscious awareness is



used to retrieve information from this component. This component was later added by Baddeley to his 1974 proposal of working memory in order to give explanation to the process of integrating information.

The episodic buffer is controlled by the central executive. Baddeley contends that the episodic buffer differs from episodic memory in that it is a temporary store and serves as an interface between a range of systems.

Phonological memory changes both qualitatively and quantitatively from the time a child is 4 years of age through adolescence. Gathercole, Baddeley, et al., (1992) report on a longitudinal study showing 4-5 year olds phonological memory skills impact directly on vocabulary acquisition but subsequently at a later age vocabulary knowledge becoming the major impact in the developmental relationship and the earlier phonological memory influence being insignificant. Their research investigates whether one factor that may constrain children's acquisition of new words is their ability to represent an unfamiliar word in the phonological component of the working memory.

The shift moves from phonological memory skills to vocabulary knowledge (Baddeley 2003). As a subject develops, the relationship between the phonological loop and vocabulary learning is more involved. Subjects between ages 4 and 5 years demonstrated that phonological memory skills had greater impact on vocabulary development than existing vocabulary knowledge (Gathercole et al., 1997). They report that the phonological loop function of working memory plays a significant role in the ability to construct long term representations of new words. When the subject develops beyond age five the relationship between phonological memory and lexical knowledge becomes more reciprocal in function (Baddeley, 2003). In their study, Baddeley and Wilson (1993) detail impairment within the phonological loop and non-word learning affecting in a reverse direction. Subjects with poor digit span were found to have impairments in phonological memory.

Children who have strong skills at repeating nonwords will have greater knowledge at learning words in their native vocabulary than those with poor nonword repetitive skills (Gathercole and Adams, 1994). Nonword repetition can also predict future vocabulary

acquisition (Gathercole and Baddeley, 1989). In additional research by Gathercole, et al. (1997), vocabulary knowledge is considered the foundation for learning about the environment and acquisition of additional language skills. Those with poor vocabulary knowledge therefore suffer delays in learning. This study concluded that children's capacity to learn novel words is related to short term verbal memory and their existing vocabulary. Their aim was to consider whether increased vocabulary knowledge was associated with a child's ability to learn new sound patterns. The presumption was that children with superior vocabulary knowledge were more able to retrieve learned words and utilize to learn words with similar formations. They found that there was a high correlation with lexical knowledge and words learning ability. Their study also designated separate cognitive processes as being involved in the phonological long term learning and nonphonological long term learning. In addition, the relationship between phonological short term memory, current lexical knowledge and new word learning was studied. The author's concluded that lexical knowledge and new word learning were linked. A child's ability to learn new words requires them to hold phonological information for short periods. The phonological loop and vocabulary knowledge are directly related, principally for memory tasks involving nonwords.

Snowling, Chiat and Hulme (1991) challenge the phonological loop theory and claim that the phonological memory actually reflects our knowledge of the structure of words in the repetition of nonwords and not a contribution of short term phonological storage to name learning.

Phonological memory changes both qualitatively and quantitatively from the time a child is 4 years of age through adolescence.

The shift moves from phonological memory skills to vocabulary knowledge.

Gathercole, et al.(1997) report that the ability to repeat nonwords is a predictor in the ability to acquire vocabulary as a child develops. Four year olds who perform well at nonword repetition tasks had stronger vocabulary knowledge when assessed approximately 12 months later. The authors relate the relationship between nonword repetition success and vocabulary acquisition to the phonological loop.

The downfall of this theory is that environment plays a factor in acquisition of new vocabulary and therefore makes it difficult to measure the conditions from which children

acquire new words. For their study, Gathercole, et al. studied 65 children ranging in age from 5 years 1 months to 6 years 3 months. Their aim was to identify whether there was a relationship between phonological short-term memory and vocabulary acquisition. The results showed:

1. *A relationship between phonological memory and vocabulary knowledge.* The phonological memory measures of digit span and phonological knowledge were both associated with vocabulary knowledge. Although both measures were significant, nonword repetition was more strongly associated than digit span.
2. *Phonological short-term memory is linked to prediction of word learning ability.* The two phonological memory tasks performed were not related to the subjects' ability to learn new words but were connected with their performance on word learning tasks that emphasized recall of new names and word-nonword learning. Nonword repetition scores showed a significance difference whereas digit span scores were not significant.

Snowling, Chiat and Hulme (1991) challenge the phonological loop theory and claim that the phonological memory actually reflects our knowledge of the structure of words in the repetition of nonwords and not a contribution of short term phonological storage to name learning.

The model of working memory presented by Just and Carpenter (1992) has been less dominated by research and is more of a computational model (Montgomery, 2003). In this model, both the storage and language computation functions of working memory share the same attentional energy. Just and Carpenter propose that working memory capacity is directly related to and limits the operation of language comprehension processes. This variation in the capacity of linguistic working memory is the cause of the differences in language comprehension in population samples. Just and Carpenter suggest that their vision of working memory is rooted in Baddeley's linguistic portion of the central executive system. Their model has been met with much controversy because of their proposal of a single working memory capacity (Waters and Caplan, 1996). Waters and Caplan as well as other aphasia researchers believe a reduction in working

memory capacity is neither the sole cause nor an adequate representation of an individual's aphasic deficits (Martin, 1995, MacDonald & Christiansen, 2002). Phonological working memory changes both qualitatively and quantitatively from the time a child is 4 years of age through adolescence. The shift moves from phonological memory skills to vocabulary knowledge.

## 4. Biological and Environmental Factors

### 4.1 Introduction

Having discussed theory at a cognitive level, this chapter examines the origins of dyslexia and describes the biological and environmental factors that impact the disability. Nation (2006) contends that there is no identified “gene for reading”. Many of the cognitive and linguistic abilities which play a role in reading development are influenced by genetic and environmental factors. There is a reciprocal relationship between psychological and genetic research into dyslexia. It is crucial to combine genetically informed studies with psychological theories to help refine knowledge of the disorder. Sustaining this principle is Bishop (2006) who describes the relationship between psychology and genetics as a two way street whereas genetic studies refine the phenotype and subsequently inform psychological models. Nation (2006) describes this union of research as “developmental cognitive genetics” and maintains there is much promise for increasing understanding of the complexities of reading disorders.

### 4.2 Genetic Factors

Reading ability has been shown to be normally distributed along the normal distribution showing individual differences in strengths and deficits (Shaywitz, Escobar, Shaywitz, & Fletcher, 1992). Olson (2006) describes the bell curve distribution as accounting for all the positive and negative influences combining to produce individuals with a mix of these influences that places them at or near the middle of the curve with a range of reading abilities.

Much of the current research has been able to find a direct link between genetic factors and the cognitive abilities that underlie reading ability (Fielding-Barnsley, 2000). Genetic factors in dyslexia complement the current neurobiological theories (Guardiola, 2001). Any structural or chemical disturbance within the brain during development can be linked to a genetic effect. Complex disorders, such as dyslexia, often are causally related to

many genetic and environmental factors (Guardiola, 2001). Dyslexia is believed to be both familial and heritable with family history being one of the most prominent risk factors (Shaywitz, 2003). Almost half of all children with a genetic risk for dyslexia are delayed in literacy development when compared with children of the same socioeconomic class (Gallagher, Frith & Snowling, 2000). Much more research is indicated before it is possible to utilize genetic factors for early identification of reading disorders. The goal of genetic research to identify reading disability has focused on increased understanding of the disorder, the relationship between genetics and environment and the appreciation of how the brain development and function impact reading ability (International Dyslexia Association, 2007).

Genetic risk is not unconditionally associated with a reading disability. Researchers seek to clarify the role that genes play in dyslexia and to determine how they interact with environment. It is possible that environmental factors can modify genetic affects (Fielding-Barnsley). Analysis of the genetic causes of dyslexia will help to identify the environmental factors that impair the typical development of reading ability. This research can then help to advance any psychological theories and remediation methods. Researchers began to identify a genetic factor in dyslexia when they began to recognize that it ran in families (Thomas, 1905; Fischer, 1905 and Stephenson, 1907). Shaywitz and Shaywitz report that dyslexia is both familial and environmental. These familial and environmental influences affect how dyslexia is expressed. According to their research, 23 to 65 percent of children who have parents with dyslexia, 40 percent of siblings dyslexics and 27 to 49 percent of parents of dyslexics may have the disorder. Hindson, Byrne, Fielding-Barnsley, Newman, Hine and Shankweiler (2005) report on a range of affected offspring at 23% to 62%. Pennington and Lefley (2001) estimate that individuals with reading disabilities with affected parents are 34%. Snowling, Gallagher, and Frith (2003) argue that this figure is as high as 66%. Geschwind and Behan (1982) describe an elevated frequency in their study of left-handed individuals and a family history of developmental learning disorders. Familial influences on dyslexia have been documented by past and current research. DeFries, Vogler and La Buda (1986) were able to document, through several familial studies, the genetic link to reading disability. A study of 1044 individuals, with 125 families with history of reading disability and 125

families with no history of same was conducted. Individuals from the identified reading disabled families performed significantly worse on reading tests than those in the control group. A Colorado study of twins was successful in further identifying the relationship between genetics and environment and the subsequent impact on specific reading and language skills. Research by DeFries and Alarcon (1996) found the heritability factor for dyslexia to be  $h^2g=0.56$  which translates to approximately half of the deficit of reading disability being related to genetics. As described in the previous chapter, other specific skills related to reading have been studied for association with genetics. This includes phonemic awareness, orthographic coding and phonological coding (Olson, Forsberg and Wise, 1994). Marshall (2004) describes dyslexia as partly inherited, with the tendency to develop dyslexia running in families. She indicates that research into the disorder has identified at least eight different chromosomes, or a combination thereof, that point to dyslexia. Shaywitz (2003) reports that linkage studies associate loci on chromosomes 6 and 15 with reading disability. DeFries, Gillis and Wadsworth (1993) argue that gender is not related to the degree of genetic influence on reading deficits. Additionally crucial to the understanding and proper definition of dyslexia is the findings by Olson, Forseberg, Gayan and DeFries (2007) that show the genetic factors related to word recognition were more highly correlated with those having a high IQ than those with a lower IQ. Hindson et al (2005) challenge that classification of families into risk and nonrisk categories can be problematic. They propose that risk status is a continuous rather than categorical factor. In addition the underpinnings for classification have been argued. Relying on self-reporting from adult risks validity in classifications. They cite evidence from Scarborough indicating that approximately 46.8% of adults who self-report reading problems were not identified as disabled readers with formal testing. Fisher et al. (1999) maintain that reading deficits have a major impact on an individual's cognitive, social, and emotional behaviour. In their study, 82 families were identified as having evidence of reading disability or reported reading disabilities. Within these families, 181 siblings were identified and assessed. Results showed involved sib-pair families were influenced by a genetic component—specifically a locus on 6p21.3. Evidence from additional studies consistently targets the locus on 6p21.3 as an area for

study. Data confirms that 6p21.3 contributes to the various components of developmental dyslexia.

Scarborough (1990) reported research on family history by comparing 2 year olds with a family history of dyslexia and those with no family history. Findings indicated that by 8 years of age, 65% of those children with a family history had also been identified as reading disabled. In addition, Pennington and Lefly (2001) tracked 57 preschool children at risk against dyslexia and 67 children considered not at risk. Their research indicated that by grade two, 34% of the at-risk group was diagnosed as dyslexic compared to 6% of the low-risk group.

In summary, there is strong evidence of a genetic component for dyslexia. A genetic component is not in disparity with the theories previously discussed. The genetic factor does complement the neurobiological theories previously outlined. Gayan (2001) insists that any structural or chemical disturbance in brain development can be caused by a genetic effect and that the fact that dyslexia is hereditary does not have negative implications for educational and psycholinguistic theories of remediation for the symptoms of dyslexia.

There seems to be a wide agreement among researchers that there is an interaction between genes and environmental factors (Hawker, Wadsworth & DeFries, 2005; Nation, 2006). The next section will describe the influence of environmental factors on the disorder.

### **4.3 Environmental Factors**

The effect of environment on reading disability has been substantiated by a multitude of research (Aylward, 1997; Bradley, Whiteside, Caldwell, Casey, Kelleher, Pope, Swanson, Barrett & Cross, 1993; Sameroff, Seifer, Barocas, Zax & Greenspan, 1982; Campbell & Ramey, 1983). The influence of direct and indirect environmental factors can be correlated with future reading ability (Molfese & Molfese, 2002). Direct environmental influences include number of books and child activities in the home and direct parent interaction with the child. Indirect influences concern the amount of parental education, income and intelligence. Opinion has remained divided with some



believing the impact of environmental influence is constant through preschool and primary age and others arguing that the familial environment influence decreases throughout childhood as other outside environmental factors are drawn in (Bee, Barnard, Eyres, Gray, Hammond, Spietz, Snyder & Clark, 1982; Yeates, MacPhee, Campbell & Ramey, 1983). Studies describe a relationship between maternal behaviors (expectancies, communication style, parenting practices, and affect) during the preschool period and a direct influence on school readiness at five and six years of age, and subsequent achievement in the sixth grade (Hess, Halloway, Dickson, & Prince, 1984). It is proposed that various activities in home environment interact with different parenting practices, both of which are influenced by a mix of education, health, housing, finances, work as well as other resources for a family (Molfese & Molfese, 2002). Analysis of the impact of biological factors on speech perception and the effect of environmental influences has been studied extensively by Molfese, (1978; 1979; 2002); Molfese, DiLalla & Lovelace, (2002). A technique that measures Event Related Potentials (ERP) was studied to determine how the brain reacts to certain stimuli and to understand its impact on subsequent reading and language development. ERP were derived from the electroencephalogram to measure time-locked waves that immediately followed a stimulus. The stimulus was repetitive so as to eliminate the invalid and non-stimulus related background. Molfese (1978a, 1978b) proposed that ERPs are effective to study both general and specific aspects of an individual's response to events in both the external and internal environment. This includes the neuropsychological study of infant early language development. Research in this area has found that infants are capable of distinguishing between differing speech sounds characteristic of their language culture as well as being able to distinguish speech sound characteristics from other cultures. In later infancy this ability to distinguish changes according to infant's unique language environment. Molfese and Molfese (1979) utilized this information to predict later language development in infants. A principle component analysis was conducted using seven measures. After analysis of variance, results found components from ERP data identified which infants three years later would perform at a high or a low level on a standardized language assessment. These results were replicated in a follow-up study in 1994 by Molfese and Molfese. To expand on this notion in the study of family

environment impact on reading performance, Molfese and Molfese considered a longitudinal study conducted from 1986 to 2002. Family environmental factors such as parental education, occupation and family income were analyzed as well as information about parenting skills and family activities. The children in the study were grouped into three categories of socio-economic status (low, medium, and high) and based on the amount of familial environment stimulation. The study found significant differences between individuals who were three and eight years of age for the intelligence scores between the “low” group and the “high” group. Between all three groups, significant differences were found in intelligence between the ages of 5 years and 8 years. The home environment information was additionally analyzed by Molfese, DiLalla and Lovelace (1995) to determine the extent to which preschool language performance could be predicted for three and four year olds using the factors of perinatal risk, socio-economic status (SES) and home environment. The variables which were most significant (accounting for 47% of the variance) were the child’s gestational age at birth, birth order, and the amount of language and academic stimulation in the family home. In a meta-analysis of the Molfese study, Espy, Molfese & DiLalla (2001) found that scores were steady predictors of Stanford-Binet verbal scores (as described in chapter 1) at three years of age. Between three and eight years of age, changing verbal scores were not found to be related to scores or to socio-economic status differences in the children. Espy et al. did find that children with lower socio-economic status scores had poorer results in non-verbal ability compared to children with higher socio-economic status scores. Espy et al. suggest that non-verbal ability is powerfully related to success in achievement in school and is related to verbal abilities.

While research indicates that there is a link between genetics and dyslexia, Snowling, et al. (2003) believe that there is a relationship between genes and environment and that this relationship is so complex the effect impacts the range and spectrum of dyslexia and its variety of symptoms. In their study, research was conducted on 56 children at risk of dyslexia and from families with an affected parent and 29 children considered low-risk for dyslexia. Snowling, et al. (2003) concludes that dyslexia is “multi-componential”. Children may show differing levels of impairment with the many language processes and

therefore subsequent problems with reading skills. The varying definitions and diagnostic criteria of dyslexia then complicate the process of defining a child as dyslexic. Snowling et al. additionally believe that early precursors of reading disability within a family include slow vocabulary development and poor expressive language and grammatical skills. Their findings conclude that those children born to dyslexic families have an increase in the risk of literacy problems and that there is a continuum of manifestations of the disorder from this group. The suggestion has been made that achievement is more amenable to intervention than cognitive ability. According to Fielding-Barnsley(2000), studies show that ability levels, not achievement levels have a higher genetic influence. It could be hypothesized from this argument that enhancing a child's early language development can enhance their later reading development. Research on twins found that achievement was influenced by both genetic and environmental factors and ability achievement associations were found to be related solely to genetic factors. Ability- achievement discrepancies were due exclusively to environmental factors (Thomson, Detterman & Plomin, 1991).

In his longitudinal study, Scarborough (1998) researched 88 children from families of ranging social classes. The group included 38 children classified as "at-risk" because of familial ties to dyslexia. The children were identified at age 2 and again assessed in grades 2 and 8. Children were assessed in spelling, rapid naming, phonological awareness and verbal memory. Results showed that predicting the future reading success of children with reading disabilities was not simply related to their performance in these assessments. Furthermore, these assessments did provide some information as to the individual strengths and weaknesses in other particular areas. Scarborough details results that show differences between groups in IQ and rapid naming as most predictive of future achievement.

Torppa, Poikkeus, Laakso, Eklund, & Lyytinen (2006) present a longitudinal study of the development of letter knowledge between children with and without familial risk of dyslexia. They found significant differences in letter knowledge development between both groups. They hypothesized that children with delayed letter knowledge would be at risk for reading difficulties. Torppa et al used logistic regression analysis to determine which skills and what environmental factors might better elucidate those children in the

at-risk group. They analyzed through stepwise regression the factors of familial risk, IQ, environmental factors and language skills. This analysis provided a robust model that correctly classified 75.6% of the children.

In their research, Petrill, Dalter-Deckard, Thompson & DeThorne (2006) studied whether naming speed or rapid automatized naming (RAN) represents an additional, independent cause of variance in early reading skills. Their study considered the impact/overlap of phonological processing and rapid naming on literacy skills and the influence of genetic and environmental factors. The results indicated an overlap between rapid automatized naming and phonological awareness when predicting dyslexia. In both the Snowling and Petrill research, the educational levels of the parent were found to be an impacting factor--in that consistency with this variable was difficult to obtain.

Wolf and Bowers (1999) conject that rapid naming processes are independent of the phonological process and are therefore causal to future prediction of reading skills. In their review of current research the authors explore independent and combined roles of phonological deficits and naming speed in reading delays.

Fielding-Barnsley (2000) argues that familial history is a definite risk factor for dyslexia but that it does not mean a child will necessarily be dyslexic. She contends that environmental factors influence the genetic precursors. Recent research has unravelled the factors influencing genetics and environment. Research on identical and fraternal twins with familial history of reading disabilities has found that identical twins share more similarities in reading and language skills than fraternal twins. Since monozygotic twins share segregating genes and dizygotic twins do not, this supports the supposition that genetic factors play an integral role in manifestations of reading disabilities.

In her research, Nation (2006) presents a multiple regression analysis of three types of influence on impairment. These sources are:

1. Shared environment factors
2. Non-shared environment factors
3. Genetic Factors

DeFries-Fulker (DF) Analysis and data from the Colorado Learning Disabilities Resource Centre (CLDRC) support the premise that reading deficits are heritable. DF analysis is an adaptation of multiple regression that is used to estimate heritability of extreme scores on a dimension. DF analysis was the statistical method for determining heritability in monozygotic and dizygotic twins when one of the set of twins has an extreme score which was the indicator of a reading disability. Using this form of regression analysis, it is possible to measure and predict whether one or more factors particularly influence reading disability (Hawke, Wadsworth & DeFries, 2005). The current research argues that there are a number of factors that genetically influence reading disability. Nation (2006) points out that there are a number of genes that affect reading disability. In addition, she proposes that, environmental influences are more difficult to measure and unless a genetically informed design is produced could be impossible to ascertain. Castles and Coltheart (2006) suggest that future research combine psychological theories and genetically informed design. Creating psychological models that utilize genetic studies can forecast future theories of reading that lead to worthwhile interventions for dyslexic individuals.

Familial history of dyslexia is a risk factor but does not guarantee an outcome of dyslexia. Genetic factors are pivotal in their relationship to reading disability. It is important to not disregard the environmental factors related to dyslexia as well. Future research on both genetic and environmental factors may influence the impact of each of these two factors and the role they play in the disorder.

#### **4.4 Sex**

Shaywitz and Shaywitz assert that dyslexia affects males and females equally (2001). Historically research identified the prevalence of reading disability as three to four times more common in boys as girls (Shaywitz, 2003). This, in part, was because previous studies utilized samples identified by school identification procedures. Shaywitz (2003) contends that in their research there was no significant difference in the prevalence of reading disability for boys and girls identified. Findings of a study conducted by Duane (1991) found that the incidence of reading disorder is four to six times greater for males

than females. Familial studies where a child is identified as dyslexic have found equal numbers of boys and girls with reading difficulties. Shaywitz proposes that teachers have incorporated a norm of classroom behaviour that reflects the norms of a female student. Therefore, male students, who display different behaviour than girls fall below this perceived norm. Analysis of data taken from identical and fraternal twin pairs was used to test the hypothesis that males differ from females in the genetic aetiology of reading disabilities. Hawke, Wadsworth and DeFries, (2005) suggest that the research in this area is divergent. The results from their study revealed little evidence for a distinguishing genetic aetiology of reading disabilities in males and females. Interestingly, Shaywitz (2003) found a significant difference between the brain activation patterns in males and females. Men activated the left inferior frontal gyrus, while the women activated both sides of the brain. Both males and females performed the required task with the same speed and accuracy. These findings by Shaywitz are relevant as they support the demonstration of a visible sex difference in the brain organization for language processing.

#### **4.5 Digit Ratio**

The ratio of the length of the 2<sup>nd</sup> digit to the length of the 4<sup>th</sup> digit is believed to be determined by week 14 of the prenatal period. This ratio has been theorized to be affected by testosterone and can be used as a measure of prenatal sex hormone exposure. This method is used by researchers to examine hormonal effects on human behaviour and capacity (Cohen-Bendahan et al., 2005). Digit ratio is thought to be stable throughout development and not to be affected by hormonal changes during puberty. Research by Cohen-Bendahan et al., 2005; McIntyre, 2006) measured digit ratios from age 1 to 17 years and report a consistent sex difference despite a small increase (0.03) during this period. Contradictory research emerges as to whether the right or left hand digit ratio is more stable during this period. McIntyre's research focused only on the left hand digit ratio and therefore is unable to substantiate these findings. Trivers, Manning and Jacobson (2006) describe a significant sex difference in the digit ratio of both hands for Jamaican children that became insignificant when measured again four years later.

As a caution, Cohen-Bendahan, et al (2005) suggests that although digit ratio reflects a foetus's exposure to prenatal testosterone, it is an indirect measure. They argue that this measurement is contaminated by other factors. They suggest that all traits depend on hormonal influences but differ in their developmental timing and cannot be correlated with each other. The authors agree that studies of digit ratio are valuable but should possibly be limited to traits already suggested to be influenced by prenatal androgens.

#### **4.5.1 Cerebral Lateralization and digit ratio**

There is some evidence that the ratio of the length of the index finger (2D) to the ring finger (4D) can be used as a measure of foetal testosterone exposure. This digit ratio has been used to examine the relationship between prenatal testosterone levels and neurodevelopmental disorders such as dyslexia (van Gelder, Tijms and Hoeks, 2005).

Research has recognized the concept of cerebral dominance for over 100 years (Geschwind and Behan, 1982). The left hemisphere specializes in analytical language. Functions of the left hemisphere include dealing with facts, abstractions, mathematics, sequencing, logic, deductive reasoning, written and spoken words. The left hemisphere also controls the right side of the body. The left hemisphere is the focus for many of the educational skills an individual acquires. The right hemisphere tends to focus on more abstract abilities such as emotion, sensitivity, visualizing and creativity Austin, Manning, McInroy & Mathews, 2002). The right hemisphere also specializes in spatial ability and includes motor skills such as play and sports (Brosnan, 2008). It is argued by some that cerebral lateralization is impacted by environment and is sensitive to stimulation from non-biological sources (Tang, 2003) The indication that brain dominance occurs and is related to both biological and environmental factors has been established (Chi, Dooling and Gilles, 1977, Geschwind and Levitsky, 1968, Geschwind, 1979). Cohen-Bendahan et al. (2005) maintain that prenatal testosterone levels are found to be related to indicators of lateralization at age 10 by measures of handedness and processing of language tasks. Their results show that males, testosterone was positively correlated with right hemisphere specialization for the recognition of emotion and for females, testosterone was positively correlated with degrees of right handedness and levels of left hemisphere

lateralization for language. They concluded their results to be consistent with a hypothesis that high androgen levels command more lateralization in both sexes. Foetal testosterone exposure has been reported to be a causal factor in the aetiology of dyslexia. Geschwind and Galaburda (1985) offered a theory of cerebral lateralization that proposed a high level of prenatal testosterone exposure delayed the development of specific areas of the left hemisphere and aided the growth of homologue areas in the right hemisphere. An overproduction or hypersensitivity to testosterone can cause a predisposition to dyslexia in the foetus. Geschwind and Behan (1983) proposed the hypothesis that dyslexia was related to testosterone exposure and impacted an individuals' phonological processing. Furthermore, they found a relationship between dyslexia and gender handedness, immune disorders and stuttering. Beech and Beauvois (2006) examined whether a biological influence on the development of auditory perception and phonology was possible and utilized digit ratio as a tool for their study. Prenatal androgens, such as testosterone can be related to the impairment or development of auditory perceptual processes in the left hemisphere and subsequently impairs the development of phonological processing in the left hemisphere.

Geschwind and Galaburda (1985) explored the theory that testosterone could influence and alter the developing structures of the brain—especially those that impact cerebral lateralization. This concept has ramifications for the study of dyslexia as studies reveal deviations in cortical regions as a result of prenatal disturbances (Beech, Beauvois, 2006). In addition, various developmental disorders, including dyslexia are found to be more frequent in males than females. Geschwind and Galaburda suggested that testosterone changes neural structures and therefore delays growth in parts of left hemisphere structures in males. This causes right hemisphere changes which subsequently affect the brain and can trigger developmental delays such as dyslexia.

Geschwind and Behan (1982) discussed the concept of cerebral lateralization and give detail to the concept of cerebral dominance. Both the left and right cerebral hemisphere has been recognized to perform certain specific functions and have greater proficiency than their counterpart in the acquisition of certain skills. Geschwind and Galaburda (1985) hypothesize that the effects of prenatal testosterone levels can compromise the



development of the left cerebral hemisphere. This may cause left-handedness, language impairments and autism spectrum disorder. These same effects of prenatal testosterone can be found to assist the right hemisphere leading to increased spatial, musical and mathematical abilities. Manning, Trivers, Thornhill and Singh (2000) found evidence in support of Geschwind and Galaburda's theory.

#### **4.5.2 Cognitive abilities and digit ratio**

Digit ratio has been examined in its association with cognitive abilities (Cohen-Bendahan et al., 2005). Spatial awareness and verbal ability make up a number of research studies when looking at the relationship with digit ratio (Brosnan, 2006; Hyde and Linn, 1988) although contradictory evidence by Austin, Manning, McInroy and Mathews (2002) found no evidence of a relationship between digit ratio and cognitive ability. According to van Gelder, Tijms and Hoeks (2005) there is a sizeable amount of research indicating that dyslexia originates from an underlying deficit in the phonological processing system and that the disorder is considered to be genetically based. The study conducted by van Gelder, Tijms & Hoecks found that there was no relationship between digit ratio and children with dyslexia and the control group. Additionally, the study found no differences in digit ratio and males and females. Van Gelder et al. caution that since no significant relationship in digit ratio between males and females was found the results are inconclusive regarding the testosterone hypothesis of dyslexia. Manning, in his response to this study, expresses concern that as there was no sexually dimorphic finding of digit ratio that particular doubt is to be cast upon the research. Manning argues that the failure to establish a 2D:4D sex difference may be due to a variance in ethnicity from the van Gelder et al. sample. Therefore, the conclusion that individuals with dyslexia and those without dyslexia do not differ in digit ratio is an incorrect assumption.

An additional topic for discussion is Manning, Fink, Neave and Caswell's (2005) finding that measurement of digit ratio from photocopies yield's lower digit ratio results than direct finger measurement. Although measuring digit ratio from a photocopy reduces sampling times, comparison with data from direct measures produces lower mean values

of 2D:4D. Manning et al believe that this finding does not invalidate measurement from photocopies but that it should be considered that measurement in this matter may bring together sex differences in finger length and fat pads.

Though there is no overall difference in general cognitive abilities between males and females, some sex differences in specific tasks have been found (Falter, Arroyo, & Davis, 2006). Halpern (2000) reports that females perform superior to males on tasks requiring verbal fluency and object location memory. Alternatively, males perform superior to females on tasks requiring spatial processing as well as sensorimotor tasks. Witkin, (1967) found that males perform superior to females on embedded figure tasks, though other studies find no difference in embedding tasks for males and females (Crandall and Lacy, 1972). It can be concluded that if there are sex differences in ability they would be found to be related to prenatal testosterone. Austin et al. (2002) maintain that a number of female-male differences have been documented when studying digit ratio. They found that males score superior on some types of spatial tasks, most markedly on mental rotation tasks. These findings are supported by Voyer, Voyer & Brydan (1995) who found evidence that spatial skills vary with testosterone level. Voyer et al. found this to be a curvilinear relationship rather than a linear relationship. Research by Sanders, Sjodin, and de Chastelaine (2002) support a linear relationship with a negative relationship between spatial ability and digit ratio but because of challenges by research that contradicts this linear relationship, Sander et al. propose that the relationship between digit ratio and spatial ability is more of a “U-shaped” curve. This is in concordance with findings by Geschwind and Galaburda (1987) who propose that extremely high levels of testosterone may impede the development of both hemispheres and cause reduced spatial abilities which is consequential to a curvilinear relationship between testosterone and spatial ability.

Research by Beech and Beauvois (2006) investigates whether there is an influence of sex hormones on the development of auditory perception, phonology and reading. In support of findings by Geschwind and Galaburda (1985), Beech and Beauvois hypothesize that sex hormones appear to impact neural substrates during a crucial time in

prenatal development and these affect the development of auditory perception, phonology and reading. Auditory perception and the consequent of phonological development can be brought about by prenatal sex hormones. Tallal (1980) demonstrated a link between auditory processing and dyslexia. An association was shown between non –word reading and auditory perception tasks. Tallal argued that phonic skills involved in reading non-words are impacted by an auditory perceptual dysfunction. Tallal's auditory temporal-processing theory illustrates that children with language impairment are incapable of dealing with rapid changes in temporal audition which directly interferes with processing of rapidly presented consonant sounds. Reviewing prior research, Wright, Bowen, and Zecker (2000) found that individuals with reading or language disorders cannot detect the discrimination of sounds occurring in rapid sequences. Breier, Gray, Fletcher, Diehl, Klaas, and Foorman (2001) suggest that problems in auditory temporal processing can influence phonology via speech perception. However, Beech et al. (2006) found that phonology-- not the main effect of reading-- was not a linear function of digit ratio. They hypothesized that the right hand digit ratio was reflecting the influence of testosterone in the left hemisphere where the influence of phonology is greater. By contrast, testosterone effects in the right hemisphere could affect reading performance, but not phonology. They propose that prenatal exposure to testosterone, measured by digit ratio, impacts the development of specific areas of the brain responsible for auditory temporal processing. The impact of these areas in the brain consequently affects phonological processing which, in turn, affects reading development.

In their research, Van Gelder, Tijms and Hocks studied close to 400 children. Of these participants, 143 had a diagnosis of dyslexia. The subjects were given several phonological tasks and the dyslexic group performed significantly lower than the non-dyslexic group. Digit length was measured using a standard protocol as suggested by John Manning (2002). Using photocopies of the hands, surface measurements were made from the crease at the base of the index and ring fingers to the tip. This measurement was calculated with vernier callipers. In their study, the percentage of males was 60% in the dyslexic group and 50% in the control group. Participants in both groups who were left handed were 10%. Their findings revealed no significant difference between groups when

testing for gender or condition. Therefore, Van Gelder, Tijms and Hock believe their results show no significant difference in the 2D/4D ratio between groups. They conclude that their research, showing no support for the relationship between 2D/4D ratio and prenatal testosterone puts the concept of this measurement at risk as a valid marker. They then argue that this contrast to similar studies is related to small sample size in other studies.

There is evidence that human behaviour and cognitive ability is influenced by sex hormones found to be present during prenatal development (Cohen-Bendahan, van de Beek, & Berenbaum, 2005). Physical, emotional, and cognitive traits can be linked to sex hormones during foetal development. Specifically, prenatal levels of testosterone can be measured with digit ratio and examined in relation to a number of traits including reading ability. Digit ratio is the ratio of the lengths of the digits when measured from the bottom crease, where the finger joins the hand to the end of the tip of the finger. It has been hypothesized that the specific ratio of the 2<sup>nd</sup> digit and the 4<sup>th</sup> digit, which are the index finger and ring finger, are affected by testosterone in the uterus and that this 2D:4D ratio can be used as an indirect measure of prenatal androgen exposure (Manning, 2002; Manning Find, Neave & Caswell, 2005; Manning, Barley, Walton, Lewis-Jones, rivers, Singh, Thornhill, Rohde, Bereckei, Henzi, Soler & Sved, 2000). 2D:4D digit ratio is sexually dimorphic (Brosnan, 2006; Manning, 2000) and in males the 2<sup>nd</sup> digit is found to be shorter than the fourth, whereas in females the 2<sup>nd</sup> digit tends to be the same size or somewhat shorter than the 4<sup>th</sup> digit. Measuring the ratio of the 2<sup>nd</sup> (index finger) and 4<sup>th</sup> (ring finger) is a simple way to determine testosterone exposure in foetal development. Manning (1998) reports that the 2D/4D ratio is negatively affected by testosterone and positively related to estrogen. Cohen-Bendahan, et al (2005), report several studies investigating other digit ratios but the 2D/4D digit ratio being the most extensively studied. Subsequently, males tend to have a larger digit ratio with a smaller numeric measurement difference and females will have a smaller digit ratio with a larger numeric measurement. The gender difference in digit ratio can be found on both hands, but with some greater effect on the right hand (Brosnan, 2006). Exposure to androgen typically occurs during the 14<sup>th</sup> week of development (Geschwind and Behan, 2003). This ratio appears to be stable from age five (Cohen-Bendahan et al., 2005). In addition, Van

Gelder, Tijms and Hocks (2005) report that exposure to androgen levels does occur at week 14 and remains relatively stable throughout childhood and adulthood. Therefore puberty and its hormonal fluxuations do not impact digit ratio (McIntyre, 2006).

There are variances in digit ratio between ethnic groups. Manning, Stewart, Bundred, & Trivers, (2004) and Manning, Barley, Walton, Lewis-Jones, Trivers, Singh, Thornhill, Rohde, Bereckei, Henzi, Soler, & Sved, (2000) have shown that the 2D:4D ratio varies among ethnic groups. This ethnic variance in 2D:4 D is greater between groups than between males and females.

Manning argues that a relationship between digit ratio and whatever symptom you are looking at suggests that this relationship should be further explored. Digit ratio is utilized to research issues including reading disabilities, autism, homosexuality, obesity as well as other cognitive and personality traits in the sexes (Manning, 2000 and Manning, 2001). Cohen-Bendahan, et al. report that various physical, sexually dimorphic traits have been examined for their relationship to digit ratio. These traits include waist measurement, body mass index, and body form.

#### **4.6 Summary**

Chapter 4 focuses on the biological and environmental factors which contribute to research in dyslexia and reading disability. To a large extent, research has established a link between genes and cognitive skills that relate to reading development. In addition, dyslexia is understood to be impacted by environmental factors as well. DeFries, Vogler & La Buda (1986) have separated some of the genetic and environmental factors in their studies on families. Additionally, the Colorado Twin Study (Wadsworth, DeFries, Olson & Wilcutt, 2007) specifically studied families with a reading disabled child and control families. Continued research would be valuable to further explore the complex interactions between genes and environment and to expand on the notion of how environmental factors can either improve or impede reading ability.

There is now substantial evidence that human behaviour and cognitive abilities are influenced by sex hormones that are present during prenatal development. We explored the theory hypothesised by Geschwind and Galaburda (1987) which maintains that

prenatal testosterone –an overproduction of, or sensitivity to—could predispose the foetus to have increased susceptibility to dyslexia.

There is controversy among researchers studying digit ratio as an indicator for reading skills (van Gelder, Tijms & Hoeks, 2005; Boets, De Smedt, Wouters, Lemay and Ghesquiere, 2007). However, many of these studies are contentious and further research is necessary before firm conclusions can be made as to what link digit ratio has for children with dyslexia.

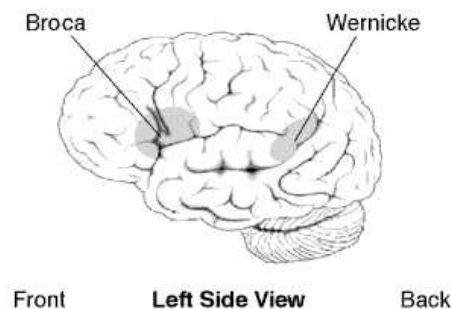
It is important for researchers to recognize the shared relationship between studies for genetics and studies of psychological theories of dyslexia. Increased expertise in both genres of research can be beneficial to the understanding of the disorder.

## 5. Brain Plasticity

Research on the brain organ began in the eighteenth century when scientists began to take an interest in the origins of personality traits, mental illness and behaviour. Franz Joseph Gall presented the theory which pinpointed the concept that brain localization of specific brain functions could be determined. This science of “phrenology” presented twenty seven associated psychological traits and their specifically related areas of the brain (Shaywitz, 2003). Though this theory was later dismissed, research began to focus on the evidence that cognitive functions could be localized within particular “regions” of the brain. In 1861, Paul Broca was able to examine the brain of a patient who experienced almost complete loss of expressive language while retaining most receptive language. Broca found a large irregular lesion on the surface of the left frontal region in the inferior frontal gyrus. The presentation of loss of language with retention of the ability to understand language is identified as Broca’s Aphasia.

The German neurologist, Carl Wernicke, defined a location along the upper part of the temporal lobe which is found behind the helix of the ear as related to another type of aphasia. In Wernicke’s aphasia, the individual is able to speak easily but does not understand receptive language.

**Figure 5.1 Left side view of brain and areas of activation (Stein, 2001)**



Language tasks are not strictly localized to the left hemisphere, though the more challenging the language task the more activated is the language system of areas situated in the left hemisphere (Stein, 2001). Analogous to cerebral lateralization theories, Demonet, Wise and Frackowiack (2003) propose that increasing phonological tasks of linguistic processing will increase the activation of the brain in the left hemisphere relative to the right.

Researchers previously considered the brain's networking to be cemented into place as an individual aged. Presently there is considerable research which indicates that the brain never stops changing and adjusting. An enormous amount of research presented in the last twenty years indicates that the brain retains its plasticity throughout an individual's lifespan. A particular focus of research provides evidence that the brain is able to overcome deficits of language reading processes. These findings can lead to understanding of the varied ways the brain is able to process language and how children and adults may overcome language-processing deficits. Additionally, research may lead to possible remediations that provide insight as to how brain networks can reroute and help those with reading disabilities.

Electroencephalogram, CAT and Functional Magnetic Resonance Imaging assist in allowing researchers to understand how the brain specifically works during reading. Requiring a subject to perform certain developmental reading tasks during testing can help pinpoint which systems in the brain are activating during the process. In her analysis, Shaywitz (2003) identified specific neural pathways for separating words into their separate, individual sounds.

Shaywitz theorizes that the parieto-temporal system activates for the novice reader. This system functions in an analytic manner, initially examining a word, separating its letters and linking them to their individual sounds. Once this process becomes analyzed correctly the occipito-temporal region of the brain activates and forms an exact neural model of the word, allowing it to be activated in this region of the brain quite automatically when the word is presented. Subsequently, those individuals who are strong readers show more activation during reading in their occipito-temporal region.



Shaywitz concludes that there are three neural pathways defined with regards to reading skills: 1. the parieto-temporal and frontal lobes and the occipito-temporal route. She indicates that the parieto-temporal and frontal zones are each responsible for a slow, analytic process and the occipito-temporal for express and skilled reading.

Kilgard (2007) asserts “We cannot simplify the system any more than is necessary” as we focus on hearing and language.” He believes that there are a number of simultaneous factors working together. Kilgard describes hearing as being within the brain and with scientists measuring the pattern of pressure on the brain made by the various sounds in our environment. He claims the brain can make use of various symbols/sounds even when they are on top of each other.

This measurement is done with the spectrogram, a device that measures various sounds approximating a “burst”, echo” etc. Kilgard explains that the pattern of speech sound is quite different than other sounds. For example; the words “bad and “pad” utilize the subtle cue of visual input from lips. In the word “bad” the release of the lips and onset of the vowel happen almost simultaneously. Whereas in the word “pad” there is a brief pause in time between the consonant and vowel which can be speeded up or slowed down.

An additional illustration is with the words “cash” and “gash” which are quite similar in pattern of speech sounds when measured on the spectrogram. Kilgard believes practice allows these similarities in such words to be more easily distinguished.

Kilgard poses the question as to what an individual’s brain is doing with all these sounds and how the brain can be rewired when it does not perform the way it is supposed to. In response, he proposes acquiring an image of the brain when it is in the process of hearing words. This includes studying activation of the central brain which is responsible for listening to words as well as the brochea—the portion of the brain whose role is for producing words. Looking at the brain’s responses to the sounds “da” versus. “ga” it seems the only signal your brain has is the tiny difference is the physics of the sounds. This “mismatch negativity” occurs when the brain shows it recognized a difference in the sounds it is hearing.

Therefore, according to Kilgard, the explanation as to why some individuals cannot make distinctions between sounds is because the brain is just not hearing or processing it correctly. These individuals may be identified as dyslexic.

The blends “sh” and “ch” are additionally difficult to process as “sh” is produced as a longer sound and “ch” a shorter sound. The consonant sound “j” is measured as the shortest of the three sounds and measure as distinct differences on a spectrogram.

Bond Chapman and Gamino (2007) reported on brain plasticity and neurocognitive rehabilitation of strategic learning deficits in attention deficit hyperactivity disorder. They examine the source of an individual and their ability to understand complex language? Bond Chapman and Gamino examine the matter of how an individual listens, how they pick and choose information and then acquire from such a large body the information desired. The researchers consider the cognitive correlate of the brain . For example, they explore how working memory is impacted as well as the other phonological correlates.

The advent of functional brain imaging allows researchers to see the brain changing in real time as an individual is learning. The brain is the most modifiable part of the body, according to Bond Chapman et al. Development of the brain moving from novice to expert – where a “novice” utilizes more brain activity and erstwhile an “expert” means less brain activation is involved. It is possible to view the brain changing as it is getting stronger and learning.

### **5.1 Neuroimaging and reading disability**

Pugh (2007) explains functional neuroimaging as a means to essentially map the systems that have to work together for reading. In dyslexia, structural abnormalities have been detected in visual system structures, the thalamus, the corpus callosum, and perisylvian cortical regions (Zeffiro and Eden, 2000). One of the potential roles for neuroimaging is for early detection of biomarkers predictive of risk for atypical development. According to Pugh, neuroimaging provides better theories for neural constraints from cooperative

and competitive dynamics in these systems that cooperate and change over time. Neurobiological measures provide mediating levels of analysis between gene and behavioural phenotype in genetic research.

Pugh substantiates the belief that phonemic awareness performance is a good predictor of reading development in the early stages. Neuroimaging allows researchers to distinguish between variant types within similar profiled individuals and varying outcomes of remediation. The more that is understood of the systems which underlie the processes the more we can understand the difference in individuals with similar reading deficits. Phonological deficits are universal, but research looks at what the underlying mechanism involved (Pugh, 2007). Varying theories include sensory deficits, compromised neural systems for language, metalinguistic deficits and attentional deficits. Pugh hypothesizes that there are multiple sub-types with different early brain pathways that result in a common end state of language delay and reading difficulty. With reading remediation it needs to be established what the phenotype is for reading disability. He questions how training modifies these differences for children with reading disability. Spoken language is a biological specialization but written language is invented by culture. Spoken language is mastered by the brain naturally whereas reading has no specific brain specialization. The implication is that reading acquisition is a major challenge to brain plasticity. The relationship between the spoken brain and the reading brain can be shown in a study of auditory versus printed representations. Many more areas of the brain are involved and are distributed in tasks that involve the printed word compared to tasks involving the spoken word. The reading brain engages three broad areas; anterior, temporal parietal and occipital temporal zones. Pugh's aim is to identify which areas involve particular deficits in individuals with reading.

Theories identifying reading disabilities and brain phenotypes involve describing these brain areas but do not provide information on why this occurs or how to remediate. Shaywitz et al. (2002) studied neuron developmental trajectories in neurologically impaired (NI) and reading delayed (RD) children. Correlating brain activation with chronological age in NI and RD was shown. Increases in reading skill are associated

with increased specialization of ventral left hemispheric areas for print. This occipito temporal zone is good at rapid pattern motion. This zone is good for pattern recognition in rapid presentation. The left ventral cortex becomes developed for rapid, fluent reading development. Pugh et al. discovered that with age, the areas of brain involvement become more and more pronounced. That is, those areas involved get increased use with age. As reading ability becomes more expert there is increased activity in the left occipital cortex. Pugh is also contemplating what conditions are evident in a 7 year old in pre reading brain conditions. His ongoing, developmental study has found that those individuals' brains show a different area for spoken words and an "emergent" area of the brain during pre-reading. This area appears to develop as reading ability does but is correlated with early phonemic awareness. Phonemic awareness individual differences correlate with the speech modality of the brain as it develops the printed modality of the brain. Treatment can allow the spoken representation to become accessible to the printed tasks and their associated development in the brain.

There is a significant link between speech and printed language. Blachman (2004) examined neurobiological changes with a nine month intervention emphasizing phonemic awareness. Subjects enrolled in second- and third-grade with poor word-reading skills received eight months of instruction in letter sounds and spelling while reading text, while control groups received regular remedial-reading programs. The study group showed significantly greater gains in reading real words, non-words and passages, in reading rate and in spelling. When re-tested a year later, they had mostly held those gains. Reliable improvement on a battery of reading related tests was found in the study group with increased activation in all three parts of the left hemisphere. The activation of the right hemisphere actually decreased as that in the left hemisphere increased. Plasticity is evident in struggling beginning readers. Also, years of reading experience may limit plasticity in older reading delayed children. Children whose reading disability persists may be more severely congenitally affected rather than neurologically based (Pugh, 2007).

Pugh et al. (In press) studied repetition and item specific learning. This study examined older adolescents with reading disability. Pugh et al. employed the learning curve

hypothesis, which is; activation levels follow an inverted U shaped function with respect to familiarity and skill in processing words. Adolescent, reading disabled individuals in a word repetition task showed an increase in activation after longer exposure to the repeated words. These results illustrate that the phonologically tuned LH system in adolescents with reading disability appears to be fundamentally in place. Low activation to the words during the first few repetitions was unusual in that these words were familiar to the RD individual. Pugh et al. concludes that these results indicate that the system is unstable. They explain that the system is capable of working but is unable to preserve the learning over time.

## **5.2 Plasticity**

Just (2007) on his research in brain imaging explores differences between good readers and poor readers. Neuro-imaging of 120 children was done as part of a much larger behavioural study directed by Torgesen (2004). In this study, participants performed a sentence comprehension task in the Positron Emission Tomography (PET) imager and were measured during this task. The subjects were instructed to view the screen behind them using a mirror and utilized a mouse for responses. Results found group differences in brain activity between good and poor readers.. Previous relative findings by (Shaywitz, Shaywitz, Pugh, Fulbright, Constable and Mencl (1998); Eden, Jones, Cappell, Garaeu, Wood, and Zeffiro (2004) were analyzed. The study done by Shaywitz et al. always employed the presentation of a word oriented task or letter oriented task, often related to rhyming. Research by Just differed in that a sentence task, not a single word was utilized. His rationale was that sentence comprehension is the ultimate goal of reading. Just argues that his is the first MRI study of this kind with children reading complete sentences. Sentence sensibility tasks were completed (participants were asked: “Does this sentence make sense?”). Third through fifth grade readers were studied. Just found a main effect area for reading ability. The parietal temporal region showed under activation. A main effect of age was found. Reading ability for age indications involving left parietal area were established. A Regression scatter plot indicated an increase in activation in the left middle temporal gyrus as a function of reading ability.

Regression scatter plot analysis revealed less activation in the temporal parietal areas in poor readers than in good readers. There was a correlation between reading score and amount of parietal activation. Just argues that neural function underpins cognitive function. Poor and good readers lie on the same activation continuum. Just reveals changes in brain activity after remedial instruction. Intervention included 100 hours of instruction. Fifth grade participants were singularly chosen due to poor date quality and quantity in 3<sup>rd</sup> grading readers. Intervention focused on word level instruction. Results revealed the under activation of poor readers present at pre test eventually developed after remedial instruction. A brain deficit disappears after remediation. Brain areas show phase related increases in activation among poor readers after remediation. The brains of poor readers were activating more in post tests than pre tests. In addition, poor readers showed a change in TOWRE scores and brain activity post remediation. The Brain signature of poor reading (temporo-parietal underactivation disappeared with remedial instruction.

Just, Cherkassky, Keller & Minshew, (2004 ) examined changes in brain tissue after remediation. They report a set of cortical areas, not just one area, activates during any cognitive task, identifying the multiple neural centres involved. According to Just et al., this activation is synchronized across participating areas. This synchronization implies that there is collaboration and communication going on in these participating areas of the brain. These areas coalesce (form sub groups) to complete language tasks. If the nature of this brain activity is to be synchronized, then measuring the interaction between these networks is imperative. A key factor in individual differences in reading abilities can be measured by diffusion tensor magnetic resonance imaging (DTI) that measures the integrity of the white matter in the brain. The measure is described as fractional anisotropy (FA). Fractional Anisotropy is a measure of the extent to which the movement of mobile water molecules is restricted in one or two directions by the tissue within a voxel. High FA is considered desirable. Previous studies on DTI found differences in an up-down direction (Davidson, 2003) Prior to instruction, poor readers had lower FA in dorsal white matter in left hemisphere (particularly corona radiata). Higher radial diffusivity implicates myelin. FA was found to be lower in poor readers in

several white matter regions in left hemisphere prior to remediation. There were no regions where the poor readers had higher FA than the good reading group. FA is positively related to reading ability through multiple regression prior to remediation. Importantly, White matter is not where the computation takes place but can be the area that links these networks. Through multiple regression FA is positively related to age. In post instruction results, substantial gains in reading ability were shown. Poor readers showed an increase in FA between the pre remediation and post remediation scans. There were not regions showing a reliable difference in FA between the two reading ability groups at the post test scan. This may be the first report showing a white matter change after remediation. Remediation improves the communication channel between these areas of the brain. Just et al believe this research offers one of the first demonstrations of instructionally triggered neuro-plasticity in the brain. The authors conclude that the increase in FA in the left anterior corona radiata among poor readers is primarily the result of a decrease in radial diffusivity.

### **5.3 Strategic Learning**

Few children have single disorders. Bond Chapman argues co-morbidity is common among brain language disorders. This Movement from “novice” to “expert” within brain activity can be impacted by; Significance and development of strategic learning, potential neuron cognitive stall in strategic learning, strategic learning deficits in attention deficit, rehabilitation for strategic learning, behavioural and brain plasticity of strategic learning.

Strategic learning involves retaining some information and discarding other information. Strategic learning involves being able to distract the central message and construction of a deeper sense of meaning. It means retaining some information and discarding others. Researchers are just beginning to learn how important “forgetting” is. Individuals who are able to block information may actually be some of the best learners, according to Bond Chapman et al. On the contrary, individuals with photographic memories can become dysfunctional because they have too many facts to sort through.

Remembering relevant information and inhibiting less relevant information requires much less neural effort (Wagner, 2007) Forming larger ideas and suppressing irrelevant details helps the brain think faster and more efficiently. Gist memory is more resilient to decay than detailed memory. The brain is most effective at extracting the gist; not at retrieving the details (Brainerd and Reyna, 1998) Gist is the deeper essence of meaning. Gist construction involves distilling the explicit details into a generalized significance.

Extracting the gist does not mean an individual does not attend to details or process information less thoroughly. Abstracted memory is more resilient to loss than remembering the details. A strategic learner is someone who knows what to learn and what to ignore in connected to language/text. In addition, a strategic learner is capable of extracting the big picture from the details of the text.

Bond Chapman et al. developed the acronym PICK to describe the process a strategic learner follows:

Prioritizing important information

Inhibiting unnecessary detail

Collapsing details into bigger ideas

Keeping the gist

### **5.3.1 Development of strategic learning**

Describing the development of strategic learning, Bond Chapman et al. argue the brain undergoes significant changes in adolescence. The most significant brain changes occur in the frontal lobes. The frontal lobes allow an individual to make sense of the massive amount of information flooding the brain in a constant manner. Development of strategic learning occurs in preschool years but during adolescence individuals face increasing demands on their attention. Strategic learning develops rapidly in adolescence.

Learning “details” activates most of the posterior part of the brain – particularly the left hemisphere. Getting the gist involves the frontal part of the brain. Multi tasking and quick responses develop a very different brain. Bond Chapman et al assert the brain



develops based on the way an individual uses it. Environmental experiences actually guide the development of the brain. Currently no formal tests or interventions exist to address strategic learning. Bond Chapman and Gamino propose the development of testing which looks at detail and gist processing and how the brain processes both.

#### **5.4 Dynamic Skill Theory**

The significance of the neuroscience of brain plasticity is in informing the practice of educational theories. An enhanced knowledge of the mechanisms which underlay the behavioural characteristics will provide educators with valued tools for approaching remediation practices.

Fischer, (2007) asserts that there is a movement in research to relate the mind, the brain and education. He affirms an essential need for sound science, and not mere brain claims. According to Fischer, a measurement for learning is that growth cycles occur in cognitive and brain development. A common process can produce diverse pathways. Fischer believes there are pathways to reading and development problems which can be studied. These are differing pathways but with the same scale and there are visual trends associated with dyslexia. The dynamic skill theory that Fischer has developed integrates theories of education, neuroscience and psychology. A basic unit of analysis for representing individual actions, thoughts and feelings is the concept of skill. An individual's ability to control factors of behaviour, thinking and feeling within a specific context and domain is defined as a skill. A skill can be described as a control structure that refers to the organization of action an individual can maintain control of in a given context. Skills are joined with specific tasks and task domains and are not general structures. Each skill domain area develops independent of another and at different rates and with differing developmental endpoints. Fischer maintains that assessment of the development of a particular skill will not necessarily predict the developmental level of other skills. Skills and domains are context-specific. An individual's skills are capable of developing and the level of skill ability fluctuates with changes in skill domain, social context, task, emotion, time, cultural group, temperament and many other processes. Skill development is therefore uneven with variation in the level of skills demonstrated

by an individual being common. For example, an individual may be highly skilled in mathematics but only moderately skilled in socialization. An adult's level of performance may be highly skilled in one or another domain drops significantly when they begin to construct a novel skill. Skills expand through a succession of four broad tiers. Each tier comprises four levels and an indefinite number of steps between levels. These tiers include reflexes (birth to age 4 months) and include innate components of action that require stimulation for them to evoke; sensorimotor actions (4 months to 24 months) which transfers to smoothly controlled actions on observed objects; representations (2 years to 10 years) which consists of symbolic meanings about concrete objects, events and persons; abstractions (beginning at age 10-11 years) and which consists of higher order representations of abstract and intangible objects and events. Within this framework of four levels, skills develop into four distinct areas. Higher order skills develop hierarchically and help to coordinate multiple lower-level skills. Within each tier there are four levels of skill development that include sets, mappings, systems and systems of systems (Fischer and Bidell, 1998). First to develop are single sets. Here, an individual can begin to construct individual meaning or representation (example; "milk can be poured from a glass") From single sets representations, individuals begin to relate these individual representations into relational mappings (example, The pitcher has more milk in it than the glass has). Next, individuals are able to coordinate their mapping skills into a single system. A system has the capacity to relate two or more mappings. Systems of systems come together and form the first level of the next broad tier of development. A young adolescent (age 10-11) is capable of explaining similarities and differences and solve problems in context that requires them to explain the similarity between two systems. Fischer's dynamic skill theory offers conceptual and empirical tools for identifying the structure, content and developmental of a set of thoughts and behaviours as they are created and utilized within a social context and domain of action. According to Fischer, brain based education has nothing to do with neuroscience. It is not based in neuroscientific work. Fischer believes there are ample studies going on in neuroscience that are related to and that impact learning. He warns researchers to avoid simplistic neural explanations and to place the importance in building the research base for education. The goal is that educators are not "users" of scientific knowledge.

Typically there is no ground for making the connection of laboratory work and what in reality happens in the classroom. He contends there needs to be a two way collaboration between education and neuroscience.

Fischer maintains a broad confusion in research about “Stages” levels and how they emerge with clusters of discontinuities across many domains/strands. Discontinuities can include “spurts” in vocabulary growth. When children develop there can be rapid spurts of growth in vocabulary in different stages. Physical, cognitive and emotional development all grow in spurts. These occur repeatedly during development marking a series of new capacities that develop – beginning in infancy and continuing through the 20’s. There is a reorganization of many skills at 4 years of age which includes theory of mind, classification skills and beginning reading. When there is a cognitive reorganization, there is a correlating neurological reorganization. This correlates to the research in 1940 by Krogman regarding change in head circumference as a trend in the physical growth of children.

Fischer describes the concept of differing pathways in the development of reading. Three diverse pathways in the development of reading can occur. Poor readers have been found to activate alternate pathways during this skill development. Fink (1996) studied successful adult dyslexics and found that all adults still had similar weaknesses with individual tasks but were good readers. Individuals were all adult readers who said they learned to read when they were 12-15 years of age. These same subjects also indicated that they were considered “stupid” by those other adults in their environment. Schneps, Rose and Fisher (2007) studied research on visual talents in dyslexic scientists and others. Schneps et al. found that many dyslexics are better at some kinds of visual skills, such as scanning fields for patterns. Schneps et al. explain how the parameter of periphery-to-centre ratio (PCR) describes the degree of peripheral bias. They argue that this PCR evidence suggests a finding that is high in many people with dyslexia. Many dyslexic individuals tend to favour the peripheral visual field over the centre. This results in not only search deficits but also talents for visual comparison.

Research by Fink (1996) and Knight and Fischer (1992) found that reading develops in this order: word definitions relate directly to letter identification and rhyme recognition.

These skills then relate to reading recognition. In analyzing this pathway, Fisher found that there were three different pathways to reading, two of which were strongly associated with poor reading. In general there are spurts, drops, and shifts in skills.

An EEG allows one to visualize brain waves of electrical activity, mainly cortical. An EEG shows development of the brain during childhood and has electrical activity in the brain being produced in fits and starts. Growth process occurs across brain areas, cyclically, providing neural grounding for cognitive changes. There is a change in the neural network, producing change in tuning of circuit, marking successive levels.

## **5.5 Interventions**

The implications for brain plasticity and reading acquisition are numerous. As reading acquisition is a challenge to plasticity of the brain because of its various areas of activation it is important to examine the relationship between neural functioning and phonological skills that make up reading. According to Zeffiro and Eden (2000) recent research into both the nature of the structural and functional abnormalities in developmental dyslexia and the functional neuroanatomy of reading have quickly advanced understanding of the localization of the processes responsible for the signs and symptoms of dyslexia. Current research in brain plasticity, language processing and reading has shown that individuals with dyslexia would benefit from interventions that are aimed at reworking failing language processing networks. The neuroscience of plasticity should be linked to the practical applications of remediation for those with dyslexia.

Just (2007) found changes in the brain's activity after intervention was undertaken. Intervention focused on word level instruction for poor readers. After the intervention, these same poor readers were found to have increased activation in the brain areas which were previously underactivated. Just concluded that the brain deficit disappeared after intervention. In a previous study done by Just et al (2004) brain tissue was examined after interventions. Just et al found that, for reading, numerous cortical areas activate during these tasks. They conclude that collaboration and communication are ongoing

between these areas of the brain and that research must focus on measuring the interaction between these networks to better understand brain plasticity and reading ability. Blachman (2004) conducted studies of neurobiological changes when emphasizing phonemic awareness tasks for intervention purposes. The study group was found to have increased brain activation following the intervention and these gains held when participants were retested a year later.

Gaining a better understanding of the biological bases and heritability of dyslexia allow researchers to identify correlates of the primary causes of dyslexia as well as the characteristics associated with the disorder. These will further inform efforts towards appropriate remediation and intervention for both the pre-literate child and the dyslexic reader.

## 6. Identification of factors related to literacy in pre-reading children

### 6.1 Introduction

In 2006, Sir Jim Rose presented an independent review of the teaching of early reading. His report described the findings of research, practice and policy and their impact on the National Literacy Strategy undertaken in 1998 as well as the Early Years Foundation Stage. This report outlined best practices for beginning readers, those in Key Stage 1 and 2 and support for children who experience significant literacy difficulties.

It is imperative that reading difficulties be assessed as early as possible so that targeted interventions can be implemented for the child. According to the Primary National Strategy (2003), children with reading difficulties would be best served by an intervention program that allows them to remain within their regular classroom setting and includes further small group support and systematic instruction.

Developmental reading disorders are one of the most common of childhood disorders as well as one of the most incessant (Hindson, Byrne, Fielding-Barnsley, Cara Newman, Hine and Shankweiler, 2005). Research has focused considerably on early identification and screening of reading problems. The identification and remediation of learning disabilities in school-age children has had a heightened focus in research (Litcher and Roberge, 1978). Studies indicate that early intervention can prevent subsequent reading problems (National Institute of Child Health and Human Development (2006); Slavin, Karweit and Wasik (1994). Prompt identification of children who are likely to develop reading difficulties is valuable because evidence indicates that early intervention can impact an individual's future literacy growth (Byrne, Fielding-Barnsley, & Ashley, 2000). Gallagher, Frith, and Snowling (2000) empathize that understanding the cause of later reading and spelling difficulties is done by examining the readiness of various subskills in relationship to later reading ability. Typically, formal instruction of literacy

begins when children enter primary school (Shaywitz and Shaywitz, 1994). Between 3 and 6% of school children are believed to have developmental reading disabilities and up to 50% of all children receiving special education display signs of reading disability (Frost and Emory, 2008). Although this prevalence rate is often cited in research on dyslexia, in practice children have often attended formal primary age school for lengthy periods before they are identified with a reading disability. Therefore much valuable time has elapsed in providing effective intervention methods to remediate the deficits. The effect of reading problems is significant for the children who struggle with proficient reading skills. Because of this impact, researchers have pursued early identification and treatment of reading disabilities (Snow, Burns and Griffin, 1998). The search for causal factors of reading disabilities is a primary focus of researchers. Catts and Hogan (2003) argue that the best evidence for a causal basis of reading disabilities arises from the study of language difficulties in poor readers. Their review of the current research on the language basis of reading disabilities highlights the implications of early identification and intervention.

Although there are some cultural exceptions, the majority of writing systems are based on language units. Written language is a transcription of what might be said orally. In the field of literacy development it is generally established that within the English language is more difficult to learn to read and write (Rose, 2003). There are linguistic differences between spoken and written language, yet spoken and written language utilize similar linguistic processes (Catts and Hogan, 2003). Previously researchers believed that children who could talk and understand spoken language would have no difficulty with phonological awareness. Phonological core deficits involve problems making use of phonological information during the processing of written and oral language (Frost and Emory, 2008). When there is a lack of appropriate development in the automaticity of subskills the ability to become a fluent reader is undermined. According to the model of automaticity developed by LaBerge and Samuels (1974) reading is becoming increasingly fluent as the development of automaticity of the subskills increases. This is important since the intervention of phonological skills can be crucial to the later development of fluency. The initial stage of the subskills in this model require the ability

to visually decode and the unitization of visual stimuli such as letters, spelling patterns, words and sight word units (Wolf and Katzir-Cohen, 2001). Research has supported a large variability in phonological awareness skills with children who have been reported to have normal language development. Torgeson (1996) reported that dyslexic children show more deficits in phonological awareness than with any other ability required for reading. Poor readers may also display difficulties in other language skills such as vocabulary, morphology, syntax and text-level processing (Fletcher, 1981; Stanovich & Siegel, 1994; Stothard & Hulme, 1992). These language difficulties impact word decoding. More importantly, they have the largest impact on comprehension. Children with difficulties in vocabulary, morphology, syntax and text processing are unable to extract proper meaning from printed language. Therefore, it makes sense that reading deficits in many children can be prevented if diagnosed early and implementation of research based interventions are in place.

A criticism of early screening is that young children have not received any formal reading instruction and therefore this lack of instruction makes it difficult to assess skills related to reading (Fawcett and Nicholson, 2000). Catts and Hogan (2003) describe a significant link between early language deficits and reading disability. Over 50% of children with deficits in vocabulary and/or grammar at preschool age were identified as having reading difficulties at primary and secondary grade levels. In a far-reaching study of 200 kindergarten children identified as having language deficits, 52.9% of these children in 4<sup>th</sup> grade scored below average on an assessment of reading comprehension (Catts, Fey, Tomblin, & Zhang, 2002). The study also found that children with lower nonverbal abilities and language impairment scored significantly lower in reading achievement than those children with high nonverbal abilities. Snowling (1998) suggests that the convergence of evidence from studies of dyslexia as well as the normal development of reading allows practitioners to both identify children at risk of dyslexia as well as provide early intervention. If researchers and practitioners merge their understanding, those with a family history of dyslexia, a history of speech-language difficulties and those at risk of reading disability can be significantly facilitated.



If the precursors to the reading process are identified, one can take a predictor approach to the identification of early reading problems (Vloedgraven and Verhoeven, 2007). The intervention process must be clearly understood in order for preschool children to benefit completely from remediation (Hindson, Byrne, Fielding-Barnsley, Newman, Hine and Shankweiler, 2005). Because research has indicated that language difficulty is related to reading disabilities, it is possible to use the identification of language deficits as an indicator for early detection of preschoolers at risk for reading disabilities. Catts and Hogan propose that this most prominent sign of later reading deficits, a developmental language impairment, can be identified during preschool years. They indicate that children with milder language impairments or problems in phonological processing must be recognized as “at risk” for reading disabilities. Snowling, Bishop, & Stothard (2000) report a longitudinal study of children who were diagnosed at age 4 (through a study by Bishop and Edmunson, 1987). These children were found to be behind their peers in performance on vocabulary growth over time. Snowling et al. describe the impact on reading and spelling skills in relation to early language and literacy skills. Children with language impairment are at risk for literacy difficulties “in terms of the cognitive processes required for learning to read”. Moreover, Snowling et al, report in their study a cautionary approach. Children whose phonological impairments persist beyond age 5 ½ are at greater risk for reading problems as the range of vocabulary the child encounters becomes increasingly more complex and the processes of syntactic, semantic and pragmatic language skills play a greater role in the development of literacy. Children at 2 ½ years of age who have gone on to be identified as dyslexic were able to utilize a wide range of vocabulary in conversation, but had a more restricted breadth of syntactic ability and were found to make more speech production errors (Gallagher, Frith, Snowling, 2000).

While developmental reading disorders have been identified as one of the most incessant of childhood disorders, more multifarious analyses of the cognitive and behavioural risk characteristics need to be identified. Bus and van Uzendoorn (1999) propose that prompt identification of young children, along with evidence of early intervention benefits is important in providing potential for literacy growth. In addition, they argue that a clear

picture of those characteristics that define and predict responsiveness to early intervention is required. They suggest that early intervention enhances the future potential of literacy growth. Children who receive appropriate early intervention could possibly avoid future reading failure (Snowling, 1998). Bond and Dykstra (1967) emphasize that a child's success in learning to read is dependent upon familiarity with print, auditory and visual discrimination skills, and intelligence. The ability to match letters during first grade correlated (.87) with the ability to recognize words later in that year (Smith, 1928). In fact, those variables that predict subsequent reading skills vary dependent on the theory of reading which initially led to the development of the screening battery and measures that were evaluated by researchers (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004).

Stanovich (1994) proposes that phonological awareness is one of the strongest predictors of reading skills. Much of research describing intervention approaches to reading disability focus on systematic and sequential presentation of the skills that comprise phonological awareness. Stanovich (1994) argues that phonological awareness can be indicated as more important than intelligence, vocabulary and comprehension in the process of reading development. Stanovich (1992) presents a continuum of phonological awareness that ranges from deep to shallow sensitivity. Ball (1993) organizes phonological awareness into categories of "emerging", "simple" and "complex". Children with strong phonological awareness skills at preschool age are later found to show strong reading skills. Children with poor phonological skills typically are found to have poor reading skills as well (Carroll, 2004). Instruction in phonological awareness skills improves subsequent reading ability (Bradley & Bryant, 1978). Phoneme awareness at preschool age is not ordinary in preschool age children and is developed when children reach primary school age. Goswami and Bryant (1990) propose that the awareness of syllables and rimes is found at preschool age and later develops into the awareness of phonemes. Scarborough (1998) credits this weakness in phoneme awareness in preschoolers to the modality of assessment. She contends that phonological awareness skills are assessed at the onset of schooling when even those who will become normal readers have not achieved much appreciation of phonological structure of

language. This makes them impossible to differentiate from those children who will later develop reading problems. Schatschneider et al. (2004) believe this is causally related to the fact that many preschool children have not had formal training in phonological awareness. This skews the effects for researchers depending on how phonological awareness is assessed.

Gallagher, Frith and Snowling (1996) assert that by three years of age a child with familial risk will demonstrate difficulty in a number of phonological tasks. These tasks include development of vocabulary, word repetition and alphabetic knowledge. The developing relationship between written and spoken language is crucial to this group. Stuart (2005) summarized differing levels of phonological awareness and the subsequent influence on reading development.

Gallagher, Frith and Snowling (2000) contend that a large body of empirical evidence supports the contention that primary deficits occur in the phonological domain for those with dyslexia. This includes deficits in phonological awareness and phonological processing. Therefore, they propose, that children with dyslexia show deficits in verbal short-term memory, verbal naming deficits and nonword repetition. To assess the weight of various language skills on later literacy development, Gallagher, et al. conducted a series of regression analyses studies. Results from five literacy tests, (including non-verbal ability, vocabulary development, expressive language, speech development, phonological processing, phonological awareness and literacy skills) were used. A literacy outcome measure was derived and all measures were loaded highly on a sole factor described as “Literacy” which accounted for 85% of the variance. Scores from preschool tests of oral language and nursery rhyme knowledge were analyzed. These results carried high loadings from Language variables, specifically receptive and expressive vocabulary, expressive language and nursery rhyme knowledge (51.9% of the variance). The second factor accounted for 17.2% variance and had high loadings from immediate and delayed nonword repetition and speech motor articulation. This second factor was labelled “Speech”. Each child’s performance on the tests labelled “Language” and “Speech” were used as predictors through multiple regression analysis in predicting literacy development for age six. The most relevant predictor of “Literacy” was letter

knowledge (at 45 months of age). Performance IQ (PIQ), Language and Speech at age 45 months also showed significant results (Performance IQ=  $p < .05$ ; Language=  $p < .05$ ; Speech=  $p < .05$ ). When familial risk was included in the prediction of Literacy skills at age 6 and a multiple regression was performed, the strongest predictor of literacy development at age 45 months was letter knowledge. The results of their study have critical implications for intervention studies in developing phonological knowledge and therefore skill in reading. In this study, Gallagher et al. found that 57% of children with familial risk of dyslexia scored more than one standard deviation below the mean of the control group when both groups were of similar socioeconomic status. In addition, the at-risk group was found to have been exposed to similar amounts of linguistic stimulation as the control group. It was interesting to note, then, that when viewed in this framework, the difference in letter knowledge between both the at-risk group and the control group was significant. At-risk, children experience more difficulties with learning letter names and sounds than the control group. Therefore, it was concluded, letter knowledge is an important predictor of reading ability and is related to difficulties in vocabulary development. Anthony and Barker found a relationship between phoneme knowledge and letter knowledge in the preschool years. A close relationship between letter knowledge and phoneme awareness has been found and suggests that intervention studies focused on teaching both letter knowledge and phoneme awareness could be effective at improving later reading skills (Carroll, 2004).

As research supports the causal role of phonological awareness, analysis of the factors that contribute to the prediction of reading is essential. In a study by Badian (1994) at Harvard University and the Children's Hospital of Boston, Massachusetts, 118 children were tested prior to entry into kindergarten and then followed up at 19 and 24 months subsequent to the kindergarten year. The aim of the study was to determine whether adding the chosen measures of naming speed, phonological awareness and orthographic processing would better predict reading ability. Prior research by Badian (1982; 1988; 1990) and Carran and Scott (1992) recommended further analysis of the Holbrook Screening Battery (HSB) and the Satz and Friel (1974) screening battery to increase reliability and predictability of validity indicators and risk indices. Additional subtests

were added to the Holbrook Screening Battery for analysis. These included Rapid Automatized Naming of Objects (RAN), syllable tapping and visual orthographic matching (Denckla and Rudel, 1974; Mann and Liberman, 1984). Analysis of Rapid Automatized Naming was essential because of the weight of research finding a relationship between naming speed and later reading ability as highlighted in chapter 2. A significant relationship between kindergarten naming speed of letters and numbers and later reading ability is recognized (Wolf 1984; 1991). Wolf (1991) makes a case in her research that all naming speed tasks are able to predict later reading skills as any visual naming task performed under timed conditions seem to be tapping sub processes that underlie reading. Badian (1994) contends that the measure of syllable tapping is capable of testing phonological awareness. Phonological awareness is significantly related to later reading ability and syllable tapping usually develops as a result of reading instruction (Torgeson, 1987; 1995). The syllable tapping measure requires preschool children to tap the number of syllables in words (maximum of 3 syllables). This is supported by research from Mann and Liberman (1984) who propose that preschool children are unable to segment words by phonemes but that 46% of preschoolers were able to segment words by syllables. Mann and Liberman believe that phoneme segmentation has a mutual relationship with reading whereas syllable segmentation is not confused by reading ability. The effectiveness of remediation using phonological information for word finding deficits were analyzed (McGregor, 1994). McGregor proposed that both individuals from the study were unable to repeat any of the three-syllable words presented on the test. He contends that phonological encoding deficits become more evident in children with language deficits as the complexity of the phonological information increases. The intervention method included presentation of eight semantically related words. Words presented included the same initial sound and number of syllables as a target word. Children were required to produce the first sound in the name of the pictured item. Children were also asked to determine the number of syllables in the pictured item and provided with visual aids (cards with the number 1 or the number 3) to assist in counting the syllables. The children were requested to tap out the number of syllables in target words and after several sessions could orally segment the word into syllables with the help of the visual aids. McGregor noted a generalization

effect prior to intervention decreased following the treatment. Initially, words that were similar in segment or shape to the target were often confused (i.e. rouge/rose). He proposed that this generalization effect was reduced due to the phonological treatment, which had an effect of reducing phonological errors for words used in the training and for words that were semantically and phonologically related to those words.

Finally, visual orthographic matching was supported by research (Adams, 1990; Bowers and Wolf, 1993) that acknowledges the relationship between phonological knowledge and orthographic knowledge. Many tasks, including nonword reading require phonological processing and orthographic knowledge. Adams (1990) believes a child's ability to recognize letters, patterns of spelling and whole words is the most crucial factor in skilled reading. Adams model of reading has implications for intervention in that it involves an association between orthography, phonology, meaning and context processing. The orthographic processor is the only processor in the model to receive direct information from the printed page. In studies of primary age school children, orthographic processing ability was significantly related to word recognition (Cunningham and Stanovich, 1993). The visual orthographic processing task analyzed by Badian required subjects to visually match single letters and sequences of two to four letters or numbers. This adaptation from typical visual matching tasks was selected because prereaders are unable to perform the task of matching real and pseudo words. Of the initial 153 children entered into the study by Badian, 31 children were withdrawn as they had moved from the school district where the study was being undertaken. The mean age of the remaining children in the study was 60.2 months at the initial phase of the study. Preschoolers who were unable to read any words and preschoolers who could read few words were classified as non-reading preschoolers (93%). Preschoolers who read many words or books were classified as preschool readers. At follow-up testing during the early part of first grade (mean age 79.3 months) there was a wide discrepancy in reading ability. Subtest results for children classified as poor readers in the first grade were analyzed showing significant deficits in spoken language, visual matching, sentence memory, naming of letters and naming of colours and shapes when compared with strong readers. Children who had been identified as non-reading preschoolers were inferior on

visual matching and syllable tapping to those identified as preschool readers when evaluated during the early part of first grade. Children identified as preschool readers performed superior to non-reading preschoolers in object naming speed and letter naming. Analysis of orthographic knowledge found that preschool readers performed superior on the orthographic task. Additionally, children identified as non-reading preschoolers who were identified as good readers during first grade analysis performed significantly superior to those identified as average and poor readers during this same time period. Badian's analysis of the three additional subtests for the Holbrook Screening Battery found that when using Stanovich's continuum or Ball's classification of phonological awareness, Syllable Tapping of large word units is a relatively shallow measure of phonological awareness. Phoneme deletion tasks which are considered more complex in the system have a stronger correlation with reading, but Badian argues that the relationship is more reciprocal than causal. Preschool children are typically unable to perform complex phoneme awareness tasks. However, various studies have assessed preschool age children on rhyming tasks successfully (MacLean, Bryant, and Bradley, 1987) with rhyming ability found to significantly predict later reading skills. Findings of the orthographic matching task possessing a strong correlation with later reading and spelling skills is consistent with other research (Adams, 1990) indicating the important relationship between orthographic knowledge and reading. Badian concludes that the three measures of phonological awareness, naming speed and orthographic processing in the Holbrook Screening Battery do contribute of prediction of early reading skills. She proposes that these subtests, along with letter naming and a rating of preschool reading ability account for 60 percent of the variance in word reading/spelling. The orthographic matching task was responsible for more than half of this variance.

## **6.2 The Alphabetic Principle**

If the core of information processing lies at the ability to decode visual symbols, then the true foundation of phonological knowledge lies in the alphabetic principle. The alphabetic principle is the foundation for languages using an alphabetic system. Rose (2006) states "all beginner readers have to come to terms with the same alphabetic principles if they are to learn to read and write". The alphabetic code is a system of

correspondences between graphemes (written symbols) and phonemes (sounds) and connects the written word to its pronunciations. Preschool children begin to be aware of the fact that phonemes can be represented by letters and that words are composed of letters that represent sound. Whenever a particular phoneme occurs in a word, regardless of the position, it can be represented by the same letter (Byrne and Fielding-Barnsley, 1989).

Understanding of the alphabetic principle is a requirement of reading in an alphabetic script. Rose (2006) implores that it cannot be left to chance for preschool children to “ferret out on their own how the alphabetic code works”. In order for children to master the alphabetic principle they must be taught the system systematically and explicitly. The alphabetic principle can be defined as more extensive appreciation of the letter sound relationship than mere letter-sound knowledge. One can have knowledge of letter names and their pronunciations but not have the understanding that these letter sounds are parts of words. The alphabetic principle lies between the knowledge of actual letter sounds and subsequent reading ability (Byrne and Fielding-Barnsley, 1989). Young children exposed to the letters of the alphabet should be taught the letter sound correspondences sequentially. When a child is exposed to and instructed in alphabet knowledge the visual features in letters become unitized and subsequently perceived as a single unit. These units begin to accumulate and letter knowledge thus becomes automatic (Wolf and Katzir-Cohen, 2001). Tunmer and Nescale (1985) agree that ability in letter identification does not mean ability in non-word decoding. They argue that some phonological awareness must be present in order for a child to gain meaning from letter-sound knowledge. Wagner and Torgeson (1987) maintain that an individual with well developed phonological processing the alphabetic system in which they work makes sense. In their study, Byrne and Fielding-Barnsley (1989) hypothesized that phonemic awareness and letter knowledge are needed in combination in order for an individual to have knowledge of the alphabetic principle. They found that children who were able to read just a small group of words (2) which differed in a single letter were able to recognize the role of these differing letters in unknown words if they understood three distinct concepts: (1) that phonemes represented by letters are separate segments in each



word, (2) that these same phonemes can also occur in other words, and (3) an understanding of the association between the distinguishing letters and phonemes in the known word groups. The researchers discovered that in order to facilitate transfer of this letter-phoneme mapping ability it was necessary to instruct them in the segmental structure of the words taught (e.g., “m...at”), to identify the initial consonants of words taught (e.g., “m” in mat and mow) and the sounds produced for the initial letters in the words taught (e.g. “m” and “s” sounds for mat and sat). Concepts 1 and 2 are described by Byrne and Fielding-Barnsley as phonemic awareness ability and concept 3 is described as letter-sound association. They contend that phonemic awareness ability and letter-sound association were needed in combination in order to acquire the alphabetic principle. Neither phonemic awareness nor letter-sound association were sufficient alone to gain this principle.

A follow up study by Byrne and Fielding-Barnsley (1990) supports the hypothesis that phonemic awareness is causally related to the alphabetic principle. In this study the instruction of phonemic awareness in final position of the word was conducted (as well as in initial position as described in chapter 3). Results show that preschool age children were successfully taught to recognize the identity of phonemic segments of both vowels and consonants across words. There was no advantage in learning the initial position letters versus the final position letters. They concluded that successful instruction in phoneme identity and letter sound knowledge can promote acquisition of the alphabetic principle. This phonological organization instruction can aid children in learning to read. Instruction in letter identity is additionally suitable for discovery of the alphabetic principle. Segmentation ability is also associated with the alphabetic principle but is not as strong in transfer in both experiments conducted by Byrne and Fielding-Barnsley. Once it is established, the alphabetic principle is a robust metalinguistic ability.

Smith’s study (1928) first introduced the hypothesis that letter knowledge is an outstanding predictor of reading achievement. Satz, Taylor, Friel & Fletcher (1978) found that letter knowledge had a strong predictive ability to reading. Jansky and de Hirsch (1972) found letter naming was correlated to second grade reading success. Letter matching tasks are viewed as examples of visual discrimination ability (Silver and Hagin,

1975). Studies which analyze the function of the alphabetic principle in acquiring reading skills have been successfully conducted on children as young as preschoolers. These young children have demonstrated that in as little as three to four short intervention sessions (Byrne & Fielding-Barnsley, 1989; Bradley & Bryant, 1983) it is possible to teach phonemic organization and letter-phoneme associations that have a lasting effect.

### **6.3 Dyslexia and the development of reading**

The Independent Review of the Teaching of Early Reading (Rose, 2006) stresses concern regarding the weak performance of up to 15 per cent of children who are unable to reach the target level for their age in reading when they reach the end of Key Stage 1. Up to 16% of children are unable to reach their target age of reading by the end of Key Stage 2. Rose argues that these figures might show improvement if teachers emphasized the importance of phonic knowledge during instruction and that it was taught more thoroughly than at present.

A key stage is a stage of the state education system established in the UK which sets the expectations of educational knowledge for students at each age. Foundation stage typically covers nursery and reception years which are ages 3-5. Following is key stage 1 for ages 5 to 7 and designated as years 1 and 2. Key stage 2 is assigned to ages 7-11 and includes years 3 to 6. Key stage 3 is indicated for ages 11-14 and years 7-9. Key stage 4 is designated for ages 14-16 and for years 10-11. Typically at the end of this stage, GCSE exams are given. Key stage 5 is also described as the sixth form and is for ages 16-18 and years 12 and 13. Following the sixth form years assessments of A-levels or AS levels are provided.

The *Every Child Matters* agenda under the Children Act of 2004 describes five outcomes for children: Being healthy, staying safe, enjoying and achieving, making a positive contribution and achieving economic well being. Rose, in his report, indicates that “literacy must be seen as a fundamental part of that agenda and (is) crucial in narrowing the gap in outcomes between those who do well and those who do not”.

When an individual lacks phonological awareness, the relationship between sound and symbol for them is variable. Scarborough (1990) argues that dyslexic individuals present a range of changing language difficulties over time during their development. In his research, he reveals that children who later were identified as dyslexic used a range of vocabulary in discussion but a more restricted range of syntactic devices as well as more speech production errors when tested at 30 months of age. At 36 and 42 months in assessments of receptive and expressive vocabulary, Scarborough found that these traits were less developed than the control group and syntactic difficulties remained in the study group. Snowling, Bishop and Stothard (2000) support this contention with their position that certain links between language development and literacy arise from studies of the precursors to dyslexia in preschool years. Snowling cites Scarborough's research, as well as research by Gallagher, Frith & Snowling to assert that delays in acquisition of oral language skills and phonological deficits lead to reading disabilities. In addition, it is conceptualized that since dyslexia is a developmental disorder, it should be recognized that language skills that contribute to literacy development change over time and therefore can place children at risk for failure at any time on the developmental continuum.

Ehri (197) describes four relationships between phonological abilities and reading:

1. Phonological ability may be a prerequisite of reading whereas the acquisition of reading is impaired without it.
2. Phonological ability may operate as a facilitator and children with the ability acquire reading skills more rapidly than those without it.
3. Phonological ability can be a consequence of learning to read rather than a cause of reading ability.
4. Phonological ability may be a correlate of reading ability—related to the ability to read via a shared relationship with a third factor such as IQ.

The investigation into causal relationships between phonological processing and reading ability is necessary for gaining knowledge for what occurs during a child's development to impact reading ability. Researchers must be cautious when examining the

relationships between reading and phonological abilities as the “third factor” correlate may impact relationships between two factors (Wagner and Torgeson, 1987).

It is relevant to make a distinction between literacy and English. In bearing on the National Curriculum and The National Strategy in the United Kingdom, the responsibility of ensuring the necessary skills is set out in the National Curriculum Orders for English at Key Stage 1. Rose (2006) describes literacy skills as reading, writing, speaking and listening and which are essential cross-curricular skills not necessarily confined to English lessons. The guidelines set out by his review of the teaching of early reading propose a programme of study for reading which includes phonemic awareness and phonological knowledge taught as early as foundation stage and throughout Key Stage 1. For reading, Rose proposes the included teaching of:

- Hear, identify, segment and blend phonemes in words
- Sound and name the letters of the alphabet
- Link sound and letter patterns, exploring rhyme, alliteration and other sound patterns
- Identify syllables in words
- Recognize that the same sounds may have different spellings and that the same spellings may relate to different sounds

For writing, the child must be taught to:

- Write each letter of the alphabet
- Use their knowledge of sound-symbol relationships and phonological patterns (for example, consonant clusters and vowel patterns).
- Write familiar words and attempt unfamiliar ones.

Rose’s skills included for the systematic teaching of reading and writing are essential content for learning. The National Curriculum respects this phonics work as a critical component for learning. A statutory part of the National Curriculum was begun in 2000 and introduced as the Foundation Stage. This stage occurs when a child reaches the age

of three. The foundation stage promotes a child's abilities at this age and begins to prepare them for learning in Key Stage 1. According to the National Curriculum, the Foundation Stage includes three relevant components: communication, language, and literacy. Foundation Stage children must be taught to hear and say initial and final sounds in words, to hear and say short vowel sounds in words, connect the letter sounds to letters and name the sounds of each letter in the alphabet and finally to use this phonic knowledge in writing regular and simple words and to endeavour at more complex words.

There is more debate as to the swiftness in which the alphabetic code should be taught in this stage than in the belief that teaching the alphabetic code is appropriate to begin teaching at this point. There is widespread agreement among researchers and practitioners that the alphabetic principle is vital in its emphasis given for teaching during the preschool learning years. The National Literacy Strategy's publication guidance, *Progression in Phonics (PIPs)* states:

*Phonics consists of the skills of segmentation and blending, knowledge of the alphabetic code and an understanding of the principles which underpin how the code is used in reading and spelling.*

#### **6.4 Interventions Methods**

The history of research in developmental reading disability has been wide-ranging. Studies on the role of phonological processes in reading disability and intervention have shown to be both successful and insufficient in recognizing the complexity of reading breakdown (Wolf & Katzir-Cohen, 2001). Complicating the matter is the discrepancy in causal factors in dyslexia which lead to copious approaches to reading intervention. Attempts to develop interventions that reflect the predictive ability of naming speed in reading failure (Wolf and Bowers, 1999) as well as studies that investigate time related deficits in several perceptual and motor areas (Nicolson & Fawcett, 1994) have been conducted. There is a large body of research demonstrating that there are individuals with dyslexia who have single deficits in naming speed or phonological processes or who display double deficits in both areas (Badian, 1996, Lovett, 1987, Wolf, Bowers &

Biddle, 2000). Analysis of previous research in reading disability and intervention by Wolf and Katzir-Cohen (2001) suggests that researchers have much to learn from preceding work in theoretically based phonologically focused treatment. They argue a greater concentration of effort must be made in defining fluency, monitoring its structure and understanding the range and type of processing speed and fluency deficits in reading subtypes as well as applying this knowledge to the development of intervention plans. Litcher and Roberge question the effectiveness of programs for the remediation of children's reading disabilities that are adopted through the schools' special education programming and used in lieu of the regular school reading curriculum. They believe the considerable expense involved in the implementation of these remediation programs has raised questions to their effectiveness. Litcher and Roberge presented a three year longitudinal study in which they compared children identified as "at risk" for reading difficulties and children not at risk for reading problems. Two remediations were compared as intervention programs were used on the at risk groups within a special instruction classroom. The control group were matched first grade age children who were placed in a regular classroom for regular instruction. The intervention used consisted of a "highly structured method of teaching the phonetic units in reading". The programming was based on a sequence of teaching this method which was developed by J.L. Orton in *A Guide to Teaching Phonics* (1964). The children in the study group received the intervention program for approximately three hours per day during the course of the school year. The control groups were taught by typical traditional methods being used in the first grade during that school year – using a basal reading series. Litcher and Roberge found that the study group outperformed the control group significantly on all subtests of the Gates-MacGinitie as well as the Metropolitan Achievement Test. The study groups' scores were significantly higher in performance than the control group on these tasks. The authors make a case that methodology in this systematic structured approach to remediation was effective in teaching this at-risk group to be better readers. It was determined, in this study that the teaching of a sequential program on phonetic units with multi-sensory integration made for significantly higher levels of reading performance in the experimental at-risk group than in the control group.

The limitation of this study is in its lack of comparison of other remedial intervention methods which might be just as effective as the one studied.

The argument for a systematic, sequential approach to teaching literacy is supported by many researchers in the field (Rose, 2006; Torgerson, Brooks, & Hall, 2006; Johnston and Watson, 2005). Synthetic Phonics is an approach to teaching literacy and to intervention that has been touted as the program “that offers the vast majority of beginners the best route to becoming skilled readers” (Rose,2006). Synthetic phonics directly teaches the knowledge of phonics that children must know in order to read. It sets out the principles of phonological knowledge in a systematic format and does not require a young child to infer meaning from the teaching. Teachers who practice this method of systematic teaching have indicated that during this process of systematic teaching, the child may begin to “self-teach” literacy skills. A great deal of practice is required in order for the child to consolidate their skills, to become a more fluent reader and to better comprehend the text. The key features of a synthetic approach to teaching phonics are outlined by Rose (2006):

- Grapheme/phoneme (letter/sound) correspondences (the alphabetic principle in a clearly defined incremental sequence
- To apply the highly important skill of blending (synthesising) phonemes in order, all through a word to read it
- To apply the skills of segmenting words into their constituent phonemes to spell
- That blending and segmenting are reversible processes.

Johnston and Watson (2005) present research of the effects of synthetic phonics teaching on reading and spelling skills. Three hundred children of primary grade level were divided into three study groups. Group one was instructed in the synthetic phonics approach, group two was given instruction in the standard analytic phonics approach and group three was presented with the standard analytic phonics programme which included a systematic phonemic awareness element. After the programming was completed, Johnston and Watson found that the group which was presented instruction in the synthetic phonics method performed significantly better than the other two groups for

reading and spelling. The synthetic phonics program was found to be more effective than an analytic phonics approach even if the analytic approach was supplemented with phonemic awareness training.

Intervention studies that focus on phonological processing difficulties concentrate on the relationship between auditory processing and phonological awareness. Auditory processing occurs as a lower level activity in the brain which recognizes and interprets sounds presented in an auditory manner. Phonological awareness arises as the individual notices, thinks about and manipulates the individual sound in a word. Goldsworthy (2003) presents several intervention methods which target auditory processing and phonological processing. The first, auditory processing, includes nine goals with suggested strategies presented as auditory processing/perceptual skill goals:

1. To increase auditory decoding through phonemic discrimination problems
2. To increase auditory decoding through decreasing temporal pattern recognition/use problems
3. To decrease auditory processing problems secondary to auditory figure/ground problems
4. To decrease auditory processing problems secondary to auditory selective attention problems
5. To decrease auditory processing problems secondary to poor auditory memory
6. To decrease auditory processing problems through increasing binary integration
7. To increase simple receptive language
8. To increase listening comprehension
9. To increase verbal repetition

Goldsworthy additionally suggests six inherent goals for use when phonological awareness is impaired. She indicates intervention must include teaching strategies which should include a combination of these goals:

1. To increase phonological awareness at the word level: implicit teaching
2. To increase phonological awareness at the word level: explicit teaching



3. To increase phonological awareness at the syllable level: implicit teaching
4. To increase phonological awareness at the syllable level: explicit teaching
5. To increase phonological awareness at the phoneme level: implicit teaching
6. To increase phonological awareness at the phoneme level: explicit teaching

Alternatively, a curriculum based assessment and therapy technique was examined to teach receptive vocabulary to children with specific language deficits. Wing (1990) found that children with language impairments gain more from interventions focused on phonological and perceptual components of the word retrieval process than a traditional approach which focused on semantics. In his study, intervention methods presented pictures of vocabulary words used to train phonological segmentation activities. Children were required to name each picture, segment the name while touching a series of small squares on a paper grid and then count the number of squares touched. Additionally, they were required to match objects and pictures that rhymed and supply rhyming words for words presented orally. Further activities to support word retrieval included imagery activities which were incorporated to increase the ability to process visual and auditory perceptual information. Children were instructed to close their eyes and visualize the auditory presentation of the picture or object presented. Results of the study described the remediation as “effective”. The intervention study was argued to have implications for the teaching and assessment of receptive vocabulary and the development of reading ability.

Snowling, Bishop and Stothard (2000) report a potential meta-study of Bishop and Edmundson (1978) of a group of children identified as speech-language impaired at 4 years of age. According to this initial study, those who had significant language difficulties from this group at age 5 years 6 months had impairments in all areas of spoken language at age 15. Snowling et al consider the reading and spelling skills of this group in correlation with their preschool language and literacy status. They question the commonality of dyslexia among adolescents with specific language impairments at preschool age. In addition, they explore the rate of literacy problems and their increase between middle childhood and adolescence. The research established that children with a history of specific language impairment at preschool age also have poor literacy skills in

adolescence. Snowling et al found that those who had phonological impairments at 4 years of age could be considered at higher risk for specific reading difficulties. This was based on the finding that the study group showed impairments in phonological processing tasks and nonword reading skills at 15 years of age, even though their reading outcomes were relatively normal. They report that the cognitive similarity between this study group and the “classical” definition of dyslexia was notable. However, the authors note that the initial longitudinal study did not include assessments for phonological awareness at the preschool age. Tests of rime and alliteration were attempted but were discarded when the majority of preschool children in the study were unable or unwilling to attempt these tasks. Therefore the sole measure of phonology in their research was limited to naming tasks. Hindson et al (2005), in their study of preschool identification and intervention, determined that those variables they selected to assess in preschoolers have already been identified as predictors of reading ability. These included tests of phoneme identification, rhyme recognition, letter knowledge, knowledge about print, receptive and expressive vocabulary, and block design (a nonverbal ability subtest of the Wechsler Preschool and Primary Scale of Intelligence). In addition, assessment of temperament was obtained with a parent/teacher questionnaire. Gallagher, Frith and Snowling (1996) assert evidence that includes recall of nursery rhymes as significant to the development of phonological knowledge. Bryant, Bradley, Maclean and Crossland (1989) argue that a preschooler’s knowledge of nursery rhymes will predict later success in reading development. Other researchers, such as Macmillan (2002) disagree.

Hindson, Byrne, Fielding-Barnsley, Newman, Hine and Shankweiler (2005) report a longitudinal intervention study of preschool children who were at familial risk for dyslexia. The purpose was to obtain a clear picture of those characteristics that respond to early intervention of pre-reading skills. Previously known predictors of reading ability were administered, including letter knowledge, digit span and word repetition, rapid naming, rhyme ability and vocabulary. Additional measures of speech perception were included as review of some studies showed differences between controls and preschool children from reading disabled families with deficits in speech production. These children showed weakness in pronunciation of consonants. Hindson et al. included two

variables not previously studied in preschool children. These were word identification and articulation rate. They believe word identification aids in discriminating older reading disabled children from non-disabled readers. Articulation rate is reported to have a relationship with verbal working memory. Block design, Raven's Coloured Progressive Matrices and visual matching was assessed to determine nonverbal abilities.

The significance of phonological awareness to later reading ability was emphasized in Chapter 3. Historically, intervention research has confirmed the importance of phonological awareness and supported its relationship to reading acquisition (Smith, Simmons & Kimeenui, 1995; Snyder, 1997). With more significance than intelligence testing or vocabulary acquisition, phonological awareness has been proven to be a strong predictor of reading ability (Griffin and Olson, 1992). The study of phonological awareness and intervention methods which focus here have the potential for the foremost impact in the science of reading (Ellis, 1997). Systematic instruction in phonological awareness for preschool children—specifically instruction in segmenting sounds of words and recognition of letters that represent the sounds and words taught has had a positive effect on spelling and reading ability (Bradley and Bryant, 1983; Ball and Blachman, 1991; Torgeson, Wagner and Rashotte, 1994 & Gillion, 2000).

Preschoolers identified for special education instruction were trained in three phonological awareness tasks. This included rhyme, blending and segmentation. Significant progress was found following intervention in these areas (O'Conner, Jenkins, Leicester & Slocum, 1993). A study comparing kindergarten children who received intervention in phonological awareness with those who did not receive intervention was conducted by Foorman, Francis and Fletcher (1997). They found that training in phonological awareness led to "significant gains in phonological skills relative to children in the same curriculum who did not receive this training". In a study of primary age children phonological skills were found to be most significant when related to word identification but was particularly true for the early stages of the children's reading development (Vellutino and Scanlon, 1991). In an additional investigation, Scanlon and Vellutino (1997) found that children who were reading at above average levels in the early primary grades had participated in kindergarten instruction that included more

phoneme awareness instruction as well as invented spelling opportunities. In a synthesis of research on phonological awareness Smith, Simmons and Kameenui (1995) that in twenty-eight sources of intervention in phonological awareness (13 primary studies and 15 secondary studies) it was firmly established that a requirement of reading acquisition was phonological awareness instruction. Smith et al. contend that the following curriculum models must take precedence when designing phonological awareness instruction:

1. Explicit teaching of sounds, words and syllables. “Phonological awareness needs to be obvious and salient because phonemes are elusive and because children pay attention to meaning, not sounds.
2. Instruction should scaffold to facilitate learning tasks. When teaching word length begin with 1-3 phonemes and progress to more difficult words containing more than 3 phonemes. Size of phonological units must begin with simple units such as compound words, syllables and onset-rimes. Movement into more difficult units such as the phonemes /m/, /n/, and /s/. Beginning and ending phonemes should be taught before more difficult placement such as medial position phonemes. The phonological properties of phonemes and clusters should be introduced before consonant clusters.
3. Integration of phonological skills should be systematic and strategic. Instruction of phonological awareness begins with simple units and focuses on initial sounds. Introduce corresponding printed letters (graphemes) and increase difficulty of phonological units.
4. Priming of background knowledge prior to teaching a new skill will facilitate new learning. For example, since the detection of individual phonemes is crucial to later segmentation, a review of this skill is pertinent before introduction of segmentation.
5. Review of skills should include practice that includes teacher modelling, moving to verbal prompting and finally the use of particular strategies. Daily review is essential to continued development of phonological awareness.

## 6.5 Summary

Literacy interventions have included approaches that emphasize many of the theories presented in chapter 2 as well as a number of other language approaches that underscore the different aspects of language. Research in dyslexia has led to practices which include explicit systematic teaching of reading skills as well as delivery of interventions in a more naturalistic approach for individuals, small groups or in the general classroom setting. With the many available options for literacy intervention, it can be difficult for practitioners to choose the best intervention program. The intervention process and research behind this process must be clearly understood in order for it to benefit the population it serves. Studies have found that practitioners who have knowledge of the underlying research of a particular intervention are more likely to better utilize this intervention appropriately. Effective, research based intervention programs are now readily available to the practitioner. Most are aimed at children between five and six years of age who without remediation are at high risk for developing reading deficits. Shaywitz (2003) maintains that reading performance tends to be stable so that when a child reaches first grade their reading ability already strongly predicts later reading achievement. If research based intervention programs are widely implemented the number of children needing intervention and/or special education when reaching the higher grades can be substantially reduced.

Goldsworthy (2003) argues that there is a fragmentation of approaches to intervention. She contends that many remedial approaches are “missing the mark” because language abilities are often divided and subdivided into receptive –expressive language units rather than treated as an oral-written language continuum with each overlapping the other. Damico (1988) proposes that a “fragmentation fallacy” occurs when language is analyzed into disconnected modules such as phonology, semantics, syntax and pragmatics. It makes sense for practitioners to break skills into teachable units nevertheless, these fragments are joined into bigger units and must be brought to an automatic skill level in order for the reader to be proficient. Rose (2006) described the findings of his study on early reading skills which show that explicit, systematic teaching of phonics was largely

the most favourable approach to intervention. Rose described the process of reading acquisition:

...it is generally accepted that it is harder to learn to read and write in English because the relationship between sounds and letters is more complex than in many other alphabetic languages. It is therefore crucial to teach phonic work systematically, regularly and explicitly because children are highly unlikely to work out this relationship for themselves. It cannot be left to chance, or for children to ferret out, on their own, how the alphabetic code works.

Other methods of intervention are being set aside in this study as it is phonology which has the focus of this research. Rose (2006) supports this premise as he maintains there is ample evidence that children must begin a systematic programme of phonic work by the age of five (if not before) with activities designed to build phonological awareness. Research supports that instruction in phonological awareness skills improves later reading ability (Bradley & Bryant, 1978). With findings that the most relevant predictor of literacy was letter knowledge (Gallagher, Frith, & Snowling, 2000) it is necessary to examine the effects of systematic teaching of letter-sound correspondence and the alphabetic principle for preschool age children. Other methods of intervention lack the reflection of how a beginning reader progresses to become a skilled reader. The National Literacy Strategy (2002) raised the concern that a “searchlights” model is ineffective in terms of demonstrating where the intensity of the “searchlights” should be at the differing stages of learning to read. According to Rose (2006) beginning readers must learn to decode effortlessly, using their knowledge of letter-sound correspondences and the skills of blending these sounds. Study 3 will explore the specific skills of pre-reading ability and exactly how these skills are impacted by systematic instruction in alphabetic knowledge. The implications for this study are far reaching as each dimension of reading development must be well understood by practitioners and teachers and backed by research so that best practices can be applied in remediation methodology.

The aims and objectives of the studies conducted for this paper were to examine dyslexic primary age children to identify the specific phonological skills in which those with

dyslexia showed deficits. Further examination of this population would enlighten this research as to what role each specific skill may play in the reading process. These findings would then allow us to assign indicators for preschool age children in attempting to replicate these same factors found in study 1 by performing similar or parallel assessments to the preschool age population. The outcome of assessments completed on preschool age children would then inform an intervention study and express how the intervention may or may not impact the pre-reading skills assessed.

## 7. Study 1

### 7.1 Introduction

For this study the aim was to produce information demonstrating associations, dissociations and eventually causal relationships between the outcome of these assessments and the diagnosis of dyslexia. Acknowledging that phonological skills affect later reading skills, it is then imperative that the specific phonological skills be identified and defined and then to find which specific skills play the most integral role in learning to read. With the data from Study 1 analyzed, this research would then progress into the second pilot with preschool age children-- the aim being to define the areas where dyslexic children are deficient within the first pilot and to show which assessments transfer well to preschool age children. If the specific indicators for reading disabilities can be defined and utilized, then these indicators can be used to provide and define appropriate interventions for the preschool age population. Much research tends to focus primarily on the many causes of dyslexia. There are a number of studies that look at the factors which predict success in reading from an early age (Muter, Hulme, Snowling and Taylor, 1998; Bailey, Manis, Pederson and Seidenberg, 2004). If it is possible to elucidate the precursors to dyslexia, then there is a great potential for early intervention at preschool age.

### 7.2 Method

#### 7.2.1 Participants

Twenty-two dyslexic, primary aged students were chosen for this study. Each had received a formal diagnosis of developmental dyslexia which was documented in each participant's current IEP. Each was a student at Calder House School, a Special Needs School for primary aged children in Wiltshire, England. Calder House is a private school for pupils with specific learning difficulties. It is registered with the Council for the Registration of Schools Teaching Dyslexic Pupils (CreSTeD). There were 32 pupils on



registration at the time of assessment, the majority of who were of white, European origin. Pupils were between the ages of five and thirteen years of age. The pupils had a level of attainment below the national expectations resulting from their learning difficulties, as reported by the February 2001 Ofsted report of the Office for Standards in Education (England).

Twenty-Two controls were selected to participate in the study from Longmeadow Primary School in Trowbridge, Wiltshire, England. Longmeadow Primary School has recently been placed on Special Measures by Ofsted (2005). There were 159 pupils on the register at the time of assessment. Gender was mixed and the majority of students were of white, European origin. Pupils were between the ages of four and eleven years of age. The proportion of students with special education needs is well above average (Ofsted 2005).

The two groups were matched similarly for age (see Table 2). The two schools shared a similar geographical location and similar OFSTED reports, referring to lower levels of attainment. The school for the dyslexic study group, however, attributed this directly to the dyslexia-related learning difficulties of the pupils which was not the case for the control school. Thus although both schools were performing below national average, different variables may be contributing to these attainment levels. All of the subjects had informed parental consent given prior to participation. Ethics were passed by the University of Bath's Department of Psychology Ethics Committee.

**Table 7.1 Group Statistics**

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
AGEINMON	Study Group	22	116.8636	18.6402	3.9741
	Control Group	22	116.7727	15.7871	3.3658
GENDER	Study Group	22	1.3182	.4767	.1016
	Control Group	22	1.5000	.5118	.1091

### 7.3 Design

A battery of psychometric phonological, visual/spatial and auditory testing was administered to each individual in several sessions lasting thirty to forty minutes each. Assessments were performed in a separate room and not in the classroom setting. This allowed for a more calm setting without distractions. Each child completed numerous tests, administered across several sessions, as described below. Phonemic awareness plays both a prerequisite role and a reciprocal role in reading and writing (Wagner, Torgeson & Rashotte, 1994). Researchers agree it is crucial to consider the various roles that phonemic awareness plays in the development of literacy skills (Foorman, Chen, Carlson, Moats, Francis & Fletcher; 2003). The assessments employed in this study were established due to research which supported the contention that these tests would help inform and broaden the phonological theory of language development. The literature presented herein indicates there are a multitude of variables which are responsible for literacy development (Byrne et al. 2006; Scarborough, 1998; Treiman & Zukowski, 1996). Therefore, the aim of this study is to examine a wide range of variables and to identify which variables are more salient. ‘

#### 7.3.1 Measures

##### *Digit Measurement*

Digit Measurement was performed on each student using a portable photocopier. Each hand was placed palms down on a photocopier and a reproduction of both left and right hands were made for each subject. The 2<sup>nd</sup> and 4<sup>th</sup> digit of both the left hand and right hand were measured using digital Vernier callipers, measuring from the crease where the finger met the hand to the furthest point of the digit at the centre. The vernier calliper is used in length measurements to gain an additional digit of accuracy a repeat measurement of the 2<sup>nd</sup> and 4<sup>th</sup> digits was done by an independent source to compare for accuracy. The foundation for measurement of digit ratio is research by Manning, (1998, 2000, 2001) who contends that measurement of the digit ratio for 2D/4D is a straightforward

way to determine testosterone in foetal development and can be utilized to study correlations with reading disabilities.

### Vocabulary

According to Metsula (1999) vocabulary development is dependent upon development of phonological awareness and acquisition of vocabulary can be linked to phonological awareness tasks (Decura & Goswami, 2003). Measures of the students' vocabulary were obtained using the British Picture Vocabulary Scale (BPVS). The BPVS measures the extent of the subject's acquisition of the English vocabulary as well as to provide an assessment of the child's receptive vocabulary knowledge. The BPVS is designed for children ages 3 years to 15 years 8 months. The subject is not required to perform any reading, speaking or writing for the BPVS. There are 168 test items, each containing four line drawings. The child's task is to point to the picture that corresponds to the vocabulary word spoken by the administrator. The test administration continues until the child makes eight errors in a set of 12 words.

### Controlled Associations

A measurement of word retrieval skills was taken with the controlled association task. The purpose of this test was to measure the participant's ability to generate words when given a stimulus word. Studies have found that individuals with dyslexia demonstrate weaknesses in the ability to produce a target word and that this may be related to the phonological loop system in working memory (Dockrell et al., 1998; Baddeley, 1986). Participants were provided with words (example: small) and asked to think of and write as many synonyms for the word as they were able to recall in a period of 6 minutes. Two examples were provided with a list of words with similar meanings. The test was divided into two separate parts with each part time for six minutes. Four words were given for each part. Score was totalled by giving one point for each correct word (word that was the same or similar meaning) in each of the two parts.

### Reading and Spelling Age

The Wide Range Achievement Test (WRAT 3) was used to obtain a spelling and reading age for each child. This test was chosen for its reliability in measuring reading ability and/or disability (Jastak & Jastak, 1978). The WRAT-3 has two alternative testing forms (tan and blue). The blue form was used in this assessment. Turner and Rack (2005) report that use of the WRAT reading and spelling test is the “first step” in assessing literacy skill. Spelling and reading assessments were performed on each student. The reading test consists of 15 letters and 42 individual words that the student is asked to name or pronounce. The spelling test consists of writing one’s name, 13 letters, and up to 40 words dictated to the assessor and used in a sentence. The spelling items increase with difficulty. Testing is discontinued when the subject makes 5 consecutive errors.

### Phonological Knowledge

Phonological knowledge addresses central questions in the foundations of phonology. The use of phonological assessments will allow us to investigate the nature, status and acquisition of phonological knowledge and its relationship to language development. The Consortium on Reading Excellence (CORE) presents a collection of formal and informal reading assessments for use with students in grades K-8. These assessments target the areas of strength and weaknesses in monitoring reading development. The rationale for use of the CORE program was to provide screening tests to assess the knowledge and skill base of each participant (Adams, 1990; Just & Carpenter, 1987).

### CORE Phoneme Segmentation Test

The CORE Phoneme Segmentation Test is appropriate for older primary students who display disabilities in reading or spelling or may have underdeveloped phonemic awareness (Joshi, 1999). This informal assessment measures the student’s ability to break a word into its component phonemes, or sounds. For example, *bag* has three phonemes /b/ /a/ /g/. The word *blue* has two phonemes: /bl/ /oo/. This assessment detects a student’s development in phonemic awareness and can determine any deficits or underdeveloped phonemic awareness. The test is administered by placing approximately 8 different colour disks on the table in a horizontal line from left to right. The different

colours represent the different sounds in the word. The assessor models using one disk for each sound in the word. Example; *big* would have three different colour disks – one to represent each sound /b/ /i/ /g/. The student is scored one point for each of the 15 items on the assessment. Total scores can then range from 0-15.

#### CORE Phoneme Deletion Test

As part of the Connecticut Longitudinal, children were assessed for their ability to isolate phonemes. Describing this study, Shaywitz (2003) proposes “one type of test in particular seemed quite sensitive to dyslexia”. The reasoning for this assessment is that these tasks determine whether deficits in phonemic, or sound, awareness account for the participant’s reading or spelling delays. According to research by Shaywitz (2003) and Joshi (1999) lack of phonemic awareness is the most powerful determinant of the likelihood of an individual’s failure to learn to read. This assessment requires participants to segment words into their phonemes and then to delete identified phonemes from the words. This assessment includes four phoneme deletion tasks arranged in order of difficulty. The assessment was auditory and the subjects did not see the items. The first task measured the subject’s ability to delete initial phonemes. In this test the assessor presents a word to the subject and then asks them to say the word without the initial consonant. For example, “Say cat...now say it without the (k) sound”. The remaining tasks assess the student’s ability to delete final phonemes (“Say seat...now say it without the (t); initial phonemes in blends (“Say slip...now say it without the (s)”; and phonemes embedded in blends (“Say play...now say it without the (l)”. Each of the four tasks contained 5 items. The student was given one point for each correct answer of the 20 total items. Scores were measured for each

#### CORE Phonics Survey

The CORE Phonics Survey is used to assess a participant’s ability to use knowledge of sound/letter correspondences (phonics) to decode words (Consortium on Reading Excellence, 1999). This decoding ability then determines his/her ability to read individual words. This detailed assessment of the participant’s phonics skills points to areas in which the participant is likely to benefit from systematic explicit phonics

instruction. The CORE Phonological Survey is appropriate for assessment of ages 5-13. It was administered individually and completed in 10-15 minutes time. There are 13 subtests included in the CORE Phonics Survey. This assessment measured several key tasks as described below. A record form is kept to document the participant's responses on each test. The record form shows the same material that appears on the participant material in a reduced size so that the assessor may easily record the participant's responses. The measures listed below describe each subtests of the CORE phonics survey and each sub-test provides an explanation and motivation for the assessment.

Letter Knowledge - upper and lower case alphabet letters.

In this assessment, the subject was asked to tell the names of the letters as the assessor pointed to them on a page. If the subject was unable to name three or more consecutive letters, the assessor would ask the subject to look at all the letters and tell which ones they did know. The letters were separated into two sets – uppercase and lowercase and not presented in consecutive or alphabetical order.

Consonant Sounds

Here the subject was presented with the twenty-one consonant sounds in mixed order. In assessing the Consonant sounds the assessor would say to the student, “look at these letters. Can you tell me the sound each letter makes?” The child was given one mark for each correct sound for a total possible score of 21.

Long Vowel Sounds and Short Vowel Sounds

For the Long and Short Vowel assessment, the student was asked to “tell the sounds of each letter”. When one sound was presented, the assessor would then ask, “Can you tell me the other sound for the letter?” The subject was given one point for each correct response with a total possible score of 10.

### Reading and Decoding Skills:

The CORE Phonics Survey presents a number of lists of letters and words for the subject to identify or decode. Pseudo words or nonsense words (also referred to as “nonwords” in the review of the research) are presented to the student for decoding in this assessment. The subject was presented with representations of word examples for short vowels in SVC words, short vowels, digraphs and tch trigraphs. The subject was asked to read both real and nonsense words presented in a sequence of one line of real words and one line of pseudo words. The subject is not presented with the multi-syllabic word section of the assessment if he/she has more than 7 errors in the previous sections.

### Short Vowels in CVC Words

Ten items are presented to the subject – one set of five real words and one set of five pseudo or non-words. The words presented contained short vowels in the consonant/vowel/consonant pattern. Examples of words presented are “sip” (real) and “vop” (nonword). Total scores could range from 0-10.

### Short Vowels, digraphs, and tch trigraphs

Ten items are presented to the subject. Again, these contained five real words and five nonwords. Words contained a short vowel and either a digraph or trigraph- a pair or trio of letters representing a single speech sound. Example of words presented are “when” (real) and “shom” (nonword). Total scores could range from 0-10.

### Consonant blends with short vowels

In this subtest, 20 items were presented. There were 10 real words and 10 nonwords presented in alternating groups of five. Words and nonwords contained short vowels and a beginning or ending consonant blend. Example of words used are “plan” (real) and “frep” (nonwords). Total possible

### Long vowel spellings

Ten items are presented – a set of five real words and a set of five nonwords. These words contained a long vowel spelling such as “tape” (real) and “joad” (nonword). Total possible score was 10.

### Variant vowels and diphthongs

Diphthongs are comprised of two distinct components — the nucleus, and the off-glide. The nucleus of the diphthong is the vowel that is most stressed, and forms the centre of the sound. The off-glide is the vowel which flows into or off of the nucleus vowel. The three major diphthongs in Standard English, known as phonemic diphthongs, are *ai*, *aw*, and *oy*.

Ten items were presented in this subtest. Words presented included 5 real and 5 nonwords utilizing variant vowel patterns and diphthongs (example – “toy” and “voot”). A total possible score of 10 could be obtained.

### R- and L- controlled vowels

Variant vowels controlled by “r” and “l” were further examined in this assessment. This test measured the subjects’ ability to read real and nonwords where the vowel sound is controlled by “r” or “l”. There were 10 words presented in this subtest—five real and five nonwords. Examples of words used were “bark”, “cold” (real) and “ferm”, “dall” (nonsense). Total possible score was 10.

### Multisyllabic Words

This subtest was administered only if the subject was able to read most of the single-syllable real and nonwords in the previous subtests. Each of the words in the multisyllabic assessment contain two syllables. The subject was presented with three columns of words. Each column contained 8 words. The first column contained real words. If the subject was able to read three of the eight words in the column they were presented with column two containing eight nonsense words. The procedure was repeated for column two whereas the subject was presented with column three if they were able to read three of eight words in column two. Examples of words used were “kidnap” and



“further” (real); “pugnad” and “wopam” (nonsense). A total possible of 24 could be obtained.

### Spelling Skills

#### *Initial consonants*

The subject is presented with five, one syllable, words and asked to write the “first sound” they hear (example “map”, “kid”).

#### *Final Consonants*

Again, the subject is asked to listen to each of the five words read and to write the last sound they heard (example “leg”, “sell”).

#### *CVC (Consonant/Vowel/Consonant) words and Long vowel spellings*

In this subtest, the subject is read aloud five words with the consonant/vowel/consonant spelling pattern. The subject was asked to listen to each of the words read and to write the whole word. Examples of words presented; “yam”, “sip”. Following the CVC words, the subject was read aloud five words with various long vowel spelling patterns and asked to write the word. Examples of long vowel words presented were “coin” and “steep”. A total possible score of five for each group could be obtained.

### Identifying Rhyme Words

Auditory and Written Rhyme skills were assessed using the PALPA. PALPA stands for “Psycholinguistic Assessments of Language Processing in Aphasia”. It consists of 60 assessments designed to measure and diagnose language processing difficulties. PALPA utilizes a psycholinguistic approach to the interpretation of an individual’s recognition, comprehension and production of spoken and written words and sentences. The PALPAS is designed with the approach that the mind’s language system is separated into individual modes of processing and that these separate modes can be impaired by defects in the brain. Each of the tasks were designed and based on neuropsychological and experimental literature (Saffran, Berndt and Schwartz, 1989).

*Auditory Rhyme Assessment:* Students were presented with 30 sets of words and asked to identify whether the pairs of words rhyme or do not rhyme by indicating a “yes” or “no” verbal response.

*Reading Rhyme Assessment:* Students were presented with 30 sets of words and asked to read the pairs and to check (tick) the words if they rhymed and to cross out (X) if the words did not rhyme.

#### **7.4 Observations**

Both the study group and the control group demonstrated the ability to name upper and lower case letters of the alphabet. However, the study group was observed frequently stating the letter sound rather than the letter name in this subtest. This most likely was due to the instruction provided to the subjects in their intensive phonics program provided by the school. School administration communicated that the literacy curriculum focuses primarily on introducing letters by sound rather than name. Subjects in the control group were able, in most cases, to name letter names after one prompt to do so.

In reading and decoding real and nonwords in the seven subtests described above, the dyslexic study group was observed to initially recognize and manage the real and nonword portion of the subtests. The dyslexic group had experience with a similar presentation of the real word/nonword pattern as their literacy program included the “Toe by Toe” reading program (Keda Cowling, 1993). This curriculum presents a similar structure to the subtests used in this study with a set of real words followed by a set of nonwords. Participants were informed that they were able to terminate their session at any time if they felt tired or frustrated. None of the participants elected to terminate any of the assessments during this study. Overall there were six sessions per participant.

## 7.5 Results

As indicated in Table 7.1 there were not differences in age between the control and study group. An analysis of performance between groups was performed to look at participants skills in reading, spelling, vocabulary and phonemic awareness. Examination of results identified ten measures where there were significant differences in performance between the dyslexic study group when compared to the control group. Participants in the dyslexic group performed significantly worse than participants in the control group. The results of these ten areas that show a difference in performance between the dyslexic and non-dyslexic groups have been ranked in order of significance in Table 7.2 below. The table below highlights the means between groups.

**Table 7.2 Results of performance on Study 1 – Reading/Spelling/Segementation**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two- tailed)
WRAT					
Spelling	95.95	15.07	126.86	38.52	.002*
WRAT					
Reading	104.41	16.33	130.14	40.18	.010*
Phonemic Segmentation	7.32	3.27	8.05	2.18	0.393

Levene's test for variances of the groups were analyzed. For WRAT Spelling  $F=11.14$ ,  $p=.002$  and for WRAT Reading,  $F=11.77$ ,  $p=.001$ . Segmentation results were  $F=5.26$ ,  $p=.027$ . For these measures the variances were significantly different between groups for reading, spelling and segmentation. When analyzed for sex we found that males and females had unequal variances in performance, WRAT Spelling  $F=5.35$ ,  $p=.03$ , WRAT Reading  $F=6.46$ ,  $p=.02$ . Males and Females had equal variances in performance for the Phonemic Segmentation task with  $F=1.08$ ,  $p=.30$ .

**Table 7.3 Results of performance on Study 1 – CORE Phoneme Deletion Tasks**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two-tailed)
Phoneme Deletion Initial Sound	4.77	0.69	4.8	0.52	0.887
Phonemic Deletion Final Sound	4.23	1.15	4.66	0.75	0.17
Phonemic Deletion first sound blend	1.55	1.71	3.65	1.56	<.001*
Phoneme deletion embedded sound blend	2.45	2.09	3.45	1.73	0.102

For the Phoneme deletion tasks measured, there was equality of variance between groups. Initial sound deletion  $F=.124$ ,  $p=.73$ , final sound deletion,  $F=2.45$ ,  $p=.13$ , first sound of blend deletion  $F=.79$ ,  $p=.38$  and deletion of embedded sound in blend  $F=2.40$ ,  $p=.13$ . Analysis of performance between sex found some significant variances. Initial sound of blend  $F=2.96$ ,  $p=.09$ ; final sound of blend  $F=2.45$ ,  $p=.13$ ; first sound of blend  $F=.104$ ,  $p=.75$  (no significance differences) and embedded sound of blend  $F=4.38$ ,  $p=.04$ .

**Table 7.4 Results of performance on Study 1 – PALPA Rhyme**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two- tailed)
Auditory Rhyme	27.23	3.16	28.68	2.03	0.077
Reading Rhyme	21.4	3.45	24.27	4.81	.028*

There was equality of variances between groups for assessments in auditory rhyme  $F=.193$ ,  $p=.66$  and reading rhyme  $F=1.092$ ,  $p=.30$ . However, analysis of sex differences found unequal variances between groups. Auditory rhyme  $F=4.97$ ,  $p=.03$  and reading rhyme  $F=7.59$ ,  $p=.01$ .

**Table 7.5 Results of performance on Study 1 – Controlled Associations/BPVS**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two- tailed)
Controlled Associations	4.05	2.54	7.17	4.01	.007*
BPVS Raw Score	94.09	14.55	93.38	13.13	0.868
BPVS Age Equiv.	114.82	23.35	114.9	21.78	0.99

The word finding assessment showed equal variances among groups and between sex. There were no significant differences for group or sex (group  $F=1.09$ ,  $p=.30$ ; sex  $F=2.37$ ,  $p=.13$ ). Additionally there were no significant variances for group or gender for the British Picture Vocabulary Scale. Between groups the raw score of the BPVS found  $F=.663$ ,  $p=.42$  and the BPVS age equivalent score was found to have  $F=.599$ ,  $p=.444$ .

For sex there was also no variance of significance in performance  $F=2.07$ ,  $p=.16$  and  $F=.68$ ,  $p=.41$ .

**Table 7.6 Results of performance on Study 1 – CORE Phonological Survey**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two- tailed)
Letter Names upper case	25.73	0.55	25.95	0.22	0.087
Letter Names lower case	25.55	0.74	25.76	0.77	0.362
Consonant Sounds	21.77	1.27	22.57	0.87	.021*
Long Vowel Sounds	4.59	1.05	4.71	1.1	0.709
Short Vowel Sounds	4.45	1.06	4.52	1.29	0.848
Short Vowel Sounds in CVC Words	9.14	0.94	9.57	1.21	0.194
Short Vowel diagraphs and tch trigraphs	7.82	1.92	8.48	2.82	0.374
Consonant blends with short vowels	15.18	4.48	17.55	4.78	0.105
Long Vowel spellings	7.86	2.38	8.55	2.58	0.375
Variant vowels and diphthongs	6.82	3.39	8.75	2.45	.042*
R and L Controlled Vowels	6.5	3.47	8.9	2.63	.015*
Multi-Syllabic Words	7.95	7.02	17.1	6.79	<.001*
Initial Consonant Sounds	4.59	1.1	4.65	1.14	0.865
Final Consonant Sounds	4.14	1.55	4.75	1.11	0.153
CVC Spellings	4.36	0.95	4.45	1.28	0.804
Spelling Skills Long Vowels	2.18	1.65	3.85	1.53	.002*

Equal variances were found between groups for all measures except for letter names (upper case )  $F=14.9$ ,  $p>.01$  and for “R” and “L” controlled vowels,  $F=5.02$ ,  $p=.03$ .

When comparing groups for sex, there were numerous tasks with inequality of variances between males and females. These were: Letter names (upper case)  $F=30.94$ ,  $p>.01$ ; Letter names (lower case)  $F=28.89$ ,  $p>.01$ ; Consonant sounds  $F=4.94$ ,  $p=.03$ ; Short vowel sounds  $F=26.42$ ,  $p>.01$ ; Short vowel diagraphs and “tch” trigraphs,  $F=5.82$ ,  $p=.02$ ;

Consonant blends with short vowels,  $F=12.25$ ,  $p>.01$ ; Long vowel spellings,  $F=4.26$ ,  $p=.05$ ; “r” and “l” controlled vowels,  $F=12.27$ ,  $p>.01$ ; Initial consonant sounds,  $F=9.10$ ,  $p>.01$ ; Final consonant sounds,  $F=18.54$ ,  $p>.01$ ; CVC spellings,  $F=11.58$ ,  $p>.01$  and Spelling skills long vowels,  $F=9.18$ ,  $p>.01$ .

When analyzing for interactions between group and gender, results show an interaction between group and gender for WRAT reading; ANOVA  $F_{1,39} 4.39$ ,  $p=.04$ . For WRAT spelling the interaction between gender and group was not significant but there were significant differences found for gender, ANOVA  $F_{1,39} 12.44$ ,  $p<.01$  and group, ANOVA  $F_{1,39} 13.72$ ,  $p<.01$ . Evaluation of the CORE Phonological Survey measures found differences between groups for phoneme deletion first sound of blend, ANOVA  $F_{1,38} 33.48$ ,  $p<.01$ , “r” and “l” controlled vowels, ANOVA  $F_{1,38} 3.89$ ,  $p=.01$ , a trend for variant vowels and diphthongs, ANOVA  $F_{1,38} 3.25$ ,  $p=.07$ , consonant sounds, ANOVA  $F_{1,39} 4.66$ ,  $p=.05$ , and multisyllabic words, ANOVA  $F_{1,38} 15.07$ ,  $p<.01$ . Differences were also found for groups for spelling of long vowels, ANOVA  $F_{1,38} 7.65$ ,  $p<.01$  A trend towards significance was found for reading rhyme judgement, ANOVA  $F_{1,40} 3.54$ ,  $p=.06$  and for controlled associations, ANOVA  $F_{1,34} 6.11$ ,  $p=.02$ .

A significant difference was found for gender as well in these measures: phoneme deletions first sound of blend, ANOVA  $F_{1,38} 7.4$ ,  $p=.01$ , “r” and “l” controlled vowels, ANOVA  $F_{1,38} 4.36$ ,  $p=.04$ , multisyllabic words  $F_{1,38} 8.21$ ,  $p<.01$ . A trend towards significance was found for consonant sounds, ANOVA  $F_{1,39} 3.40$ ,  $p=.07$  and variant vowels and diphthongs, ANOVA  $F_{1,38} 3.07$ ,  $p=.08$ . Significant differences were also found for spelling skills long vowels, ANOVA  $F_{1,38} 14.45$ ,  $p<.01$ , WRAT spelling, ANOVA  $F_{1,39} 12.44$ ,  $p<.01$  and reading rhyme judgement, ANOVA  $F_{1,40} 15.45$ ,  $p<.01$ . There were no significant differences in gender for controlled associations.

**Figure 7.1 Interaction for Group and Gender – WRAT Reading**



**Table 7.7 Results of performance on Study 1 – Digit Ratio**

Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value (two-tailed)
Average digit ratio	0.96	0.04	0.97	0.4	0.517
Digit ratio right minus left	-0.02	0.03	-0.04	0.04	0.088
Left hand digit ratio	0.97	0.04	0.99	0.04	0.206
Right hand digit ratio	0.95	0.04	0.95	0.04	0.901

Results were calculated using a two-tailed measure. The basis for using two-tailed data was the variability of research reviewed which indicated an inconsistency in phonemic awareness skills and their impact upon dyslexics. It was pertinent to this research to approach the data without a determination regarding which group might perform superior to the other.

Effect sizes were calculated as a measure of the difference between means. Effect size is advantageous for use with results as it is useful to understand the size of observed significant effects. Cohen’s standardized effect size was determined utilizing *d* as the size of the difference between means in terms of standard deviations. Results indicate



significant values performed on t-tests were consistent with effect sizes equal to or greater than  $d=.065$ . Table 7.8-7.10 illustrate results of measures sorted by effect size (small to large). All effect sizes were noted in the tables below in order to allow for comparisons between measures. Only those measures with larger effect sizes were significant and were effects. All of the small effects did not approach significance and therefore were not considered effects.

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**Table 7.8 Results of measures sorted by effect size (Small)**

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Measure	Dyslexic Mean	Dyslexic SD	Control Mean	Control SD	Probability Value	Effect Size
BPVS Age Equiv	114.82	23.35	114.9	21.78	0.99	0
Right hand digit ratio	0.95	0.04	0.95	0.04	0.9	0
Initial consonant sounds	4.59	1.1	4.65	1.14	0.865	0.05
BPVS Raw Score	94.09	14.55	93.38	13.13	0.868	0.05
Phoneme Deletion initial sound	4.77	0.69	4.8	0.52	0.887	0.05
Short Vowel Sounds	4.45	1.06	4.52	1.29	0.848	0.06
CVC Spellings	4.36	0.95	4.45	1.28	0.804	0.08
Long Vowel Sounds	4.59	1.05	4.71	1.1	0.709	0.11
Average digit ratio	0.96	0.04	0.97	0.04	0.517	0.25
Phoneme Segmentation	7.32	3.27	8.05	2.18	0.393	0.26
Short vowel diagraphs/tch trigraphs	7.82	1.92	8.48	2.82	0.374	0.27
Long Vowel spellings	7.86	2.38	8.55	2.58	0.375	0.28
Letter names lower case	25.55	0.74	25.76	0.77	0.362	0.28
Short vowel sounds in CVC words	9.14	0.94	9.57	1.21	0.194	0.4
Phoneme Deletion final sound	4.23	1.15	4.66	0.75	0.17	0.44
Final consonant sounds	4.14	1.55	4.75	1.11	0.153	0.45

**Table 7.9 Results of measures sorted by effect size (Medium)**

Measure	Dyslexic	Dyslexic	Control	Control	Probability Value	Effect Size
	Mean	SD	Mean	SD		
Left hand digit ratio	0.97	0.04	0.99	0.04	0.206	0.5
Consonant blends with short vowels	15.18	4.48	17.55	4.78	0.105	0.51
Phoneme deletion embedded in blend	2.45	2.09	3.45	1.73	0.102	0.52
Letter names upper case	25.73	0.55	25.95	0.22	0.087	0.53
Auditory Rhyme Judgement	27.23	3.16	28.68	2.03	0.077	0.55
Digit ratio right - left	-0.02	0.03	-0.04	0.04	0.088	0.57
Variant vowels/diphthongs	6.82	3.39	8.75	2.45	0.042	0.65
Reading Rhyme Judgement	21.4	3.45	24.27	4.81	0.028	0.69
Consonant sounds	21.77	1.27	22.57	0.87	0.021	0.73
R and L controlled vowels	6.5	3.47	8.9	2.63	0.015	0.78

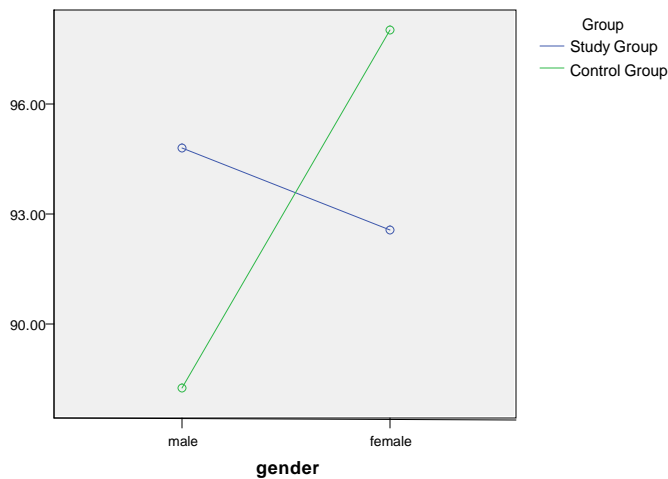
**Table 7.10 Results of measures sorted by effect size (Large)**

Measure	Dyslexic	Dyslexic	Control	Control	Probability Value	Effect Size
	Mean	c SD	Mean	Control SD		
WRAT Reading	104.41	16.33	130.14	40.18	0.01	0.84
Controlled Associations	4.05	2.54	7.17	4.01	0.007	0.93
Spelling skills - long vowels	2.18	1.65	3.85	1.53	0.002	1.05
WRAT Spelling	95.95	15.07	126.86	38.52	0.002	1.06
Phoneme deletion first sound blend	1.55	1.71	3.65	1.56	<0.001	1.28
Multi-syllabic words	7.95	7.02	17.1	6.72	<0.001	1.33

## 7.6 Interactions with Sex

Although the groups were matched for sex, sex differences have been reported and interactions were investigated between sex and dyslexia. In Study 1 when analyzing for interactions between groups and gender, results show that males in the dyslexic group performed slightly superior to females of the same group (males 95.0/females 93) and in the control group, females performed superior to males of the same group (males 85.0/females 98.0) and both genders in the dyslexic group. ANOVA  $F=_{1,39}, 1.89, p=.178$  (see plot). The BPVS was the dependent variable with significant differences found in the control group for sex on this task.

**Figure 7.2 Interactions between group and gender for British Picture Vocabulary Scale (BPVS)**



## 7.7 Digit Ratio

As sex differences have been identified in digit ratio, ANOVAs were conducted on the digit ratio variables using dyslexia status and sex as the independent variables to investigate potential interactions. The means for males and females are reported in table 7.6

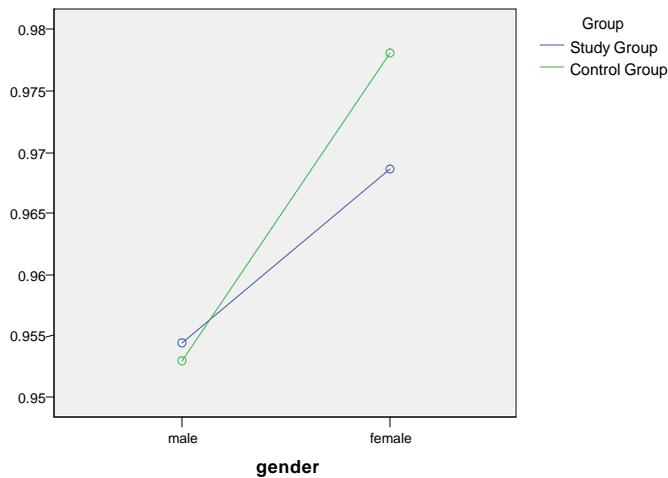
When analyzing digit ratio between sex, results show some almost significant difference in the right hand and the average digit ratio (right hand ANOVA  $F_{=1,39}$ , 3.57,  $p=0.066$  and average digit ratio ANOVA  $F_{=1,39}$ , 3.04,  $p=.089$ ). Supporting results from Independent Sampling indicates stronger significance in a one-tailed t-test with right hand digit ratio  $p=.035$ , average digit ratio  $p=.032$ . Left hand digit ratio compared between groups one-tailed then shows a trend toward significance at  $p=.061$ . Results for digit ratio, right minus left, indicates a smaller difference between the dyslexic group and the control group( study group mean; .023, (SD 0.27) and control group mean .040,( SD 0.37). Table 5 illustrates the results between sexes for both groups:

**Table 7.11 Comparison of Digit Ratio between Genders for Both Groups**

	Gender	N	Mean	Std. Deviation
Left	male			
Hand				
Digit				
Ratio		25	0.97	0.04
	female	18	0.99	0.04
Right	male			
Hand				
Digit				
Ratio		25	0.94	0.04
	female	18	0.96	0.04
Average	male			
Digit				
Ratio		25	0.95	0.03
	female	18	0.97	0.03
Digit	male			
Ratio				
Right				
minus				
Left		25	-0.03	0.03
	female	18	-0.03	0.04

Research has reported that typically the right hand has a greater effect when comparing gender. On the contrary, when comparing between gender for both groups, females show a higher digit ratio than males (see plot), but females in the control group show a larger difference than males when compared to the study group. Results for average digit ratio for gender (ANOVA  $F=1,39$ ,  $3.04$ ,  $p=.089$ ). When examining left hand digit ratio between groups and gender there was no significant difference (ANOVA  $F=1,39$   $.545$ ,  $p=.465$ ). Right hand digit ratio results were (ANOVA  $F=1,39$   $.018$ ,  $p=.895$ ). Therefore no significant interaction could be established for either right or left hand between group and gender.

**Figure 7.3 Interactions between gender and group for average digit ratio**



### 7.8 Wide Range Achievement Test (WRAT) Reading

Analysis of scores for the Wide Range Achievement Test (WRAT) for Reading show a significant difference in performance between the dyslexic group and the study group ( $t = -2.782$ ,  $df = 27.756$ ,  $p = .010$ ). Additionally, a significant difference was found in the analysis between genders (ANOVA  $F_{1,40} = 12.14$ ,  $p = 0.001$ ). Histograms for the conditions were inspected and as data was skewed with small participant numbers, the most appropriate statistical test was Mann-Whitney. Descriptive statistics showed that subjects in the study group scored inferior to subjects in the control group. The Mann-Whitney U was found to be 147.0 ( $z = -2.23$ ) with an associated probability of 0.03. This indicates that results demonstrate that subjects with dyslexia were more likely to score lower than subjects without dyslexia on the Wide Range Achievement Test.

**Table 7.12 Results for Dyslexic Group and Control Group in WRAT Reading**

	Group	N	Mean	Std. Deviation	Std. Error Mean
WRAT Reading	Study Group	22	104.4091	16.33477	3.48258
	Control Group	22	130.1364	40.18208	8.56685

When examining interactions between group and gender it was found that males in both the dyslexic group and the control group performed inferior to females. Females in the dyslexic group scored slightly better than male dyslexics but similar to male non-dyslexics. Males in both study and control groups performed inferior to females. The difference in performance between males and females in both groups may be attributed to evidence that shows males developing at a slower rate than females. Univariate Analysis results for interaction between group and gender was (ANOVA  $F_{=1,40} 6.85, p=.012$ ). Therefore there was a significant difference between group/gender as well.

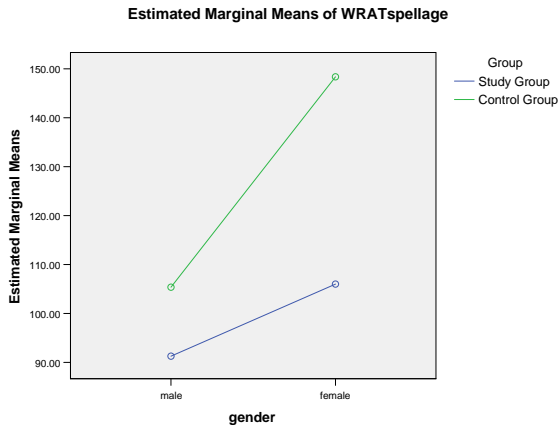
This suggests there is an interaction --with the higher age in the control group being due to just one sex (females). Control males are like dyslexic males. That is, boys are performing like the dyslexic boys and girls. As is the national trend, this study shows that males are underachieving in reading.

### 7.9 Wide Range Achievement Test Spelling

Comparisons of groups for the Wide Range Achievement Test Spelling indicate a significant effect between groups (ANOVA  $F_{=1,40} 13.18, p=.001$ ) and between gender (ANOVA  $F_{=1,40} 13.78, p=.001$ ). In addition, interactions of both group and gender show a trend towards noteworthy significance (ANOVA  $F_{=1,40} 3.30, p=.077$ ). Resembling the WRAT Reading results, females in both groups scored superior than males and female dyslexics scored in a similar fashion to the non-dyslexic males. Levene's Equality of Variances confirmed that data was skewed, again making the most appropriate statistical test the Mann-Whitney. Descriptive statistics here again showed that subjects in the study group scored inferior to subjects in the control group. The

Mann-Whitney U was found to be 104.0 ( $z = -3.25$ ) with an associated probability of 0.001. These results demonstrate that subjects with dyslexia were more likely to score lower than subjects without dyslexia on the Wide Range Achievement Test for spelling.

**Figure 7.4 Interaction between group and gender for WRAT Spelling**

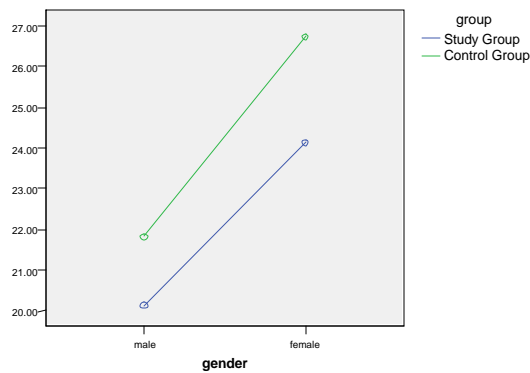


### 7.10 Identification of Rhyme

Duncan, Seymour and Hill (1997) argue that pre-literate rhyming skills have a direct relationship with later reading ability. Study 1 assessed the auditory and reading rhyme skills of both groups. Results show that dyslexic subjects scored inferior to the control group on both the auditory and reading rhyme assessment but that there was a significant difference in groups for reading of rhymes ( $p = .028$  one-tailed). Univariate analysis between groups reveals (ANOVA  $F_{(1,40)} = 3.54$ ,  $p = .067$ ). Also remarkable is the analysis of results between genders. Females in both the dyslexic and the control group scored superior to males. Females' scores in the dyslexic group were superior to non-dyslexic males (ANOVA  $F_{(1,40)} = 203.25$ ,  $p = .001$ ).

**Figure 7.5 Interaction between group and gender for Rhyme**





## 7.11 Phonemic Segmentation

Results of both groups in the phonemic segmentation task reveal difficulties in performance for both the dyslexic group and the control group. The mean score reveals that subjects in both groups were successful on roughly half the tasks presented.

**Table 7.13 Results for Study Group and Control for Phoneme Segmentation**

	Group	N	Mean	Std. Deviation	Std. Error Mean
Phoneme Segmentation	Study Group	22	7.3182	3.27161	0.69751
	Control Group	21	8.0476	2.1789	0.47548

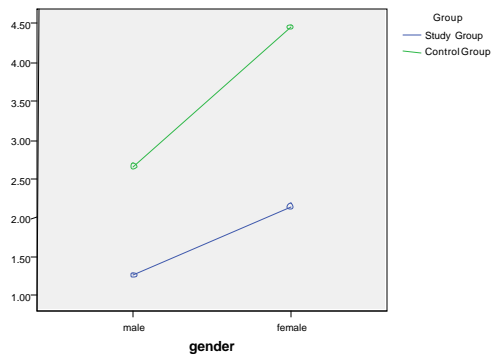
A Mann-Whitney test was performed as initial analysis showed the data as not normally distributed. Results for Study 1 indicate no significant difference between groups for phoneme segmentation tasks. There was also no significant difference between genders in this task, though it is interesting to relate that female dyslexics performed worse on this task than any of the other 3 groups (male dyslexics, female non-dyslexics and male non-dyslexics). Female non-dyslexics displayed the strongest performance.

## 7.12 Phoneme related tasks

Carroll (2004) reports on studies that point to letter knowledge as crucial to the development of more complex phoneme tasks. She deduces that letter knowledge helps children begin to segment phonemes in several ways. In this study, several measures were completed in order to explore the relationships that might exist between letter knowledge and more complex phonemic tasks. Both the study group and the control group were able to name between 24 and 26 of both upper and lower case letters presented. Examination of results in metaphonological tasks reveal differences in performance involving the dyslexic group.

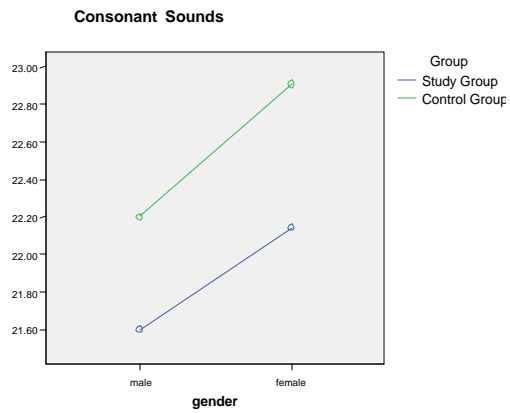
As related in Table 1, significant differences between groups were found in tasks related to phoneme manipulation. These included; (1) consonant sounds, (2) phoneme deletion first sound in a blend, (3) R and L controlled vowels and (4) variant vowels and diphthongs. Further analysis of these tasks found that variances for consonant sounds, phoneme deletion first sound in a blend and variant vowels and diphthongs, was judged to be relatively equal between groups. Parametric analysis was maintained for the these three measurements.

**Figure 7.6 Interaction between group and gender for phoneme deletion first sound of blend**



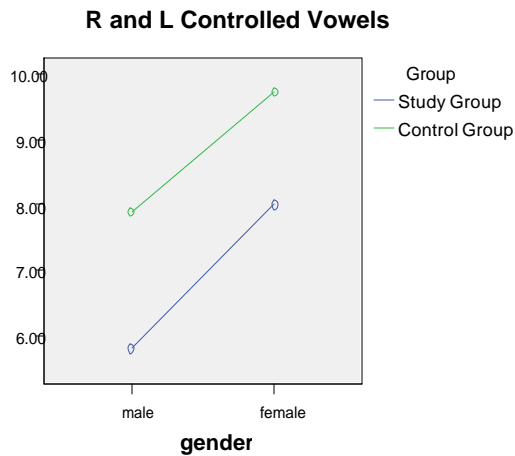
Univariate analysis for measurements indicate results for (2) phoneme deletion initial sound of blend between groups (ANOVA  $F= 1,38, 2.33, p=.001$ ) and between gender (ANOVA  $F= 1,38, 2.33, p=.010$ ). Both males and females in the dyslexic group performed consistently poorer than those in the control group.

**Figure 7.7 Interaction between group and gender for consonant sound**



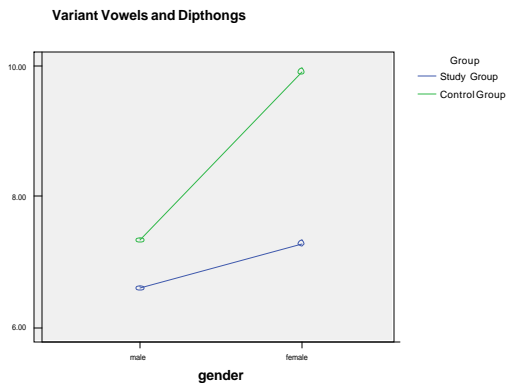
For the consonant sounds assessment, results showed significance between groups (ANOVA  $F=_{1,39}, 1.15, p=.05$ ) with both genders of the dyslexic group performing inferior to the control group.

## 7.8 Interaction between group and gender for “R” and “L” controlled vowels



Results for R and L controlled vowels showed unequal variances between groups. Consequently non-parametric analysis was utilized for this particular assessment. . Outcome of R and L controlled vowel tasks shows a trend towards significance between groups (ANOVA  $F=_{1,38}, 9.09, p=.06$ ), though variances were unequal. Dyslexic performance was inferior to the control group. Further examination of results determined use of the Mann Whitney for the R and L controlled vowels, as the data was skewed, and Mann Whitney was the most appropriate test. Results indicate Mann Whitney U was found to be 88 with a  $p=.001$ .

**Figure 7.9 Interaction between group and gender for variant vowels and diphthongs**



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There was less significance between groups for the variant vowel and diphthong task (4) but results nevertheless show a trend in this area (ANOVA  $F=1,38, 8.42, p= .09$ ). Notably, females in the control group showed advanced performance over dyslexic females and males from both groups.

### 7.13 Controlled Associations

Study 1 included a controlled association task to identify word finding difficulties and the subsequent relationship with other literacy tasks.

The performance of the dyslexic group and the control group were compared to measure the differences in the controlled association task. Both the study group and the control group displayed some difficulty in this word retrieval task. Subjects in the study group scored a mean of 4.05 on this task whereas the control group scored a mean of 7.16. Analysis of results between groups found a difference in performance between the dyslexic group and the control group (ANOVA  $_{1,34}$ , 10.63,  $p = .02$ ). There was some significant difference in word finding skills between genders with females in the control group showing slightly stronger performance than dyslexic females and males from both groups. Females in both groups performed somewhat superior to males (Females mean 6.78; Males mean 4.40;  $p = .04$ ).

**Table 7.14 Results between Groups and Gender for Controlled Associations**

	Group	N	Mean	Std. Deviation	Std. Error Mean
Controlled Associations	Study Group	20	4.05	2.54383	0.56882
	Control Group	18	7.1667	4.01834	0.94713

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Controlled Associations	male	20	4.4	2.54227	0.56847
	female	18	6.7778	4.29165	1.01155

Messer et al point out that a link between children with dyslexia and children without dyslexia implies that children with word finding difficulties will experience difficulties in literacy related tasks. Dockrell et al, (1998) reveals word finding difficulties in children

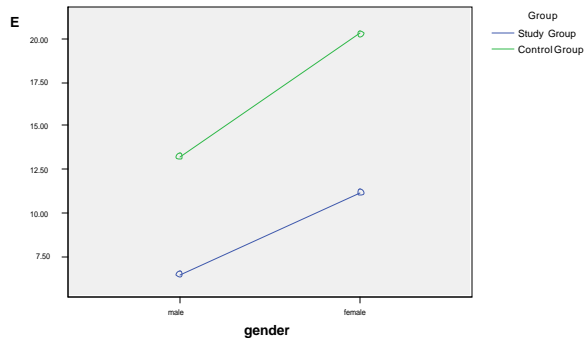
with dyslexia, children who do not make adequate progress in formal school and children with language difficulties. Analysis in Study 1 found a correlation between controlled associations and specific literacy tasks. A correlation was found with the Wide Range Achievement Test for Reading ( $p=.008$ ) and the Wide Range Achievement Test for Spelling ( $p=.024$ ). This is consistent with Messer et al's research. Significant correlations were also found with two assessments obtained that showed a considerable difference in performance between the dyslexic group and the non-dyslexic group. Correlation of controlled associations and reading rhyme judgement ( $p=.024$ ) and phoneme deletion first sound of blend ( $p=.004$ ). Muter et al (1998) have presented research identifying rhyme as impacting later reading skills. This same pattern of findings appears in Study One with these reported findings.

#### **7.14 Reading of Multi-Syllabic Words**

The CORE Phonological Survey required subjects who were successful in reading single syllable words and non-words to decode and read multi-syllabic words and nonwords. These orthographic chunks utilized typical patterns of sounds and spellings. Results show a homogeneity of variance in groups. There was a significant difference in results between groups ( $p=.002$ ). Comparisons between group and gender showed a significant difference in the performance separately for group as well as gender. Group: ANOVA  $_{1,38, 40.693, p=.001}$  and Gender: ANOVA  $_{1,38, 40.693, p=.007}$ . It was interesting to note that in the dyslexic group females performed similar to males in the control group. Males in both the study and the control group had inferior performance to females.



**Figure 7.10 Interaction between groups and gender for Multi-syllabic words**



**Table 7.15 Significant differences in performance between dyslexic and non-dyslexic groups.**

<u>Measure</u>	<u>Results</u>
Phoneme deletion first sound of blend	$t=-4.145, df=40, p<.001$
Multi-syllabic words	$t=-4.299, df=40, p<.001$
WRAT Spelling	$t=-3.505, df=27.282, p=.002$
Spelling Skills: long vowels	$t=-3.384, df=40, p=.002$
Controlled Associations	$t=-2.887, df=36, p=.007$
WRAT Reading	$t=-2.782, df=27.756, p=.010$
R and L Controlled Vowels	$t=-2.536, df=38.803, p=.015$
Consonant Sounds	$t=-2.395, df=41, p=.021$
Reading Rhyme Judgement	$t=-2.269, df=42, p=.028$
Variant vowels and diphthongs	$t=-2.131, df=38.128, p=.040$

In four noteworthy assessments, the dyslexic group did not show any significant deficits over the control group: Long vowel sounds,  $t= -.375, df=41, p=.709$ ; Short vowel sounds,  $t=-.193, df=41, p=.848$ ; British Picture Vocabulary Scale,  $t=-.013, df =40.980, p=$

.990; and CVC spellings,  $t = -.250$ ,  $df = 40$ ,  $p = .804$ . It is interesting to note the significance in consonant sound performance and lack of significance in long and short sound performance. This may be due to the assessment procedure wherein the subject was given credit for the long vowel sound when saying the letter name and could convey within the measurement some overlapping of processing abilities.

### **7.15 Correlations**

After identifying the areas assessed that confirm significant disparity between dyslexic primary age children and non-dyslexic primary age children, it is feasible to conduct correlational studies to test the relationship between tasks. Muter et al presents studies that examine the pattern of intercorrelations between different measures of reading skills. They furthermore argue that phonological skills are highly correlated and that each specific element of phonological knowledge can be highly intercorrelated. Wagner, Torgeson and Rashotte (1994) studied children in beginning reading instruction and found that variables identified in early stages did predict later reading success. Correlation analysis of the above selected assessments was done to look at the relationships of these tasks. Phonemic segmentation showed lesser correlations to the assessments analyzed than the other tasks. Segmentation was correlated with the BPVS vocabulary task and slightly correlated with the controlled association task. Stronger correlations were found in five of the tasks analyzed. Each of these five tasks was strongly correlated distinctively with eight other tasks. Duncan et al (1997) report on interactions that occur between different forms of phoneme awareness tasks. They found that initial skills in phoneme blending were predictive of subsequent decoding skills and that phoneme deletion skill supported blending skills rather than stemming from them. Results from Study 1 support this consideration. Analysis of the relationship between the phoneme deletion initial sound of blend task found strong correlations between this task and Wide Range Achievement for spelling and for reading, variant vowels and diphthongs, multi-syllabic words, long vowel spellings, controlled associations, reading rhyme judgement and the British Picture Vocabulary Test.

## 7.16 Discussion

The central question addressed in this study was the extent to which there are differences in reading, spelling and vocabulary skills between dyslexic and non-dyslexic primary age children and the extent to which they relate to core phonological knowledge. This question is pertinent to researchers, practitioners and policy makers as it provides insight into the specific areas where individuals with language disabilities are deficient. A more definitive representation of the strengths and weaknesses of young children who go on to develop dyslexia and other language disorders will inform further research and alert policymakers to the successful and sustainable methods which can be utilized in curriculum planning for early foundation and primary years. Results of study one demonstrated the substantial differences in performance between reading disabled children and control children.

In summary, ten measures of reading, spelling, phonological knowledge and working memory were found to be significantly different for the dyslexic group. These were both WRAT reading and spelling, knowledge of consonant sounds, “r” and “l” controlled vowels, variant vowels and diphthongs, phonemic deletion first sound in a blend, reading of multisyllabic words, spelling skills for long vowels, reading rhyme judgement and controlled associations. The twenty-two psychometric measures were taken to obtain a picture of each participant’s skill set in reading, spelling, vocabulary and phonemic awareness skills. An additional measure was taken for digit ratio. Participants in both the dyslexic group and non-dyslexic group were found to perform similarly on vocabulary. These results are in concurrence with Shaywitz (2003) who describes the acquisition of vocabulary in an individual’s native language as “innate”. Researchers agree that a dyslexic displays normal intelligence and that the manifestation of dyslexia is typically an information processing deficit rather than a difficulty with receptive language skills (International Dyslexia Association, 2002). The British Dyslexia Association concurs that dyslexia is identified primarily by reading, spelling and writing weaknesses whereas no so great to an extent vocabulary difficulties. Stuart’s research on lexical restructuring

(2005) contends vocabulary development provokes phonological awareness as vocabulary growth occurs. The ability of the lexicon to organize a dyslexic's vocabulary knowledge is where the breakdown occurs. Even as there was no difference in performance between groups for vocabulary, there were interesting results when comparing genders in ability. Contrary to findings by Hyde and Linn (1988) it was found that dyslexic males scored superior to dyslexic females. Non-dyslexic females surpassed both groups, performing better than dyslexic females and males in both groups. These results in vocabulary performance are similar to findings by Johnston and Watson (2005) who surveyed 35 countries and found the reading comprehension of males to be significantly behind the same ability in females. Control males performed similarly to dyslexic males and females. This is supported by research from Rose (2006) and Shaywitz (2003) who contend that research findings indicate a generally weaker performance for males compared to that of girls in reading comprehension and spelling.

In their meta-analysis of the research, Hyde and Linn (1988) describe the relationship between verbal ability and gender. Contrary to the view of current research, Hyde and Linn conclude that there is no evidence of gender difference in vocabulary development. In contrast to the measures of vocabulary knowledge, results from this study found a significant difference in performance between groups for controlled association measures. Messer, Dockrell and Murphy (2004) discuss the specific problems with naming and word-finding difficulties in children with dyslexia. In addition, they describe the small number of studies on children with word finding difficulties. Dockrell, Messer, George and Wilson (1998) indicate that although interest has been shown in word finding difficulties, most of the present data draws from small samples and therefore little is known about the prevalence these difficulties or the occurrence of associated difficulties. Controlled associations are a measure of word retrieval skills. Wing (1990) also found that children with language impairments had deficits of the word retrieval process and benefitted from a focused approach on teaching the phonological and perceptual components of the retrieval process. McGregor (1994) found word-finding problems in boys with mild to moderate expressive language delays (and appropriate receptive language abilities). He also contends that the use of phonological information is

appropriate for treating these difficulties. Similarly, in study 1 females were found to perform superior to males on controlled associations. The female control group outperformed all other groups but both control and dyslexic females showed stronger performances than the males in both groups. Results for controlled associations in study one have established that the dyslexic participants performed significantly worse on this measure of word retrieval than the non-dyslexic group. These findings are consistent with research that supports the rapid auditory processing deficit hypothesis. Denkla (1972) and Denkla and Rudel (1972;1974;1976) propose that word finding difficulties are significant in their long latency and hesitancy to come up with the appropriate vocabulary. Substantial research in rapid naming and word finding has further confirmed the notion that RAN is a predictor of reading success (Blachman, 1984; Vellutino et al., 1996). It is still debated whether RAN is a skill independent of other skill sets that develop strong reading ability (Denkla and Cutting, 1999). Current research does consider RAN to be a critical component of phonological processing and working memory (Wagner et al., 1993). These findings are maintained by Dockrell et al. (1998) who described word findings in children as an inability to produce a target word when presented with a picture or in conversation. Those with word finding difficulties are able to select the appropriate word with a referent but unable to produce a target word independently. Word finding difficulties relate directly to language rules, word meaning and comprehension. Correlations were found in study one between controlled associations and other literacy skills. Controlled associations measures were significantly related to scores in WRAT reading and spelling. A strong relationship was also found between controlled associations and reading rhyme ability as well as with phoneme deletion of the first sound in a blend. These findings are consistent with research presented by Messer et al. (2004) who indicates a relationship between naming abilities and performance on literacy assessments. Messer et al. found a correlation between word finding (naming) and literacy ability. These findings support research on word associations and literacy skills performed by Muter et al., (1998), Dockrell et al., (1998) and Messer et al., (2004) whereas a deficit in naming and word finding skills is related to several other literacy factors which include rhyming, phoneme awareness, reading and spelling ability. Although Savage & Carless (2004); Carroll (2004), Hulme, (1988) and

Snowling, (1995) support a progression to phonological development with phonemic segmentation following fundamental tasks, this study was unable to support those findings. There were no significant differences between groups or sex for phonemic segmentation tasks.

Gelder et al (2005) investigated the link between dyslexia and prenatal testosterone, using the 2D:4D ratio as a factor. Their findings reveal no significant differences between the digit ratios of the dyslexic group and the control group.

Dyslexic participants in this study were inferior readers when compared to the non-dyslexic group. The spelling skills of the dyslexic group were subordinate to the non-dyslexic group. As there was a significant relationship when correlating the WRAT Reading and WRAT Spelling measures it is possible to maintain a reciprocal association between these two skills. The dyslexic group additionally performed worse than the control group in the spelling of long vowel words. These results are in agreement with Uta Frith's theory of language development whereas the orthographic processor interrelates with both the meaning and phonological processor. During the stepwise progression of development, deficits occurred for the dyslexic group that resulted in their subsequent weaknesses in both spelling and reading ability. Results for gender interactions show a difference in the reading ability of males and females. These results are supported by research from (Miles, Haslum & Wheeler, 1998; Finucci and Childs, 1981) that contend a higher ratio of dyslexic males than females. Shaywitz et al., (1990, 2003) argue that this discrepancy in gender ratio is not quite so disproportionate. The present study found that males in both the dyslexic group and control group performed inferior to females. The female dyslexics did perform better than male dyslexics and similarly to non-dyslexic males. This finding is dissimilar to results of Johnston and Watson who showed males performing equal to females in reading ability during the early primary years and subsequently outperforming females from primary 3 to 7. It may be possible to hypothesize that the difference in performance between males and females over time reflects the notion that males develop at a slower rate than females.

Five levels of phonemic awareness have been outlined by Adams (1990) as evidence for the specific phonological deficits that occur during development of reading in dyslexia. Knowledge of rhyme, comparing and contrasting of individual sounds and blends, segmentation of phonemes, combining and separating syllables, and phoneme manipulation of onset and rime are tasks that are required for skill in reading and writing. For this study, six individual measures of phonemic awareness were found to be significantly different between the two groups. Dyslexic participants performed worse than non-dyslexics with consonant sounds, phoneme deletion-first sound of a blend, reading rhyme ability, reading of variant vowels and diphthongs, vowels controlled by the letters “r” and “l” and multi-syllabic words. Growth in phonological skills influences reading development (Byrne, Samuelsson, Wadsworth, Hulslander, Corley, DeFries, Quain, Wilcutt and Wilson, 2006). Children who display weaknesses within the various aspects of the phonetic code are characterized as dyslexic (Shaywitz, 2003). Research has established that phonological knowledge and ability to rhyme are a continuous process that is essential to the ability to read (Anthony and Francis, 2005; Shaywitz, 2003; Anthony et al., 2007). Results from this study show that dyslexics display a definitive deficit in the ability to hear rhyme. Dyslexics in this study also exhibited weaknesses in the phonological knowledge ability to recognize consonant letter sounds to identify variant vowels such as “oo”, “ow”, “ew”, “oy” and “oi”. More specifically, dyslexics in this study also displayed deficits in the ability to distinguish “r” and “l” controlled vowels and diphthongs such as “ay”, “ai” and “oy”. Further investigation is warranted for measures of long and short vowel sounds as this study found no significant differences between groups, however the CORE phonological assessment used for this study accepted the naming of the vowel as indication of the long vowel sound. This causes some uncertainty as to whether the participant actually understood the difference between long and short vowel sounds. Typically for reading development, children must have mastered long and short vowel sounds prior to being able to read variant vowels and diphthongs as well as “r” and “l” controlled vowels. Therefore it is remarkable to note the lack of significance in reading of short and long vowels in this study and more examination is warranted for future research.

Dyslexics were substandard to control participants in both auditory rhyme ability and reading rhyme ability. These results were consistent with findings by Muter et al., (1998) who contend that one key factor in identifying later reading deficits was rhyme ability. Shaywitz (2003) additionally supports this premise in her description of rhyme as an important part of the progression of phonemic awareness. Noticing rhyme is a skill obtained prior to the skill of comparing sounds in different words. As many children vary in their progress of obtaining the necessary reading skills, the ability to rhyme can become insufficient if a child has a reading disability. For this study, dyslexic participants performed significantly worse than control subject in the measure of reading rhyme. Findings by Ball (1993) are comparable to findings of this study whereas the ability to hear rhyme when the words are presented orally is relatively low in terms of explicitness and that the reading of words in order to determine rhyme requires a more intricate skill set from the reader. Ball additionally found that a rhyme judgement task requires more memory than either a production of rhyming words or a task requiring the identification of rhyme oddity. This metalinguistic skill requires a child to reflect consciously on the properties of language as they engage in the reading of the pair of words. Further analysis of study 1 for differences in gender showed that females were superior to males in both the study group and control group. Female dyslexic participants scored superior to male control participants as well.

Language awareness is crucial to a child's emergent literacy activities. This awareness includes the ability to divide sentences into separate words, words into syllables, to isolate beginning, middle and ending sounds, to rhyme words and to rearrange words into grammatically correct sentences (Van Kleeck, 1994). The ability to segment phonemes is a complex task which requires metalinguistic abilities. Tremain's (1983) progressive theory in which a child progresses, requires first the ability to segment words into syllables, then intrasyllabically into onset and rime and finally by individual phonemes. In Study 1, participants were required to segment 15 words by individual phonemes. Both the dyslexic and control group found this task demanding. Even as both groups were unable to correctly segment words by phoneme on more than half the words presented there were no significant differences between dyslexics and non-dyslexics.



Findings in study 1 for segmentation tasks are contradictory to the previously noted study by Muter et al., (1998) who hypothesize that segmentation tasks were strongly correlated with reading and spelling ability by the end of the first year of school. Even as there was no significant difference between gender groups on this task, the performance of dyslexic females was poorer than any other group. The task of phonemic segmentation was found to be significantly related to vocabulary knowledge and with the word finding abilities measured on the controlled association task. These results found are in disparity to findings by Muter et al., (1998) who found a number of relationships between phonemic segmentation and various other measures of reading skills. It is possible, perhaps, that this task was difficult for both groups because of the procedure used for the assessment. Participants were asked to identify each individual phoneme by moving a coloured chip as they produced the individual phonemes within the word presented. In many instances, it was noted, that participants were moving the coloured chip as they segmented the word into syllables. Therefore, then Muter et al.'s proposal of a relationship between phoneme segmentation tasks and measures of reading skills could not be accurately measured in this study as all the participants struggled with this particular task. These findings are consistent with Tremain's progressive theory and it could be proposed that those measured in this study had not advanced meta-linguistically to be able to segment by individual phonemes.

There were numerous significant differences between groups for tasks that required phonemic manipulation. Differences between dyslexic participants and controls were found for consonant sounds, phoneme deletion of the first sound in a blend, "r" and "l" controlled vowels, as well as other variant vowels and diphthongs. Though unequal variances were found between groups, non-parametric analysis showed significant differences between dyslexics and non-dyslexics in ability to isolate the first sound of a consonant blend and for proficiency in naming consonant sounds. Less significant, but still showing tendency was reading of variant vowels and diphthongs and decoding of "r" and "l" controlled vowels. These findings of differences in phonological awareness skill are in harmony with Fletcher, et al. (1994) who contend that children with dyslexia are

consistently more impaired in phonological awareness skills—more than any other verbal or non-verbal task—than children without dyslexia.

It is clear from the range of difficulties found between dyslexics and non-dyslexics in this study that phonological awareness skills are complex and variable. In concurrence with Treiman and Zukowski (1996) this study found that phonological awareness and subsequently reading and spelling ability are not singly homogenous abilities. However, Treiman and Zukowski propose that the heterogeneity found in phonological awareness is directly reflective of the linguist level for the units concerned. Study 1 findings could reflect both agreement and disparity with this hypothesis. Whereas there were differences in many fundamental skills, such as consonant sounds, rhyme, and isolating the first sound of a blend, both groups in study one experienced similar difficulties when presented with more complex phonological awareness activities such as deletion of phoneme in the final sound of a word, phoneme deletion of embedded sounds in a blend and short vowel diagraphs and “tch” trigraphs. There was not sufficient variance between groups to distinguish whether there are significant differences in performance on these more complex tasks. It could be concurred that, to a great extent, research that supports the linguistic status of phonological awareness should be further examined. Finally, this heterogeneity of phonological awareness can be argued to have implications for the relationship between phonological awareness and the alphabetic principle as the learning of letter/sound relationships can be crucial when providing the sign posts to early reading indicators for preschoolers (Bowey, 1994).

It has been established in the field of research in dyslexia that there are definitive deficits in reading and spelling. The question many seek to answer is: what are the contributory factors involved in causing these deficits? Additionally, it is recognized that males are found to have more deficits than females. An issue when researching this theme is that it may be difficult to confirm and corroborate many studies when the participants in the control group and study group are compared—as males have been proven to perform more poorly regardless of a diagnosis of dyslexia. There are also multiple skills required to become proficient in reading and spelling. Research has been contradictory when indicating which skill or skills can be identified as directly causal to the deficit.

With a reciprocal relationship between reading/spelling and phonological knowledge, further examination of these skills in the younger age developing child is warranted. Therefore study 2 will investigate the factors related to reading deficits in preschool age children. As these participants can be viewed in the early stages of development of literacy there is no diagnosis of reading disorder to scrutinize. This allows us the benefit of appraisal at this young age without the issue of comparison between control groups and dyslexic groups. Study 2 will take forward the key elements of study 1. Findings from study 1 will inform study 2 with the erudition essential to examining a preschool group for all significant literacy skills found causal to dyslexia.

## 8. Study 2

### 8.1 Method

#### 8.1.1 Participants

This study was an 18 month longitudinal design. Thirty-nine preschool age children were chosen for this study. The participants were enrolled at the Owens Community College Childcare Technology Lab. The Technology Lab's mission is to provide quality childcare to preschool aged children of staff, students and the local community. The Childcare Technology Lab received accreditation by the National Academy of Early Childhood programs in 2007. For this design, parents were informed and provided written consent allowing participation of their child in the study. Thirty-nine children were initially assessed on several psychometric tests. Of the 39 subjects, one child was Hispanic, one child was African American and the remaining 37 participants for this study were Caucasian. The total enrollment at the preschool was 46 however, a number of children were deemed too young for the intended assessments (ranging in age from 2 years 1 month to 2 years 6 months). Participants ranged in age 3 years 2 months to 5 years 2 months.

As noted in Table 1 the group was fairly well matched for gender. The mean age for participants remaining in the study was approximately 7 months less than those no longer participating. Those participants remaining in the study had a mean age of 3 years 6 months at the end of the first phase of testing. It is important to note that the predictors of

reading disability revealed in this study must be interpreted cautiously as the sample size was small.

**Table 8.1 Demographic Information**

Participation		N	Mean	Std. Deviation	Std. Error Mean
Gender	Number of males and females	23	1.61	0.5	0.1
Age in months		23	46.74	8.62	1.8

### 8.1.2 Design

The aim of the study was three part: (1) to identify and assess intelligence scales (verbal IQ, performance IQ and full-scale IQ) for the preschool age participants (2) analyze the relationship of intelligence to performance in reading related tasks (3) to measure performance on language and phonological related tasks, similarly matched with tasks from Study 1 where a significant difference was noted. Results of these analyses would then lead to further evaluation with the intention to initiate an intervention (Study 3) carried out within a subset of the group which was related to the areas of phonological awareness measured. Following the intervention, specific skills would be reassessed to determine any relationship between the intervention and these skills. During the first phase of this study, multiple psychometric, phonological and visual/spatial testing was performed. Initial and follow up assessments were carried out over a period of 19 months with multiple individual sessions to allow familiarity between the assessor and the participants. In addition, the ability of the participants to remain focused on a task was limited. Therefore the brief, recurring sessions facilitated more accurate testing outcomes. All assessments were conducted during the day in a separate room in the preschool.

As outlined in Chapter 1, reading disability is impacted by the effect of intelligence (Anderson, 2008; Shaywitz, 2003). Researchers contend that even if intelligence scores are not connected with phonological processing, the metalinguistic skills which tap phonological awareness are correlated (Snowling, 1998). These measures for the WPPSI-III were selected for the purpose of further discrimination with relation to pre-reading skills. The WPPSI-III was determined to be appropriate for measuring intelligence as it is one of the most current measurements of intelligence (Dumont and Willis, 2001). The WPPSI-III was normed on a sample of 1700 children ages two years, two months to seven years, three months. Historically the WPPSI-III is understood to be the standard of measurement in evaluating preschool intelligence factors. By examining intelligence, this paper acknowledges the crucial consequences for intelligence and reading ability and attempts to further define these specific underlying skills. Those phonological and language assessments chosen for this study are central to research presented as well as the outcomes of the previous study. Language and phonological assessments performed were the Wide Range Achievement Test (WRAT) for spelling and reading, PALPA rhyme picture selection, Earobics Rhyme, alphabet knowledge, onset and rime, and child embedded figures testing.

Research on Earobics has validated and quantified its' reading intervention program as reviewed by the Florida Centre for Reading Research. Bryant and Torgeson (1994) report that students who received intervention with Earobics phoneme awareness skills performed significantly better than those who did not receive the intervention. Robert and Salter (1997) reported on preschool age children receiving instruction with earobics for three 20 minute sessions per week. The study showed that those students who used the Earobics instruction performed significantly better on phonemic awareness tasks than those who did not receive the instruction.

Tremain (1983) in her research supports a developmental theory whereas onset and rime understanding is fundamental to further successful reading development. In her research she explores three distinctive levels in reading development and which onset and rime play a significant part.

1. The ability to segment spoken words into syllables

2. The ability to segment syllables into onsets and rimes
3. The ability to segment onsets and rimes into phonemes.

Tremain's proposes that rime is the major structure and that each syllable conforms to an onset-rime division. Therefore the ability to recognize similarities in onset and rime patterns is vital to the developmental process of reading.

Early phonological knowledge is causally related to later success in reading ability (Wagner and Torgesen, 1987). Muter et al (1998) present information outlining the importance of onset and rime in preceding a child's ability to read. They argue that an awareness of phonemes develops after or as a consequence of learning to read. Muter et al propose that phonological awareness skills are highly correlated. Their research supports previous studies which contend that it can be defined by a single factor but that this single factor can be broken down into separate and highly intercorrelated factors.

Onset-rime awareness is the ability to distinguish between word families. Rime refers to an identical string of letters such as "ate" and "ight". A preliterate child develops awareness of spelling patterns in written words. The use of the term, rime, for the end units makes obvious reference to the fact that words which finish with similar rimes do rhyme. Rhymes are a very significant part of a preschoolers' life. These rhymes are modelled and taught to the child and they subsequently make up their own long before primary school instruction (Dowker, 1989). Children are able to detect rhyme and alliteration before they begin to read (Bradley & Bryant, 1983). Their experience of and sensitivity to rhymes seems to be closely linked to their fluency in reading and to their experience of nursery rhymes in their early years (Bryant, Bradley, MacLean & Crossland, 1989). Carroll (2004) determines that awareness of larger segments of phonology, such as syllables and rimes is a precursor to phoneme awareness in preschoolers. Goswami and Bryant (1990) propose that an awareness of rimes and syllables develops in a natural way for the preschool child. Phoneme awareness subsequently develops from this awareness as the child learns to read. When looking at indicators of phonemic awareness, Anthony and Barker (1998) found an interaction with alphabetic knowledge in preschool children. Therefore, it has been found that there is substantive evidence that learning letters is a precursor to phoneme awareness in

preschool children. The word reasoning subtest of the WPPSI-III measures word retrieval skills. Research has revealed that dyslexics and non-dyslexics perform differently on tasks with a verbal recall component. Those with dyslexia show deficits in verbal memory abilities. Individuals considered non-dyslexics performed better on these tasks with a verbal component. On tasks without a verbal component, both non-dyslexics and dyslexics perform on the same level (Vellutino, 1979).

The Child Embedded Figures Testing was selected for this design as well. In this assessment, children attempt to locate simple geometrical shapes which are hidden in more complex designs. This test is sometimes used to measure field dependence and independence. Field dependence and independence was initially studied by the German Gestalt psychologist, Kurt Gottschaldt (1902-1991) Gottschaldt developed a measure of this skill also identified as the Gottschaldt Figures Test. Subsequently, Herman A. Witkin in his research of learning styles developed a model of learning styles in terms of process. His belief was that learning styles impact how individuals perceive, think, solve problems, learn and relate to others (Witkin, Moore, Goodenough, & Cox, 1977). Witkin demonstrated the differences in perception an individual possessed and how this perception was impacted by the surrounding field in which an item was presented. His research maintained that there were distinct differences in how individuals perceived discrete items within a surrounding field. These differences could be measured on a spectrum in which those described as “field dependent” had perception skills strongly dominated by the prevailing field and those who were “field independent” could visualize items as separate from the field. Witkin influenced the development of the Group Embedded Figures Test, a perceptual test which necessitates a participant to locate a previously seen figure within a larger complex figure. In the GEFT there are 18 complex figures presented. Administration of the GEFT typically takes 20-30 minutes. Individuals who are field independent often are able to perform the task required significantly better than individuals who are field dependent. Scores range from 0 to 18 with the norm being between 11 and 12. A high score on the measure is an indication the participant is more field-independent whereas lower scores indicate likelihood the participant is more field-dependent. Gardner (1985) proposed that this spatial



visualization skill was important for perceiving the visual world, transforming and modifying initial perceptions and mentally recreating spatial aspects of one's visual experience without the relevant stimuli. Though there is a relationship between how an individual performs on verbal and non-verbal tasks, the strength of verbal versus nonverbal skill can be unbalanced (Linn and Peterson, 1985).

## **8.2 Measures**

The Wechsler Preschool and Primary Scale of Intelligence edition III (WPPSI-III) was used for the purposes of this study. The WPPSI-III allows the examiner to obtain a full scale IQ for the subject. The WPPSI-III divides the Full Scale assessment into subtests that provide verbal and performance assessment. A full scale intelligence quotient (FSIQ) as well as performance IQ (PIQ) and verbal IQ (VIQ) were acquired for each participant. No predetermination was made for reading disability with the participants (as they were too young to have a diagnosis) and no familial risk was established prior to selection of the group. In addition, the Processing Speed Quotient (known as the Processing Speed Index on previous Wechsler scales) can be derived for children aged 4:0 - 7:3, and a General Language Composite can be determined for children in both age bands (2:6–3:11 & 4:0–7:3).

The WPPSI-III, for children between the ages of 2 years 6 months through 3 years 11 months, includes four core subtests: Receptive Vocabulary, Information, Block Design, and Object Assembly. The older version of the WPPSI-III, for children between the ages of 4 years through 5 years 11 months, includes seven core subtests: Information, Vocabulary, Word Reasoning, Block Design, Matrix Reasoning, Picture Concepts, and Coding. Both configurations of the WPPSI-III generate composite scores for Verbal IQ, Performance IQ, and Full Scale IQ. Age-based standard scores are generated for all indices. The optional symbol search and coding tests assess processing speed (Wechsler 2002). For this study, seven subtests were utilized. The rationale behind these measurements was to establish cognitive function for this study group. WPPSI-III scores can be weighed against those in this age range so as to ascertain the standard.

## Description of WPPSI-III Subtests

### *Information*

The information subtest is a core verbal assessment. It is used with children ages 2:6 to 7:3. The information subtest is intended to assess a child's ability to acquire, retain and retrieve general knowledge. This subtest measures a subject's intelligence, long term memory and his/her ability to retain and retrieve knowledge. The information subtest has 34 test items, which include 6 picture items and a subsequent 28 verbal items. The 6 picture items require the subject to point to the correct response picture when presented with a set of 4 choices and a request to point to the object referenced (ex: "Show me what you can eat"). The subsequent 28 verbal items require a brief verbal response from the subject (ex: "What comes in a bottle?") The verbal questions address a broad range of general knowledge topics. The subject is given a score of 1 point for a correct response and 0 points for an incorrect response or no response.

### *Vocabulary*

The vocabulary subtest is a core verbal assessment for children ages 4:0 – 7:3. This subtest measures a subject's word knowledge and verbal concept formation. In addition, the subtest measures a subject's long term memory, fund of knowledge, learning ability and degree of language development. The vocabulary assessment presents 25 items which include 5 picture and 20 verbal prompts. The subject is asked to name each of the 5 picture prompts. The subject is then asked to provide definitions for each of the verbal prompts that the assessor presents (Example; "What is an umbrella?").

### *Word Reasoning*

The Word Reasoning subtest is a core verbal assessment for ages 4:0-7:3. The Word Reasoning measures verbal comprehension, general and logical reasoning as well as the subject's ability to integrate and synthesize concepts. There are 28 assessment items in

the Word Reasoning subtest. Each test item solicits identification of common concepts with verbal clues (Example; “This is made of two wheels.....and it needs gas to run”).

### *Block Design*

Block Design is a subtest designed to measure a subject’s ability to analyze and synthesize information, visual perception, organization and nonverbal concept formation. Cooper (1995) and Kaufman (1994) additionally propose that the Block Design subtest measures simultaneous processing, visual motor coordination, learning and the ability to separate figure and ground within a visual stimulus. This subtest offers 20 test items using red and white blocks and two-colour (red/white) blocks. In the assessment, the subject is asked to view a constructed model and replicate it and then move on to replication of a pictured model within a specific time limit.

### *Matrix Reasoning*

Matrix Reasoning is a subtest intended for ages 4:0-7:3. This subtest measures a subject’s ability to process visual stimuli as well as abstract reasoning skills. The Matrix Reasoning subtest has 29 assessment items. In each visual prompt, the subject is presented with an incomplete matrix of pictures and asked to choose the missing piece from a group of response pictures.

### *Picture Concepts*

Picture Concepts is a subtest for ages 4:0-7:3. Picture Concepts is designed to measure abstract reasoning abilities. The test items are set out in increasing order to measure the subject’s categorical reasoning. This assessment has 28 items. In each item, the subject is presented with two or three rows of pictures and must choose one picture from each row that displays common characteristics (Example: picture of fork from first row and picture of spoon from second row).

### *Coding*

Coding is a subtest designed for ages 4:0-7:3. Coding measures a subject’s short term memory, visual-motor coordination, learning ability, attention, visual perception and

Motivation (Kaufman 1994). This assessment presents simple geometric shapes that the subject must copy. Using a key, the subject then draws each symbol in its corresponding shape. This assessment has 59 items and is timed—allowing 120 seconds for completion.

### *Digit Measurement*

Digit measurement was taken of each subject by producing a photocopy of both the left and right hands. Each hand was placed palms down on the photocopier and a reproduction of both left and right hands was made for each subject. The 2<sup>nd</sup> and 4<sup>th</sup> digit of both the left and right hand was measured employing vernier callipers for accurate measurement. The vernier calliper is used in length measurements to gain an additional digit of accuracy. Measurement was taken from the crease where the finger met the hand to the furthest point of the digit at the centre. Measurements were taken from the basal crease of each finger to the central top of each finger (Brosnan, 2008). A repeat measurement of the 2<sup>nd</sup> and 4<sup>th</sup> digits of both hands was done by an independent source to compare for accuracy. Each of the subjects hands was measured a second time by an independent party. The left and right digit ratios were analyzed separately as well as the mean of digit ratio in both hands. In addition, the difference between the two digit ratios was analyzed to mark the variability between both hands.

### **8.3 Identification of Language and Phonological Assessments**

Upon completion of analysis of intelligence in Study 2, a battery of phonological and language based assessments were chosen for the subsequent phase of Study 2. These particular selections were based on previous research and from results in Study 1 which included those outcomes that identified a significant difference in performance between the dyslexic and non-dyslexic participants of primary age. Given the support of the breadth of research on dyslexia and phonological knowledge, the selected assessments were believed to be developmental indicators for phonological knowledge and successive reading acquisition. Additionally, these assessments, once matched with those of Study 1, were suitable to the age group they were administered to. The motivation behind the

use of the chosen assessments was that these particular tests were a good fit with the assessments employed in the first study with primary age children.

#### *Wide Range Achievement Test (WRAT) Reading and Spelling*

The WRAT measures spelling and reading ability for this age group and was appropriate for use of assessment in letter recognition and ability to write letters. The Wide Range Achievement Test (WRAT 3) was used to obtain a spelling and reading age for each child. The WRAT-3 has two alternative testing forms (tan and blue). The blue form was used in this assessment. The spelling and reading assessment were performed on each student. The reading test consisted of 15 letters and 42 individual words that the student is asked to name or pronounce. The Wide Range Achievement Test is normed for children ages 5.0 to 11.11 (level 1). Although the subjects in Study 2 ranged in age from 3.2 to 5.2, it was important to utilize this assessment for its letter recognition and spelling analysis as it was appropriate to evaluate these cognitive skills at this basic level in an equivalent level to study 1. Therefore the 15 letter portion of the assessment was performed on the preschool age subjects.

#### *Rhyme Judgement Requiring Picture Selection*

This assessment paired suitably with the PALPA auditory and written rhyme skills measurement utilized with primary aged participants in study 1. Rhyme Judgement was assessed using the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA). Subjects were presented with twenty sets of two pictures. For each set of pictures, the subject was asked to look at the pictures and listen as they were said aloud. They were required to indicate if each set of pictures “sounded the same” or “sounded different”. The test was presented in picture format with four demonstration items followed by 20 test items. This assessment was chosen for this particular age range as it closely complemented the PALPA Reading and Auditory rhyme judgement measure utilized in Study 1 with primary age children.

It was determined that a more multi-sensory modality of assessing knowledge of rhyme was necessary. An additional measure of rhyme detection was taken using the Earobics software program and its rhyme subtest. Earobics is a research based reading intervention visual learning program. The purpose of using the earobics program rhyme component for an assessment of rhyme was to provide a more valid result in rhyme assessment overall for this study. During the Earobics assessment, participants were presented with 10 sets of word. In each set, the participant was shown a set of three frogs. Each frog stated a word and the participants were asked to choose the word that did not sound the same (example, “say, hay, lock”). The participant received a point for each correct response.

#### *Alphabetic Knowledge*

Participants were assessed on ability to name upper and lower case letters of the English alphabet. Twenty-six upper case letters were presented in a random order and participants were asked to name the letter when pointed to. Additionally, participants were asked to name 26 lower case letters presented in the same random format.

#### *Onset and Rime*

For this particular exam, each participant was asked to sort picture cards that were from the same family from words that were not. Six sets of three cards that included the word, as well as a picture of the word were shown. During the practice set the examiner modelled the appropriate choice stating that “these two go together. They have the same ending letters and sound. This one does not belong. It has a different ending sound and letters.” The child was given one point for each set in which they made the correct match of onset-rime pairs.

#### *Controlled Associations/Word Reasoning*

Results of Study 1 on primary age school children showed a significant difference in measurement of controlled associations. Controlled associations evaluate an individual’s word retrieval skills. Consistent with research from Baddeley (1993) and (2003) participants with dyslexia showed significantly weaker skills than participants without

dyslexia. Assessment of this skill for preschool age participants was determined to be most appropriate in looking at working memory and reasoning as an indicator of reading disability. The WPPSI-III Word Reasoning subtest is a measurement of verbal comprehension, reasoning ability, verbal abstraction, domain knowledge and the ability to generate alternate concepts. The Word Reasoning subtest is a core verbal assessment for ages 4:0-7:3. There are 28 assessment items in the Word Reasoning subtest. Each test item solicits identification of common concepts with verbal clues (Example; “This is made of two wheels.....and it needs gas to run”).

#### Child Embedded Figures Test

The child embedded figures test (CEFT) was used to assess each participant’s ability to reduce the processing of irrelevant context. In the child embedded figures test, preschool participants were shown and then allowed to practice placing two differing simple figures within a more complex visual array. The participants were timed in two five minute sessions and scored one point for each correctly placed figure in the picture. The purpose of the visual array was to provide a framework for making the placement of the disembedded figure more difficult. For example, one of the arrays consisted of a drawing of an upside down kite. Within this drawing, there were a series of similar outlines for the disembedded figure that were possibly longer, wider, shorter or narrower. Additionally within the drawing were distracters which included other shapes and lines shaded various colours. The preschool participant was required to inhibit references to irrelevant information and/or avoid impulsive responding on the basis of the most obvious phenomena as is the presumption with this activity.

## **8.4 Results**

### Results of Wechsler Preschool and Primary Scale of Intelligence-III

When compared for gender, both males and females showed no significant difference in IQ scoring for Full-Scale IQ or Performance IQ but a tendency towards significance in Verbal IQ. Here females scored slightly higher with verbal IQ sub testing than boys ( $p \leq .067$ ).

Research has diverging findings related to verbal ability and gender. A number of researchers propose no evidence of gender difference in vocabulary development. Study 1 of this research compared dyslexic readers with a control group and found the males in the dyslexic group performed slightly superior to females in the dyslexic group, yet in the control group, females performed superior to males and superior to both males and females in the dyslexic group.

Initial assessment of results on subjects assessed using WPPSI-III and the Wide Range Achievement Test for reading and spelling were analyzed for demographics of age, gender and handedness. Not every child was able to complete all assessments. This was due to failure in attention span and concentration. Twenty-three females and seventeen males were initially entered into the study. Wechsler Preschool and Primary Scale of Intelligence III results were completed for nineteen females and eleven males to obtain performance IQ, verbal IQ and full-scale IQ. T-test results show no significant difference in the performance of males and females for PIQ, VIQ or FSIQ. In order to control for age, standard or scaled scores were used for the WPPSI-III subtests performed. As the Wide Range Achievement Test (WRAT) for reading and spelling was standardized for a minimum age of 5 years and 0 months, the raw score was utilized for the purpose of this analysis. The intent of the WRAT was exploratory and was employed without use of norms. Results were examined for gender differences. As there were no gender differences revealed in the course of analysis, results of tests were correlated using both genders. Most subjects were reported to be right-handed generally but the majority of subjects, because of age, had no determined hand of preference. Mean comparison for IQ results as well as performance in reading and spelling showed no significant difference between groups for handedness. Analysis of results for intelligence and reading and spelling ability were conducted. Table 2 illustrates the significant relationship found between Verbal Intelligence (VIQ) and reading ( $r_{19}=+0.46$ ,  $p=.024$ ; one-tailed). Full Scale IQ results show a trend towards significance with reading ( $r_{19}=+0.37$ ,  $p=.061$ ; one-tailed) but no correlation with spelling. Performance in reading is significantly related to spelling ability ( $r_{24}=+0.67$ ,  $p<.01$ ).



**Table 8.2 Correlations between Intelligence and Reading Scores**

		Verbal IQ	Performance IQ	Full Scale IQ	WRAT Reading	WRAT Spelling
Verbal IQ	Pearson Correlation	1	.552(**)	.786(**)	.458(*)	0.333
	Sig. (1-tailed)		0.001	0	0.024	0.082
	N	30	30	30	19	19
Performance IQ	Pearson Correlation	.552(**)	1	.865(**)	0.327	0.277
	Sig. (1-tailed)	0.001		0	0.086	0.126
	N	30	30	30	19	19
Full Scale IQ	Pearson Correlation	.786(**)	.865(**)	1	0.368	0.216
	Sig. (1-tailed)	0	0		0.061	0.187
	N	30	30	30	19	19
WRAT Reading	Pearson Correlation	.458(*)	0.327	0.368	1	.685(**)
	Sig. (1-tailed)	0.024	0.086	0.061		0
	N	19	19	19	24	24
WRAT Spelling	Pearson Correlation	0.333	0.277	0.216	.685(**)	1
	Sig. (1-tailed)	0.082	0.126	0.187	0	
	N	19	19	19	24	24

The relationship between reading ability and each subtest of the WPPSI-III was examined. A moderately strong relationship between reading ability and Block Design was indicated ( $r_{21}=+0.60$ ,  $p=.004$ ). A moderate relationship between reading ability and Word Reasoning was also found ( $r_{20}=+0.56$ ,  $p=.010$ ). A negative correlation between reading ability and Coding ( $r_{12}=-0.55$ ,  $p=.066$ ) may signify that poor performance in

coding is related to strong performance in reading. These results may be spurious and require further research. Analyses of results for spelling ability (WRAT spelling) signify a similar relationship with Block Design and Word Reasoning. Correlation coefficients for WRAT Spelling and block design ( $r_{21}=+0.51$ ,  $p=.019$ ) block design and word reasoning ( $r_{20}=+0.60$ ,  $p=.005$ ). The Block Design subtest measures simultaneous processing, visual motor coordination, and the ability to separate figure and ground within a visual stimulus. The Block Design subtest contributes to the formation of a Performance IQ (PIQ). The Word Reasoning subtest is a measurement of verbal comprehension, reasoning ability, verbal abstraction, domain knowledge and the ability to generate alternate concepts. Word reasoning is a subtest used to help calculate Verbal IQ (VIQ).

#### *Pre-Reading Skills and Intelligence*

The relationship of other pre-cursor tests of reading ability and intelligence was examined. Strong correlations between Full Scale intelligence (FSIQ) was found with three pre-reading measures: Embedded figures ( $r_{16}=+0.63$ ,  $p=.01$ ), alphabet knowledge ( $r_{16}=+0.62$ ,  $p=.01$ ) and Earobics rhyme assessment ( $r_{17}=+0.62$ ,  $p=.01$ ). Examination of performance IQ (PIQ) revealed correlations with embedded figure assessment ( $r_{16}=+0.70$ ,  $p=.03$ ), alphabet knowledge ( $r_{16}=+0.56$ ,  $p=.03$ ) and Earobics rhyme ( $r_{17}=+0.56$ ,  $p=.02$ ). Verbal intelligence (VIQ) was found to be related to Earobics rhyme assessment ( $r_{17}=+0.50$ ,  $p=.04$ ). A negative correlation was found for VIQ and onset-rime ability ( $r_{17}=-0.42$ ,  $p=.05$ ).

#### *Relationship between pre-cursors to reading*

Analysis of the link between alphabet knowledge and WRAT reading was performed. As the Wide Range Achievement Test was normed for the minimum age of 5 years 0 months, it was determined that both the raw score and the standard score would be recorded as separate variables. A partial correlation was performed separately for the raw WRAT read score with alphabet knowledge as well as the standard WRAT score with alphabet knowledge—both controlling for age. When controlling for age, it was

interesting to note that a similar association between these two assessments was established. Results for WRAT Reading (raw score) and alphabet knowledge was ( $r_9=+0.67$ ,  $p=.02$ ). Results for WRAT Reading (standard score) and alphabet knowledge was ( $r_{10}=+0.64$ ,  $p=.02$ ) No direct correlations between WRAT spelling and the prereading skills was found except for a trend between spelling and alphabet knowledge ( $r_{13}=+0.52$ ,  $p=.07$ ). Clearly there was a relationship between spelling and reading ability ( $r=+0.68$ ,  $p=.01$ ).

Subsequently the relationship between assessments of pre-cursors to reading was examined. A large significant relationship was found between performance on embedded figure testing and both assessments of rhyming ability (PALPA rhyme  $r_{22}=+0.51$ ,  $p=.01$ ; Earobics rhyme,  $r_{19}=+0.60$ ,  $p=.01$ ). This appears to indicate that ability to reduce the processing of irrelevant context is associated with ability to rhyme.

Alphabet knowledge was found to be correlated with both rhyme assessments (PALPA rhyme,  $r_{22}=+0.46$ ,  $p=.02$ ; and Earobics rhyme,  $r_{19}=+0.43$ ,  $p=.03$ ). PALPA rhyme, but not Earobics rhyme indicates a trend with onset-rime testing ( $r_{19}=+0.43$ ,  $p=.06$ ).

### Digit Ratio

Examination of left and right hand digit ratio, as well as average digit ratio was done to explore possible relationships with intelligence. Digit ratio was obtained for twelve males and fourteen females. Typically males tend to have a larger digit ratio with a smaller numeric measurement and females have a lower digit ratio with a subsequent larger numeric measurement. For this study, predicted results did not transpire as digit ratio for female preschoolers was lower than for male preschoolers. The relatively young sample group was presumed to be the cause for these unusual results. Correlations between the four factors; left hand digit ratio, right hand digit ratio, average digit ratio and age in months showed a significant relationship between these findings (age/left hand digit ratio =  $r_{26}=+0.41$ ,  $p=.04$ ; age/right hand digit ratio =  $r_{26}=+0.33$ ,  $p=.09$ ; age/average digit ratio= $r_{26}=+0.44$ ,  $p=.02$ ). Consequently study two reveals a significant shift in digit ratio with age.

**Table 8.3 Digit Ratio: Males vs. Females**

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Left hand digit ratio	Male	12	.9822	.02780	.00802
	Female	14	.9623	.03434	.00918
Right hand digit ratio	Male	12	.9457	.02974	.00859
	Female	14	.9346	.02512	.00671
Average digit ratio	Male	12	.9640	.02384	.00688
	Female	14	.9485	.02504	.00669

No significant correlations were found between digit ratio and performance IQ, verbal IQ, or full scale IQ for males for females analyzed separately. Further examination of the possible relationships between digit ratio and the subtests of the Wechsler Preschool and Primary Scale of Intelligence was performed. The correlation between left hand digit ratio and the subtest of matrix reasoning was significant ( $r_{23}=+0.47$ ,  $p=.04$ ) as well as between right hand digit ratio and matrix reasoning ( $r_{23}=+0.43$ ,  $p=.04$ ) and average digit ratio and matrix ( $r_{23}=+0.51$ ,  $p=.01$ ). The matrix reasoning subtest measures a subject's ability to process visual stimuli as well as abstract reasoning skills. Performance of a partial correlation to control for age and gender shows there is still a trend towards a significant relationship between right hand digit ratio and matrix reasoning ( $r_{19}=+0.35$ ,  $p=.06$ ) and a definitive significance between average digit ratio and matrix reasoning ( $r_{19}=+0.39$ ,  $p=.04$ ).

Examination of the relationship between digit ratio and reading and spelling skills was completed. There was a significant negative relationship between right hand digit ratio and WRAT reading ( $r_{21}=-0.45$ ,  $p=.04$ ) and a significant negative relationship between average digit ratio and reading ( $r_{21}=-0.42$ ,  $p=.05$ ). A partial correlation, one-tailed, was

performed controlling for factors of age and gender. There was a trend shown in a negative relationship between left hand digit ratio and WRAT reading performance ( $r_{17}=-0.31, p=.06$ ). Additionally a significant relationship between WRAT spelling and left hand digit ratio was found ( $r_{17}=-0.48, p=.03$ ). Right hand digit ratio and WRAT reading reveals a negative significant relationship ( $r_{17}=-0.53, p=.01$ ). There was no significant relationship for right hand digit ratio and WRAT spelling outcomes. Average digit ratio and WRAT reading were found to have a significant negative relationship ( $r_{17}=-0.54, p=.01$ ) as well as with WRAT spelling ( $r_{17}=-0.40, p=.05$ ).

The relationship between digit ratio and other cognitive abilities related to reading was examined. No significant relationship between left hand digit ratio, right hand digit ratio and reading ability was found. Similar results, indicating no correlation, were found for left hand digit ratio and spelling and right hand digit ratio and spelling. A negative correlation was revealed for average digit ratio and reading ability ( $r_{18}=-0.50, p=.03$ ).

Cognitive capabilities related to literacy in this study were examined. The relationship between left hand, right hand, average digit ratio and pre-literacy skills did not reach significance.

**Table 8.4 Digit Ratio and Pre-literacy Skills**

	Embedded	Alphabet	PALPA Rhyme	Earobics	Onset-Rime
lhdr	$r_{16}=+0.10, p=.35$	$r_{16}=+0.02, p=.47$	$r_{16}=-0.20, p=0.23$	$r_{17}=-0.12, p=.32$	$r_{17}=+.18, p=.25$
rhdr	$r_{16}=-0.18, p=.47$	$r_{16}=-0.00, p=.49$	$r_{16}=+0.36, p=.40$	$r_{17}=-.11, p=.34$	$r_{17}=-.04, p=.44$
avedr	$r_{16}=+0.05, p=.42$	$r_{16}=+0.01, p=.48$	$r_{16}=-.07, p=.40$	$r_{17}=-0.14, p=.29$	$r_{17}=+0.09, p=.36$

## 8.5 Discussion

This study aimed to examine the relationships between preschool age children, intelligence and pre-reading skills. The analysis of these factors would then lead to further evaluation with a subset of preschool age subjects before and use of a selected intervention which would be carried out for this group and therefore be related to the areas of phonological awareness measured. Following the intervention, a predetermined set of skills would be reassessed to determine a relationship between the intervention and these skills. Researchers typically choose children who have difficulty with their reading in relation to their intelligence for participation in studies (Miles, Haslum & Wheeler, 1998). For study 2 the relationship between pre-reading skills and intelligence was examined. Several strong correlations between Full Scale IQ and the child embedded figures testing, Earobics rhyme assessment and alphabet knowledge were found. Furthermore, examination of performance IQ (PIQ) found strong correlations with child embedded figure testing, alphabet knowledge and Earobics rhyme. Verbal Intelligence (VIQ) was significantly related to Earobics rhyme assessment. Moreover, research by Gus and Samuelsson (2002) examines the “theoretical issues and practical consequences of including IQ in the definition of dyslexia. According to the discrepancy criterion individuals are classified as dyslexic if their reading skills are below what would be expected from their IQ scores.” Gus and Samuelsson maintain that intelligence is a vague concept and that there is no clear causal relationship between an individual’s intelligence level and word decoding skills. Additionally, high and low IQ poor readers show the same reading performance patterns, specifying that both groups might benefit from the same remedial activities. In a similar strand, Stanovich (1991) reasons that a discrepancy criterion between reading ability and intelligence has led researchers astray. He argues that the concept of intelligence as a benchmark in the identification of reading disability is “puzzling”. Stanovich proposes that more involved research in psychometric measurement must be done in order to expand upon the method for measuring discrepancy in reading and listening comprehension or some other verbal indicator. Results from this study have pursued these research questions through analysis of the

factors involved in measuring intelligence and their correlations with pre-reading skills. It is clear that further research to examine the distinct characteristics that make up intelligence and their relationship to reading development is warranted. This is supported by Anderson (2008) who states “the effect of general intelligence on reading performance in ways that will remain unclear without an explicit model of how general intelligence influences reading”. This study demonstrates the causal relationship between factors of intelligence and pre-literacy skills—remarkably for one of the youngest group of participants to be examined.

Research has established the risk of developmental dyslexia in preschool age children who demonstrate difficulties in phonological knowledge related tasks (Gallagher, Frith, & Snowling, 2000). They report that by age three children with a familial risk of dyslexia show weaknesses in vocabulary development, novel word repetition, letter name knowledge and knowledge of nursery rhymes. It appears a reciprocal relationship exists between phonemic awareness and the development of reading (Goswami, 2002). Early letter knowledge predicts later phoneme awareness (Goswami, 2002; Snowling, 1998; Anthony and Francis, 2005). Preschoolers with letter knowledge show more success on phonemic awareness tasks (Carroll, 2004). Carroll additionally reports on research by Anthony and Barker (1998) that shows interaction between letter knowledge and phonemic sensitivity in the preschool years. Preschoolers that experience instruction with alphabet knowledge show stronger reading skills subsequent to this instruction. This hypothesis is supported by Muter, Hulme, Snowling and Taylor (1998) who describes research showing links between phonological skills in preschool development and the later skills in reading and spelling. In study 2 significant correlations were found between reading and spelling skills which demonstrates the reciprocal relationship these skills encompass. Additionally alphabet knowledge is correlated with FSIQ as well with reading ability. Likewise, a trend was found to exist between alphabet knowledge and spelling ability.

Study 2 examined the potential relationships between reading and spelling ability for preschoolers and alphabet knowledge. According to Torgeson (1998) most children who later become poor readers experience early and continuing difficulties in identifying

printed words. Torgeson claims this difficulty is expressed in two types of reading tasks: Children who have difficulty with reading by the elementary school years have invariably struggled with understanding and applying the alphabetic principle during the foundation years. Next, children who have difficulty reading and decoding unknown words at all grade levels have been identified as those with slower than normal development of a basic sight word vocabulary. This, slower than typical, sight word development hinders the fluency and automaticity of reading for the child. Study 2 compared both the WRAT Reading raw score and standard score with alphabet knowledge and found when controlling for age, a significant relationship between alphabet knowledge and the raw and standard score for reading for these participants. As supported by research, there was a clear relationship between spelling and reading ability for this study (Torgeson, 1998; Shaywitz, 2003; Liberman et al, 1989).

Preschoolers as young as 4 years of age are able to distinguish between rhyming and non-rhyming words (Bradley & Bryant, 1978). Participants in study 2 were required to choose the non-rhyming word when presented with three words in sequence. Two different measurements were taken to measure ability in rhyme—PALPA and Earobics rhyme. Examination of these measures was done to look for correlations with other measures completed. A large significant relationship was found between both measures of rhyming and the child embedded figures testing. As the child embedded figures testing measures an individual's ability to reduce the processing of irrelevant context it appears this measure is associated with one's ability to rhyme. Additionally, alphabet knowledge was found to be correlated with both rhyme measurements. This is consistent with Goswami and Bryant (1990) who indicated that letter name knowledge was related to rhyme and causally related to a child's ability to read.

This study assessed 2D:4D as an indicator of fetal testosterone exposure. Associations with age, intelligence, reading, spelling and phonological ability were investigated. Female subjects were found to have a lower digit ratio than males which is contrary to research (Brosnan, 2006, 2008; Manning, 1998). A young study group was suspected and further examination of results, controlling for age, confirms a significant shift in digit ratio. Similar results were found in both Brosnan (2008) and Trivers, Manning and



Jacobson (2006) where shifts in digit ratio were examined and found to occur up to thirteen years of age. Sexually dimorphic digit ratio has been reported across and between ethnic groups (Peters, Mackenzie, & Bryan, 2002; Manning, Steward, Bundred and Trivers, 2004). It was reported by Williams, Greenhalgh and Manning (2003) that a greater change in right hand digit ratio versus left hand digit ratio occurs with age. Trivers et al., (2006) found it was the left hand that had the greater increase with age. Research as spotlighted the relationship between 2D:4D and psychopathology in a young preschool group (Williams, Greenhalgh & Manning, 2003) but not as definitively for psychometric assessments. Study two addresses perhaps the youngest preschool population with regards to pre-literacy skills and digit ratio whereas digit ratio has been found to be related to reading development. The study by Williams et al. found that real differences occur between sexes which can be correlated with digit ratio. Even as the effects of digit ratio has been recognized to be associated with many psychometric skills, study two highlights the correlation with age and the actuality of change in 2D:4D that can occur with aging.

Whilst digit ratio did not correlate with full-scale intelligence, verbal intelligence or performance intelligence, further examination of the subtests of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III) revealed a relationship between left hand digit ratio, right hand digit ratio, average digit ratio and Matrix Reasoning. These results were also found when age and gender were controlled for. The Matrix Reasoning subtest of the WPPSI-III examines nonverbal perceptual reasoning by requiring an individual to complete the missing portion of abstract patterns. Non verbal reasoning requires an individual to analyze information, solve problems using visual or hands-on reasoning and includes the ability to recognize and remember sequences. These findings concur with Brosnan (2008) who found that average digit ratio correlated with the relative difference between numeracy and literacy. These findings suggest that prenatal testosterone is related to non-verbal reasoning skills and subsequently reading development. The implications for these findings are essential to the question of how literacy develops. These findings support the premise that preschool age children are more visual learners. As Rose (2003) establishes the importance and significance of systematic, sequential

presentation of the skills required for reading ability, it is crucial to understand the underlying factors related to development that occurs in a similarly systematic manner.

Therefore, deliberation as to which specific phonological skills play the most important role in the process of reading development is essential. Identification of the precise skills which causally relate to deficits in reading ability will then lead to the process of appropriate intervention during the preschool years. Researchers cannot always agree on which indicators of reading development are most important to the later development of reading.

## **8.6 Summary**

Study 2 evaluated preschool age participants for factors of intelligence, including full-scale IQ, performance IQ and verbal IQ. In addition the relationship between intelligence and tasks required of reading were appraised. Assessments similar to those in the previous study were utilized. There were no significant differences found for sex in performance on full scale IQ, performance IQ and verbal IQ. A relationship was found for both verbal IQ and full-scale IQ with reading. No correlation was found between IQ and spelling. Reading and spelling ability was found to be strongly related to block design and word reasoning. A relationship was found to exist between full-scale intelligence and the CEFT, alphabet knowledge and Earobics rhyme. Verbal IQ was related to Earobics rhyme. Analysis of intelligence factors found that performance IQ was additionally related to the CEFT, alphabet knowledge and Earobics. Verbal IQ was correlated with Earobics rhyme. These results clearly suggest that visual and spatial abilities and perceptual skills found in performance IQ are associated with the tasks required for embedded figures testing, alphabet knowledge and rhyming. Similarly the ability to analyze and determine the analogous sounds in words requires skills equivalent to those in embedded figure testing and for recognition of the letters of the alphabet. The ability to name letters was also determined to be correlated with reading and spelling ability. Historically, alphabet knowledge has been found to predict reading achievement (Chall, 1983, Snow et al., 1998). This study presents evidence that alphabet knowledge

may be related to intelligence and that specific tasks associated with performance and verbal IQ can be established as having a reciprocal relationship with alphabet knowledge. Findings of study 2 support research which indicate a shift in digit ratio for age. These findings were in concordance with current research with the exception that these findings were uniquely established for a young study group. Digit ratio also correlated with a subtest utilized in scoring performance IQ—Matrix reasoning. These findings lead to the promising conclusion that matrix reasoning, and therefore performance IQ, are related to prenatal testosterone. There are several implications for these findings. Typically, it is expected that a discrepancy definition with intelligence should predict reading and that there are expected consequences for IQ with regards to reading ability. The findings of this study lead us to contemplate the impact of sex on intelligence as well as to examine the precise capabilities measured for IQ and to identify their impact on reading skills. Rather than summing intelligence as the abilities of an individual, it may be possible to utilize intelligence to determine the future capabilities of an individual. Study 3 will examine the impact of an intervention for alphabet knowledge on skills related to performance IQ. If early intervention in the alphabetic principle can positively impact intelligence, what are the implications for reading ability? What is the potential for predicting dyslexia in preschool children during the early stages of intellectual development? Further examination of those pre-reading skills found related to intelligence will be conducted in order to consider the impact of these factors and their improvement subsequent to the intervention.

## 9. Study 3 Preschool Intervention Plan

Having completed a large group analysis it was important to examine whether these identified pre-literacy skills could change through intervention. Assessments that were appropriate for pre-reading skills and which, during statistical analysis, demonstrated significant relationships with IQ performance (both verbal IQ and performance IQ) and with reading and spelling outcomes were chosen for study 3. A limitation in much of current research is that studies finding positive evidence for reading and phonological deficits in dyslexia are done on a majority of individuals who have dyslexia or other established reading problems. Moray, Cary, Alegria, and Bertelson, (1979) indicate that phonological deficits seen among dyslexic readers are exacerbated by the reading impairment itself because of the reciprocal relationship between phonological skills and reading. It was expected that in this study none of the subjects, because of age, had a formal diagnosis of dyslexia or other related deficits. Therefore analysis of this sample of assumed typically developing preschoolers would inform research of what crucial factors might bear influence on typical or deficient reading development. Researchers agree that measurement of phonological awareness in preschool can be an excellent predictor of subsequent reading achievement (Snowling, 1998; Hindson, Byrne, Fielding-Barnsley, Newman, Hine and Shankweiler, 2005). This is true even while controlling for effects of IQ (Bradley and Bryant, 1983, Lundberg, 1994, Snowling, 1998). The aptitude to understand the sound structure of phonemes is crucial to the development of the alphabetic principle which leads children to decode words they have not previously been presented with (Byrne and Fielding-Barnsley, 1989). The characteristics that predict responsiveness to early intervention of reading must be depicted as well as the tracking of short and long term efficacy of early intervention (Hindson et al., 2005).

This chapter reports the findings of from 16 preschool age children who had completed previous psychometric measures in Study 2. Additional measures were taken of various

pre-reading skills. At 5 years of age, children in the United States typically begin a traditional kindergarten program which includes literacy instruction. At the time of formal school entry, it is argued that the foundations of reading are already established in a typical child (Muter and Snowling, 1998; Gallagher, Frith, & Snowling, 2000). The previous study (study 2) was designed from the variables that informed which distinct reading measures showed differences in the first study on dyslexic and non-dyslexic readers. Subsequently, in study 3 comparisons could be made to findings from the prior two studies in the pursuit of suitable intervention techniques for preschool children whose early literacy skills have begun to develop. The focus was on the two following questions:

1. Does the intervention chosen result in improvement in specific pre-reading skills?
2. What factors predict the level of improvement?
3. What impact does genetics and environment play in the development of literacy skills?

The differences in performance pre and post intervention are the focus of this study.

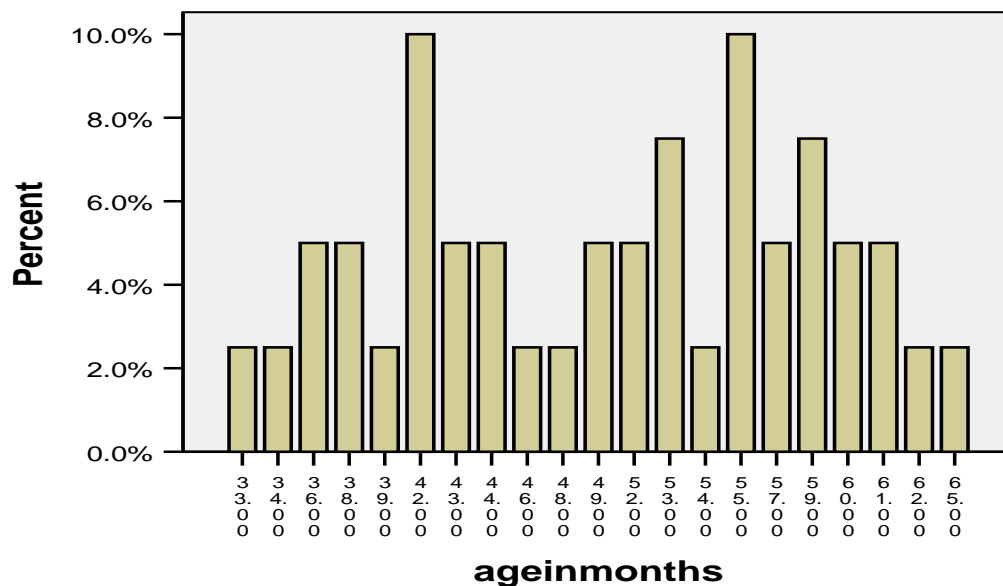
## **9.1 Method**

### Participants

Seventeen preschool age children participated in this study. Of this sample, ten were female and seven were male. Age range was from 33 months to 59 months. One child failed to complete the intervention portion of the study and was not included in the results. Therefore, nine female and seven males were analyzed prior to and after the chosen intervention. Table 1 indicates the frequencies of age for the participating preschoolers. Participants in Study 3 had been previously assessed with those in the sample group for study 2 on a battery of psychometric testing. The participants in this study were enrolled in the Owens Community College Childcare Technology Lab. These participants were chosen based on several factors: they were enrolled and attended preschool at the preschool centre on a routine schedule and would be available for

assessment and a schedule of intervention, results of intelligence testing did not reveal any difficulties or major deficits in verbal, performance or full scale IQ, and participants would be attending preschool at the centre throughout the course of intervention and follow up testing. The subjects were Caucasian (100%) and parents had identified either one or both parents as having ethnicity of white/Caucasian. The participants were comprised of those whose parents gave permission for their children to participate.

**Figure 9.1 Age range of participants for Study 3**



Those participants involved in this study were preschool age children from study 2 who were present in the follow-up year for study 3 and who did not progress to formal kindergarten programming. It was plausible to consider whether there were any differences between those participants who left the preschool subsequent to study 3 and those preschoolers who remained for study 3. A one way ANOVA was performed to analyze for possible differences between these two groups. No significant differences between participants who remained for study 3 and participants from study 2 who left the school to begin primary education were found for the WPPSI-III subtests of information,

block design, coding, picture concepts, word reasoning or matrix reasoning. Additionally no significant differences were found in measures of embedded figures testing, Earobics Rhyme, PALPA rhyme, WRAT reading and spelling or alphabet knowledge. There was a significant difference between groups for performance in onset-rime ability ( $F_{1,10} 5.3$ ,  $p=.04$ ) and for the subtest of vocabulary ( $F_{1,14} 9.2$ ,  $p<.01$ ) Although control of who entered the study intervention was with parents, those who did and those who didn't from study were largely similar. Parents of children participating in the study were given a parental survey form to complete. Of the 17 children participating in the study, 11 parent survey forms were returned.

### **9.1.1 Design**

The measures for study 3 were selected as these measures indicate skills that were found to show differences between primary age readers and primary age dyslexics in study one. Additionally, study 2 established additional consistent findings of a relationship between reading and the measures chosen. Results from the chosen measures were utilized from study 2 with an intervention in alphabetic principle prepared and completed and a follow-up with those same measures to allow for an analysis of progression. No control group was used as the purpose for this study was to predict changes from the study 2 variables and not to compare groups.

As it was crucial to continue with the participants from study 2 when investigating the impact of the alphabet knowledge intervention, preschool age children from the Owen's Community College childcare program who remained at the centre prior to entry into formal kindergarten were studied. The study group analyzed was small given that the elapse of time from the initiation and completion of study two to the onset of study 3 allowed for several of the preschool age children to progress to formal kindergarten age and to leave the preschool program.

The difference between performance for the preschool group before and after implementation of the intervention program was examined. The intervention program focused on instruction of the alphabetic principle. No control group was used in Study 3

as the purpose of this study was not to compare groups but rather to look at how the participants developed during the intervention and why certain areas developed more than others.

### *Analysis of Parental Surveys*

Examination of genetic and environments was done using a parental survey. Included were ten questions were for mother response and a repeated ten questions for father's responses. Parental responses provided information on biological relationships between parents and children in the study, the number and age of male and female siblings, parent's level of education, marital status, ethnicity and family history of learning disorders.

### *Assessments*

The process taken in study 3 included five assessments, prior to intervention, of pre-reading skills, an eight week intervention program and post intervention repeated assessments of these same skills. It was hypothesized that the eight week intervention on alphabetic principle would improve the performance on the pre-reading skills assessed. The aim of this study was to analyze and evaluate the chosen intervention to examine whether the intervention was successful as well as to determine what the outcome to precursors to reading would be, and (2) to determine what factors predict the level of improvement, including which factors predicted the largest amount of improvement versus which factors predicted the least improvement. The focus of this study is on what the differences in performance were before and after the chosen intervention. In order to understand the causes of later reading and spelling disability for young children, it is vital to examine the readiness of language subskills that children utilize in their development of reading.



### Measures

The rationale for selection of variables to be included as measures on the pre-intervention assessment was made based on several factors. All variables chosen for assessment prior to intervention were known to be predictors of reading ability when utilized during preschool or preceding school entry (Anthony & Francis, 2005; Carroll, 2004; Foorman et al., 2003 & Frith, 1986). Prior to the intervention taking place, measures were completed for Block Design, Word Reasoning, Embedded Figures, Earobics Rhyme and Onset-Rime ability. As the participants had also been analyzed for study 2 the key pre-intervention measures were used.

### Block Design

Block design is subtest of intelligence testing. Block design measures visuospatial and motor skills. The child is required to use blocks that are all red, all white, or a combination of red and white and arrange them according to a pattern. This is a timed assessment. The subtest offers 20 test items using red and white blocks and two-colour (red/white) blocks.

### Word Reasoning

Word reasoning is also a subtest of intelligence testing. Word reasoning requires the child to identify the common concept being described in an increasingly specific set of clues. There are 28 assessment items in the word reasoning measure.

### Embedded Figures

The child embedded figures test (CEFT) was used to assess each participant's ability to reduce the processing of irrelevant context. In the child embedded figures test, preschool participants were shown and then allowed to practice placing two differing simple figures within a more complex visual array. The participants were timed in two five minute

sessions and scored one point for each correctly placed figure in the picture. There were 18 assessments on the CEFT.

### *Earobics Rhyme*

The child was presented with a set of three words both in auditory presentation and with visual encouragement. As the words were pronounced orally the child watched a series of frogs jump above a lily pad (one frog for each individual word). The child was asked to choose the word “that did not sound the same” from the set. A correct response was confirmed with the frog jumping into the lily pad on the answer bar. An incorrect response was demonstrated by the frog jumping into the water. Ten sets of words were presented in this assessment.

### *Onset-Rime ability*

Each participant was asked to sort picture cards that were from the same family from words that were not. Six sets of three cards that included the word, as well as a picture of the word were shown. During the practice set the examiner modelled the appropriate choice stating that “these two go together. They have the same ending letters and sound. This one does not belong. It has a different ending sound and letters. The child was given one point for each set in which they made the correct match of onset-rime pairs.

## **9.2 Preschool Intervention Plan**

Letter knowledge is an essential early predictor of literacy ability (Gallagher et al, 2000). Acquisition of the alphabetic principle is undoubtedly a necessary condition for learning to read (Foorman et al, 2003). Learning to read an alphabetic orthography involves making intentional and conventional connections between the letters of the alphabet and the phonemes they represent. The ability to rapidly name alphabetic letters is a predictor of early reading development (Foorman, Francis, Fletcher, Schatschneider & Mehta, 1988). Learning letters is a precursor to phoneme awareness in preschool age children (Carroll, 2004). Correspondingly, research has suggested although the alphabetic principle is essential for learning to read, it is not adequate in itself. Researchers are at

odds as to whether acquisition of the alphabetic principle is a sufficient condition of learning to read (Adams, 1990). Foorman et al. (2003) argue the alphabetic principle is a necessary condition of literacy but is not adequate in itself. Conversely, other researchers propose that phonemic awareness is not sufficient for acquisition of the alphabetic principle (Adams, 1990; Stanovich, 1992). Bradley and Bryant (1983) found in their study, results that support a hypothesis that explicit instruction of the mapping of letters to phonemes is effective in later reading ability. Even as there is this reciprocal relationship between phonemic awareness and alphabet knowledge, the ability to learn letters is the element of reading that is causally related to phoneme awareness (Carroll, 2004). Studies have shown phonemic awareness to correlated letter knowledge in cultures that utilize an alphabetic writing system and that the learning of letters is critical to development of phonemic awareness (Read, Zhang, Nie and Ding, 1986). During preschool development of reading skills an interaction between phoneme sensitivity and letter knowledge develops (Anthony and Barker, 1998)

The intervention for Study 3 was planned to follow the reasoning invoked by research on the alphabetic principle. As with the recommendations in the Independent Review of the Teaching of Early Reading (Rose, 2006) the program utilized a highly systematic approach to teaching the alphabet. A program to teach letter sounds and letter formations entitled “Itchy’s Alphabet” was employed. Itchy’s Alphabet, developed by Brenda Larson, M. ed., is a multisensory alphabet instruction program that presents visual cues for learning the alphabet shapes which then create a connection to the auditory task of learning sounds. Some of the picture cues are actions to involve the kinaesthetic pathway as well. Mnemonics such as a bat and a ball for the letter “b” are used to help preschoolers memorize letters. Handwriting of the letters was included as a kinaesthetic activity. Rose (2006) argues that multi-sensory activities are vital to high quality phonic work and encompass a variety of visual, auditory and kinaesthetic activities. Multi-sensory learning activities provide children with the opportunity to learn using as many of their senses as possible rather than limiting them to one particular sensory pathway. Research by the National Reading Panel (2000) indicates that systematic phonics instruction is necessary for successful reading ability. The Itchy’s Alphabet program

focuses on the order of presentation of letters (Logical Letter Formations) and is based on the concept of building on prior knowledge. This high quality program of phonological awareness and the alphabetic principle was implemented consistently each day to reinforce and build upon the preschool child's previous knowledge of the letters and to secure progress in learning the alphabet. Programming was generally short—a span of around 20 minutes daily with additional time spent integrating the letter lessons into other aspects of the curriculum. Children were encouraged through learning centres to play freely with solid letters and to incorporate the visual cues for each letter into other play lessons. Instruction included emphasis on letter sounds (not names) and lower case letters (not upper case). The reasoning behind this approach is those children who struggle don't need to learn 52 sounds/names and 52 symbols when 26 of each will suffice to meet the goal of beginning to read. With this program, unique pictures in the shape of each letter are presented to give children a cue to remember both the sound and the shape of the letter simultaneously. Accuracy and Automaticity drills develop instant word recognition skills using a one-minute timed drill format. As each letter and sound were introduced, multisensory activities were included in the presentation to allow for multiple types of learning. As the order of presentation of letters was based on the grouping of letter formation, the participants were able to build from one letter to the next. Larson emphasizes that, in this way preschool children always have a pattern to refer to in transferring knowledge to new letters learned. A variety of activities were used which appealed to preschool age children with their achievement and effort praised consistently.

The Itchy Alphabet program is comparable to the Jolly Phonics program developed in 1977 by Sue Lloyd. Jolly Phonics utilizes a systematic, sequential approach designed to teach children to read. In Jolly Phonics, children learn the 42 identified sounds of the English language, rather than the alphabet. After that, they are then taken through the stages of blending and segmenting words to develop reading and writing skills. The widespread use of the Jolly Phonics Program in the UK has been proven to show that those students who were previously demonstrating difficulty in reading and writing had significant improvements in abilities when instructed in the program.

Activities that highlight the phonological structure of language are generally beneficial. Preschool children should be given experience and practice naming letters and objects, listening to stories and nursery rhymes (Mann, 1984).

### **9.3 Results**

Those participants involved in this study were preschool age children from study 2 who were present in the follow-up year for study 3 and who did not progress to formal kindergarten programming. It was plausible to consider whether there were any differences between those participants who left the preschool subsequent to study 3 and those preschoolers who remained for study 3. A one way ANOVA was performed to analyze for possible differences between these two groups. No significant differences between participants who remained for study 3 and participants from study 2 who left the school to begin primary education were found for the WPPSI-III subtests of information, block design, coding, picture concepts, word reasoning or matrix reasoning. There was a significant difference in the performance between these two groups for the subtest of vocabulary ( $F_{1, 14}, 9.2, p < .01$ ). Additionally, no significant differences were found in measures of embedded figures testing, Earobics Rhyme, PALPA rhyme, WRAT reading and spelling or alphabet knowledge. There was a significant difference between groups for performance in onset-rime ability ( $F=1, 10, 5.3, p=.04$ ).

#### *Parental Survey*

Examination of completed parental surveys revealed several factors. Parent age range for mothers was 24 years to 38 years of age and parent age range for fathers was 24 to 41 years. Mean age was 31 years (SD 3.8) for mothers and 33 years for fathers (SD 4.4). An estimate of parental education status (PES) was derived from the parent survey questions on educational background, combining both mother and father's education to obtain a mean score. A 6-point scale was utilized: 1=no high school graduate, 2=high school graduate, 3=GED (General Education Degree), 4=some college, 5=college graduate and 6=post college coursework or degree. The mean score for mothers was 4.53 (SD 1.1). The mean score for fathers was 3.91 (SD 1.5). The mean combined PES for

parents was 4.22. None of the mothers reported any family history of dyslexia, reading disorders, learning disability or attention deficit disorder. Two of the fathers surveyed reported a family history of reading difficulty. Analysis of family history for language disabilities showed no variability for the responses. As a result, family history results were too low to investigate further. The relationship between parental age and psychometric assessments (done prior to the intervention) was performed. No relationship was found for the father's age and any of these assessments. A positive relationship was found between mother's age and VIQ ( $r_{11}=+0.64$ ,  $p=.036$ ) and word reasoning ability ( $r_{12}=+0.56$ ,  $p=0.59$ ). A negative correlation was found to exist between mother age and tests of picture rhyme ability ( $r_{12}=-0.75$ ,  $p=.005$ ) and onset and rime ( $r_{12}=-0.71$ ,  $p=.011$ ). None of the preschool children in this study, as reported by the parental survey, had any older female siblings. A number of older male siblings were accounted. A negative relationship was found between two specific measures of phonemic awareness and older siblings: alphabet knowledge ( $r_{12}=-0.74$ ,  $p=.006$ ) and Earobics rhyme ( $r_{12}=-0.61$ ,  $p=.034$ ). The relationship between parent age and performance on the pre-intervention measures was analyzed. Results found no significant relationship between the father's age and performance on the six measures. A significant relationship was found between the mother's age and child's performance on rhyme assessment ( $r_{11}=-0.79$ ,  $p=.01$ ) and onset-rime ( $r_{11}=-0.72$ ,  $p=.01$ ). There was a slight trend towards significance for mother's age and word reasoning results ( $r_{11}=+0.56$ ,  $p=.07$ ). Investigation was performed to examine relationships between the number of elder siblings and the individual's performance on measures. Two relationships were found: the number of elder male siblings and alphabet knowledge ( $r_{11}=-0.73$ ,  $p=.01$ ) and the number of elder male siblings and rhyming ability ( $r_{11}=-0.61$ ,  $p=.05$ ).

The use of this parental survey was to identify, if any, the participants who were likely to be dyslexic. As this was a brief survey the results were unable to make this indication as the participants were too young to be evaluated further.

*Psychometric measures*

Results of the six measures performed prior to intervention were analyzed for gender differences. Table 1 indicates the mean score of performance on the six measures preceding intervention, with the subsample from study 2. No significant differences between males and females were found for these assessments as found in study 2. A slight trend towards significance was indicated for the word reasoning subtest ( $p=0.08$ ).

**Table 9.1 Comparison of performances on pre and post intervention measures**

Measure	Gender	N	Mean	Std. Deviation
Block	Male	7	10.71	3.9
Design	Female	9	13	3.38
Word	Male	7	10	4.47
Reasoning	Female	10	12.66	5.33
CEFT	Male	7	5.44	3.97
	Female	10	6.92	3.35
Earobics	Male	7	4.14	1.95
	Female	10	3.92	1.43
Onset-	Male	7	3.14	1.34
Rime	Female	10	3.14	1.02

**Table 9.2 Comparison of performances on pre and post intervention measures**

Measure	Gender	N	Mean	Std. Deviation
Block	Male	1	18	0
Design2	Female	6	10.33	5.27
Word	Male	7	12	4
Reasoning	Female	11	14.18	6.72
2				
CEFT 2	Male	7	7.71	1.79
	Female	11	10.5	4.24
Onset-	Male	7	3.42	2.14
Rime 2	Female	10	3.72	1.61
Earobics 2	Male	7	4	2.94
	Female	10	4.1	2.18



**Table 9.3 Comparison of performances on pre and post intervention measures**

Measure	Gender	N	Mean	Std. Deviation
Difference	Male	1	10	0
Block	Female	5	10.2	1.1
Design				
Difference	Male	7	2.4	2.4
CEFT	Female	10	3.5	2.5
Difference	Male	7	0.29	2.8
Onset-Rime	Female	11	0.36	2.1
Difference	Male	7	-0.14	2.6
Earobics	Female	10	0.2	1.4
Difference	Male	7	3.3	3.3
Word	Female	11	1.8	4.1
Reasoning				

For Earobics Rhyme, mean score for males prior to intervention was 4.14 (SD 1.95) and after intervention 4.0 (SD 2.94). Males showed a mean drop in scores for follow up testing of this measure at -0.14 (SD 2.6). Females showed a slight improvement in rhyme ability with the pre-intervention mean score being 3.92 (SD 1.43) and post intervention mean at 4.1 (SD 2.18) and a mean improvement of +0.20 (SD 1.4).

Findings for onset-rime ability were examined and males and females were found to perform similarly on this task. Mean score for males prior to intervention was 3.14 (SD 1.34) and for females 3.14 (SD 1.02). Females on this task had slightly more improvement after intervention with mean differences being 0.29 (SD 2.8) for males and 0.36 (SD 2.1) for females.

On the Wechsler Preschool and Primary Scale of Intelligence III subtest for word reasoning, females performed superior to males both prior to intervention and post intervention. Testing before intervention showed the mean score for males to be 10.0 (SD 4.47) and for females 12.66 (SD 5.33). Subsequent to intervention, the mean score for males was 12.0 (SD 4.0) and 14.18 (SD 6.72) for females. The deviation in scores was high and therefore the difference in performance was not significant. Of interest was the mean difference of both tests showing that although females performed better than males in both assessments, males showed more improvement between tests with the mean for males at 3.3 (SD 3.3) and for females 1.8 (SD 4.1).

In the WPPSI-III subtest for Block Design females performed superior to males with a mean performance of 13.0 (SD 3.38) prior to intervention yet inferior to males subsequent to intervention at 10.33 (SD 5.27). Male performance prior to intervention was 10.71 (SD 3.9) and 18.0 (SD 0) subsequent to intervention. These results were spurious as the number of participants measured after intervention was small and may have skewed the results. Males showed a mean improvement of 10.0 (SD 0) and females 10.2 (SD 1.1).

For the Child Embedded Figures Testing, females performed superior to males with a mean score of 6.92 (SD 3.35); males 5.44 (SD 3.97). Subsequent to intervention females

again performed superior to males at 10.5 (SD 4.24); males 7.71 (SD 1.79). This was a mean improvement for females at 2.4 (SD 2.4) and for males 3.5 (SD 2.5).

**Table 9.4 Mean performance on measures pre and post intervention**

	Embedded			Onset-Rime			
	Pre	Post	Mean Improvement		Pre	Post	Mean Improvement
Male	5.89	7.71	2.43	Male	3.14	3.43	0.29
Female	6.89	10.67	3.78	Female	3.44	3.77	0.33

	Block Design			Eaobics			Word Reasoning				
	Pre	Post	Mean Improvement	Pre	Post	Mean Improvement	Pre	Post	Mean Improvement		
Male	11.07	17.43	6.71	Male	4.14	4.00	-0.14	Male	8.71	12.00	3.29
Female	12.35	18.36	7.80	Female	3.89	4.33	0.44	Female	13.00	14.67	1.60

There were no significant differences found for males and females in the five measures either prior to intervention or subsequent to intervention. Mean results were compared for handedness and no significant difference between groups was found. This particular sample group was chosen from the prior study (Study 2) and results of that study found the young age of the participants to be a factor and that hand preference was not a reliable measure for this group.

Differences in performance pre and post intervention

Examination of the relationships between assessments prior to and subsequent to the intervention found that in four of the five assessments given there was a significant

association. Clearly, as the intervention focused on teaching of the alphabetic principle, a considerable relationship was also found between measures of alphabet prior to the intervention and afterwards ( $r_{16}=+0.77$ ,  $p<.001$ ). Correlations were as follows for the assessments when relating the pre intervention measure with the post intervention measure: Block Design;  $r_{16}=+0.85$ ,  $p<.001$ , Word Reasoning;  $r_{17}=+0.76$ ,  $p<.001$ , Embedded Figures Test;  $r_{17}=+0.77$ ,  $p<.001$ , Earobics Rhyme;  $r_{17}=+0.62$ ,  $p=.007$ . There was not relationship found to exist between the two instances of onset-rime assessment ( $r_{18}= -0.25$ ,  $p=.32$ ).

An analysis of all five conditions was investigated using repeated measures ANOVA. Results between groups, gender and performance pre and post intervention were examined. Significant differences were found in both conditions of alphabet knowledge within groups ( $F_{1, 19}=16$ ,  $p<.001$ ). No differences were found between genders on each of the two measurements.

Analysis of performances in word reasoning found no significant differences within group between the first and second assessments ( $F_{1, 16}=7.7$ ,  $p=0.13$ ). Again there were no differences found between gender groups.

On the two tests of onset-rime there was not a significant difference in performance within groups on testing prior to intervention and post-intervention. Additionally, there was not a significant variance in the Earobics testing prior and post intervention.

The assessment of embedded figures found a noteworthy difference within groups between the two measures ( $F_{1, 15}=23$ ,  $p<.001$ ). Participants showed improved performance on the subsequent embedded figures measure after intervention. No considerable variances were found within gender groups.

With a smaller sample size, Block design was measured before and after intervention programming. A significant difference within groups between these two measurements was found ( $F_{1, 4}=283$ ,  $p<.001$ ) but no noteworthy differences between groups.

#### *Interrelationships between variables*

Having identified the changes pre and post intervention, the next analysis identified what variables from study 2 correlated with the changes in study 3.

In the WPPSI-III subtest for Block Design females performed superior to males with a mean performance of 12.35 (SD 2.8) prior to intervention and 18.36 (SD 1.8) post intervention. This was a mean improvement of 7.8 (SD 1.8). The mean score for males prior to intervention was 11.07 (SD 3.9) and 17.43 (SD 3.6) subsequently. Males showed a mean improvement of 6.71 (SD 1.7).

Further investigation of association between these five measures and other psychometric testing was performed. A significant relationship was found between alphabet knowledge (prior to intervention) and Earobics (1)  $r_{17}=+0.48$ ,  $p=.05$ ) but no relationship was found between alphabet knowledge subsequent to intervention and rhyming ability. Block design assessment was highly correlated with embedded figures testing both prior to and post intervention ( $r_{16}=+0.75$ ,  $p=.001$  and  $r_{16}=+0.63$ ,  $p=0.10$ ). Block Design also correlated with Earobics rhyme ( $r_{16}=+0.60$ ,  $p=.014$ ).

Word reasoning was related to embedded figures testing (pre and post intervention); pre-intervention correlation was  $r_{17}=+0.54$ ,  $p=.025$  and post-intervention  $r_{17}=+0.61$ ,  $p=.009$ . Furthermore, word reasoning was related to Earobics rhyme prior to intervention but not significantly afterwards ( $r_{17}=+0.49$ ,  $p=.044$ ).

A considerable relationship was found between embedded figures testing and Earobics rhyme for both pre and post intervention measures. Embedded figures prior to intervention was related to Earobics Rhyme prior to testing ( $r_{17}=+0.57$ ,  $p=.020$ ). Embedded Figures and Earobics were also significantly correlated when measured post intervention ( $r_{17}=+0.51$ ,  $p=.035$ ). Embedded figures test post intervention was found to be correlated with onset-rime assessment done after intervention as well ( $r_{17}=+0.48$ ,  $p=.053$ ).

A trend was found when correlating onset-rime assessment with Block Design post-intervention ( $r_{17}=+0.43$ ,  $p=.085$ ). Onset rime assessment done after the intervention was

found to be correlated with embedded figures testing ( $r_{17}=+0.48$ ,  $p=.05$ ). Performance in onset-rime also correlated with Earobics Rhyme ( $r_{17}=.047$ ,  $p=.06$ ).

Examination of the relationship between measures in Study 2 and Study 3 was done. Although sample sizes were small several significant relationships were found. Post intervention measurements in Earobics rhyming found there to be no relationship with performance on VIQ, PIQ as well as several of the subtests of the WPPSI-III. No relationship was found between the post-intervention testing on Earobics and matrix reasoning, vocabulary, picture concepts, word reasoning or information. A slight trend was found between post-intervention Earobics and the coding subtest ( $r_9=+0.65$ ,  $p=.06$ ).

### Digit Ratio

There was a large significant relationship between right hand digit ratio and the difference in embedded figures measures ( $r_9=+0.84$ ,  $p<.01$ ). No relationship was seen in left hand digit ratio and the difference in embedded figures measures, although a trend towards significance was found in the average digit ratio when compared with this factor ( $r_9=+0.61$ ,  $p=.08$ ). This leads to the conclusion that digit ratio can be related to the capacity to learn. No noteworthy relationship was found between digit ratio and the difference of performance in rhyming ability. There was no correlation between digit ratio and the differences on the onset-rime test. No relationship was found for digit ratio and performance in word reasoning (a subtest of VIQ).

Examination of the relationship between the difference in pre and post intervention measures was made with the subtests of the Wechsler Preschool and Primary Scale of Intelligence as well as other measures taken in study 2. A correlation in the negative direction was found between the difference in Earobics and three measures. These were block design ( $r_{16}=-0.57$ ,  $p=.02$ ), Coding ( $r_9=-0.80$ ,  $p=.01$ ) and the PIQ ( $r_{16}=-0.66$ ,  $p<.01$ ). Block design and coding are subtests used to calculate the PIQ. A slight trend towards significance was found between the difference in Earobics and the picture concepts subtest- also a subtest for PIQ ( $r_9=-0.64$ ,  $p=.06$ ). No relationship was found in the difference in the child embedded figures test and the other measures. The difference in

onset-rime testing showed trend towards significance with the WPPSI-III subtest of coding ( $r_{17}=+0.44$ ,  $p=.08$ ) and a negative relationship with the first measure of onset-rime ( $r_{18}=-0.66$ ,  $p<.01$ ). The difference in word reasoning was related in a positive direction to coding ( $r_9=+0.72$ ,  $p=.03$ ) and PALPA rhyme ( $r_{18}=+0.60$ ,  $p<.01$ ) as well as a tendency towards significance with Earobics rhyme ( $r_{18}=+0.46$ ,  $p=.06$ ), child embedded figures testing ( $r_{18}=+0.46$ ,  $p=.06$ ), and block design ( $r_{17}=+0.46$ ,  $p=.06$ ). The difference in block design negatively correlated with the information subtest of the WPPSI-III ( $r_{17}=-0.54$ ,  $p=.02$ ).

#### **9.4 Discussion**

To begin with it is necessary to clarify that the predictors of reading disability revealed by this study must be interpreted with caution as the sample size was small with measures taken on just seventeen preschool age children. Similar small samples have been utilized to examine family history of dyslexia and preschool indicators of reading ability (Scarborough, 1990, Wesseling and Reitsma, 2001).

The central question examined was the extent to which an intervention and incorporation of alphabetic principle instruction affected follow-up performance in key phonemic awareness tasks. The Itchy Alphabet program was utilized as an intervention of instruction in the alphabetic principle. The methodology of this program parallels programming developed by Sue Lloyd (1977) and supported in the Rose report (2006) as the recommended approach to teaching phonics. These findings led to an amendment of the Education (National Curriculum) in the Foundation Stage Early Learning Goals. It is well documented that an understanding of phonemic awareness supports the acquisition of the alphabetic principle and subsequent reading skills (Byrne & Fielding-Barnsley, 1986 and 1998; Juel, Griffith & Gough, 1986). Byrne & Fielding-Barnsley reason that children need to be provided instruction in the identity of consonant sounds and when this instruction pairs with phonemic awareness they are able to better understand the alphabetic principle (1989). These findings are consistent with results from similar studies with claims that instruction in phonological awareness will support children in learning to read (Byrne & Fielding-Barnsley, 1990; Bradley & Bryant, 1983; Williams,

1980). Byrne & Fielding-Barnsley (1990) argue that this type of specific instruction of phoneme identity is more effective, less problematic to teach and is a more reliable foundation of the alphabetic principle. Phonemic awareness ability fortifies the ability to acquire the alphabetic principle (Byrne & Fielding-Barnsley, 1990; Bradley & Bryant, 1983). The ability to acquire the alphabetic principle is more complex and explicit and necessitates a conscious effort (Torgeson, 1995). This study considers what cognitive factors are involved in the acquisition of alphabetic knowledge. Findings from study 1 and 2 directed the focus of the intervention performed in this study.

Parental surveys completed by eleven of the parents for participants in study 3 were completed to examine biological, educational, marital and ethnic factors. Mothers were found to have more education than fathers. On average, mothers fell between the margins of “some” college coursework and a completed higher education degree. Fathers surveyed were found to have, on average, a high school diploma or general education degree, taken some college coursework but did not complete a degree in higher education. Two of the eleven surveys indicated a paternal family history of any reading disability with this result too low to investigate further. A positive relationship was found between the mother’s age and the child’s verbal intelligence and word reasoning ability. In contrast, a negative relationship was found between mother’s age and two specific phonemic awareness factors—picture rhyming ability and matching of onset and rime patterns. These results could suggest that preschoolers with older mothers are exposed to elevated levels of vocabulary in their home environments but that the older mothers have less time to spend with their preschooler and therefore to coach or instruct them directly in phonemic awareness skills. This hypothesis is further supported by the negative relationship found between the number of older siblings and alphabet knowledge and the number of older siblings and Earobics rhyme. These suggest an older mother with a number of children has less time to spend with her younger preschool age child and therefore this child may perform worse in areas of phonemic awareness. These findings are supported by Torgeson (1995) who describes the substantial variability in the level of phonological awareness in children when they begin formal school instruction. Torgeson contends that the two factors responsible for variation among children in



phonological awareness upon entry to school is “preschool linguistic experience and genetic endowment”.

Even with a small sample size, there nevertheless was a large significant relationship between right hand digit ratio and the difference in embedded figure measures. It is also important to note the trend in significance between average digit ratio and the difference in embedded figures measure pre and post intervention. These findings lead to a hypothesis that digit ratio is therefore related to the capacity to learn. Also indicated is the effect of practice that participants obtained from the opportunity to repeat assessments. Findings by Manning (2002) and Brosnan (2006) support the premise that digit ratio is related to cognitive ability although research has been inconsistent. A difference in gender for digit ratio is not typically found for digit ratio until after the age of 13 years (Brosnan, 2006; Halpern, 2000). Research has established that the “male” lower digit ratio is more commonly related to spatial ability whereas “female” higher digit ratio correlates with verbal ability. For study 3 there were no significant differences found between genders for digit ratio or handedness. The young age of the study group was a factor; therefore hand preference was not a reliable measure for these participants. As results for both genders showed a significant relationship for digit ratio and CEFT, it is believed that no sex differences for this age group can be argued. Hyde, Fennema and Lamo (1990) were unable to find sex differences for ages 5-14 when analyzing data in a collection of 100 studies.

As the rationale was to examine the growth (or lack of) in participants prior to and subsequent to intervention no control group was used. Participants were measured for alphabet knowledge prior to the intervention program as well as following it. Significant differences were found within the group for both conditions of alphabet testing. There were no differences in gender for either pre or post intervention measure of alphabet knowledge.

For the word reasoning subtest of the Wechsler Preschool and Primary Scale of Intelligence this study found significant differences within groups in both pre and post intervention measures. Word reasoning is a one of the core verbal assessments within the

WPPSI-III and measures verbal comprehension, general and logical reasoning skills and an individual's ability to integrate and synthesize concepts. According to a study prepared by Denno (1982) females are superior in verbal ability, particularly in the preschool years. This study found a slight trend towards significance between males and females in performance on the word reasoning subtest with females having a higher mean performance in both instances. Hyde and Linn (1988) argue that there are no gender differences for verbal ability. Researchers have proposed various theories of brain lateralization as the basis for the discrepancy in performance between males and females in verbal ability. Studies by Shaywitz (2003) assert that when brain imaging was performed during reading activities females were found to have activation of both the left and right sides of the brain whereas males had activation in just the left side. Levy (1976) supports these findings with the assertion that females are bilateral for verbal functions. Buffery and Gray (1972) hypothesize that left hemisphere dominance occurs in females and the verbal ability of females is superior to males at an early age. Correlational examination of the word reasoning subtest found several significant relationships with other measures of phonological ability. Both measures of rhyme (PALPA and Earobics) were linked with word reasoning ability. The child embedded figures testing and block design were associated as well. These findings support research which describe the reciprocal relationship between vocabulary skills and literacy. Shaywitz (2003) maintains that a large vocabulary is a crucial factor in facilitating reading comprehension and consecutively reading influences vocabulary development. Therefore it could be hypothesized that preschool participants who had more developed word reasoning skills performed superior on rhyming, block design and CEFT because their ability to analyze and synthesize the information on these measures was reciprocally related to their verbal ability.

In his response to research on onset and rime as a predictor of reading skills, Bryant (2002) argues that a child's awareness of onset and rime impacts their reading and spelling skills. Study 3 found no difference in the performance of preschoolers for onset-rime knowledge before or after intervention. Correlational studies revealed a negative relationship between the measure of onset-rime prior to intervention and post

intervention. A slight trend in significance was found between onset – rime and the coding subtest of the WPPSI-III. Both males and females showed a slight improvement in their performance of this skill when retested. These findings could be due to the young age of the participants as supported by Treiman and Zukowski (1996) who describe the varying linguistic levels required for tasks in sensitivity to syllables, onset and rime and phonemes. Additional research would be warranted to determine the merit of the linguistic levels of language for this study and the relative ability for these preschoolers to distinguish between syllables, onset-rime and phonemes.

Preschool children, beginning at around 4 years of age, are able to distinguish between words that rhyme and those that do not rhyme. Beginning at this early age, preschoolers are capable of picking out non-rhyming words (Bradley and Bryant, 1978; 1983). The ability to distinguish rhyme has been determined to be highly predictive of later success in reading and spelling (Bradley & Bryant, 1983). For study 3, participants were successful in the rhyming task at nearly 40% both before and after presentation of the intervention for alphabetic principle. No significant differences were found within the group or between genders on this measure. Muter et al. (1998) suggest that one approach to identifying the structure of phonological skills is to perform correlational studies. Correlational analysis was conducted to examine the performance between measures of phonological skills for this group. Significant correlations in a negative direction were found for the difference in Earobics rhyme ability with block design, coding and performance IQ. As these three measures are associated with working memory, learning ability, visual perception and attentional skills it is remarkable to note their negative relationship with the ability to learn rhyme. In an analysis of phonological skills for kindergarten age children, Lefly and Pennington (1996) found that children with phonological awareness deficits and those without did not differ on rhyming awareness measures until the first grade. Additionally, Snowling et al. (2003) studied preschool age children at three years of age and found that nursery rhyme knowledge was deficient in children who later manifested weaknesses in reading and spelling skills. In contrast, Puolakanaho, Poikkeus, Ahonen, Tolvanen & Lyytinen (2004) maintain that rhyming as a phonological awareness skill does not prove to be a strong predictor of later literacy

development when compared with letter knowledge, vocabulary and phonological memory. One possible explanation for this negative correlation could be the young age of the participants. Potentially, the ability to recognize rhyme cannot be measured consistently until phonological skills have advanced in the developing child. Another rationalization is the finding that learning ability and attentional skills (tasks measured for the measures of Coding, Block design and performance IQ) were not developed adequately and the young participants were unable to comprehend and process the verbal instructions given with the Earobics rhyme assessment. This hypothesis is supported by findings from Puolakanaho et al. (2004) who found that among the tasks of phonemic awareness measured in their study; those that required comprehension of instructions and drew on the ability to process and respond to verbal instructions were those with the most variance in results.

The focal point of study 3 was the incorporation of an intervention for the alphabetic principle. Findings revealed that in all but one measure (Earobics rhyme) preschool participants showed a mean improvement for key phonemic skills measured after implementation of the intervention. The intervention program for study 3 utilized an approach that taught not only the letter names but the corresponding letter sounds as well. The intervention methodology used in this study is in concurrence with Byrne and Fielding Barnsley (1990) who contend that successful teaching of phonemic awareness should include a combination of letter-sound knowledge and phoneme identity. Johnston and Watson (2005) found that the synthetic approach to teaching phonics was the best approach to developing reading skills. Johnston and Watson concluded that the synthetic phonics approach was the foundation for better progress in reading and spelling skills. Alphabet knowledge is a visual and multi-sensory process. It could be hypothesized that the explicit teaching of alphabet knowledge would enhance abilities in those areas related to performance IQ more than those associated with verbal IQ. Study 3 results confirm this hypothesis as participants showed improvement in measures of block design and child embedded figures testing. Both of these measures are related to performance IQ as they directly measure visual perception and organizational abilities. Additionally, the same intervention produced improvement in word reasoning skills which was

significantly correlated with the coding, a subtest which measures visual perception and visual-motor coordination. It is also possible that the intervention was not the reason for this change but rather the effects of practice in the repeated assessments. The difference in word reasoning was also related to child embedded figures testing and to block design. These results are consistent with previous research findings that indicate instruction in the alphabetic principle can assist pre-reading children with phoneme awareness skills and subsequent reading and spelling ability (Bradley & Bryant, 1983; Williams, 1980; Byrne and Fielding-Barnsley, 1989; 1990).

Performance IQ can be correlated with alphabet knowledge subsequent to the intervention as well as the difference in rhyme knowledge. This implies that PIQ can predict the change in these measures. It is reasonable to conclude that intervention (or practice) in these measures can forecast a change in PIQ. These findings do not establish that the specific intervention of alphabet knowledge is causal to improved PIQ but rather suggests further research in this area is necessary. It would be practical to compare other interventions researched as well as to evaluate an intervention for the alphabetic principle with the addition of a control group. Potential implications for these findings are immense. If early intervention in alphabet knowledge for preschool age children is put to practice, the ramifications for literacy development may well include the diminution of weaknesses in phonological skills related to reading acquisition.

## 10. Implications and Conclusions

The purpose of this research was to identify the indicators of reading disability and to analyze the effect of these factors when presented to preschool age children to distinguish which factors play a principal role in whether or not children develop dyslexia. In the study of these definitive factors, what type of intervention is appropriate and shall make a critical impact in helping to advance and improve the skills identified? It is important to recapture the matter raised in these studies in order to reflect on the impact of the findings. Issues raised herein are of importance to research in reading disability in that the direction of research in dyslexia and other reading disorders must be better refined. Those in the field of research, policy and practice must coalesce findings to better classify the disability as well as to determine the approach to intervention that will be taken as early in an individual's development as possible. This study is of importance to curriculum developers who are guided by mandates which specify the direction of instructional approaches. Those who develop policy at the local and national levels can more efficiently guide practitioners when a clear direction is provided as to the factors impacted during preschool development. In a study by Foorman et al. (2003) various curricula chosen by practitioners could be categorized into "Less Choice" and More Choice" based upon the extent to which the curriculum presented teacher flexibility in activities as well as the number of actual phonemic awareness activities presented in the material. Their study found that kindergarteners performed better in letter knowledge and phonemic awareness skills when professional development was provided to practitioners regarding the concepts of phonemic awareness and the concepts underlying the actions suggested in the activities for their particular reading program. Even when

consideration was made for structural and socio-economical differences, children of kindergarten age who participated in curriculum that included specific and systematic phonemic awareness instruction and whose instructions was guided by teachers with knowledge in the underlying factors of reading did much better than those children without phonemic awareness instruction and less consideration by instructors as to the skills underlying reading development. This paper concurs with current research highlighting the importance of quality professional development based on informed research which outlines the importance of explicit instruction in phonemic awareness skills in the context of research based curriculum. Consequently, the performance of reading and language based skills was higher when the presentation of the curriculum was systematic in teaching phonemic awareness and the link to the alphabet principle was made explicit in the presentation of letter-sound correspondences.

It is important to recognize that the definition of dyslexia has been unclear and is clouded by discrepancies among researchers regarding identification and classification. The findings from this paper and the three studies performed reflect the difficulty of identifying the specific indicators for reading disability in the developing child. The multiple operational definitions translate into numerous theories as to how and why the disorder manifests. The British Psychological Association (1999) suggests up to 10% of the UK population displays some signs of dyslexia. Shaywitz and Shaywitz (2001) claim it is up to 40% of the population who suffer with some type of reading disability. With prevalence rates this elevated considerable emphasis has been placed upon identification of the causal factors as well as investigations into suitable treatments for the disorder. This study examined typical readers and dyslexic readers to seek the factors involved in the path to development of normal reading versus dyslexia. Study 1 found the expected discrepancy in reading and spelling skills for dyslexic participants and control participants. Substantial evidence between groups for specific phonological ability was not as clear. Results from the first study designate definitive deficits in reading and spelling which is supported by current research. Further investigation revealed multiple literacy skills correlated with reading and spelling ability. As it is agreed that dyslexics display normal intelligence compared to non-dyslexics, further analysis of the cognitive

abilities related to intelligence were examined in the second study. The identification of the tasks which showed differences in group performance was then followed by consideration of how these factors operate in the preschool child as they develop phonological awareness and subsequent reading skills. Enquiry as to how each skill related to pre-reading ability was conducted. Finally, analysis of preschool children's pre-reading factors informed an intervention program to determine whether systematic instruction in the alphabetic principle produced improved skills in those established factors. Despite the fact that many researchers disagree whether phonological awareness is the sole cause of reading disability, most will concede that it plays a significant role (Torgeson, 1995; Coltheart and Jackson, 1998; Gathercole et al, 1995). A deficit in phonological awareness leads to difficulties with reading fluency, comprehension, and typical development of vocabulary. As phonological awareness develops continuously throughout preschool, primary and even secondary school ages, research has its influence in reading development (Byrne et al., 2006). Many of the theories of developmental dyslexia presented in this paper are well-founded. Moreover, the conceptualisation is that the early years of learning influence the dynamics for later academic learning. The Organization for Economic Co-operation and Development acknowledges early childhood education as greatly influencing children's later academic achievement and learning and supporting the social and emotional needs of the family (2001). This paper illustrates the complexity of dyslexia and the affects of these discrepancies on research and policy. Hartas (2006) describes dyslexia as a "contentious concept meaning different things to different people". For preschool age children whose development is shifting rapidly, it is vital to understand the factors that can be most affected by remediation. As Hartas explains, "issues regarding dyslexia in young learners are complex, and the limited research on early indicators of dyslexia is a grey area within which early years staff strive to meet children's learning needs effectively".

It is the phonological theory of language development that captures the attention and provides the basis for this research. The area of phonological knowledge in reading research has gained much attention over the last two decades. Leading the findings of research is the concept that "critical levels" of phonological awareness can be impacted



through specific instruction and this instruction has profound effects on reading development (Chard & Dickson, 1999). As intelligence and the discrepancy definition described by researchers are critical to research, this study aims to further evaluate and explain the complex relationship between reading and spelling ability and cognitive development. Phonological knowledge and the development of reading skills are biologically and culturally pre-programmed. In other words, development is affected internally through factors such as genetic predisposition and growth within the brain and externally by environmental factors such as social and emotional adjustment, culture, family and training in pre-reading skills. An inherent factor of the discrepancy definition for dyslexia is the postulation that intelligence must be measured independently of reading ability. This study maintains that it is plausible to identify specific subskills of intelligence and to define their relationship with literacy. Therefore, a firm grasp of the etiological aspects of reading paired with a robust plan of intervention during the earliest possible point of preschool development can help strengthen the skills necessary for effective reading.

Deficits in phonological knowledge evolve into poor reading ability (Anthony and Davis, 2005). Research by Byrne, Samuelsson, Wadsworth, Hulslander, Corley, DeFries, Quain, Wilcutt and Wilson (2006) demonstrate the ongoing influence of phonological awareness during development at preschool age through primary age. The reading development of typical readers takes a different “track” than those identified with reading disabilities. With this acknowledged continuous course of development, is it possible to impact the direction in which deficient readers take in development through identified approaches?

As phonological awareness is the ability to comprehend the ways in which oral language can be divided and manipulated into smaller components an individual must be able to break spoken language such as sentences into words and words into syllables, then onset and rime and finally individual phonemes. An understanding of these various levels of language is considered phonological awareness. Phonological awareness develops on a continuum with less complex activities such as distinguishing rhyme words and segmenting sentences to more complex activities such as separating and blending onset and rime as well as individual phonemes. According to Anthony and Francis (2005)

phonological awareness begins to develop at preschool age and continues to operate during primary and secondary school years in many aspects.

Even as researchers debate the various roles of the simple to complex tasks required of phonological awareness, they can agree to the impact it has on later reading development. Although there are three studies presented in this paper, there is a common theme, or core element running throughout. The common theme in this study and among all theories and theorists includes the support of dyslexia as a range of levels of reading disability that can be defined by a substantial deficit in reading and spelling as well as a relationship with factors related to phonological development and intelligence. An individual must have phonological awareness in order to grasp the alphabetic principle (Chard & Dickson, 1999). Adams (1990) argues that in order to benefit from reading instruction, an individual must be sensitive to the internal structure of words and sounds. A distinction must be made between phonological awareness and phonics. The two concepts are elaborately entangled but are not synonymous. Phonics can be defined as the association of letters and sounds to sound out written symbols whereas phonological awareness involves auditory and oral manipulation. Chard and Dickson contend that phonological awareness does not always develop into a phonemic awareness so readily. The more complex activities related to phonemic awareness can be more difficult for children to develop. Bradley and Bryant (1985) argue the importance of early phonological awareness training for children as young as age 4. This includes the explicit instruction of the alphabetic principle. Preschool age children can be taught that words are comprised of symbols (letters) that represent sounds. Teaching students to phonologically recode word and sentences is crucial to proper reading development (Liberman & Liberman, 1990). Once this fundamental concept is precisely taught and mastered, then this systematic relationship between letters and sounds can be utilized to begin to retrieve the unknown pronunciation of a string of letters or to spell out sounds. According to Juel (1991) letter sound knowledge is a requirement of effective word identification and the distinguishing factor between good and poor readers is the ability to use letter sound correspondences to identify words.

Children who are instructed in and acquire the alphabetic principle early in language development go on to become strong readers (Stanovich, 1986). Therefore a blend of

instruction in letter sound correspondence and phonological awareness is the most solid approach to success in early reading (Haskell, Foorman and Swank, 1982).

### **10.1 Study 1**

The goal of study 1 was to determine the discrepancies in performance between non-dyslexic readers and dyslexic readers. What are the particular strengths and weaknesses in literacy in children identified as dyslexic compared to children without this diagnosis? What do these strengths and weaknesses imply about the development of the reading process and in which specific components of language does this occur consistently? Performance was measured in a group of 22 dyslexic children and 22 non-dyslexic children between the ages of five and thirteen. In ten measures a significant difference was found between groups. These included assessments which measured reading, spelling, phonological knowledge and working memory. As expected, significant differences were found between the dyslexic and non-dyslexic groups for reading and spelling. Non-parametric analysis of the two groups supported the assumption that the dyslexic group would do poorly compared to the non-dyslexic group. These results suggest a substantial reciprocal relationship between spelling and reading. This concurs with research which correlates orthographic processing with phonological processing—whereas one impacts the other. Further analysis of the components of reading skills found a number of differences between groups as well. Both groups were able to identify a minimum of 24 upper case letters. There was some trend towards significance in difference between the two groups for naming of lower case letters. Of interest was the ability to correspond the letter sound with its name. These findings are supported by research from Foulin (2005) and Adams (1990) who acknowledge the consequence of learning alphabet letters as a major landmark in alphabetic literacy acquisition. Foulin explains that children must become acquainted with multiple identities for each letter as well as the graphic shapes in uppercase and lowercase forms. As the system of utilizing letters to represent sounds is fundamental to alphabetic systems of writing, the

development of letter knowledge in any aspect can be likely to impact the course of alphabetic literacy acquisition. Letter recognition is a foundational skill of literacy development and consequently impacts visual word recognition (Adams, 1990, McClelland & Rumelhart, 1981). Successive to letter recognition is the ability to identify the letter sounds. Results of study one demonstrate that dyslexic children performed substandard to non-dyslexic children in the ability to name consonant sounds. During the assessment of letter names and letter sounds the dyslexic group demonstrated a consistent pattern of producing the letter sound rather than the name when asked to name the letters. This was a result of specific instruction provided through their literacy instruction at the special needs school. This particular instruction in letter sounds rather than introduction of letter names did not appear to impact the outcome of letter sound knowledge when compared with the control group who did not receive this particular instruction. It is accepted that the ability to correspond letter names with letter sounds is a necessary skill in acquiring the alphabetic principle. The letter sound knowledge acquired supports the ability to read and spell alphabetic texts effectively (Byrne, 1998; Stuart & Coltheart, 1988). In the assessment of vowel letter sounds results were not as clear. A slight significance was found in the naming of short vowels sounds whereas there was no significance between groups for long vowel sounds. This may be due to the assessment procedure in which the child was asked to identify both the long and short vowel sounds for each vowel presented. The child was given a positive score for the long vowel sound if they were able to name the letter. This particular assessment process may have skewed the results of this measure as it was unclear if the child actually understood the long and short vowel sounds of the letters presented. Tremain, Tincoff, Rodriguez, Mouaki and Francis (1998) had similar issues in their study, finding that the properties of the phoneme—whether it was a vowel or consonant—does not appear to have relevance to a child’s learning of basic grapheme/phoneme learning. This argument is in contrast to research by Bryson & Werker (1989) and Tremain (1993) who propose that children make more errors on vowels than consonants while reading. As it is evident that children have more difficulty learning letter sound relationships when letters have more than one common sound, more examination of research in this area is warranted.

Assessment of auditory rhyme ability and reading rhyme ability found the dyslexic group did poorly compared to the control group. Results of measures in reading rhyme showed slightly more significant differences than measures of auditory rhyme performance. Both groups were more successful in their ability to hear the rhyme in pairs of words presented orally. The process of decoding the word and capturing the rhyming sounds independently was more difficult for both groups, but especially for the study group. In reflecting back it is clear that individuals with reading disability are poor spellers because of difficulties in phonological processing. Although we found differences in spelling as well as reading there were few differences in phonological knowledge with the exception of reading rhyme, consonant sounds, “r” and “l” controlled vowels, variant vowels and diphthongs and phonemic deletion first sound of blend. It appears that many of the underlying phonological skills measured are still intact but that the deficit still occurs in reading and spelling. This suggests that the phonological hypothesis needs more definition as some of the skills underlying phonological knowledge appear to be more impacted than others. Additionally, the phonological deficit hypothesis may exist in tandem with other theories. These findings are in agreement with Goldsworthy (2003) who recommends that research support the teaching of reading and spelling (writing) with the idea that there is an oral-written language continuum whereas one skill overlaps another.

Further investigation to investigate the underlying cognitive abilities which relate to the skills where a significant difference occurs is warranted. It would be preeminent to avoid the fragmentation approach to these deficient skills which often occurs in research and practice and to better define the impacted skills by probing the relationship between cognitive ability and phonological knowledge.

Study 1 examined the working memory ability of primary age children. Subjects were required to produce as many synonymic words related to a word given within a brief period of time. On this controlled association task, children with dyslexia performed significantly worse than children who did not have dyslexia. Both the study group and the control group did display difficulties with performance in this task as total scores for both groups were low (Study group mean 4.05; Control group mean 7.16). Similar results were found by Montgomery (2000) where children with specific language

impairment were compared with children with no diagnosis of specific language impairment. In a single-load condition both groups performed similarly. Differences began to appear when children were presented with more complex conditions. Dyslexic children have difficulty in both the storage and processing functions as seen in this study and supported by Montgomery's findings as well. The controlled associations measure performed on study 1 is related to research in working memory (Montgomery, 2000; Just & Carpenter, 1992). Children with reading disability struggle with several factors related to working memory. This includes the ability to store speech material in a given instant and then to generate a representation of this material. Their capacity to handle the information processing demands when presented with word or sentence representations is weaker than a non-dyslexic individual. In addition, it can be suggested that the performance of dyslexics on this task could be inextricably connected to preschool age environmental factors, such as exposure to literature and development of vocabulary knowledge. It is interesting to note that both groups in Study 1 were assessed with the British Picture Vocabulary Scale (BPVS) and performed similarly—with some remarkable differences in performance for gender. Gender difference results for areas measured are discussed further later. This information signifies that both groups had a similar grasp of vocabulary for their particular age group and the problem with performance for the dyslexic group is not related to vocabulary acquisition in as much as it can be related to the processing function of working memory. These results confirm the difference in word retrieval skills for dyslexics and further investigation of this task as it relates to intelligence was indicated for the follow-up study with preschool age children.

During the stage of reading development described by Chall (1983) as initial reading (stage 1) a child is able to appreciate the differences between sounds represented by letters and word combinations. Similarly, Frith (1985) portrays this stage as the orthographic processing stage whereas the alphabetic principle is displaced for more complete recognition of the morphemic parts of words. Results examining the elements of phonological awareness found variations between the two groups. Specifically, the dyslexic group displayed weaker performance than the non-dyslexic group in ability to

isolate phonemes. In results similar to research by Shaywitz (2003) poor readers performed substandard to strong readers when required to segment words into their phonemes and to delete selected phonemes from the words. This particular measurement showed the strongest correlation between groups ( $p=.001$ ). The dyslexic group also displayed weaknesses in their ability to read words and non-words that included “r” and “l” controlled vowels and variant vowel and diphthongs. These findings are in agreement with current research that indicates dyslexics are impaired in phonological tasks which include segmenting, blending, counting and deletion of phonemes (Castles & Coltheart, 2004; Scarborough, 1990; Badian, 1988; Shaywitz et al, 1992). The implications for these findings are supportive of the fact that dyslexics have greater difficulty than non-dyslexics in this phoneme deletion task and that this is indicative of a deficiency in phonological awareness connected to their lower reading abilities (Shaywitz, 2003).

### *Sex*

In Study 1 there were several findings of note with regard to gender. In an analysis of reading and spelling performance results found that males in both the dyslexic group and the control group performed inferior to females both groups. The female dyslexics scored similarly to non-dyslexic males on measures of reading and spelling. Comparable results can be reported for auditory and reading rhyme assessment. Females in both the study group and the control group performed better than males on these assessments. Females with dyslexia also performed slightly better than non-dyslexic males. Measures of vocabulary ability, using the British Picture Vocabulary Scale, found notable differences in performance between males and females. Dyslexic males performed superior to dyslexic females on this measure. Non-dyslexic females performed superior to both non-dyslexic males and both males and females in the dyslexic group. When evaluating phoneme related tasks there was less variance in the differences between males and females on these tasks. Both males and females in the study group performed inferior to males and females in the control group on tasks requiring identification of phonemes, initial phoneme deletion, segmentation and reading of words with “r” and “l” controlled vowels and variant vowels and diphthongs. Although there was significant

difference between groups in performance on these tasks, there was no difference in performance between gender groups.

In the ability to name words there were some inconsistencies found between genders. Word finding difficulties have been documented in individuals with dyslexia (Messer, Dockrell & Murphy (2004). On a measure of controlled associations there was significant difference in performance between males and females. Females in the control group performed superior to dyslexic females as well as superior to males and females in the control group. No significant relationship was found when correlating the results of the BPVS and controlled associations therefore this requires consideration to the question as to why dyslexic males have enhanced vocabulary knowledge yet struggle with word finding difficulties. A partial correlation was found between digit ratio and the phoneme deletion tasks as well as for auditory rhyme judgement tasks when controlling for gender and group. Although some aspects of phonological processing did correlate with digit ratio, most findings match predictions and are not supportive of digit ratio indexing dyslexia.

There is a large disagreement among researchers as to the accurate representation of children with dyslexia among genders. As most research studies measure reading disabled children who have been identified by their school system, the question of the validity of school identity is raised. Shaywitz (2003) discusses the common assumption that reading disability is more common in males than females with the ratio falling anywhere within 1:1.6 to 1:5. She indicates that according to school identification procedures, reading disability is three to four times more common in males than females. This is in concurrence with past reports of the prevalence in gender ratio varying from 2:1 to 5:1 (Shaywitz, Shaywitz, Fletcher & Escobar, 1990). These reports were all founded on identification procedures based in clinic or school settings. Shaywitz (2003) disagrees with these findings and reports not significant difference in the prevalence of reading disability between boys and girls. A review of the research presented by Miles, Haslum and Wheeler (1998) discusses the ratio of gender in dyslexia. Miles et al. found that when the definition of dyslexia is based solely on measures of reading and intelligence a gender ratio closer to 1:1 is noted. However, when the criteria for dyslexia includes poor reading and spelling skills in relation to general intelligence as well as



manifestations of uncertainty between left and right, difficulty in recalling digits when presented auditorily, as well as a myriad of additional symptoms the ratio has been reported to be as high as 4.5 to 1 (males: females). The purpose of Miles et al.'s paper was to inform on the discrepancies in gender ration in dyslexia. What was discovered by the authors were other theoretical issues involving disagreement in the accepted criteria to describe dyslexia.

Overall, the results from this study found that males with dyslexia performed substandard to females in most tasks. More specifically, males with dyslexia and without dyslexia were outperformed by females. Females with dyslexia performed superior to males with dyslexia and similarly to males without dyslexia. Females without dyslexia outscored all three groups. These findings correspond to current research which finds a preponderance for occurrence of reading disability in males at a ratio of 8:1 (Shaywitz et al, 1990).

## **10.2 Study 2**

The rationale for study 2 was to investigate the phonological awareness in preschool age children and the relationships between these skills. In contrast to claims that intelligence does not relate to tasks specific to reading skills, Study 2 found significant relationships between measurements of full scale IQ and three psychometric assessments: child embedded figures testing (CEFT), Earobics rhyme and alphabet knowledge. Subsequent evaluation of the elements of IQ found an additional significant relationship between performance IQ and these same three assessments. Verbal IQ was strongly related to Earobics rhyme ability. Ingesson (2005) investigated the stability of IQ measurements in a group of dyslexic young adults. He found a significant decrease in verbal IQ which was interpreted as a consequence of less experience with reading and writing. Ingesson additionally found that PIQ (performance IQ) had significantly improved in this study group which could be construed that dyslexic individuals develop a more visual and creative way to process information and solve problems. The subtests of the Wechsler Preschool and Primary scale of intelligence provide a standardized means of measuring PIQ and VIQ. Analysis of results found a significant relationship between VIQ and reading which supports claims made by Ingesson's study. Full Scale IQ was also found

to be related to reading and reading significantly related to spelling. Meta-analysis of VIQ and PIQ found that Block Design, a factor in PIQ is strongly related to reading ability. Spelling ability was related to both subtests for block design and word reasoning which may indicate a reciprocal relationship between VIQ and PIQ. These findings maintain the three step theory of reading development introduced by Frith (1985).

Preschool participants in study two may perhaps be in the early to middle phase of the logographic stage of development whereas they would be classified as pre-literate with their writing of letters being associations between particular scribbles and meaning.

Follow-up with Study 2 investigated the task of working memory through assessment of the WPPSI-III word reasoning measure. Word reasoning is a factor utilized to obtain VIQ. In this preschool sample, word reasoning measured their ability to deduce the meaning of a word when provided with one, two, or three cues. Word reasoning correlated with reading ability which is consistent with Stanovich (1986), Ingesson (2005) and Thomson (2003) who propose that reading ability can affect cognitive skills that restrain performance on related tasks.

The ability to understand rhyme was measured in study 2. Bradley and Bryant (1978) suggest that preschoolers as young as 4 years of age can distinguish between words that rhyme and those that do not. Results from this study indicate that preschool participants were able to correctly choose rhyming pairs of words from pictures in the PALPA rhyme assessment and to choose the word that did not rhyme from a set of three words presented in the Earobics rhyme measure. The ability to understand rhyme was found to be related to embedded figure measures which examine a participant's ability to reduce the processing of irrelevant context. Rhyme was also found to be related to alphabet knowledge which is consistent with other research studies which found a causal relationship between knowledge of letter names, rhyme and reading ability (Goswami and Bryant, 1990).

As the use of IQ discrepancy definitions for dyslexia are accepted by many researchers and policy makers (World Federation of Neurology, 1968; International Dyslexia Association, 2002) it is practical to explore the characteristics of intelligence and its relationship to the development of reading. These findings will then guide follow-up studies which explore the stability of intelligence throughout an individual's development

in reading. In contrast, Stanovich (1991) cautions the use of IQ scores as a measure of intellectual potential. He proposes that the practice of diagnosing dyslexia by measuring discrepancies from IQ scores has been misconceived at the onset. Stanovich introduces a phonological-core variable-difference model which proposes that a child with dyslexia has a brain/cognitive deficit that is specific to the task of reading. Dyslexic individuals do not display deficits in other areas of cognitive functioning therefore not impacting the abilities relating to intelligence. Research implicates phonological processing deficits as the basis of dyslexia (Bradley & Bryant, 1985; Stanovich, 1986, 1988; Wagner, 1988; Wagner and Torgeson, 1987).

### Digit Ratio

Results of study 1 found that there were gender differences in digit ratio in the predicted direction but none found between the dyslexic group and the control group. For study 2 the digit ratio results were analyzed for any associations with age, intelligence, reading, spelling and phonological knowledge. The young participant age in study 2 showed female subjects having a lower digit ratio than males which contradicts much of the current research (Brosnan, 2006, 2008; Manning, 1998). When controlling the data for age, a significant shift in digit ratio was found which is consistent with other research findings that indicate shifts in digit ratio can be found to occur up to age thirteen (Trivers, Manning and Jacobson, 2006). Digit ratio did not correlate with Full Scale IQ, VIQ or PIQ but was found to be related with the subtest of Matrix Reasoning which measures non-verbal perceptual reasoning. These findings are consistent with Brosnan (2008) and his research findings which indicate a correlation with average digit ratio and the relative difference between numeracy and literacy. There are several implications for these findings. Digit ratio used to measure exposure to androgens prenatally can predict numerous traits including cognitive abilities as supported by research (Manning, 1998; Brosnan, 2008, Romani, Leoni and Saino, 2006). The digit ratio of preschool age children is not stable and therefore may not be dependable for study of correlations with cognitive abilities. Further studies to analyze the relationship of digit ratio with spatial awareness and cognitive abilities in preschool age children is warranted.

### 10.3 Study 3

Results from Study 2 found that alphabet knowledge was significantly related to PIQ but not with VIQ. These findings are supported by Bakkar's research (1979, 1990, 2002, and 2006) which identifies the initial and advanced phases of learning to read as being very different. A beginning reader is presented with letter shapes with which they are unfamiliar with. Unlike objects which remain the same regardless of the position they are presented in, letters in various spatial positions represent various meanings (i.e. p,d,b,q). Though the meaning of a common shape changes when the shape itself changes, changing "b" to "B" does not change its meaning. Different combinations of the same letters can also produce different meanings (i.e. mane, mean, name). According to Bakkar, Strien, Licht & Smit-Glaude (2007) mastering script is quite a perceptual burden for the beginning reader and early reading is predominately mediated by the right hemisphere. Alphabet knowledge is both visual and multisensory. Presentation of alphabet knowledge in this manner is critical for preschool age children as this modality is advantageous for brain development in children under age 7. According to Torgeson (1995) learning the alphabetic principle requires explicit and conscious awareness. The National Reading Panel's (2000) report established that intensive instruction in phonological awareness concepts such as the alphabetic principle improves literacy. Study 3 explored the extent to which an intervention in the alphabetic principle would impact follow-up performance in phonemic awareness tasks as well as subtests for PIQ. According to Torgeson (1995) there is considerable variation in the level of phonological awareness between children prior to entering formal education. As they enter formal schooling, this variability of individual differences grows even larger. He indicates that two factors are responsible for the difference in phonological awareness among children. These are preschool linguistic experience and genetic endowment. Parental surveys completed during study 3 investigated biological, educational, marital and ethnic factors. Parental reporting of family history of reading disabilities was too minute to investigate further. Additionally, those who reported would not expect to have a diagnosis of reading disability for their preschool age child. However, examination of preschool linguistic experience factors found a significant relationship between the mother's age and the

child's verbal intelligence and word reasoning ability. Additionally a significant negative relationship between mother's age and the phonemic awareness skills of rhyme and onset-rime ability was found. This suggests that the preschool linguistic experience for participants with older mothers was greater for the development of vocabulary but less for specific phonemic awareness skills. This indicates that older mothers were unable to provide the time to offer the explicit learning opportunities to their preschool age children. Further support of this hypothesis was found in the negative relationship between the number of older siblings with alphabet knowledge and with rhyme ability. Therefore, the greater number of older siblings in the home environment, the less time available to spend with the preschool child, which significantly impacts their abilities in phoneme awareness., This is in keeping with other evidence that supports the role of the home environment and other factors that influence the intellectual degree of the child's environment and subsequently their development of language and reading skills (Molfese & Molfese, 2002). Evidence from research done by Molfese and Molfese indicates that the experiences a young child has from the home environment and from family activities directly impacts their cognitive abilities and correlates with their literacy skills. Research sustains the premise of a reciprocal relationship between vocabulary and literacy skills (Gathercole and Baddeley, 1989; Gathercole et al., 1992; Shaywitz, 2003). The word reasoning subtest used to measure verbal comprehension, logical reasoning skills and the ability to integrate concepts was significantly related to several measures both pre-intervention and post intervention for this study. The measure of word reasoning was significantly related to both rhyme assessments as well as with CEFT and the block design exam. Preschool participants in study three who had stronger word reasoning skills also performed superior on these specific measures of phonological awareness and spatial ability. Messer et al. (1998) recommends further research to examine which specific cognitive abilities effect word reasoning, working memory and therefore literacy abilities. As study 3 indicates that word reasoning is associated with CEFT, this suggests that the ability to reduce the processing of irrelevant context within a visual presentation is similarly impacted by the ability to choose vocabulary based on relevant information presented in an auditory format. Moreover, it is remarkable to note the parallel within the relationship between word reasoning and block design. The

cognitive aptitudes measured in the PIQ subtest of block design are similar in concept to the CEFT in that block design measures simultaneous processing, visual motor coordination, learning and the ability to separate figure and ground within a visual stimulus. Correspondingly, as phonological awareness develops in the preschool child they become aware of rhyme. Tuning into rhyme requires children to be sensitive to the fact that the words can be broken into parts. The child must be able to attend to just a part of the word (Shaywitz, 2003). These findings sustain not only a reciprocal relationship between vocabulary and literacy skills but also for the cognitive abilities related to PIQ and literacy. Results for this study also demonstrated a negative relationship between the ability to learn rhyme and both subtests for performance IQ as well as the overall PIQ score. It is likely that the participants in this study had not yet developed the ability to attend to parts of a word and to understand rhyme. Therefore results of performance in rhyme assessment prior to and subsequent to alphabet intervention were capricious. This can be supported by Lefly and Pennington (1996) who argue that differences in ability to detect rhyme cannot be established until early primary school age. Conversely, Puolakanaho, et al. (2004) proposes that letter knowledge, vocabulary and phonological memory are strong predictors of literacy development whereas ability to rhyme is not. Finally, an additional rationalization may be that these young participants were unable to adequately comprehend the verbal instructions provided during the presentation of the Earobics rhyme assessment. Participants were instructed to choose “the word that does not sound the same” from a set of three words. Rather than choosing two similar words the participant needed to find the dissimilar word in the set and this task may have been too complex for this particular age group. Puolakanaho et al. made comparable analysis in their study and maintain that tasks that required the ability to process and respond to a verbal prompt showed more variance in responses.

The Curriculum Guidance for the Foundation Stage sets out the concepts and skills necessary by the end of the Foundation Stage in order to attain literacy. A principal skill addressed in this document is the ability to link sounds to letters, naming and sounding the letters of the alphabet (DfEE/QCA, 2000). Study 3 utilized the implementation of an intervention of the alphabetic principle for the preschool age participants. The selection

of this intervention was supported by research on the necessity of the alphabetic principle in the development of phonemic awareness and consequently literacy skills (Byrne & Fielding-Barnsley, 1989, 1990; Foorman et al., 2003; Hartas, 2006). Results of study 3 show that after the intervention participants improved in all measures of phonemic awareness except for the measure of rhyme. These findings are consistent with other studies that indicate direct, systematic instruction in letter-sound correspondence impacts future proficiency in reading, writing and spelling (Byrne & Fielding-Barnsley, 1989, 1990; Foorman, Chen, Carlson, Mosts, Francis & Fletcher, 2003; Foorman, Fletcher, Francis & Schatschneider, 1998; Liberman, Shankweiler & Liberman, 1989; National Institute of Child Health and Human Development, 2000). It can be reasoned that alphabet knowledge requires visual perceptual and multisensory capacities. Study 3 examined the impact of instruction in alphabetic knowledge on measures of ability in performance IQ. It was hypothesized that this particular intervention would instigate improvements in PIQ. We were able to confirm this theory as results showed improvement in both block design and CEFT after the intervention. Participants also showed improvement in word reasoning (a subtest of VIQ) as well. The improvement in word reasoning measures was found to also be significantly related to block design and CEFT. These findings are comparable to Bakkar's (1979, 1990, 2002, 2006) conclusions that young children employ more visuospatial abilities when learning tasks.

#### **10.4 Conclusions**

Study 1 found differences between dyslexics and non-dyslexics for reading and spelling ability. In addition, significant differences were found for specific measures of phonological knowledge, namely identification of consonant sounds, reading of “r” and “l” controlled vowels and variant vowels and diphthongs, phonemic deletion of the first sound in a blend and spelling skills for long vowels. On the other hand, no significant differences were found between dyslexics and non-dyslexics for other specific measure of phonological awareness (phoneme segmentation, phoneme deletion of first or final sound in a blend, short or long vowel sounds, consonant blends with short vowels, short vowel sounds in CVC words, and short vowel diagraphs and “tch” trigraphs). There were

also significant differences in performance between groups for the working memory assessment of controlled associations and for reading rhyme judgement. There was a trend found between groups for auditory rhyme judgement. There were no differences found between groups in vocabulary ability. From these results, it is evident that individuals with dyslexia present differing literacy abilities than those without dyslexia. Researchers agree that dyslexia is a multifaceted disorder which is rooted in the systems of the brain that manage the ability to comprehend and to communicate language. Shaywitz (2003) maintains that the diagnosis of dyslexia is often delayed or overlooked because an individual fails to “demonstrate one or more of the presumed symptoms”. At the outset, research focused primarily on the visual system for the symptoms of dyslexia. Subsequently research is concentrating on the phonological model as the basis for the deficits in the language system. It is no longer a controversial issue whether phonological skills and learning to read are significantly related. Ostensibly the case for which particular phonological skills are impacted must be validated. The foundation of phonological awareness has been identified as the ability to correspond letter names with letter sounds and the dyslexic participants in this study were found to be substandard to the control group on this skill. This is consistent with research by Shaywitz (2003), Byrne (1998), Stuart & Coltheart (1988), and Tremain (1993). An important conclusion of these results is that dyslexics have both strengths and weaknesses in their linguistic skills. Tasks which can be analyzed into morphemes (units of meaning) may be less difficult for dyslexics (e.g. phoneme segmentation, phoneme deletion first sound of blend and final sound in blend) than tasks which require only phonological skill such as consonant sounds, multi-syllabic words, “r” and “l” controlled vowels and variant vowels and diphthongs. Dyslexics in this study performed worse on tasks which required strong phonological analysis and/or which necessitated knowledge of phonological conditional rules (Nunes, 2002). Also in uniform with research (Torgeson, 1995; Adams, 1990; Bradley & Bryant, 1978) the dyslexic participants for study 1 performed inferior to the control group in the ability to hear rhyme. It is interesting to note that both the study and the control group had more success in their ability to distinguish rhyme when presented in an auditory manner. The study group performed inferior to the control group when asked to read the pairs of word and determine if they rhymed. The process of decoding



the words presented a difficulty for the dyslexic participants and they were unable to attend to both the decoding process and the sound of the word pairs simultaneously. These findings concur with research by Goswami and Bryant (1990) who found that rhyme detection and production was causally related to reading.

Results for study 1 found the study group to be substandard to the control group on the measure of controlled associations. This task measured ability in working memory. This is in concurrence with research which indicates that dyslexics are deficient in tasks of working memory—particularly the phonological loop (Baddeley, 1993, 1998, 2003). Dyslexics struggle with tasks related to working memory and although both groups had difficulty with the task, it was the dyslexic participants who presented significantly weaker performance in generating associated words for the task. Alternatively, both groups performed similarly in vocabulary knowledge which confirmed the premise that working memory was deficient in the dyslexic group as compared to the control group. Similar findings by Montgomery show that dyslexic individuals have difficulty in both storage and processing functions related to working memory when compared to non-dyslexics. The implications for these findings are that dyslexics have disorganized working memory and this is a crucial factor which limits their abilities. A deficiency in working memory impacts both verbal and written communication skills as well as planning and organizational abilities. Therefore, as dyslexics have reduced use of the phonological code they have less capacity in short term memory.

The National Institute of Child Health and Human Development (2006) indicates early identification and intervention of deficits in language and literacy acquisition can prevent subsequent deficits in reading. An appreciation of the causes underlying development of literacy is fundamental to the approach of both future research as well as current instructional practices. Study 2 examined the early indicators of dyslexia in preschool-age children. Although much of current research proposes that pre-reading skills can be identified in children as young as age four, this study challenges that premise and examines the developmental literacy abilities in children as young as three years old. Few studies have examined such a young population to examine specific pre-reading abilities. The purpose of study 2 was to examine intelligence, analyze the relationship of

intelligence to reading related tasks and to measure performance on language and phonological related tasks which were similarly matched with study 1 measures. Although we recognize much of the research and use of the discrepancy definition for dyslexia, the purpose of examining intelligence in this study was to determine the characteristics of intelligence and their subsequent relationship with developing literacy skills. Historically researcher have made several assumptions for the use of intelligence in defining reading disability (Siegel, 1989). These include the assumption that intelligence and achievement are independent of each other and that a reading disability will not affect IQ scores. It has also been proposed that IQ scores predict reading and that children with low IQ scores will subsequently be poor readers. Children with dyslexia actually possess differing IQ scores and therefore can be found to have diverse cognitive processes and information skills. Evidence shows that poor readers have a variety of IQ levels and demonstrate similar reading, spelling, language and memory deficits (Siegel, 1989). Intelligence scores are not necessary for the definition of dyslexia but can be beneficial in better defining the underlying causal factors. We can conclude from study 2 that full scale IQ is significantly related to CEFT, rhyme and alphabet knowledge. Meta-analysis of IQ found a significant relationship between performance IQ and these same three measures. Similar to Ingesson's research (2005) these findings suggest that young children process information and elucidate using a more visual approach. Bakkar (1990) has suggested that the right hemisphere is predominately dominant for visual perceptual commands in young children's literacy development. In a similar small scale study on 4 and 5 year olds, Woodrome and Johnson (2007) found that visual discrimination skills play a significant role in acquisition of the alphabet and were positively related to phonemic awareness skills. Additionally, it is evident there is a relationship between reading and spelling skills and verbal IQ. For this age group, findings revealed noteworthy relationships for block design and reading ability which can additionally sustain the principle of stalwart visual discrimination skills for preschool age participants. A reciprocal relationship can be argued to exist between verbal intelligence and performance intelligence as emergent spelling skills were related to both block design and word reasoning measures. This concurs with Uta Frith's stepwise theory of reading development (1985). In conformity with Frith's theory, preschool participants in

this study can be reasoned to be in the early to middle phase of the logographic stage of development and are able to identify letters as being associated with specific meanings. The implications for these findings indicate that when we critically examine the practical consequences of including IQ in the definition of dyslexia it is imperative to separate the function of performance IQ and verbal IQ and to analyze the role that each plays in the disorder. Although there may be no causal relationship between IQ levels and dyslexia, the critical role that both PIQ and VIQ play in the process of reading development is evident and should be examined further. Empirical evidence from this study points toward PIQ as being critical to several pre-reading skills. Therefore, practical interventions for this young age group must include tasks that emphasize the use of skills which underscore visuo-spatial abilities. The use of appropriate methods for instruction and intervention in preschool age children can have a positive impact in their later cognitive performance.

Study 3 explored the relationship between acquisition of letter knowledge and visual discrimination ability. Badian (1994) maintains that visual discrimination is a significant factor in learning to read by facilitating the acquisition of the alphabetic principle. Letter knowledge is one of the strongest predictors of future reading ability (Woodrome & Johnson (2007)). Overall we can conclude that there is an explicit relationship between letter knowledge and visual discrimination for preschool age children. These findings are supported by similar research presented by Woodrome and Johnson (2007) as well as by neuroimaging research that addresses the relevance of visual processing skills in early reading development (Eden, VanMeter, Ramsey & Zeffiro, 1996). Results from study 2 helped to inform study 3 as the intervention method chosen was as a result of research by Bakkar (1990) which contends that visuo-spatial abilities are prevalent in children under age seven. Results from study two sustained Bakkar's findings and indicated a strong relationship existed between performance IQ and letter knowledge.

This intervention study presented explicit and systematic instruction in letter sound correspondences. Instruction was multi-sensory and direct.

Rather than finding effects related to socio-economic status, study 3 found a significant relationship between the mother's age and performance on verbal intelligence measures.

A negative relationship for mother's age and performance for the phonemic ability to comprehend onset-rime was indicated. A possible explanation for these findings is that these older mothers have more sophisticated verbal abilities which the preschool child is exposed to but that they do not have the time to spend in providing explicit instruction for their young child. Supportive of this line of reasoning is the finding of a negative relationship between the number of older siblings with alphabet knowledge and rhyming ability. These findings are in concurrence with Molfese and Molfese (2002) who reported that a young child's experiences in the home environment directly influences their cognitive abilities and can be related to later literacy skills. Pre-reading skills associated with developing literacy can be impacted by "at risk" factors such as socio-economic status (Nichols, Rupley, Rickelman, & Algozzine, 2004). Children from lower SES often encounter different experiences due to lower parental education levels as well as other risk factors. Torgeson (1995) has found that a variation occurs in the development of phonological awareness skills between children at (and prior to) the foundation stage of learning. This variation is related to a child's linguistic experiences as well as their genetic background.

As word reasoning was associated with the child embedded figures testing we can conclude that the capacity to reduce irrelevant context visually is related to the ability to choose vocabulary based upon relevant information. Woodrome and Johnson (2007) suggest that cognitive abilities play an essential role in positive outcomes for children who are acquiring the alphabetic principle. Study 3 findings conform to this premise as those participants who displayed stronger word reasoning skills also performed superior in the specific tasks related to phonological awareness and visual discrimination.

Research by Bond and Dykstra (1967) contend that a young child's auditory and visual discrimination skills, intelligence and familiarity with print were all features of reading development.

Following the prescribed intervention on alphabet knowledge, participants showed improvement in all measures of phonemic awareness except for rhyme. These findings are analogous with Muter et al. (1998) who found evidence that early rhyming skills were not a determinant of early reading skills. They maintain that interventions which facilitate skills for literacy should focus on training which integrates the teaching of letter names

and sounds. We can also conclude that this intervention improved performance in measures for performance IQ as participants increased scores in both block design and child embedded figures testing subsequent to the intervention. In contrast to the hypothesis that visual discrimination contributes to reading ability through the acquisition of letter knowledge (Badian, 1994; Sawyers, 1992) we propose that there is a reciprocal relationship that exists whereas cognitive abilities for PIQ impact acquisition of letter knowledge and vice versa. There are critical implications for the presence of an association between letter knowledge and visual discrimination. This finding has the potential to influence not only the understanding of the development of reading skills but also the practical decisions for appropriate interventions.

When comparing the findings of our study to theories and research presented in this paper it is clear that the both Frith's theory of reading development and Chall's stages of reading development help to define the developmental process that occurs in literacy on a given timeline. Both recognize the stages that occur as milestones in development as well as which skills must be acquired during these individual stages. The implications for these findings as they relate to both theories is that they underscore the critical importance of the early stages in literacy development. Without the skills developed in the early stages of literacy it is not possible to progress forward into the more advanced stages of reading and comprehension. Furthermore, remediation for reading deficits takes place at these lower levels of development. Results of this study confirm the value of these first stages in budding literacy ability. Our results reinforce the model of reading systems presented in this paper by Adams (1990). They indicate the process of several systems working together continuously to receive and process information for phonological knowledge, working memory and visuo-spatial awareness. We can conclude from our findings that dyslexia is not a domain specific disorder but that it impacts a wide range of domains. Our findings are in concordance with researchers who describe visual disorders, such as processing of letters and words as being causal to reading deficits. Dyslexics in these studies were often deficient their ability to correctly interpret visual information (letter names) when compared to non-dyslexics. Moreover, in accordance with the philosophy for the magnocellular theory, the processing of incoming verbal information, by phonological storage and retrieval and

which is essential to other short-term verbal memory tasks was found to be substandard in dyslexics when compared to non-dyslexics. These similarities in our findings to the theories described above do not present the entire picture. Findings from our three studies found that an inefficient working memory was implicated as a factor in reading ability. Correlations between controlled associations and WRAT reading and spelling were significant. Ability in this task of working memory is related to the understanding of language rules and comprehension. Therefore, the implications for these findings is that dyslexics can be identified as having difficulties with the phonological code aspect of working memory which therefore negatively impacts their reading ability. These difficulties limit their short term memory capacity and often lead to compensatory processes while reading. Because dyslexic readers have deficits in memory function they also struggle with automatised abilities (rapid-auditory processing theory) as they are often so focused on decoding the letter-sound correspondences that they display weaknesses in comprehension. The findings from these studies lead us to conclude that the phonological theory has critical bearing on the results of this paper. Proponents of the phonological theory contend that individuals with dyslexia have not only a deficit in phonological processing but with central processing speed. We found a significant relationship between processing speed (as measured by PIQ) and the ability to understand letter-sound correspondences. The implications for these findings are that the teaching of the alphabetic principle has direct impact on an individual's PIQ and therefore supports their development from beginning stages of literacy into the subsequent stages. Additionally, intervention with the alphabetic principle can develop phonological skills in very young children and assist in moving them along the continuum from the logographic phase into the alphabetic phase of reading development (Frith, 1985). Finally, analysis of digit ratio and its relationship with cognitive factors found significant relationships between digit ratio and non-verbal learning abilities. Further analysis revealed an additional relationship with digit ratio and the difference for embedded figures testing. We can conclude that exposure to prenatal testosterone, as measured by 2D:4D is related to the capacity to learn. Further studies should consider the investigation of associations between learning ability and prenatal testosterone to confirm the effects of digit ratio on cognitive abilities. No differences were found for sex

between groups in the intervention study and this was attributed to the young age of participants. These findings are supported by Hyde et al. (1990) who were also unable to find difference in sex for young participants. On the other hand, Study 1 found significant differences in performance between sex for reading, spelling, phonological skills and working memory. These findings are consistent with current research which has found that males typically underachieve when compared to females for many literacy tasks. Males typically show lower verbal ability than females but higher spatial abilities. Males have been found to have differences in hemispheric specialization whereas males demonstrate robust left hemispheric specialization for verbal processes and strong right hemispheric specialization for spatial processing. Females tend to display strong bihemispheric processing for both verbal and spatial abilities (Hier, 1979). These differences offer evidence as to the cause of reading disabilities in more males versus females.

### **10.5 Limitations and Suggested Further Research**

Some limitations for these studies must be acknowledged. Given the limited sample size for all three studies, these findings should be considered groundwork for further research. It is possible that the size of the sample recruited for this research led to some limitations in the analyses. In spite of this, the structure of the small sample size allowed us to examine the relationships between recognized and theorized tasks which are a factor in the developmental literacy process for dyslexic, non-dyslexic and preschool age children. The population sample utilized for each of the three studies included a combination of various socio-economic backgrounds. Research has often demonstrated a relationship between low socio-economic status and poorer academic performance in literacy. Additionally, much of the literature on reading development has incorporated the use of predominately middle class samples. Findings for this study cannot address issues of socio-economic status and literacy as the samples included a variety of SES backgrounds. Future research should continue to concentrate on issues of diversity in sample groups. It is possible that erroneous results occurred in study one's assessment of letter knowledge—specifically for long and short vowel sounds. It is interesting to note that

the study group, who were receiving specialized instruction for their reading disabilities, provided the letter sound when asked to name the letter. Further investigation revealed that these children were being trained in the letter-sound correspondences and the practice of their programming held to the belief that identifying the sound took precedence over naming the letter. This was not the case for the control group who had received instruction in identifying the letter names prior to the sounds. Even with this discrepancy between groups in the methodology used for letter knowledge, the dyslexic group performed inferior to the control group for consonant sounds identification. A weakness in the assessment of long and short vowel sounds may have contributed to the results showing no significance between groups for long vowel sounds. This was caused by the assessment procedure itself as participants were given credit for understanding the long vowel sound by stating its name. Therefore it is unclear if the participants were actually able to distinguish between the long and short sounds for each vowel. Further research would be warranted to determine the specific difficulties children possess when letters have more than one common sound. Despite the differences in educational practice which may have impacted this study, results found are supported by current research (Raij, Uutela, & Hari, 2000; van Atteveldt, Formisano, Goebel, & Blomert, 2004) which maintains that children who are exposed to letter symbols and letter sounds in unison utilize a relationship between the two independent brain regions for visual and auditory processing to develop literacy skills. Results for these studies are in agreement with current research that describes reading as a multifaceted process utilizing visual skills, phonological processing abilities and higher-order cognitive abilities which work together for the purpose of reading.

Study 2 investigated the relationship between cognitive ability and phonological awareness in preschool age children. Even as results were controlled for age, the wide range between ages for this study may have diluted the findings. Vast developmental differences occur between the ages of 3 years and 6 years with regards to literacy and cognitive development. It was necessary to include the breadth of age ranges in order to obtain a sufficient study group. In future research an examination may be warranted using a less significant range of preschool age children.



Study 3 investigated the role of verbal and non-verbal intelligence and their interaction with phonological skills in developing readers. Research has established that intervention studies which train phonological skills can help improve children's reading skills (Ball & Blachman, 1991; Bradley & Bryant, 1985; Byrne and Fielding-Barnsley, 1995). Study 3 confirmed the hypothesis that intervention in the alphabetic principle improved performance IQ. Additionally, improvements were found in the verbal IQ subtest of word reasoning. The word reasoning subtest was found to be significantly related to block design and CEFT which both measure visuo-spatial skills. These findings have important applied implications. Contemporary educational policy indicates the necessity of providing intervention for individuals with reading deficits when there is a discrepancy between reading ability and intelligence. The present findings suggest that early intervention for preschool age children can develop the multifaceted processes which work together for the purpose of learning to read. These include visual skills, phonological skills and cognitive processes. These findings are supported by research from Hatcher & Hulme (1999) and Woodrome and Johnson (2007) who make a case that there is no justification to satisfy the discrepancy definition of reading problems and that training in phonological skills greatly improves overall ability to read. It would be valuable for further research to include differing designs which include separate interventions and the use of a control group to expand upon these findings.

## **10.6 Summary**

In summary, it is evident that phonological skills are vital to the development of reading skills. Present and previous research findings have described which specific phonological skills make a greater impact in the development of reading and have created a complicated portrait of the developing reader. This study considers that early identification of weaknesses in visual discrimination skills and phonological awareness can be mediated by well informed instruction in letter-sound correspondence and can be a critical determinant of future reading abilities. It is clear that more empirical and theoretical research is needed to determine the theories presented in this study. However, it appears likely from this study and other research that a relationship exists between visual discrimination skills and the alphabetic principle and that future interventions

chosen need to address a learner's position on the literacy continuum and strive to move this position forward.

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# Appendix

## Parent Survey

Thank you for taking part in this research. As you will know, I have assessed you child on a number of reading measures. We are investigating the relationships between parents and children, specifically looking and reading and writing abilities. I examining if there is any relationship between these measures and any family histories of reading problems. I would be grateful if you could provide the following details. For the following questions can you please provide the details for A: the child, B: the child's mother and then C: the father. The name is only required so that I can link the data together. Once, linked the data will be anonymous and confidential.

### **A. Child and brothers/ sisters**

Child's name:

Child's age:

Please list the ages of any (biological) brothers:

Please list the ages of any (biological) sisters:

### **B. Questions for the child's mother:**

1. Are you the biological mother of the child? Yes / No
2. What is your age? \_\_\_\_\_ years
3. What is the highest level of education you have completed? (please tick one)

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Did not graduate high school

Some College

High school graduate

College Graduate

GED (General Degree)

Other (please state)

4. What is your current marital status?

\_\_\_Single

\_\_\_Married

\_\_\_Widowed

\_\_\_Divorce

5. What is your ethnic background?

Caucasian

Asian

African American

Other

Latino/Hispanic

6. Have you or anyone in your immediate family (biological parents and grandparents, brother, sister, aunts/uncles, cousins, children) been FORMALLY diagnosed (e.g. by a clinician) with the following (check all that apply):

Dyslexia

Reading Difficulties

Attention Deficit

Learning Disorders

7. Please list who has been diagnosed and what diagnoses they were given (e.g. Cousin – Reading Difficulties)?

**C. Questions for the child's Father:**

5. Are you the biological Father of the child? Yes / No

6. What is your age? \_\_\_\_\_ years

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7. What is the highest level of education you have completed? (please tick one)

- |   |   |
|---|---|
| <input type="checkbox"/> Did not graduate high school | <input type="checkbox"/> Some College                                 |
| <input type="checkbox"/> High school graduate         | <input type="checkbox"/> College Graduate                             |
| <input type="checkbox"/> GED (General Degree)         | <input type="checkbox"/> Other (please state)<br><input type="text"/> |

8. What is your current marital status?

Single       Married       Widowed       Divorced

5. What is your ethnic background?

- |   |                                |
|---|--------------------------------|
| <input type="checkbox"/> Caucasian        | <input type="checkbox"/> Asian |
| <input type="checkbox"/> African American | <input type="checkbox"/> Other |
| <input type="checkbox"/> Latino/Hispanic  |                                |

6. Have you or anyone in your immediate family (biological parents and grandparents, brother, sister, aunts/uncles, cousins, children) been FORMALLY diagnosed (e.g. by a clinician) with the following (check all that apply):

- |  |   |
|--|---|
| <input type="checkbox"/> Dyslexia          | <input type="checkbox"/> Reading Difficulties |
| <input type="checkbox"/> Attention Deficit | <input type="checkbox"/> Learning Disorders   |

7. Please list who has been diagnosed and what diagnoses they were given (e.g. Cousin – Reading Difficulties)?