A LATENT GROWTH CURVE ANALYSIS OF READING ACHIEVEMENT FOR AN AT-RISK POPULATION

By

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To the Faculty of Washington State University:

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The development of reading skills from age seven until age 19 was investigated for children who were referred for special education preschool intervention using latent growth curve analysis (n=206). Approximately one-third of the study sample did not require special education services after preschool, providing a natural comparison group. Reading achievement was conceptualized as the Simple View of Reading, where reading is assumed to be the product of decoding and comprehension. Since reading is a developmental process, it is theorized to grow at a non-linear rate, with large differences among individuals. Reading trajectories are apparently stable from an early age, thus predictors of individual trajectories can be hypothesized and their effects estimated. Latent growth curve models allow for intraindividual differences and can accommodate various growth trajectories. In addition, early predictors of reading trajectories for individuals who are at risk for reading difficulties can be added to the model.
Results indicate that there were large differences in intercept, or starting point of reading achievement for children who required special education services post-preschool intervention and children who did not. Although there were small but significant differences in growth over time, the trajectories of these two groups were remarkably similar. Both groups had negative trajectories that were quadratic in form, indicating that children who started higher experienced slower growth than children who started lower, and that they both lost ground in reading skills compared to same aged peers over time. In this sample, girls experienced lower achievement than boys, and children with lower SES (as measured by free and reduced lunch) experienced more growth than children with higher SES. The preschool verbal intelligence post-intervention scores of the children accounted for a moderate amount of variance in reading achievement outcomes.
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Introduction

There is a critical need to address the literacy achievement gap in the United States today. Approximately 24% of eighth graders are unable to reach basic proficiency levels in reading (National Center of Educational Statistics; NCES, 2007). For students with disabilities, that number rises to 66% for eighth graders and 72% for twelfth graders (NCES, 2007). When students are referred to special education for remediation of reading skills, it is estimated to cost 90% more per student than general education (U.S Dept. of Education, 2002). The cost of special education is calculated in more than dollars. Students with (and without) disabilities who fail to develop adequate literacy skills are a greater risk for a host of problems such as lack of motivation, dropping out of school, delinquency, poor employment opportunities, poverty, and even poor health (Baker et al., 2007; Morgan, Frisco, Farkas & Hibel, 2010; Torgesen, 2002).

It is important for researchers, educators, and parents to uncover the source of reading difficulties, and help all students achieve in school. Identifying the underlying causes of reading difficulty can also contribute to early identification and remediation. According to the National Reading Panel (NRP, 2000), if children cannot be identified as at risk for reading difficulty by age nine, approximately 75% will experience reading problems and be further at-risk academically. Research suggests early identification and intervention is the most effective way to prevent reading difficulties (Snow, Burns, & Griffin, 1998; Torgesen, 2002; Menzies, Mahdavi & Lewis, 2008. Although progress has been made in understanding the key elements in reading difficulty, educators and researchers still lack accurate tools to identify those in need of early intervention in a
timely manner (Boscardin, Muthen, Francis, & Baker, 2008). It is particularly problematic to find early predictors for young children because of the normal variability of development in this population, which fluctuates rapidly and is unlikely to be captured with short-term assessment (Speece, 2005). Adding to the complexity of early identification, research also indicates that labeling children as delayed or disabled at an early age could negatively influence the beliefs of school professionals (McGill-Franzen & Goatley, 2002). For example, Hauser-Cram and Sirin (2003) discovered when teachers perceived students as coming from low-literacy backgrounds, they maintained less than adequate support for those students, yet reported the students as being less competent. Therefore, a critical need exists to understand how children at-risk for reading difficulty develop (or fail to develop) literacy skills over time.

Brief Literature Review

Development of Reading

Reading is a complex set of skills with its origins in language and communication skills. Knowledge of the sounds of a language, the grammar, and vocabulary are essential pre-literacy skills that children gain from listening and speaking with others. As a child enters school, language skills become more formalized and objective. This knowledge of spoken language begins to be transferred to written language, as children become more able to divide words up into syllables and phonemes, and then to recognize that letters are the objective representation of those sounds in the English language (Verhoeven, 2011).

The Simple View of Reading (SVR; Gough & Tunmer, 1986; Hoover & Gough, 1990) is a framework for understanding the components of successful reading. In this theory, reading is seen as the product of decoding and comprehension. The authors do not
assert that these are the only factors involved in reading, but that they are the primary means for understanding how a child processes text. Decoding is defined as word recognition, with an understanding that this is accomplished primarily through phonemic awareness. Comprehension refers to listening comprehension of oral language, not written material. The product term means that if either decoding or comprehension is lacking, the result will be an impaired reader. This model predicts three types of reading difficulty, dyslexia, hyperlexia, and “garden-variety” poor readers. The authors define dyslexia as an inexplicable deficiency in reading alongside normal development in other areas. Hyperlexia refers to the ability to read fluently without understanding what has been read, and garden variety poor readers have difficulty with both decoding and comprehension of language. There have been a number of empirical studies showing the SVR to be a useful way to understand the underlying components of reading, especially with students who struggle with reading. Kendeou, Savage and van den Broek (2009) state that generally, research shows that the SVR can account for 40% to 80% of the variability in readers. However, this theory can only speak to the psychological process of an individual who is already reading, and does not offer any conceptualization of how the reading process developed.

Chall (1983, 1996) offers a description of the typical progression of reading development as follows:

1) Prereading (birth to 6) – knowledge about books, understanding of symbolic representation, produces purposeful scribbles, recognizes environmental print
2) Decoding (6 to 7) – using a phonological decoding process, words are identified, vocabulary is expanded, use of knowledge of grammar to achieve comprehension

3) Fluency (7 to 8) – speed and accuracy are improved through repeated practice, metacognitive strategies used to monitor comprehension

4) Reading for Learning (8-14) – phonological processes are automatic, comprehension is the focus, vocabulary is built

Chall’s model may or may not be appropriate for all children. For example, Fischer, Rose and Rose (2007) suggest that certain children may go through an alternate sequence of reading development, which puts them at risk for being labeled as “learning disabled” because the instruction they receive is not aligned with how they process textual information. These developmental differences may go undetected because of statistical analyses that focus on groups of children rather than on individual differences (Paris, 2005). This model also represents a “stage” theory of development, which appears to be a linear process, with static age constraints. Contemporary theories of development suggest that development is more dynamic, with skills growing in a web-like or cyclical fashion as the individual moves through different contexts and interacts with others (such as teachers, parents, or peers) (Fischer, Rose & Rose, 2007; Thelen & Smith, 1994; Van Geert, 2009).

More recently, “stages” have been replaced by “phases”, which can be overlapping instead of having rigid thresholds that must be mastered before the next stage can begin (Snowling & Hume, 2005). Ehri (1999, Ehri & Roberts, 2005) offers a phase theory of learning to read words. Each phase is characterized by the “pre-dominant type
of connection that is activated to secure sight words in memory” (p.116). These phases are as follows:

1) Pre-alphabetic phase – recognizes environmental print, heavily reliant on visual or context cues without much letter knowledge.

2) Partial alphabetic phase – some knowledge of letters and sounds, which is used to form incomplete connections in memory.

3) Full alphabetic phase – decoding emerges, and connections between letters and sounds are used to read unfamiliar words.

4) Consolidated alphabetic phase – whole words, spellings patterns, rime and syllables are stored as useable connections.

It should be noted that this particular theory only refers to beginning readers who are at the word level of text. There is some question as to whether or not this theory is helpful when considering why some children have difficulty learning to read, but it seems clear that children may encounter difficulties in any or all of the phases (Ehri & Snowling, 2004).

**Development of Reading Disabilities**

If a lack of consensus exists about how reading develops, there may be even greater disagreement about how reading fails to develop. In an effort to identify reading difficulties at the earliest possible juncture, researchers conduct studies focusing on early indicators of later reading difficulty. These studies have identified some initial abilities that are linked to later reading outcomes. Many scholars agree that phonological awareness, early print knowledge, and persistent deficits in word identification are the strongest predictors of developmental reading difficulties (Anthony, Williams,
McDonald, & Francis, 2007; Davis, Lindo, & Compton, 2007; Mann, & Foy, 2003; Torgesen, 2002; Vellutino & Fletcher, 2005). In addition, poor vocabulary and verbal memory are consistently seen in low readers (Al Otaiba & Fuchs, 2006), but may not always be present for some (Vellutino & Fletcher, 2005). Another theory is the “double-deficit” hypothesis, which refers to weakness in phonological processing in concert with poor ability to rapidly processing information, often referred to as rapid automatic naming or RAN (McCardle, Scarborough, & Catts, 2001). The predictive utility of RAN may be stronger with transparent orthographies such as Finnish and less of an indicator in deep orthographies like English (Torppa et al., 2007). Other researchers question that the method for assessing RAN really differentiates it from phonological weakness. RAN continues to be of interest, but its role in learning to read is not clear (Smith, Scott, Roberts & Locke, 2008).

Types of Reading Difficulty

Evidence supports the assertion that there are different models or subtypes of reading difficulty. Empirical work on developmental reading subtypes has attempted to identify if there are poor readers who demonstrate different developmental patterns than average or good readers. These theories can be described as 1) the double discrepancy, where the students who are most at risk for reading disabilities are the ones who score low on screening measures and also show slow growth rates over time (Speece, 2005), 2) the Matthew effect in reading, where good readers get better over time and poor readers get worse (Stanovich, 1986), 3) the developmental lag hypothesis, where poor readers eventually narrow the achievement gap (Catts, Hogan & Fey, 2003; Parrila, Aunola, Leskinen, Nurmi & Kirby, 2005), and lastly 4) the deficit hypothesis, where poor readers
evidence a significant deficit in their reading ability that is largely stable over time (Boscardin, et al., 2008; Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996).

Research on individual differences in reading development, which may occur from these diverse origins of development, has been confounded by the uneven developmental nature of reading itself. Early reading requires a heavy focus on word identification, while later reading is more strongly related to language comprehension (Vellutino & Fletcher, 2005). Early deficits in reading can compound over time, for example, as children who have poor oral vocabulary not only know less words, they are also less likely to be able to decode unknown words, because a rich oral vocabulary increases a child’s knowledge about semantics, syntax, morphology and the interrelatedness of words (Juel, 2005). Even though word-level reading is the target of many investigations and interventions “a failure to understand the alphabetic principle (that graphemes map onto phonemes) is just one point at which children can become discouraged about the reading enterprise” (Snowling & Hume, 2007, p.101). Therefore, to get a fuller picture of the course of development for children who struggle with reading, more longitudinal studies of reading development with typically and non-typically developing children are needed.

**Longitudinal Studies of Reading Difficulty**

Longitudinal studies allow for the examination of growth over time, which can be used to study early predictors and later outcomes of disability. Comprehensive descriptions of the developmental trajectories of reading with different groups of children are extremely rare (Dickinson & McCabe, 2001; McCardle et al, 2001; Parrila et al., 2005). By far the bulk of longitudinal studies addressing reading investigate learning
disabilities (LD), which is the most commonly occurring disability as identified by the Individuals with Disabilities Education Act (IDEA, 2004). The Connecticut longitudinal study investigated the stability of reading deficits over time, (Francis et al., 1996; Shaywitz et al., 1999). Results of that study indicated that low readers consistently scored much lower on initial levels of reading achievement, but demonstrated rate of growth on par with average readers. The Colorado Twins study and the Twin Early Development study investigated the genetic and environmental influences on reading disability (Harlaar, Dale, & Plomin, 2007; Wadsworth, Defries, Olson, & Willcutt, 2007). By selecting participants who had shared genetics and environment (twins), and then using family history of dyslexia as an indicator of genetic origin of reading difficulty, the researchers were able to use a sophisticated factor analysis to parcel out genetic versus environmental factors of reading disability. These studies demonstrated that reading deficits are more likely not a lag in development but represent a lower end of a continuum of reading abilities. These deficits are long lasting and largely mediated by a genetic component. In other words, children with a disability were lower performing, but grew in skills comparably to the children without disabilities. The Jyvaskyla Longitudinal Study of Dyslexia (Torppa et al., 2007) was conducted in Finland with a group of 100 children with familial risk of dyslexia, and a control group of 100 children with no family history of dyslexia. The researchers identified developmental reading trajectories of five distinct groups of readers, labeled persistently 1) persistently good, 2) good, 3) average, 4) poor, and 5) persistently poor. They identified the children with familial risk of dyslexia as performing, on average, significantly lower than classmates. Similarly, researchers in Canada and Finland (Parrila et al., 2005) examined the growth of reading
skills in children in both countries from first to fifth grade, but only found three groups (good, average, poor). The differences in these groups could be due to the smaller number of participants in the Parrila et al., (2005) study.

In each of the previous investigations, children who were eventually diagnosed with a learning disability consistently scored below competent readers on measures of word-level reading and comprehension. All of the previous studies began with children who were ages 7, 8, or 9, and therefore may not reveal earlier predictors of reading difficulty. More specifically, these studies began when children were already receiving instruction in reading. It would be beneficial to conduct an empirical investigation of pre-literacy skill development beginning with a pre-literate population, which may aid in understanding the early predictors of reading difficulty. As shown, reading outcomes are very stable over time, so finding earlier intervention points is critical for struggling readers.

Another group of children who may experience considerable difficulty in learning to read are those with speech and/or language impairments, which is the next most frequently occurring disability after LD (NCES, 2010). Researchers studying reading deficits in children with language impairment (LI) concluded that children diagnosed with LI showed a significantly lower initial level of reading ability, and never closed the gap with their same age peers without a LI. However, there was no significant difference in rate of growth between the two groups (Catts, Bridges, Little, & Tomblin, 2008; Catts, Hogan & Fey, 2003; Francis et al., 1996). These results are strikingly similar to the studies involving students with LD discussed previously.
Students with behavioral disabilities such as Attention Deficit Hyperactivity Disorder (ADHD), or Emotional Behavior Disorder (EBD) often experience difficulty in learning to read due to behavioral disturbances, which interrupts their learning. This often co-occurs with LD, which may or may not be formally diagnosed (Seeley et al., 2009). There are no longitudinal studies of reading growth, which compare students with and without behavior disorders or ADHD. However, research does indicate that similar to students with LD and LI, children with persistent ADHD symptoms have relatively stable lower achievement in academic areas such as reading over time (Biederman et al., 2010).

There is little research on reading development of children with cognitive impairments, and no longitudinal research to date (Browder, 2006). The research on reading with this population has focused on the acquisition of word-level reading skills in a functional manner (Browder & Xin, 1998). These studies indicate that students with cognitive disabilities can be taught to read, using evidence-based methods such as recommended by the National Reading Panel (Al Otaiba & Hosp, 2004). Evidence suggests that a core deficit in phonological processing and phonological memory contribute the majority of variance in reading performance of students with cognitive impairments (Snowling & Hume, 2005).

Most studies on reading development examine relatively short-term outcomes, one to three years after initial testing. To give a brief example, in the seminal study by Catts, Fey, Zhang & Tomblin (1999), which provided support for the phonological basis of reading disability, kindergarten skills were linked to second grade outcomes. Another study by Roth, Speece and Cooper (2002) also provided evidence for the link between oral language and reading skills by examining kindergarten abilities and second grade
outcomes. While these important studies have added to the evidence of reading etiology, Fischer and Bidell (2006) assert that when assessments are repeated at close developmental ages, scores tend to cluster around the mean and not give a true picture of the variability in the population. Reading ability is theorized to change at a non-linear rate and eventually become stable (Francis et al., 1996). Since reading skills are likely to be different for early and later reading, a long-term bigger picture of the course of reading development would add to the existing body of knowledge about the necessary components of early intervention and reading instruction (Lonigan & Shanahan, 2010).

**Characteristics of an At-risk Population**

How are children currently identified as needing early reading interventions? Much of the research on early intervention refers to risk factors, which aid in the identification of children who will require literacy interventions. Common risk factors for reading failure include sensory deficits, low language skills, low cognitive skills and/or verbal memory, lack of print experiences, socio-economic status, poor resources and lack of access to quality instruction (Aikens & Barbarin, 2008; Snow et al., 1998; Torgesen, 2002). A student with one or more of these risk factors has an increased chance of experiencing reading difficulties.

In the follow up study of the Longitudinal Comparison Project (LCP), researchers investigated the long-term outcomes of early intervention curriculum that children at risk for academic difficulty received in preschool (Dale, Mills, Cole, & Jenkins, 2004; Jenkins, Dale, Mills & Cole, 2006). Students were randomly assigned to a Direct Instruction (DI) classroom, or a Mediated Learning (ML) classroom. While this study focused on the lasting effects of early childhood intervention on children at risk for
disabilities, and not specifically literacy, the researchers did report on the literacy outcomes of the children involved in the study. They identified three groups of students who had very similar profiles but very different Peabody Individual Achievement Test (PIAT; Dunn & Markwardt, 1970) scores at age 13. Using multiple regression, the researchers attempted to predict the age 13 PIAT score from the McCarthy General Cognitive Index (GCI; McCarthy, 1972) and Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981). Residuals were also calculated, so that those students who were above, below and at the regression line could be identified as “improvers”, “deceasers” and a comparison group. These students were closely matched on their GCI scores. By examining different factors from these 3 groups, the researchers were able to identify some outside factors that influenced the children’s development. Factors that were associated with risk for lower PIAT scores at age 13 included; lower family income, non-European ethnicity, special education placement, difficult temperament, and being female. Factors that were associated with higher PIAT scores were higher family income, European ethnicity, general education placement, easy-going temperament, and being male. Surprisingly, these differences were only found with the PIAT – an achievement measure and not with the age 13 Stanford-Binet – a cognitive measure.

The researchers also found an aptitude by treatment interaction effect between the initial cognitive levels of the participants and the teaching style of their classroom. Students with lower McCarthy General Cognitive Index (GCI) scores did better in the ML condition than in the DI condition. Alternatively, students with higher GCI scores did better in the DI condition than students with similar GCI’s in the ML condition. This effect lasted throughout Elementary school and into Middle school while the children
were mastering reading (Dale et al., 2004). This raises interesting questions about the appropriateness of implementing literacy interventions in a one-size-fits-all approach without applying different types of interventions for the diverse levels of reading ability teachers may encounter (Gersten & Dimino, 2006).

The purpose of the present study is to model the change in a group of at-risk children’s development of reading skills over time and determine if predictions can be made based on the patterns of development for different subgroups of the sample (e.g. those who were placed in regular education post-preschool intervention versus those placed in special education following intervention). Latent growth curve analysis is well suited for this type of investigation because it allows for individual difference in initial level of skills and rate of change. This retrospective analysis permits an investigation into questions of early predictors of later academic difficulty, and perhaps can illustrate critical time periods of growth and regression for the individuals who participated in the early intervention study. Preschool language skill, which represents one of the foundations of reading ability, can be added as a predictor of individual growth in reading. Research questions include: 1) what is the form of growth in reading achievement from kindergarten to high school for a referred population? 2) To what extent does the growth in reading differ between individuals? 3) What is the relationship between individual characteristics in preschool and growth in reading? 4) What is the relationship between initial level of reading ability and growth in reading over time?

Methods

Population
The Longitudinal Curriculum Comparison Project (LCP), which was initiated in 1984 at the University of Washington in Seattle, followed the participants throughout their school careers until graduation provides an ideal opportunity for researching these issues. This twenty year longitudinal study was unique in three ways: 1) it was a randomized study, where participants were assigned to either Direction Instruction or Mediated Learning; 2) researchers followed the participants throughout their school careers until the end of secondary schooling, and 3) researchers investigated the interaction between child characteristics and program variables (Jenkins, Dale, Mills, Cole, Pious, & Ronk, 2006). Yearly data was collected on each student in several domains including cognitive, social, academic achievement, language development, motor skills, and personal characteristics such as demographic information and quality of life.

The children who participated in the project were initially referred for developmental delays in cognitive, language, social, motor skills, or medical concerns. Many of the students demonstrated delays in more than one developmental area. All students met the state of Washington’s eligibility requirements for early childhood services, based on multiple types of assessments, medical history, observations, and parent reports. Overall, 206 students were provided services over a four year period (1984-1988). Demographic information is presented in Table 1. The sample has a majority of white, male students, which is representative of the special education population in the U.S. (NCES, 2007). The mean age of students at the start of the program was 4.9 years, and their average IQ was 76.7 as measured by the McCarthy
Scales of Children’s Abilities. The children were referred to the intervention program for a variety of concerns, and some children qualified under more than one area.

Table 1. Demographic information (Cole, Dale, Mills, & Jenkins, 1993)

<table>
<thead>
<tr>
<th>Description</th>
<th>N</th>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>142</td>
<td>European American</td>
<td>64%</td>
</tr>
<tr>
<td>Female</td>
<td>64</td>
<td>African American</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other</td>
<td>07%</td>
</tr>
<tr>
<td>Total</td>
<td>206</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Referral category by percentage

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>Language delay</td>
<td>81%</td>
</tr>
<tr>
<td>Fine motor delay</td>
<td>59%</td>
</tr>
<tr>
<td>Social delay</td>
<td>62%</td>
</tr>
<tr>
<td>Cognitive delay</td>
<td>54%</td>
</tr>
<tr>
<td>Gross motor delay</td>
<td>68%</td>
</tr>
<tr>
<td>Medical concern</td>
<td>20%</td>
</tr>
</tbody>
</table>

In order to estimate causal effects of the intervention program, the children were randomly assigned to either a direct instruction (DI) or a mediated learning (ML) classroom. Random assignment reduces the systematic differences between participants, allowing researchers to attribute the changes in participants to the intervention (Schneider, Carnoy, Kilpatrick, Schmidt, & Shavelson, 2007). The two interventions differed in philosophy, theoretical principles, and instructional methods. DI was developed in the late 1960’s-early 1970’s by Engelmann and his colleagues as a way to teach disadvantaged preschoolers (Bereiter & Engelmann, 1966; Becker, Engelmann, & Thomas, 1975; Engelmann, 1969). The method was based on task analysis, in which academic skills were taught in a strict sequence with immediate corrective feedback and reinforcement provided. DI is a very teacher-directed type of teaching, characterized by a fast pace, use of scripts, and specific student response. ML focused on developing a
child’s cognitive problem solving ability. Feuerstein (Feuerstein, Rand, Hoffman, & Miller, 1980) developed the technique based on theories of development from Piaget (1952) and Vygotsky (1962). In a ML classroom, teachers arranged the environment to allow children to interact in a natural way. The curriculum was child-driven, and the teacher capitalizes on a child’s interest to question, expand and model during instructional interactions. Generalization and self-control are emphasized, and the teacher aims to increase intrinsic motivation, rather than give extrinsic rewards. Although each program has the same primary goal of early intervention, the two programs arrive there from very different places. DI directly teaches academic skills children will use in elementary school and ML relies on indirect teaching of problem solving and self-monitoring. The LCP researchers hypothesized that the DI students would show an early advantage over the ML students that would fade over time, and that ML students would receive long-term benefit from the intervention.

At the end of the study, the children went on to various types of public and private education. The experimental intervention phase ended after one to two years of preschool/kindergarten, and then the descriptive phase of the study began (see figure 1). The children were followed and assessed throughout their school careers with measures of academic, cognitive, social-emotional skills, and 124 individuals took part in the final assessment. At age 19, 56 (40.3%) were not classified with a disability, students with learning disabilities represented the next highest category at 25 students, followed by other health impaired at 14, and the other disability categories of emotional disorder, mental retardation, and multiple disabilities making up the rest of the sample at 7, 17, and 6 respectively (Jenkins et al., 2006).
Figure 1. Illustration of the Phases of the LCP Study

It should be noted that many of the children in the study moved in and out of disability categories over time, so it is difficult to pinpoint an exact number of individuals with and without disability since this is a variable construct. However, approximately one-third of the participants never received special education services after the pre-school intervention. Table 2 presents the descriptive statistics for the participants of the study at age 19.
Table 2.  
*Descriptive Statistics for Children in Follow-up Sample at 19 Years*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Direct Instruction</th>
<th>Mediated learning</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age at pretest (years)</td>
<td>4.9(0.90)</td>
<td>4.83(0.95)</td>
<td>4.86(0.92)</td>
</tr>
<tr>
<td>Mean age at follow up</td>
<td>19.00(0.28)</td>
<td>19.08(0.28)</td>
<td>19.03(0.28)</td>
</tr>
<tr>
<td>Mean number of years in preschool</td>
<td>1.62(0.70)</td>
<td>1.66(0.79)</td>
<td>1.64(0.75)</td>
</tr>
<tr>
<td>intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean McCarthy IQ pretest</td>
<td>77.9(18.07)</td>
<td>75.65(16.69)</td>
<td>76.70(17.32)</td>
</tr>
<tr>
<td>Mean McCarthy IQ posttest</td>
<td>80.77(16.97)</td>
<td>79.31(17.26)</td>
<td>79.90(17.18)</td>
</tr>
<tr>
<td>No special education</td>
<td>31</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Received special education</td>
<td>62</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(20 missing)</td>
</tr>
</tbody>
</table>

**Instruments**

The measure of reading achievement, as conceptualized by the SVR as decoding and comprehension, used in this study is the Peabody Individual Achievement Test (PIAT). The PIAT was first published in 1970, and then revised in 1989. According to the authors, the PIAT is intended “to provide a wide-range, screening measure of achievement in the areas of mathematics, reading, spelling, and general information” (Dunn & Markwardt, 1970, p.1). It is an individually administered, screening test that is relatively short in duration and appropriate for children 4 to 21. The average test-retest reliability is reported as .89 for reading recognition, and .64 for reading comprehension (Sattler, 1998). Concurrent validity with the PPVT and the Wide Range Achievement Test (WRAT) are .55 for reading recognition and .66 for reading comprehension. Correlations between the PIAT and the WRAT (grade 3) are .95 for reading recognition, and .90 for reading comprehension. The PIAT is ideal for longitudinal research, because it provides a measure of achievement with a continuous scale of increasing difficulty. The
standard scores of the reading recognition and reading comprehension subtests were used for this analysis.

**Reading Recognition and Reading Comprehension.** The reading recognition (RR) subtest of the PIAT measures single-word identification and pronunciation (Dunn & Markwardt, 1970). Children are asked to match letters, read words silently, and read them aloud. A basal level is established by responding correctly five times in a row, a ceiling level is established by missing five out of seven responses. The reading comprehension (RC) subtest of the PIAT measures a child’s ability to obtain meaning from a written passage (Dunn & Markwardt, 1970). Children silently read a sentence, and then select one picture from a field of four that best represents the meaning of the sentence. The basal and ceiling levels are obtained in the same way as the RR subtest.

**The McCarthy Scales.** The McCarthy Scales (McCarthy, 1972) are an individually administered cognitive test that is appropriate for children ages 2.5 to 8.5 years old. McCarthy subtests include Verbal, Perceptual, Quantitative, Memory, Motor, and sub scores can be combined to form a General Cognitive Index (GCI). The authors report a split-half reliability of .93, and norms collected on 1,000 children. The McCarthy has exceptional internal consistency, and the test-retest reliability is well within the acceptable range for young children, with the average GCI at .90. The correlations of the subtests are also acceptable, with ranges from .69-.89 (Paget, 2009). The verbal scale of the McCarthy (MVB) is comprised of five subtests including: a) pictorial memory, memory for pictures b) word knowledge, to identify and define common vocabulary c) verbal memory, assess memory for words d) verbal fluency, to name as many words in a category as possible, and e) opposite analogies, to be able to supply the opposite of a
concept (such as hot). The McCarthy is considered a good predictor of learning potential for young children (Massoth & Levenson, 1982). The post-intervention McCarthy standard scores were used for this analysis.

**Procedures**

The PIAT (Dunn & Markwardt, 1970) was administered beginning at age five every year until age nineteen for as many participants as possible, with retention rates ranging from 85% to 64% (Dale, et al., 2004). The preschool assessment battery (including the PIAT and McCarthy Scales) was administered as a pretest during the fall of the school year, and as a posttest during the following spring/summer. The testing staff was aware of students’ classroom placements, but they were not aware of the hypotheses of any of the studies. The PIAT was designed to be appropriate for individuals at the lower end of achievement. The test items only require a pointing response so that expressive language ability is not a factor in item response. The subtests are relatively short in duration, with total test time being approximately and hour. Although a revised version of the PIAT became available and was utilized after 1989, the researchers continued to administer the original version of the PIAT in order to maintain consistency for longitudinal data analysis.

**Analysis**

**Framework: Dynamic analysis.** Contemporary theories of human development acknowledge that growth and change of any cognitive function is a dynamic, constructive process that occurs between an individual and his or her cultural context (Fischer & Bidell, 2006). Although this theory has been accepted as superior to older ideas of stage-like growth, often researchers and educators continue to utilize a serial framework of
reading development (Ferrer et al., 2007; Fischer & Bidell, 2006; Sadoski & Paivio, 2007). Assumptions of linear movement through stages does not account for individual differences, and can lead to assumptions of deficit or disability. Dynamic analysis allows for the modeling of non-linear growth and change over time. Dynamic analysis also acknowledges the influence of other factors on an individual’s development over time. Standard multivariate analysis may reveal general associations and overall change in a variable of interest, but does not allow for the variance in individual initial levels and growth in a particular variable to be examined (Ferrer & McCordle, 2010).

**Latent growth curve model.** A latent growth curve (LGC) analysis was conducted with the archived PIAT scores from the LCP database. Latent growth models represent the pattern of growth over time of a selected construct (reading achievement) and are considered a special type of structure equation modeling (SEM). Similar to an ANOVA or multiple regression models, there is an intercept, which represents the initial level of the outcome measure (PIAT) and a slope, which represents the rate of change in the outcome measure (Preacher, Wichman, MacCallum & Briggs, 2008). More specifically, the intercept and slopes are latent factors which indicates the pattern of growth, i.e. linear, or quadratic (Hox, 2010). Unlike ANOVA or regression models, a non-linear growth pattern can be modeled and tested for adequacy of fit (in other words how well the model reproduces the data). As the data are longitudinal, it violates the independence of observation requirement of ANOVA, and so a different analysis is desirable. Using the dynamic analysis framework, the model is fit to allow for quadratic growth, and then the parameter estimates are obtained to ascertain if the quadratic model is a good fit to the data (Byrne & Crombie, 2003).
LCG offers advantages over more traditional methods of assessing growth and change because it allows for the imputation of missing data points; it can adequately represent non-normal data, and allows for non-linear growth patterns to emerge (Curran, Obeidat, & Losardo, 2010). Each participant’s standardized PIAT score for the RR and RC was utilized for the analysis, using the Maximum Likelihood estimation procedure in AMOS v 17.0 (Arbuckle, 2008). Subtests were modeled separately according to the SVR, which indicates that decoding and comprehension are two different (but related) processes. Data were screened for multivariate normality assumptions. Both subtests of the PIAT are slightly skewed towards the lower end of the normal curve, as would be expected for an at-risk population. Average skewness and kurtosis was .18 and -.65 for reading recognition and .16 and -.70 for reading comprehension respectively.

**Missing data.** Missing data can be adequately modeled with the use of multiple imputation or maximum likelihood methods, assuming the data is missing completely at random (MCAR) or missing at random (MAR). MCAR can be assumed if the missing data is not related to the variable under examination. MAR has a slightly less strict definition that states the probability of the data missing may be related to the variable under investigation but the value of that variable does not affect the probability of missingness (Allison, 2003). Some of the participants of the LCP are missing data, but since there are data points before and after the incidents of missingness, it can be assumed that the data are at least MAR. Table 3 summarizes the sample size for the two level growth design.
Table 3.

**Summary of Sample Sizes for Latent Growth Curve Design**

<table>
<thead>
<tr>
<th>Time points observed</th>
<th>Number of individuals</th>
<th>% of individuals</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>91</td>
<td>44</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>154</td>
<td>78</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>167</td>
<td>81</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>179</td>
<td>87</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>134</td>
<td>65</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>181</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>180</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>178</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>10</td>
<td>175</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>11</td>
<td>167</td>
<td>81</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>161</td>
<td>78</td>
<td>17</td>
</tr>
<tr>
<td>13</td>
<td>150</td>
<td>73</td>
<td>18</td>
</tr>
<tr>
<td>14</td>
<td>129</td>
<td>63</td>
<td>19</td>
</tr>
</tbody>
</table>

Since time point one had so few data points, it was dropped from the analysis. The LGC was limited to time points 2, 4, 6, 8, 10, 12, and 14. Every other year is modeled due to consideration of sample size and the numbers of parameters that would need to be estimated if all time points were employed.

Deleting missing data was not a good option in this case, as the small number of participants would not produce robust parameter estimates. According to Graham (2009), missing data can be safely estimated in longitudinal models using multiple imputation. The data imputation procedure was carried out in AMOS v 17.0 (Arbuckle, 2008), and estimated data sets were examined to ensure error variances were still in the acceptable range (Graham, 2009).

**Model fit.** Assessing model fit in a LGC is complex and must be based on a priori theory (Curran, 2010). The method of assessing model fit then is to determine how well the sample data fits into the proposed model. Several factors must be assessed to determine if the proposed model is a good fitting model or not. The fit indices, the
parameter estimates, and residual variances are all examined. First, the basic model estimates are obtained. Then each successively more complex model is compared to the base model and likelihood ratio test can be performed on the deviance statistic (or chi-square, $X^2$) (Curran, 2010). Likewise, the Akaike Information Criterion (AIC) is used to compare nested models, with the lowest value of AIC indicating the best fitting model (Byrne, 2010). In addition, the Comparative Fit Index (CFI) and the Root Mean Error of Approximation (RMSEA) are used as stand alone indices. The $X^2$, and RMSEA are absolute fit indices, which appraise how well the model being tested is reproduced with the sample data (Hu & Bentler, 1999). The CFI is an incremental fit index, which assesses the model compared to a restrictive baseline or null model (Brown, 2006). As recommended by Hu and Bentler (1999), the following cutoff values were used to determine a good fit: CFI $\geq$.95, RMSEA < .06, and a non-significant $X^2$. However, the $X^2$ statistic will be interpreted with caution as it tends to over-reject models that are good fitting according to other fit indices, especially in small sample sizes or in the face of non-normality (Brown, 2006). The confidence interval around the RMSEA will also be reported to address the accuracy of the estimates (Byrne, 2010).

**Predictors.** Variables will be added to the model to ascertain the relationship between early characteristics and growth in reading achievement over time. The McCarthy GCI was consistently one of the best early predictors of later outcomes in the LCP survey (Dale, et al., 2004). The McCarthy verbal was also a reliable predictor, and may be more related to reading outcomes given the relationship between verbal abilities and reading (Dickinson, Golinkoff, & Hirsh-Pasek, 2010) and will be used in this analysis. A disability variable was created which reflected the special education service
status of the children post-preschool intervention. Children who only received special education preschool intervention were coded with a zero, and children who had received continuing special education services at some time in their school career after the preschool intervention were coded with a one. Socio-economic status (SES) has historically been very related to reading outcomes (Morgan, Farkas, & Hibel, 2008). Research suggests that income level and parental education have a strong positive relationship to reading achievement. This appears to stem from lack of quality literacy experiences and lack of access to literacy resources (Aikens & Barbarin, 2008; Dickinson & McCabe, 2001; McCoach, O’Connell, Reis, & Levitt, 2006). SES is represented in this study as qualification for free and reduced lunch. Students who did not receive free and reduced lunch were coded with a zero, and students who received free and/or reduced lunch were coded with a one. Lastly, gender can be a significant factor in reading achievement as boys are much more likely to be identified with a disability than girls (Morgan et al., 2008; NCES, 2007). Boys were identified with a number one, and girls with a number two. The program variable of DI versus ML was not utilized for this analysis because the effects of the program had faded by middle school (Dale et al., 2004).

Results

Descriptive Statistics

Table 4 reports the observed means and standard deviations for the PIAT at each time point. On average, these scores indicate that performance on both the RR and RC tests declined over time. There are also large, consistent standard deviations that indicate there is a great deal of variability in the scores.
Table 4.  
Means and Standard Deviations for PIAT by Age

<table>
<thead>
<tr>
<th>Age</th>
<th>7</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIAT RR Mean (SD)</td>
<td>92.42(13.68)</td>
<td>90.29(15.67)</td>
<td>88.74(15.28)</td>
<td>88.58(15.11)</td>
<td>87.55(15.12)</td>
</tr>
<tr>
<td>17</td>
<td>85.62(15.58)</td>
<td>85.82(15.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIAT RC Mean (SD)</td>
<td>88.99(15.15)</td>
<td>87.68(14.53)</td>
<td>86.80(15.58)</td>
<td>86.82(14.49)</td>
<td>87.55(15.12)</td>
</tr>
<tr>
<td>17</td>
<td>85.82(15.43)</td>
<td>85.82(15.43)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. RR=reading recognition, RC=reading comprehension, SD=standard deviation.

Average Growth in RR and RC Over Time

Figure 2. Mean growth in reading achievement over time. A zero represents children who did not receive special education services post intervention and a one indicates having received special education services at some point in the school career.
A visual comparison of the graph reveals that each group experienced a decline in performance relative to age norms, but the group who had never received special education services post intervention had higher starting and ending scores. In order to compare this picture to individual differences in growth, 25% of participants were randomly selected and their growth in RR and RC was plotted. Figure two displays these individual growth curves. Individual growth in RR and RC vary widely from person to person. Both RR and RC appear to have linear and quadratic trends, with perhaps more of a quadratic trend in RC. Theoretically, this pattern fits with the idea that RR or decoding is a skill with a ceiling, while RC can continue to grow throughout the lifetime (Paris, 2005).
Individual Growth Curves

![Graph of individual growth curves over time.](image)

*Figure 3.* Individual growth curves in RC and RR over time. Each line represents the growth of one individual randomly selected from the study for an approximate total of 80 individuals.

Latent Growth Curve Analyses
Next, the standardized scores of ages seven through 19 were modeled in a parallel latent growth curve model. Figure one displays the schematic of the base model, where intercepts of RR and RC represent the initial level of performance on the PIAT, and the slopes of RR and RC represent the growth factor in the PIAT over time. RR and RC are modeled as separate but related processes in the construct of reading achievement. The errors in this model represent individual variation in performance in RR and RC rather than measurement error. These error terms were allowed to co-vary over time, from year to year and from RR to RC. These covariance arrows are not represented in schematic for ease of interpretation.

Structure Equation Model of Latent Growth Curves of Reading
Figure 4. Structure equation model of latent growth curves of reading comprehension (RC) and reading recognition (RR). Estimated with maximum likelihood parameter estimates. The residual variances (E1-E14) indicate the amount of individual variance in the observed scores of the PIAT. Squares indicate observed scores of the PIAT RC and RR subtests at each age. Circles indicate latent intercept of RR and RC, and latent growth slope, and double-headed arrows indicate these latent factors are allowed to co-vary.

The base or unconditional model was fit to allow for linear growth, and then a quadratic term was fit to the model in order to compare the shape of developmental trajectories over time. Table five presents the estimated means of the latent intercept and slopes, along with the model fit indices of the base model with linear growth compared to the quadratic model. The quadratic model appears to be the better fitting model. The final schematic of the model is pictured in appendix B.

Table 5.

Mean Intercept, Slope, Deviance Statistic and AIC

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Intercept</th>
<th>Mean Slope</th>
<th>-2Lnl</th>
<th>df</th>
<th>p</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR</td>
<td>Linear model</td>
<td>91.75</td>
<td>-1.15</td>
<td>86839.72</td>
<td>72</td>
<td>.000</td>
</tr>
<tr>
<td>RC</td>
<td>87.97</td>
<td>-.322</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>Quadratic model</td>
<td>91.98</td>
<td>-1.18</td>
<td>70628.73</td>
<td>66</td>
<td>.000</td>
</tr>
<tr>
<td>RC</td>
<td>88.29</td>
<td>-.372</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quad term</td>
<td></td>
<td>-.289</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. -2LnL= deviance statistic, df=degrees of freedom, AIC = Akaike Information Criterion (smaller values are preferred), RR=reading recognition, RC=reading comprehension.

A further comparison of the fit indices for the linear and quadratic model is presented in table 6.
<table>
<thead>
<tr>
<th>Model</th>
<th>$X^2$</th>
<th>p</th>
<th>CFI</th>
<th>RMSEA</th>
<th>90% CI RMSEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>86839.72</td>
<td>.000</td>
<td>.98</td>
<td>.076</td>
<td>.076-.077</td>
</tr>
<tr>
<td>Quadratic</td>
<td>70628.73</td>
<td>.000</td>
<td>.98</td>
<td>.072</td>
<td>.071-.072</td>
</tr>
</tbody>
</table>

*Note. $X^2$=chi squared, CFI= comparative fit index, RMSEA= root mean error of approximation, CI=confidence interval.*

n=206

Although the significant $X^2$ indicates a less-than-perfect model fit, the other fit indices indicate that the quadratic model is better fitting than the linear model, and has an acceptable over all fit. A negative relationship between intercept and slope means that those students whose intercept was higher initially made less gain in reading achievement than those who were lower. This is a common psychological phenomenon called “law of initial values”, which states that higher values in starting levels will show less growth than lower initial values (Jamieson, 1995). The negative value of the quadratic term indicates that there is a downward concavity or an overall propensity for individuals’ change to increase over time (in this case, become increasingly lower) (Hancock & Lawrence, 2006).

Next, examining the variances and correlations among the factors in the model can give more information about individual differences and the relationships between the variables over time (see appendix A for tables seven and eight of these values). Large variance estimates indicate that there is a great deal of variation between individuals’ intercepts and slopes that is not accounted for by the model. The largest of these occurs at age seven, indicating there is greater variability in younger children’s performance in
reading. The correlations between the factors indicate that RR and RC are highly related, as would be predicted by the SVR. For example the correlation between age seven RR intercept and RC intercept is .76. The correlation between age seven RC and age 19 RC is .50, indicating that initial level in RC can account for approximately twenty-five percent of the variance in high school final RC.

Subsequently, the predictor variables are added to the model, and a regression weight is obtained (see table 9). The effect of the predictor variables on the model (regression weights) may be interpreted as: a one-point change in the predictor variable will change the intercept or slope of RR and RC by the given amount. For example, when disability goes up by one (0=no post-intervention special education services, 1=post-intervention special education services), there is a dramatic negative effect on the latent means of intercept for both RR (-13.0) and RC (-11.7). Predictor variable and regression weights are listed in table nine, and all are highly significant. The gender variable indicates that when gender goes from male to female (males=1, females=2), there is a decrease in both intercept and slope. The preschool McCarthy verbal score influences the intercept. When the McCarthy verbal increases by one point, the initial RC score goes up by almost half a point (.49 rounded) and RR also goes up by almost half a point (.46). The McCarthy verbal also has a small, but statistically significant positive effect on the slopes of RC and RR (.02 and .01).
Table 9.
Regression Weights of Predictor Variables

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>S.E.</th>
<th>C.R.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCinter &lt;--- mcvbpos</td>
<td>.485</td>
<td>.002</td>
<td>215.953</td>
<td>***</td>
</tr>
<tr>
<td>RCslope &lt;--- mcvbpos</td>
<td>.022</td>
<td>.000</td>
<td>46.392</td>
<td>***</td>
</tr>
<tr>
<td>quad &lt;--- mcvbpos</td>
<td>.039</td>
<td>.000</td>
<td>88.325</td>
<td>***</td>
</tr>
<tr>
<td>RRinter &lt;--- mcvbpos</td>
<td>.460</td>
<td>.002</td>
<td>192.754</td>
<td>***</td>
</tr>
<tr>
<td>RRslope &lt;--- mcvbpos</td>
<td>.009</td>
<td>.000</td>
<td>22.974</td>
<td>***</td>
</tr>
<tr>
<td>RCinter &lt;--- disability</td>
<td>-11.097</td>
<td>.051</td>
<td>-216.427</td>
<td>***</td>
</tr>
<tr>
<td>RCslope &lt;--- disability</td>
<td>.146</td>
<td>.011</td>
<td>13.459</td>
<td>***</td>
</tr>
<tr>
<td>quad &lt;--- disability</td>
<td>-10.170</td>
<td>.010</td>
<td>-5.047</td>
<td>***</td>
</tr>
<tr>
<td>RRinter &lt;--- disability</td>
<td>-12.973</td>
<td>.054</td>
<td>-239.151</td>
<td>***</td>
</tr>
<tr>
<td>RRslope &lt;--- disability</td>
<td>-.225</td>
<td>.009</td>
<td>-24.274</td>
<td>***</td>
</tr>
<tr>
<td>RRinter &lt;--- gender</td>
<td>-2.459</td>
<td>.053</td>
<td>-46.338</td>
<td>***</td>
</tr>
<tr>
<td>RRslope &lt;--- gender</td>
<td>-1.254</td>
<td>.079</td>
<td>-15.883</td>
<td>***</td>
</tr>
<tr>
<td>quad &lt;--- gender</td>
<td>-5.047</td>
<td>.010</td>
<td>-5.047</td>
<td>***</td>
</tr>
<tr>
<td>RCslope &lt;--- gender</td>
<td>-1.507</td>
<td>.090</td>
<td>-52.824</td>
<td>***</td>
</tr>
<tr>
<td>RCinter &lt;--- gender</td>
<td>-3.265</td>
<td>.050</td>
<td>-65.260</td>
<td>***</td>
</tr>
<tr>
<td>RRinter &lt;--- SES</td>
<td>1.254</td>
<td>.079</td>
<td>15.883</td>
<td>***</td>
</tr>
<tr>
<td>RRinter &lt;--- SES</td>
<td>-909</td>
<td>.080</td>
<td>-11.356</td>
<td>***</td>
</tr>
<tr>
<td>quad &lt;--- SES</td>
<td>-2.88</td>
<td>.079</td>
<td>-3.670</td>
<td>***</td>
</tr>
<tr>
<td>RCslope &lt;--- SES</td>
<td>1.507</td>
<td>.090</td>
<td>16.789</td>
<td>***</td>
</tr>
<tr>
<td>RCinter &lt;--- SES</td>
<td>-557</td>
<td>.066</td>
<td>-8.405</td>
<td>***</td>
</tr>
</tbody>
</table>

Note. S.E.=standard error, C.R. = critical ratio, ***= p values below zero
RCinter=reading comprehension intercept, RCslope=reading comprehension slope, mcvbpos=McCarty Verbal post-test, RRinter=reading recognition intercept, RRslope=reading recognition slope, quad=quadratic term, SES=socio-economic status.

While adding predictors to the model is illustrative in terms of highlighting relationships between early predictor variables and growth in reading over time, the model fit indices are not improved with their addition to the model. The \(X^2\) or deviance statistic rises to 118776.276, the AIC increases to 118930.276, while the RMSEA and CFI remain closer to their original values at .07 and .97 respectively. The variances remain high, indicating that these predictors are not explaining the large variations in the development of reading over time. Another way to look at the relationship between these predictor variables and the trajectory of the PIAT is to examine the standardized regression weights, which may
be interpreted as the amount of variance each variable is accounting for in the model. For example, the SES variable appears to contributing a great deal to the growth in both RR and RC over time at .63 and .73, whereas gender does not (-.12, -.15).

Table 10. 
Standardized regression weights

<table>
<thead>
<tr>
<th>Estimate</th>
<th>RCinter &lt;--- mcvbpos</th>
<th>.448</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCslope &lt;--- mcvbpos</td>
<td>.136</td>
<td></td>
</tr>
<tr>
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Note. S.E.=standard error, C.R. = critical ratio, ***= p values below zero  
RCinter=reading comprehension intercept, RCslope=reading comprehension slope, mcvbpos=McCarty Verbal post-test, RRinter=reading recognition intercept, RRslope=reading recognition slope, quad=quadratic term, FR Lunch=free & reduced lunch status.

Discussion

The results of this longitudinal study provide insight into the reading trajectories of children who received early childhood special education intervention in pre-school. By using the framework of the SVR, reading achievement can be understood as the growth in decoding and reading comprehension over time. These results must be interpreted in
light of understanding what statistical models can and cannot do. By their very nature, models are reductionist tools, which assume a philosophy of empiricism. Models can aid in understanding complex processes, such as reading, but cannot capture all of the essential components necessary (Schatzschneider, & Petscher, 2010). A quote from Box and Draper (1987) that is often repeated is worth reiterating here “Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful” (p. 74). For example, a better fitting model could be obtained by dropping the age seven PIAT score from the model, because it is responsible for a large part of the variability in the model. However, since the purpose of this study was to investigate the trajectory of reading from the earliest possible time point, theoretically it does not make sense to modify the model in this manner. Model building and conclusions must be driven by theory in the field of literacy and special education.

The results of this model show that although there is great variability in children’s individual growth in reading post-preschool intervention, the general trend was a curvilinear downward slope. For children who required special education services post-pre-school intervention, the negative trend was even more pronounced given that their initial level was significantly below their peers. Children who had higher initial level of performance experienced slower growth over time than children who had a lower level of performance. Although that trend may seem counterintuitive, other research has found a similar pattern (Petrill et al., 2010). Disparity in the rate of growth between the children who required additional special education services and the children who did not was not nearly as pronounced. In other words, the largest difference between children who continued to require special education intervention and the children who did not was
really in the intercept, indicating the starting point of reading skills. The children who required on-going special education services began lower than more typically developing peers and never caught up or closed the gap. Additionally, although there is a small but statistically significant difference in growth between these two groups, the gap does not appear to widen to a great extent. This is consistent with the deficit model posited by Francis et al, (1996) who found “disabled readers fail to develop adequate reading skills, implying a problem that persists into adulthood” (p. 14).

For this sample, some early individual characteristics were related to the initial level of reading and growth over time. Not surprisingly, a higher McCarthy verbal score led to a higher initial PIAT score. When the McCarthy verbal score went up one point, the PIAT score went up .46-.48 points. Given that reading is built on language skills (Dickinson et al., 2010), this finding is not unexpected. Some researchers argue that general I.Q. is not highly related to reading skills (for example see Fuchs & Young, 2006 and Vellutino, Scanlon, Small, & Fanuele, 2006) but that measures of verbal cognitive skills are related to reading and can identify children who are at-risk for reading delays or disabilities (Al Otaiba & Fuchs, 2006; Vellutino, Scanlon, Zhang, & Schatschneider, 2008). Language skills are rarely a target of screening or intervention for children with reading difficulty however, perhaps because language is viewed the purview of Speech-Language Pathologists and not teachers (Moats, 2009).

As stated previously, the gender effect in this study may be a characteristic of this sample. Given that the sample population is comprised of children who had been referred for special education, the decrease is understandable. Girls are not referred for early intervention at the rate boys are, and therefore girls who are referred early tend to be
more developmentally delayed or affected than the boys (Dale et al., 2004; Judge, 2011). The effect of SES, represented here by a free and reduced lunch variable is a thorny issue. The negative effects of SES on reading achievement are well known and documented in the literature (Aikens & Barbarin, 2008; Dickinson & McCabe, 2001; McCoach, et al., 2006). For this sample, SES had a mixed effect on reading achievement. Recall that students who did not qualify for free and reduced lunch were coded with a zero, and students who did qualify were coded with a one. When examining the regression weights, a one-point increase in free and reduced lunch (those who were lower SES) resulted in a negative effect on the intercepts, but a positive effect in growth. When looking at standardized regression weights, we see that SES has a negative relationship with intercept but a strong positive relationship with slope. It may be that because those children with lower SES started lower, they had more growth over time due to their delay being related to environmental factors and not necessarily a reading deficit. Research indicates that students who are at-risk academically because of poverty can make gains on par with middle-class peers when they have access to quality early intervention (Mashburn et al., 2008).

**Implications for practice**

One of the persistent questions in the field of education is “does early childhood intervention have long lasting effects on students?” Various personal, social, and environment factors affect an individual’s likelihood of success or failure in school. It is well known that early intervention can be effective in reducing the risk for later reading difficulty (Snow et al., 1998; Whitehurst & Lonigan, 2001; VanDerHeyden, Snyder, Broussard & Ramsdell, 2007). The children in this study all received high quality
special education preschool intervention. They also were referred for special education preschool for a variety of developmental issues. Some children obviously have long-lasting disabilities that negatively affect their academic achievement. There is some question as to how much high quality early literacy instruction is generally happening in preschools that serve children with disabilities (VanDerHeyden et al., 2007; Lonigan, Farver, Phillips, & Clancy-Menchetti, 2011). Consequently, there has been an increase in focus on a Response to Intervention (RTI) model for early childhood (Gettinger & Stoiber, 2007; VanDerHeyden et al., 2007). RTI is a multi-tiered intervention framework that provides increasingly intensive instruction based on a child’s individual needs. Progress monitoring and data based decision-making are also hallmarks of an RTI model. These factors are extremely relevant to early childhood special education classrooms, and early childhood special education professionals may need to implement a more RTI-focused evidence-based literacy model alongside their existing intervention programs.

Current work in RTI at the preschool level has had more of a focus on identifying behavioral interventions (Gettinger & Stoiber, 2007). The emphasis on addressing behavior in preschool can lead to over-identifying boys and under-identifying girls for targeted intervention, because boys tend to display more externalizing behavior, while girls’ behavior is generally more internalizing. Boys are referred at three times the rate of girls, but the actual incidence rate is approximately equal (Judge, 2011). Given that the girls in this sample experienced a decrease in reading achievement compared to the boys, professionals who work with the pre-school population may need to be more sensitive to developmental delays in girls, and aware of the bias in identifying boys for early
intervention. Adding language screening to the battery of early identification measures for all children may increase the accuracy of identification of at-risk children.

Previous analysis of the LCP study found special education was negatively related to achievement, even when controlling for other variables of gender, race, SES and preschool cognitive measures (Jenkins et al., 2006). This could be a reflection of the more intensive needs of students who stayed in special education over their careers, or perhaps a result of lower expectations of achievement due to special education status. A recent study by Morgan, Frisco, Farkas and Hibel (2010) employed a propensity score matching analysis of the effects of special education and found that “special education services had negative or statistically nonsignificant effects on young children’s reading and mathematics skills” (p.249). Therefore it is possible that receiving special education services hinders or at least does not help a student’s reading development. As Al Otaiba and Hosp (2004) acknowledged, children with disabilities begin school with less experience with print, have fewer opportunities to participate in literacy activities and could be less likely to benefit from otherwise effective reading instruction. Lee (2007) noted educators and policy makers should be aware of not just the achievement gap, but also an opportunity-to-learn gap for at-risk students.

**Intervention Targets**

Language. As it appears that developmental trajectories are largely stable early on in a child’s schooling career, educators and researchers need to find and leverage malleable factors in development of at-risk children. One possibility is an increase of language interventions in early childhood classrooms. Little research exists on the effect of reading interventions which target language skills (including vocabulary), even at the
preschool level (Bowyer-Crane et al., 2008; McCardle et al., 2001). High quality preschool programs that incorporate a language rich environment are recommended for children who are at risk for reading failure (Hindman & Wasik, 2008), but many of these programs available to low-income families such as Head Start do not provide quality language programs (Wasik, Bond, & Hindman, 2006). The Harvard Home-School Study of Language and Literacy Development concluded that many teachers in low-income preschool programs had few conversations with children and spent less than eight minutes a day reading aloud (Dickinson, & McCabe, 2001). According to researchers of the twenty-year Twins Early Development Study (TEDS), language skills have a large genetic component, but are more susceptible to environmental influence and could positively influence reading ability (Harlaar, Hayiou-Thomas, Dale & Plomin, 2008; Hayiou-Thomas, Harlaar, Dale, & Plomin, 2010).

**Neurocognitive and developmental.** As Diamond (2007) states:

Developmental science has been influenced more and more by an appreciation of the profound and multilayered interrelations between the ‘intellect’ (our cognitive abilities), ‘heart’ (emotions and motivation), ‘eyes and ears’ (perception), human spirit, physical body, social relations and culture (p.152).

Neurocognitive skills such as executive functioning, working memory and social-emotional skills may be important targets for early intervention. Executive functioning provides the ability to shift attention, inhibit impulses, and plan goal-directed behavior. In a sense, executive functioning provides the focus and working memory carries out the cognitive problem solving (Blair & Razza, 2007). The results of working memory deficits in the classroom are problematic to separate from other learning difficulties, but
researchers suggest that children would be unable to manage simultaneous processing and storage demands (such as copying from the board) complex multi-step directions, and synthesizing information from varying sources. Thus far, there is no good evidence of interventions that can improve working memory, so educators are encouraged to find ways to reduce the working memory load of instruction (Alloway & Gathercole, 2006). On the other hand, there is some indication that executive functioning, especially self-regulation, can be positively affected by classroom interventions with young children (Barnett et al., 2008).

In the original LCP study, researchers found that children who were lower-functioning did better in the ML curriculum (Dale et al., 2004). ML is characterized by an enriching environment and facilitated instruction. One can only speculate about the types of environments and instruction that the children who required special education throughout their schooling encountered. Diamond and Hopson (2008) acknowledge that research on learning and the brain indicates that enriching environments contribute to the stimulation of a child’s development. When studying long-term effects of a quality preschool program, researchers Magnuson, Ruhm, and Waldfogel (2007) found that the strength of intervention effect partially depended on the quality of classroom experienced in the first few years of schooling. Perhaps a ML type approach with an enriching, prepared environment should be revisited for those students who are placed in special education after pre-school.

Children who are exposed to early stress or abuse will be more prone to anxiety or negative behavior in the classroom. Such children have difficulty engaging their executive functioning to monitor attention and manage impulses (Goswami, 2006).
Emotion can be understood to be the primary player in motivation, and heavily influences perception, attention, memory, and decision-making (Immordino-Yang & Damasio, 2007). Although children’s academic skills are emphasized in schools, in reality social skills, self-esteem, and “emotional intelligence” are perhaps a bigger factor in long-term success than traditional intelligence (Diamond, 2007).

**Combination approaches.** Literacy interventions including instruction of vocabulary were the focus of a recent meta-analysis by Marulis and Neuman (2010). Overall they found that more powerful effect sizes for interventions implemented by researchers rather than teachers, and little effect of interventions provided by child-care centers. They also found using a mixture of explicit and implicit instruction yielded larger effect sizes than either method used solitarily. Finally, with respect to group size and length of intervention, there was no advantage for small group or intensive instruction. Even moderately intensive instruction in groups of six or more resulted in growth in vocabulary. Besides combinations of implicit and explicit instruction, one preliminary study on the combination of providing professional development to the teacher, and direct interventions to children found this might be more effective than either approach alone (Lonigan et al., 2011).

**Structure of schools.** At an earlier point in American schooling, local school districts were allowed to set their schedules based on the needs of their particular community and children. That practice declined when the federal government decided to standardize the amount of time students spent in school (Cooper, 2003). Loss of skills over summer is an area of concern for students who are at-risk, including students with disabilities (Alexander, Entwisle, & Olson, 2007; Cooper, 2003; McCoach et al., 2006).
If policy-makers, educators and parents are serious about addressing the literacy acquisition gap in the U.S., then summer programs may need to be considered for students who require intensive intervention.

Research indicates that when teachers and schools focus on developmental approaches to learning, which take children’s individual learning needs into account, student achievement can be greatly increased (NCATE, 2010). School systems that tie children’s learning to grade level instead of developmental level may be increasing focus on deficit models of learning. A deficit model sees outcomes as what children cannot do instead of focusing on what children need to learn (Griffin, Murray, Care, Thomas & Perri, 2010). Grounding teacher education and structuring school systems to focus on social, emotional and cognitive domains, with appropriate developmental practice is critical in moving forward with education in the future (NCATE, 2010).

**Implications for Research**

Research on evidence-based practice in reading has been successful at uncovering the necessary elements of reading instruction (NRP, 2000). It has not addressed clearly for which students these practices are effective and under what circumstances. The majority of research in reading difficulty is in the area of learning disabilities, and there is a clear lack of longitudinal research for children with other disabilities such as behavior disorders and cognitive delays.

Secondly, and related to the first, is a need for a more global perspective on the interrelated and interdependent (Diamond, 2007) nature of a child’s responsiveness to intervention. We are understanding more about how an individual’s brain and environment interact to build knowledge, but studies are needed where personal
characteristics such as language development, cognitive ability, social skills and executive functioning are investigated within the home and school environment in a interdisciplinary and collaborative fashion (Dehaene, 2009; Fisher et al, 2007; McCardle et al., 2001) This will allow for an increased understanding of how to create interventions and programs that are responsive to individual needs.

Lastly, one of the drawbacks of implementing a RTI model in preschool is the lack of clear benchmarks and guidelines about appropriate pre-literacy levels. Additionally, curriculums that specifically address early literacy have not been researched as thoroughly as curriculum in elementary settings (Lonigan et al., 2011). More research is needed in both of these areas in order to generate specific guidelines for implementing a RTI model in early childhood special education classrooms, as well as other early childhood classrooms that serve high-risk children.

**Limitations**

As stated previously, the latent growth curve model was an imperfect fit to the existing data. Interpretation of this model must be undertaken with caution. Structural equation models (SEM) are relatively new to education and have not been widely used in special education or literacy research (Schatchneider & Petscher, 2010). The special education population by its very nature has small numbers and does not always meet the statistical requirements of multivariate normality. However, SEM models can be very valuable in understanding what constructs may be highly related to reading, and can be effective in handling multivariate, correlated variables such as are common in the literacy field (Schatchneider & Petscher, 2010).
The population of this study was a group of children who had been referred for special education services, which limits the generalizability of these findings. This was also a prospective study, and the variables investigated were limited to the pre-existing variables in the data set. The free and reduced lunch variable was the only measure of SES in the LCP database, which some researchers feel is not the most reliable and valid measure of SES (Harwell & LeBeau, 2010) and therefore the effect of SES on the growth in reading for this study should be interpreted with caution.

The last limitation that must be acknowledged is the limitation of measurement with a singular instrument such as the PIAT. Previous factor analysis on the PIAT suggests that the PIAT has two factors, a general information factor and a verbal factor (Beecher, 2011). Consequently, the constructs of reading recognition and reading comprehension do not stand well on their own. The decision to model them separately is based on theoretical considerations of the SVR, where reading can be explained by decoding and language comprehension. This is not the only view of reading. Reading development can be discussed from two perspectives. A psychological perspective views reading as a cognitive exercise. The sociological perspective views literacy as a largely cultural enterprise encompassing the shared ways of interacting with print. The socio-cultural aspects of reading can also be a factor in determining if a child is going to be able to develop adequate literacy skills (Snow et al, 1998). However, the psychological perspective is the only one addressed in this study.

Conclusion

In conclusion, this study adds to the body of knowledge about how children who receive early childhood special education may develop in the area of reading over time.
Contrary to a commonly held notion of a “double-discrepancy”, or a lower initial level and slower growth, in this sample the children who required on-going special education and those who did not had significant differences in starting level, but not in growth over time. Although it is difficult to predict development from preschool variables, verbal I.Q. and SES seemed to be significant influences on the trajectories of these children. The children’s trajectories were remarkably stable over time. Lastly, we are reminded once again how much variability exists when working children of all ability levels – hence the continuing need for IDEA legislation to provide for individualized education for students with special needs.
References:


Barnett, S.W., Jung, K., Yarosz, D., Thomas, J., Hornbeck, A., Stechuk, R., & Burns, S.


Child Psychology and Psychiatry, 49(4), 422-432.


of Reading, 3(4), 331-361.


research associates.


Parrila, R., Aunola, K., Leskinen, E., Nurmi, J., & Kirby, J.R. (2005). Development of
individual differences in reading: Results from longitudinal studies in English and Finnish. *Journal of Educational Psychology, 97*(3), 299-319.


a vehicle for distinguishing between children with and without reading
disabilities: Evidence for the role of kindergarten and first-grade interventions.


kindergarten and first grade intervention to identify children at-risk for long-term


from prereaders to readers. In S. B. Neuman & D. K. Dickinson (Eds.), *Handbook
of early literacy research* (pp. 11–42). New York: Guilford.

Appendix A
Tables of Correlations and Variances

Table 7.
Implied Correlations Among the Factors of Quadratic Model

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<td>.32</td>
<td>.81</td>
<td>.69</td>
<td>.72</td>
<td>.73</td>
<td>.74</td>
<td>.70</td>
<td>.68</td>
<td>.62</td>
<td>.77</td>
<td>.79</td>
<td>.82</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>pi11RC</td>
<td>.65</td>
<td>.18</td>
<td>.70</td>
<td>.21</td>
<td>.82</td>
<td>.67</td>
<td>.69</td>
<td>.71</td>
<td>.71</td>
<td>.74</td>
<td>.67</td>
<td>.62</td>
<td>.71</td>
<td>.74</td>
<td>.75</td>
<td>.72</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>pia9RC</td>
<td>.64</td>
<td>.13</td>
<td>.72</td>
<td>.11</td>
<td>.84</td>
<td>.65</td>
<td>.68</td>
<td>.70</td>
<td>.70</td>
<td>.77</td>
<td>.64</td>
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<td>.72</td>
<td>.73</td>
<td>.72</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>pia7RC</td>
<td>.49</td>
<td>.03</td>
<td>.62</td>
<td>-.03</td>
<td>.73</td>
<td>.52</td>
<td>.55</td>
<td>.58</td>
<td>.58</td>
<td>.59</td>
<td>.58</td>
<td>.66</td>
<td>.50</td>
<td>.54</td>
<td>.57</td>
<td>.59</td>
<td>.60</td>
<td>.65</td>
</tr>
</tbody>
</table>

Note. Correlations are displayed on the diagonal. Slpe=slope, intr=intercept, RR=reading recognition, RC=reading comprehension.
Table of Parameter Variance

Table 8.
Variances in the parameters of the quadratic model.

<table>
<thead>
<tr>
<th>Variances</th>
<th>Estimate</th>
<th>S.E</th>
<th>C.R.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCinter</td>
<td>138.473</td>
<td>.574</td>
<td>241.436</td>
<td>***</td>
</tr>
<tr>
<td>RCslope</td>
<td>2.744</td>
<td>.020</td>
<td>137.309</td>
<td>***</td>
</tr>
<tr>
<td>RRinter</td>
<td>177.637</td>
<td>.620</td>
<td>286.604</td>
<td>***</td>
</tr>
<tr>
<td>RRslope</td>
<td>2.437</td>
<td>.013</td>
<td>183.115</td>
<td>***</td>
</tr>
<tr>
<td>quad</td>
<td>.439</td>
<td>.022</td>
<td>19.565</td>
<td>***</td>
</tr>
<tr>
<td>E1</td>
<td>113.009</td>
<td>.479</td>
<td>235.943</td>
<td>***</td>
</tr>
<tr>
<td>E2</td>
<td>57.378</td>
<td>.262</td>
<td>219.414</td>
<td>***</td>
</tr>
<tr>
<td>E3</td>
<td>58.539</td>
<td>.231</td>
<td>253.667</td>
<td>***</td>
</tr>
<tr>
<td>E4</td>
<td>48.805</td>
<td>.191</td>
<td>255.792</td>
<td>***</td>
</tr>
<tr>
<td>E5</td>
<td>45.171</td>
<td>.191</td>
<td>236.972</td>
<td>***</td>
</tr>
<tr>
<td>E6</td>
<td>39.282</td>
<td>.239</td>
<td>164.509</td>
<td>***</td>
</tr>
<tr>
<td>E7</td>
<td>41.298</td>
<td>.336</td>
<td>122.755</td>
<td>***</td>
</tr>
<tr>
<td>E8</td>
<td>36.048</td>
<td>.280</td>
<td>128.941</td>
<td>***</td>
</tr>
<tr>
<td>E9</td>
<td>37.205</td>
<td>.183</td>
<td>203.580</td>
<td>***</td>
</tr>
<tr>
<td>E10</td>
<td>30.060</td>
<td>.125</td>
<td>240.077</td>
<td>***</td>
</tr>
<tr>
<td>E11</td>
<td>24.264</td>
<td>.104</td>
<td>234.438</td>
<td>***</td>
</tr>
<tr>
<td>E12</td>
<td>19.368</td>
<td>.102</td>
<td>190.612</td>
<td>***</td>
</tr>
<tr>
<td>E13</td>
<td>26.267</td>
<td>.158</td>
<td>166.360</td>
<td>***</td>
</tr>
<tr>
<td>E14</td>
<td>23.809</td>
<td>.246</td>
<td>96.969</td>
<td>***</td>
</tr>
</tbody>
</table>

Note. S.E.= standard error, C.R. = critical ratio, *** = p values below zero
Figure 4. Structure equation model of latent growth curves of reading comprehension (RC) and reading recognition (RR). Estimated with maximum likelihood parameter estimates. The residual variances (E1-E14) indicate the amount of individual variance in the observed scores of the PIAT. Squares indicate observed scores of the PIAT RC and RR subtests at each age. Circles indicate latent intercept of RR and RC, and latent growth slope, and double-headed arrows indicate these latent factors are allowed to co-vary. Rectangles indicate predictor variables, mcvbpos=McCarthy verbal post-test, FRLunch=free & reduced lunch.
Appendix C

Literature Review

A Review of the Development of Reading

Constance C. Beecher

Washington State University
Introduction

Reading and Writing, the Optional Accessories

Psychologist Steven Pinker (1997) pointed out:

children are wired for sound, but print is an optional accessory that must be painstakingly bolted on. This basic fact about human nature should be the starting point for any discussion on how to teach our children to read and write (p.ix).

Through investigating the developmental process of reading, researchers and educators can implement instruction, interventions and support, which enable all children to develop into strong readers. If one wishes to understand how and/or why a child has difficulty learning to read, then one must begin with understanding typical reading development. The neurologist Stanislas Dehaene (2009) describes the process of reading development as “neuronal recycling” (p.196). This hypothesis states that reading begins in the area of the brain whose function is to recognize objects. Dehaene identifies the left occipito-temporal area as the “letterbox” of the brain (p.196). This area will become the word recognition vehicle of the brain’s reading system. But the beginnings of reading happen long before children learn to recognize letters. The foundation of reading is our oral language, which develops from infancy by listening to adult’s language. Infants can distinguish between different syllables almost immediately after birth, and are exquisitely sensitive to the sounds of their native language (Kuhl, 2007). Children’s language develops into a deep knowledge of grammar, semantics, morphology, and phonology. Although a young child cannot verbalize this information he or she has it all the same.
These are the systems upon which reading is built, but the exact way in which this happens is largely unknown (Dehaene, 2009).

It is important to define what it means to be literate because the way in which literacy is defined will affect how it is measured, who achieves it, and who requires intervention. The meaning of literacy has evolved and changed over time, based on the requirements of society. In the United States, we are increasing our connection to global communities and changing the foundation of our economy from industry to technology. This changes the expectations for being literate beyond traditional print-based literacy (New London Group, 2000). The New London Group’s (2000) definition of literacy includes multimedia and the proliferation of visual imagery that is related to print. They argue that being able to “read” means to make meaning of the world. Not all scholars agree on the definition of literacy. The Committee on the Prevention of Reading Difficulties in Young Children (Snow, Burns, & Griffin, 1998) state that they conceptualized reading instruction as leading to children who can: “use reading to obtain meaning from print; have frequent and intensive opportunities to read; are exposed to frequent, regular spelling-sound relationships; learn about the nature of the alphabetic writing system, and understand the structure of spoken words” (p.3). This view indicates a definition of literacy that leads to very specific practices around print.

**Theories Of Reading Development**

Reading development can be discussed from two perspectives. A psychological perspective views reading as a cognitive exercise which incorporates five components; phonemic awareness, phonics, fluency, vocabulary and comprehension (National Reading Panel [NRP], 2000). In this view, the reader is the knower, largely apart from
the world and representing reality through cognitive representations (McVee, Dunsmore, & Gavelek, 2005), The sociological perspective views literacy as a largely cultural enterprise encompassing the shared ways of interacting with print. The reader and the world are constructing reality together, and there is no real separation of the self from context (McVee et al., 2005). The National Early Literacy Panel (NELP; 2008), describes early literacy as consisting of conventional literacy skills and precursor or foundational literacy skills. Conventional literacy skills include decoding, oral reading fluency, reading comprehension, writing, and spelling. Foundational or precursor skills included domains that may not be actual literacy practices themselves, but are the basis upon which literacy skills are built. Policy in the U.S. (such as The No Child Left Behind Act, 2002) has created an increased requirement for schools to demonstrate achievement in traditional, print-based literacy as measured by standardized testing (Coiro, Knobel, Lankshear, & Leu, 2008), which fits more under the psychological view of reading. However, the socio-cultural aspects of reading can also be a factor in determining if a child is going to be able to develop adequate literacy skills (Snow et al, 1998).

**Stages/Phases of Reading Development**

The typical progression of reading development is often described as follows:

5) Prereading – knowledge about books, understanding of symbolic representation, produces purposeful scribbles, recognizes environmental print

6) Decoding – using a phonological decoding process, words are identified, vocabulary is expanded, use of knowledge of grammar to achieve comprehension
7) Fluency – speed and accuracy are improved through repeated practice, metacognitive strategies used to monitor comprehension.

8) Reading for Learning – phonological processes are automatic, comprehension is the focus, vocabulary is built (Chall, 1983, 1996; Snow et al., 1998). However, this model may or may not be appropriate for all children. For example, Fischer, Rose and Rose (2007) suggest that certain children may go through an alternate sequence of reading development, which puts them at risk for being labeled as “learning disabled” because the instruction they receive is not aligned with how they process textual information. These developmental differences may go undetected because of statistical analyses that focus on groups of children rather than on individual differences (Paris, 2005). This model also represents a “stage” theory of development, which appears to be a linear process. Contemporary theories of development suggest that development is more dynamic, with skills growing in a web-like or cyclical fashion as the individual moves through different contexts and interacts with others (such as teachers, parents, or peers) (Fischer, Rose & Rose, 2007; Thelen & Smith, 1994; Van Geert, 2009).

More recently, “stages” have been replaced by “phases”, which can be overlapping instead of having rigid thresholds that must be mastered before the next stage can begin (Snowling & Hume, 2005). Ehri (1999, Ehri & Roberts, 2006) offers a phases theory of learning to read words; each phase is characterized by the “pre-dominant type of connection that is activated to secure sight words in memory” (p.116). These phases are as follows:
5) Pre-alphabetic phase – recognizes environmental print, heavily reliant on visual or context cues without much letter knowledge.

6) Partial alphabetic phase – some knowledge of letters and sounds, which is used to form incomplete connections in memory.

7) Full alphabetic phase – decoding emerges, and connections between letters and sounds are used to read unfamiliar words.

8) Consolidated alphabetic phase – whole words, spellings patterns, rime and syllables are stored as useable connections.

It should be noted that this particular theory only refers to beginning readers who are at the word level of text. There is some question as to whether or not this theory is helpful when considering why some children have difficulty learning to read, but it seems clear that children may encounter difficulties in any or all of the phases (Ehri & Snowling, 2004).

The field of reading research is characterized by polarizing discussions such as the importance of skills versus context, the developmental progression of reading, and the importance of cognition versus culture (Paris, 2005, Sadoski & Paivio, 2007). Therefore, there is not really one overarching theory of reading development; rather there are multiple theories, which address different aspects of the reading process. Next, we consider the two major components of beginning reading, decoding and comprehension. First, an overview of typical development in these areas will be discussed, and then atypical development will be addressed.

**The Simple View of Reading**
The Simple View of Reading (SVR; Gough & Tunmer, 1986; Hoover & Gough, 1990) is a framework for understanding the components of successful reading. As the title suggests, the authors tried to keep the model as simple as possible in order to facilitate an understanding that could translate easily into classroom practice. In this theory, reading is seen as the product of decoding and comprehension. The authors do not assert that these are the only factors involved in reading, but that they are the primary means for understanding how a child processes text. Decoding is defined as word recognition, with an understanding that this is accomplished primarily through phonemic awareness. Comprehension is referring to listening comprehension of oral language, not comprehension of written material. The product term means that if either decoding or comprehension is lacking, the result will be an impaired reader. This model predicts three types of reading difficulty, dyslexia, hyperlexia, and garden-variety poor readers. The authors define dyslexia as an inexplicable deficiency in reading alongside normal development in other areas. Hyperlexia refers to the ability to read fluently without understanding what has been read, and garden variety poor readers have difficulty with both decoding and comprehension of language.

There have been a number of empirical studies since this theory was put forth, and it has been shown to be a useful way to understand the underlying components of reading, especially with students who struggle with reading. Kendeou, Savage and van den Broek (2009) state that generally, research shows that the SVR can account for 40% to 80% of the variability in readers. Many questions have been raised about the SRV including; are decoding and comprehension separate processes? what other processes could be added to this model to increase its utility?; what does the model imply for
teaching and intervention? How does phonological processing turn into decoding? The following graph from Roberts and Scott (2006) illustrates the process of decoding from the theory of the SVR. As is

Figure 1. Simple View of Reading.

![Diagram showing the process of decoding](image)

Figure 1. Simple view of reading. Adapted from “The Simple View of Reading: Assessment and Intervention” by J.A. Roberts & K.A. Scott, 2006, *Topics in Language Disorders*, 26(2), 127-143.

evidenced by figure one, the SRV does not really give specific details on how knowledge of phonology gets translated into decoding. Obviously, each of the areas of decoding and comprehension has complex underlying processes, which are discussed next.

**Phonology and Decoding**

Oral language skills such as phonological development are directly related to a child’s later literacy skills. Phonological awareness is one of the most reliable predictors of reading ability (Snow et al., 1998). Lonigan (2006) states that phonological development has been conceived as three interrelated processes; phonological awareness, phonological access to lexical store, and phonological memory. He explains that phonological awareness is the ability to perceive and control the sounds of a language. This awareness develops into phonics skills that enable a child to associate the sounds of language with its alphabetic letter. Phonological access to the lexical store is the ability to
quickly retrieve phonemes from memory in order to decode new words. The speed at which children are able to do this is has been related to reading growth. Lastly phonological memory is the ability to permanently store phonemes in memory so as to gain automatic processing of words. This is sometimes conceived as a part of working memory, but there is disagreement on which system actually holds phonologic information (Savage, Lavers, & Pillay, 2007). Deficits in working memory will be linked to poor recall of phonemes and inefficient reading (Gorman, 2009).

The beginning reader (of English) must be able to take their phonological knowledge and apply it to English orthography. That is, the child must learn that a letter can represent the smallest sound in the English language, a phoneme. Furthermore, combinations of phonemes and their corresponding letters make up words. Many scholars agree that phonological awareness and early print knowledge are the strongest predictors of reading success or failure (Anthony, Williams, McDonald, & Francis, 2007; Davis, Lindo, & Compton, 2007; Mann, & Foy, 2003). This basic idea has been supported by many empirical studies (McCardle, Scarborough, & Catts, 2001; NRP, 2000; NELP, 2008; Snow et al., 1998). The process of mapping sounds onto print has been referred to as phonological recoding (Ziegler & Goswami, 2005). Even in non-alphabetic languages such as Chinese, phonological awareness is correlated with recognition of the orthographic system, although not always with the same strength (Troia, 2004).

As with many other skills that people learn, phonological recoding appears to follow a developmental process, which begins with awareness of rhymes and ends with awareness of individual phonemes (Berninger, Abbott, Nagy & Carlisle, 2010). Ziegler and Goswami (2005) suggest a framework for this developmental process, which they
call “psycholinguistic grain size theory”. This framework posits that the sequence of phonological development roughly begins from larger grain sizes of words and syllables and then these units are broken down further into onset-rime, nucleus-coda, and finally phoneme and phone (smallest grain size). Table 1 illustrates this concept.

**Table 1.**
Hierarchical Sequence of Phonological Awareness

<table>
<thead>
<tr>
<th>Syllable</th>
<th>Pon</th>
<th>der</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset-Rim</td>
<td>P</td>
<td>On</td>
</tr>
<tr>
<td>Phonemes</td>
<td>P</td>
<td>O</td>
</tr>
</tbody>
</table>

As a child begins to learn to read, this developmental progression is influenced by the orthography of their language. English is considered a deep or inconsistent orthography, with many irregular spelling. For example, “ball” and “shall” do not rhyme and not all of the letters are pronounced in the word “yacht”. Goswami (2007) states that this characteristic of the English language makes it likely that beginning readers will have to “develop phonological recoding strategies at more than one grain size in order to become competent readers” (p.154). This idea fits in very nicely with the dual-route theory of reading.

**The Dual Route Theory**

The SVR does not offer us a specific theory about how a reader turns phonology into decoding, but the dual-route theory offers a model for how this may happen for reading text aloud. The two routes this theory refers to are the lexical and non-lexical routes. The lexical route involves “looking up” the word in one’s pre-existing mental lexicon, where information about spelling and pronunciations are kept. The non-lexical
route can be utilized when the word does not exist in the mental lexicon, and rule-based knowledge of how to break segment the word into phonemes may be used instead (Coltheart, 2005).

Figure 2. Expanded Dual-processing Model

As figure two illustrates, three types of knowledge characterize the lexical route: orthographic (knowledge of letters), phonological (knowledge of sounds), and semantic (knowledge of meaning). According to Ehri’s phase theory (1999, 2005), the reader may use any or all of these lexical routes, depending on the context of the word being read, and the phase the reader is experiencing (Coltheart, 2005). The dual-route theory also helps explain difficulty in reading. If poor readers have an innate phonological process difficulty as some researchers suggest, (Dehaene, 2009, Shaywitz & Shaywitz, 2004,
2008; Noble & McCandliss, 2005) then some of the “routes” of this model may be broken or very slow to access the required information. Likewise, if children have developmental delays in any or all of these routes, then reading will also be acquired more slowly (Coltheart, 2005). Children may only be able to utilize their knowledge of orthography and semantics to guess at words in text. The more practice a child gets at reading and phonologically recoding words, the stronger and faster these routes become (Ziegler & Goswami, 2005). These systems are distributed locally, which explains why when a child is asked to read a non-word like “dake”, a reader who already knows “cake” will easily be able to do so (Coltheart, 2006). A drawback of this model may be that it does not really explain how the reader may change over time, and therefore must be considered in concert with other developmental theories such as Ehri’s (1999; 2005) phase theory.

Connectionist models of reading are similar to the dual-route model, but according to Coltheart (2006), there are three important differences. 1) Connectionist models posit that words are distributed widely, and can be accessed through any number of connections. Dual-route theories suggest words can be activated as whole units, stored locally. 2) Connectionist models state that processing of phonemes happens in parallel, while the dual route theory supports serial processing. 3) Lastly the connectionist model is akin to a computer learning simulation – the more the model runs, the more accurate and specific the connections become. The dual-route theory does not say much about how the system learns, it only addresses how the processing happens.

As implied earlier, connectionist models borrow from computer modeling simulations to describe how a child learns to read. These models are attractive because
they are analogous to how the brain creates neuronal connections. Through experience of two stimuli being presented at the same time (e.g. phoneme and letter), these units become connected. The more these units are activated, the stronger and faster the connections become (Plaut, 2005). This model is also similar theoretically to the way infants learn the speech sounds of their language. Both imply a statistical probability function for learning new words or new sounds (Pennington, & Bishop, 2009). A criticism that can be leveled at this model is that research does not really support parallel processing. For example, when presented with the stimulus “ball” versus “grall” children will read “ball” much more quickly than “grall” (Ziegler & Goswami, 2005). If these words were processed in a parallel manner, the odd beginning phoneme should not slow a reader down.

Although there are differences between the connectionist and dual route models, they are not necessarily mutually exclusive. The connectionist framework actually fits nicely into the dual-route model. As Zeigler and Goswami (2005) suggest, the irregular orthography of English may force readers to develop multiple strategies of analysis. Highly regular words could be developed and processed in a serial, locally distributed manner. Irregular, low-incidence words would necessarily have fewer connections and be accessed less often, therefore resulting in more widely distributed storage, which may require a parallel processing strategy.

In summary, reading is a complex skill that develops through the coordination of several systems in the brain. There are many theories about exactly how this happens, but no real consensus in the literacy field. In general, the field agrees that reading is based on oral language skills, involving decoding and understanding the text. Children must be
able to map the sounds of their spoken language onto the written symbols that represent them. The stronger these mappings are, the more likely children are to become good readers. The method by which that happens is still under debate, but the process of acquiring phonemic representations is a developmental learning process that is theorized to happen much in the same way that language is learned.

**Reading Comprehension**

Thus far, only the aspect of decoding a word has been reviewed. Once the reader has successfully decoded a word, then he or she must next connect meaning to that word. Although decoding and comprehension are typically discussed as separate constructs, in reality, they work in concert. Children who have limited language skill and poor oral vocabulary not only know fewer words, they are also less likely to be able to decode unknown words, because a rich oral vocabulary increases a child’s knowledge about semantics, syntax, morphology and the interrelatedness of words (Juel, 2005). Under the SVR, reading comprehension is equated to language comprehension. That is, if the word is in the reader’s spoken vocabulary, once he or she can decode it, the meaning will be known. Empirical research has demonstrated a lower correlation between oral language skills and reading in young readers, which increases as the reader develops (NELP, 2008). This is due to the nature of the reading task, which is different for beginning and later readers. Beginning readers are primarily decoding simple words, while later readers must create meaning from text (Perfetti, Landi, & Oakhill, 2005). Paris (2005) describes decoding as a “constrained” skill, meaning that there is a ceiling to the development of decoding. Comprehension, on the other hand, is an “unconstrained” skill that continues to develop over the lifespan. Sadoski and Paivio (2007) define comprehension as involving
“the construction of a meaningful interpretation or mental model of the text and is typically seen as occurring at levels such as literal, inferential, and interpretive/critical.”(p.341).

Models of Comprehension

Outside/In and Inside/out. Whitehurst and Lonigan (2002) proposed a framework for the development of fluent reading. They suggest that the individual receives information from two networks: outside in and inside out. Outside-in systems “represent sources of information from outside the printed word that directly support children’s understanding of the meaning of print (e.g. vocabulary, conceptual knowledge, and story schemas)”(p.13). By contrast, the inside-out system includes the information sources available from the text (e.g. the dual-route of processing). According to Whitehurst and Lonigan (2002), a reader must use both of these sources of information to comprehend text. Unlike the DCT or connectionists models, this theory does not refer to the processing happening in the brain, but only the source the information the reader is accessing.

Schema Theory

The schema that Whitehurst and Lonigan (2002) refer to was a prominent theory of comprehension in reading research, which was built on Vygotsky’s (1978, 1986) ideas of “tools of the mind” and Piaget’s (1952) developmental assimilations. Schemas do signify a process, and are a way for an individual to represent concepts stored in memories (McVee, Dunsmore, & Gavelek, 2005). For example, when a child is reading a text about a dog, their personal schema of knowledge, experience and feelings about dogs are activated and utilized to comprehend the text. However, critics of this model question
the origins of the schema, and the disembodied nature of purely mind-oriented information storage and retrieval (Krasny, Sadoski, & Paivio, 2007). Despite the criticism from the research community, schema theory remains a useful way to understand reading comprehension, and is widely taught to pre-service teachers (McVee et al., 2005).

Dual Coding Theory

Dual-coding theory (DCT), not to be confused with the dual-route theory of processing, is a cognitive theory of mind that has been applied to literacy. The dual codes in DCT are verbal and non-verbal representations, which arise from sensory input. The verbal code utilizes the language of the text to process the lexical meaning and creates the non-verbal mental imagery from which the individual draws meaning, creates memories, and builds connections (Sadoski & Paivio, 2007). The pictures in the text add to the non-verbal imagery. These two systems are interrelated and work together to integrate meaning, although the exact mechanism as to how this happens is unclear (Verhoeven & Perfetti, 2008).

Lexical Quality Hypothesis

For younger readers, comprehension may best be understood through the lexical quality hypothesis (Perfetti, 2007). This is because young readers are only asked to read simple text, with fewer words and sentences per page. As Perfetti (2007) explains, “Lexical quality (LQ) refers to the extent to which the reader’s knowledge of a given word represents the word’s form and meaning constituents and knowledge of the word use that combines meaning with pragmatic features.” (p.359). A word can have high or low lexical quality depending on the combination of features including, the orthography, phonology, morpho-syntax and meaning (Perfetti). An example of a high quality word
would be “cat”. The orthography and phonology are regular and easily accessed, the meaning is very general and not bound to context, and the word is a regular noun, which does not change classes. An example of a low quality word would be “yacht”, because the word is very context dependent and has irregular phonology.

LQ hypothesis demonstrates the idea that assessing vocabulary is not as simple as a right or wrong answer. Young readers can recognize some of the features of a word, and have access to partial meanings. This could help explain the moderate relationship that vocabulary has with reading comprehension (Senechal, Ouellette, & Rodney, 2006), which ranges from 38% to 45% according to a recent meta-analysis from the NELP (2008). As the NELP panel summarized, vocabulary is necessary for early literacy but is not sufficient by itself. Research has also consistently demonstrated that the importance of vocabulary grows over time, especially as older readers encounter content-area reading (NRP, 2000; NELP, 2008; Senechal et al., 2006).

As with decoding, the field of literacy is not in agreement about how readers ultimately comprehend text. Children must be able to recognize words in print and then be able to access their meaning, but this exact process is not well understood. Children bring their background knowledge and vocabulary to this task, which becomes increasingly more important as the complexity of the text increases. Unlike decoding, which is a skill that may have an endpoint or ceiling, comprehension skills continue to develop over a lifetime. Like decoding, comprehension skills are built around early language experience and access to literacy activities.

**Developmental Reading Disabilities**
Children who have a primary difficulty learning to read have many labels: learning disabled, reading disabled, or dyslexic. Children with other types of disabilities such as cognitive, language-related, or behavioral also can have difficulty with reading. Schools use the category “specific learning disability” (SLD), and physicians or psychologists use the term “developmental dyslexia” to refer to children whose primary disability involves accessing print. 80% of children who are diagnosed SLD have reading difficulties, and the other 20% may experience difficulties in writing and math as well. Dyslexia refers to an unexpected difficulty in reading for children who have otherwise typically developing cognitive abilities, appropriate instruction, and for whom English is their native language (Shaywitz & Shaywitz, 2004). This difficulty arises from a deficit in the phonological processing of language, and may also include impeded growth in vocabulary and background knowledge as a result of poor access to quality reading experiences (Lyon, Shaywitz, & Shaywitz, 2003). It does not include children with sensory processing difficulties, cognitive delays, or other disabling conditions. Approximately 13% of students in the U.S. are served under the Individuals with Disabilities Education Act (IDEA, 2004), and 48% of those students are under the category of SLD. This represents the largest portion of the categories of disability served (National Center of Educational Statistics; NCES, 2010). According to the NCES Early Childhood Longitudinal Study-Kindergarten Class of 1998-1999 (ECLS-K), children diagnosed with SLD increased from 4.1% in kindergarten to 11.9% in fifth grade (Herring, McGrath & Buckley, 2007).

**Neurological Evidence of Dyslexia/SLD**
The disorder can be traced to differences in processing in the brain that precede reading in children and also occur across different nations, meaning that these differences are already present and not occurring as a result of poor reading practices (Shaywitz & Shaywitz, 2008). While there is still debate on precisely what structures or processing of the brain are affected with dyslexia, most researchers agree that the left hemisphere posterior phonological system (utilized for reading) is failing to activate leading to a reliance on a more inefficient over activation of the anterior system of the right hemisphere of the brain. The larger right frontal activation indicates an effortful attempt to utilize memory and executive systems to read words, instead of the more efficient phonemic processing system of the left hemisphere. Figure 1. illustrates the difference in activation pattern between the nonimpaired system and the dyslexic system (Dehaene, 2009; Shaywitz & Shaywitz, 2004, 2008; Noble & McCandliss, 2005). These differences can even be seen in infants. In a longitudinal study by Molfese (2001), auditory event-related potentials (ERP’s) were measured in infants with contrasting syllables such as “ba” and “ma”. When these children were eight years old, Molfese collected information about their reading abilities. He was able to demonstrate a 76% accuracy rate in predicting children with dyslexia from their neonatal ERP’s. The children who were later diagnosed with dyslexia displayed lower and slower responses to contrasting auditory input. This converges with fMRI data, which shows under activation of those brain systems responsible for processing phonetic information.
Social/behavioral evidence of dyslexia/SLD

While neurobiological evidence of reading difficulties is mounting, the greater body of evidence is from social and behavioral research (Sherman & Cowen, 2009). Many scholars agree that phonological awareness and early print knowledge are the strongest predictors of reading success or failure and poor phonological skills are considered the hallmark of dyslexia or SLD (Anthony et al., 2007; Davis et al., 2007; Mann, & Foy, 2003). In addition, poor vocabulary and verbal memory are consistently seen in low readers (Al Otaiba & Fuchs, 2006). Other researchers refer to the “double discrepancy” or “non-responders.” They see that the students who are most at risk for reading disabilities are the ones who score low on screening measures and also show slow growth rates over time (Speece, 2005). Another “double-deficit” hypothesis refers
to weakness in phonological processing in concert with poor ability to rapidly processing information, often referred to as rapid automatic naming or RAN (McCardle et al, 2001). Other researchers question that the method for assessing RAN really differentiates it from phonological weakness. RAN continues to be of interest, but its role in learning to read is not clear (Smith, Roberts & Locke, 2008). Evidence supports the assertion that dyslexia is a heterogeneous disorder, which includes different models or subtypes of reading difficulty. McCardle and colleagues (2001) summarize the different models/theories of reading difficulty as follows:

1) Phonological core deficit causes weak phonemic awareness and other language weaknesses, leading to reading difficulty.

2) Auditory processing deficits lead to phonological deficits and other auditory weaknesses which give rise to poor phonological awareness and language issues, resulting in reading difficulty.

3) A double deficit in phonological awareness and speed of processing causes weak phonological skills and slow naming abilities, causing reading difficulty.

4) A language impairment leads to weak phonological, syntax, and semantic skills, which all contribute to difficulty in decoding and comprehension.

**Interaction of neurobiology and environment**

Scientists recognize that cognitive ability is not fixed at birth, and the interaction of an individual with the environment can change the activity in the brain (Fisher, 2009). In a 2005 study by Noble and McCandliss, researchers found that if children had good phonological process skills, they could decode well no regardless of their socio-economic status (SES). However, among the students with poor phonological processing,
individuals from low SES backgrounds were struggling with the decoding task, while
individuals from higher SES were still able to complete the task. These differences can be
seen neurobiologically in studies which demonstrate that an impoverished environment is
associated with planar asymmetry in the right temporal lobe – leading to poor
performance on phonological measures (Eckert, Lombardino, & Leonard, 2001; Noble,
Wolmetz, Ochs, Farah, & McCandliss, 2006). Yet these studies must be viewed with
caution because there is no direction indicated in the hypothesis. It is just as likely that
these brain differences are a result of being a poor reader and that interactions are
reciprocal. These studies also have small sample sizes, which may limit generalizability,
and use proxy variables for SES that involve self-reporting measures (Noble et al., 2006).

Shaywitz and Shaywitz (2008), compared persistently poor readers (PPR) with accuracy
improved readers (AIR), and found that not only did PPR have increased connection
between the right prefrontal areas and the word form area (indicating increased reliance
on effortful memorization), PPR readers tended to have lower cognitive ability and attend
disadvantaged schools. The researches concluded that an interaction of a disadvantaged
environment in addition to an innate reading difficulty led to poorer performance on tasks
for PPR readers. On the other hand, they hypothesized that AIR readers also have the
innate reading difficulty, but a more supportive environment allowed them to improve
their reading at a greater rate. These studies are difficult to interpret because of the
complexity of the interaction of outside variables, such as parental education level, that
are not reported. In another intriguing study, vocabulary knowledge was measured with
twenty-month old children using ERP’s. Researchers measured ERP waves when
introducing known and novel words. When they saw a decrease in the wave activity, they
assumed it meant that the child was familiar with the word, because increased waves are associated with novel stimuli. The children were then divided into two groups, a high vocabulary group, and a low vocabulary group. Researchers found that the low vocabulary group needed at least five repetitions of a word to reach familiarity, while the high vocabulary group needed only three (Vonn Koss Torkildsen et al., 2009). The implications of this study are that these children’s future vocabulary skills will be influenced by the amount of exposure and repetition of new words in their environment, demonstrating the developmental interaction of cognitive skills with the environment.

**Many Pathways to Dysfluent Reading**

Although there is strong evidence for the neurobiological base of reading difficulty, it does not explain all iterations of reading problems. Reading is a sociocultural phenomenon that a child learns in a cultural system. Each child has a different background of experience, and it is the interaction of the child’s cognitive ability with their environment that supports (or not) their reading acquisition (Noble & McCandliss, 2005). Children who struggle with literacy can acquire many different labels. Snow et al. (1998) articulate that some children can come to school and experience low literacy achievement because of the cultural mismatch between their home and the school. Students from low income, disadvantaged, minority, or non-native English speaking household may experience practices around language and literacy use at home that differ so from school that these children can experience confusion and ultimately low achievement. The achievement differences between these children and other students often widen over time, particularly in the areas of text comprehension and writing (McNaughton, 2006). In the seminal study by Hart and Risley (1995), children from
impoverished families heard approximately 32 million fewer words than children from professional families. Other mediating variables such as motivation, parental education, access to resources, and quality of schools all can play a role in reading difficulties (Aikens, & Barbarin, 2008; Snow et al., 1998; Torgesen, 2002).

Some researchers now believe that certain children who are identified as learning disabled are really “instructionally disabled,” in other words, they have not received a quality reading program (Vellutino, Scanlon, Small & Fanuele, 2006; Torgesen, 2002). When studying children who were at risk for reading difficulty, Vellutino and colleagues (2006) found that the majority of students who had received small group instruction twice a week for thirty minutes went on to be successful in the general curriculum. The instruction consisted of activities that were focused on print awareness, letter recognition, letter-sound mapping, phonological awareness, sight-word learning, shared and guided reading, and print concepts. They theorized that the small group of students who were still having difficulty were truly learning disabled and needed more intense and frequent intervention.

**Other Types of Disability**

Another group of children who may experience considerable difficulty in learning to read are those with speech and/or language impairments, which is the next most frequently occurring disability after LD (NCES, 2010). Children with language disorders can experience a delay or disruption in oral language skills, which leads to poor decoding and/or comprehension (Roberts & Scott, 2006). Researchers studying reading deficits in children with language impairment (LI) concluded that children diagnosed with a language impairment (LI) showed a significantly lower initial level of reading ability, and
never closed the gap with their same age peers without a LI. However, there was no
significant difference in rate of growth between the two groups (Catts, Bridges, Little, &
Tomblin, 2008; Catts, Hogan & Fey, 2003; Francis et al., 1996).

Students with behavioral disabilities such as Attention Deficit Hyperactivity
Disorder (ADHD), or Emotional Behavior Disorder (EBD) often experience difficulty in
learning to read due to behavioral disturbances, which interrupts their learning. This often
coco-occurs with LD, which may or may not be formally diagnosed (Seeley et al., 2009).
There are no longitudinal studies of reading growth that compare students with and
without behavior disorders or ADHD. However, research does indicate that similar to
students with LD and LI, children with persistent ADHD symptoms have relatively stable
lower achievement in academic areas such as reading over time (Biederman et al., 2010).

There is little research on reading development of children with cognitive
impairments, and no longitudinal research to date (Browder, 2006). The research on
reading with this population has focused on the acquisition of word-level reading skills in
a functional manner (Browder & Xin, 1998). These studies indicate that students with
cognitive disabilities can be taught to read, using evidence-based methods such as
recommended by the National Reading Panel (Al Otaiba & Hosp, 2004). Evidence
suggests that a core deficit in phonological processing and phonological memory
contribute the majority of variance in reading performance of students with cognitive
impairments (Snowling & Hume, 2005).

Implications for Assessment

The intricacy of disorders involving reading makes it complicated for the
educational community to come to consensus on the methods of assessment. In the field
there are different views of how reading disability should be operationalized, and therefore, there are also debates about what model of assessment is selected to diagnosis individuals (Fletcher, Francis, Morris, & Lyon, 2005). Historically, SLD has been described for diagnostic purposes as an unexpected underachievement in one of the academic areas of reading, writing or mathematics (Fletcher et al., 2005). The underachievement is unexpected because the individual is assumed to have intellectual development in the normal range. The 2004 reauthorization of the Individuals with Disabilities Education Act (IDEA) defines SLD with inclusionary and exclusionary terms.

(A) In General.- The term “specific learning disability” means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations.

(B) Disorders Included.- Such term includes such conditions as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia.

(C) Disorders Not Included.-Such term does not include a learning problem that is primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or environmental, cultural, or economic disadvantage. (IDEA Amendments, 2004, p.118)
Following the logic of these definitions, many schools use a discrepancy formula to qualify individuals for the SLD category of special education services. This means that aptitude, as measured by intelligence testing, is compared to standardized achievement tests in the academic areas of concern. If there is a large enough gap between the scores (this is determined by each state), then the individual is qualified for SLD (Buttner & Hasselhorn, 2011). Researchers and educators question the discrepancy model for a number of reasons. This model is based on “snapshot” measurement that represents a child’s status at a single point in time (Fletcher et al., 2005), and young children are particularly variable in their performance (Speece, 2005). Theoretically, there are many concerns about the validity of traditional assessment procedures such as intelligence (I.Q.) tests. They are not good predictors of school achievement, they are culturally biased, and young children do not have enough experience to do well with I.Q. tests (Fuchs, Fuchs, Compton, Bouton, Caffrey, & Hill, 2007). Since the discrepancy formula necessitates academic difficulty, it does not offer much utility for early identification of learning difficulties, which is known to be essential for successful remediation (Fletcher et al., 2005).

Recently researchers and educators have questioned the validity of the discrepancy model and under IDEA (2004) can utilize an alternate model called “Response to Intervention”. Response to Intervention (RTI) is a problem solving approach to identifying students who are not making progress in the regular education curriculum. Instead of waiting until there is a measurable discrepancy that would qualify a student for specialized services, a teacher can intervene with effective, targeted instruction as soon as a child shows signs of difficulty (Fuchs & Young, 2006;
VanDerHeyden, Snyder, Broussard, & Ramsdell, 2008). In other words, in the RTI model, a child is assessed over time and his or her response to intervention that is effective for other students is the basis of the SLD diagnosis (Fletcher et al., 2005).

Children who have difficulty learning to read can be labeled with a variety of names, or have different types of disabilities. However, the majority appears to have a core phonological deficit, which interferes with their ability to make strong connections between the sounds of language and the written symbols. Because of this weak connection, they may also be slow to learn new words and develop a robust vocabulary. Some researchers feel that children with reading disabilities also have poor recall of sounds and symbols, or slow processing of sounds and symbols, or a combination of both. Longitudinal studies of reading with typical and non-typical readers can aid in the understanding of why some children do not develop reading skills easily.

**Longitudinal Studies of Reading Achievement**

It is important for researchers, educators, and parents to uncover the source of reading difficulties, and help students achieve in school. Identifying the underlying causes of reading difficulty can also contribute to early identification and remediation. According to the National Reading Panel (NRP, 2000), if children cannot be identified as at risk for reading difficulty by age nine, approximately 75% will experience reading problems and be further at-risk academically. Although progress has been made in understanding the key elements in reading disability, educators and researchers still lack the ability to accurately identify those in need of early intervention in a timely manner (Boscardin, Muthen, Francis, and Baker, 2008). The Individuals with Disabilities Education Act (IDEA, 2006) defines three areas of SLD within reading: basic reading
skills, reading fluency, and reading comprehension. Children may qualify for SLD services based on performance in one or all of the previous categories.

Longitudinal studies of individuals with and without reading problems can provide information about the cognitive, academic and social-emotional factors that increase or decrease a child’s risk for reading difficulty (Judge & Bell, 2011). However, comprehensive descriptions of the developmental trajectories of reading of children with different types of disability or difficulty are extremely rare (Dickinson & McCabe, 2001; McCardle et al, 2001; Parrila, Aunola, Leskinen, Nurmi & Kirby, 2005). The majority of longitudinal studies can be grouped into three types. Some studies have focused on the developmental trajectories of students who have been identified with SLD and those who are typically developing readers. Other studies concentrate on predictors of later reading risk or disability. Lastly, a third group of longitudinal research investigates long-term effects of intervention. Each of these groups of studies will be reviewed, and implications of the research discussed subsequently.

**Studies of Developmental Trajectories**

Judge and Bell (2011) used hierarchical linear modeling with data from the Early Childhood Longitudinal Study-Kindergarten (K through 5th grade) cohort, and found that students who were identified with SLD scored significantly lower on measures of reading achievement in kindergarten. Although these students grew in reading skills over time, they never caught up to typically developing peers by fifth grade. Also, there were no differences in initial reading scores for students who were identified early or later in elementary school, and unfortunately no significant differences in fifth grade reading
level either. Thus, the reading trajectories of both early and later identified children were largely stable by kindergarten.

Similarly, researchers in Canada and Finland (Parrila et al., 2005) examined the growth of reading skills in children in both countries from first to fifth grade, using latent growth curve modeling and latent class modeling. Reading skills were measured by sentence comprehension, oral reading fluency, and word attack from the Woodcock Reading Mastery Test-Revised (Woodcock, 1987). Researcher found three distinct subtypes of readers, which they labeled 1) persistently good, 2) average, and 3) persistently poor. As expected, the persistently poor readers showed deficits in reading from the very beginning of first grade on all measures. Although this group did not catch up with average readers, they also increased their skills over time, and did not fall farther behind. More specifically, the variance in scores in both decoding and comprehension increased slightly from first grade to second grade and then decreased from second grade to third grade. The researchers concluded that overall, initial performance level was negatively associated with growth over time. In other words, those children who began at the lowest achievement level also experienced the slowest growth in reading skills over time.

The Jyvaskyla Longitudinal Study of Dyslexia (Torppa et al., 2007) was conducted in Finland with a group of 100 children with familial risk of dyslexia, and a control group of 100 children with no family history of dyslexia. Torppa et al. (2007) studied the heterogeneity in the children’s developmental profiles with latent class mixture modeling. Researchers measured reading skills including: letter knowledge, word recognition (not decoding), rapid serial naming and reading comprehension. Assessments
of receptive and expressive language, memory, intelligence and phonological awareness were also administered. They also used factor analysis to determine the underlying factors that best represented the construct of reading achievement. A two-factor solution of word recognition and comprehension was found to be the best fit for the data. Lastly, the researchers identified developmental reading trajectories of five distinct groups of readers, identifying the children with familial risk of dyslexia as performing on average significantly lower than classmates. Torppa and colleagues labeled their groups 1) poor readers, 2) slow decoders, 3) poor comprehenders, 4) average readers, and 5) good readers. They found that “even though word recognition and reading comprehension were highly correlated (r=0.81 between across-age factors of fluent word recognition and reading comprehension), children with a discrepancy in reading skills can be identified in our data.” (p.22). This appears to support the SVR, in demonstrating that some children with good decoding skills can be poor comprehenders and likewise some children with poor decoding skills could still comprehend text.

The Connecticut longitudinal study investigated the stability of reading achievement over time (Francis, Shaywitz, Stuebing, Shaywitz, & Fletcher, 1996; Shaywitz et al., 1999; Shaywitz et al., 2003). This study drew a cohort of 445 children entering kindergarten in Connecticut in 1983, and this cohort was followed with yearly assessments of academics, behavior, and a bi-annual assessment of intelligence until completion of grade 12. Children who had been identified with SLD in 9th grade were selected for comparison to a nondisabled group of children. Researchers operationalized reading skills as decoding, rate, accuracy comprehension and spelling. They utilized the Basic Reading subtests of the Woodcock-Johnson Psycho-Educational battery to create
individual growth curves for the two groups of children. Researchers found three distinct groups of readers, persistently poor, average, and superior. These three groups showed similar growth over time, but the persistently poor group never caught up with the other two groups. Therefore, the “children who were initially poor readers in the early school years remain poor readers relative to other children in the sample” (Shaywitz et al., 1999, p.1357).

One of the major findings of longitudinal studies of reading trajectories is that children who are poor readers appear to be at the lower end of a continuum of reading abilities. In general, these children do not “catch-up” to their peers. The gap between poor and good readers is apparent early on, and appears to have a large genetic component. Although there are large differences in where poor and good readers start, their growth in reading over time is not hugely discrepant. The inability of poor readers to reach traditional benchmarks appears to because they start so much lower than other children. This stability in early levels of reading leads to the need for research in early predictors of reading difficulty.

**Longitudinal Studies of Predictors of Reading Difficulty**

Another type of longitudinal study in reading investigates early predictors of later reading ability in order to optimize the early identification and prevention of reading difficulties. In these studies, children in primary classes are tested on a range of skills that researchers propose are relevant predictors of reading achievement. These children are followed for a number of years, and then tested again for their literacy outcome. Then researchers perform regression analysis to find the strength of the relationship between those early measures and the later reading achievement outcome. Studies in this area can
be considered in two ways, one largely quantitative, defined by an individual’s skill in reading as measured by empirical assessments. Another is more qualitative, looking at the context, environment, and activities around literacy practices. The majority of studies involving prediction of reading skills are short-term, measuring proximal effects of early skills on reading. Reading is a developmental skill, which is different for early and later reading, so long-term studies can better address questions of prediction (Shanahan & Lonigan, 2010). Unfortunately, long-term prediction studies are rare.

**Phonological Awareness.** Research in the quantitative area suggests that phonological awareness (PA) is a key predictor. For example, in a study by Smith et al., (2008), children with a reading disability were distinguished from typical readers by their PA abilities in both preschool and kindergarten. Foster and Miller (2007) studied children’s growth in reading from kindergarten through third grade. They state that children must have the ability to use phonics by kindergarten in order to develop the decoding skills necessary to achieve literacy. The strength of PA may dissipate over time, and be replaced by general word-reading ability (Huslander, Olson, Willcutt & Wadsworth, 2010). A recent meta-analysis by the National Early Literacy Panel (2008) suggested that early phonological skills contribute significant and unique variance to later reading skills, even when controlling for other variables. Some researchers find that PA only predicts single word reading and not comprehension, which may be dependent on broader language skills (Roth, Speece & Cooper, 2002) but others argue that PA affects reading comprehension through the skill of decoding (Hayiou-Thomas, Harlaar, Dale, & Plomin, 2010; Kendeou, van den Broek, White, & Lynch, 2009). Parrila, Kirby and McQuarrie (2004) note “In sum, existing research suggests a developmental progression
from phonological processing skills to word reading, and further to passage comprehension” (p.4).

Research in PA suffers from complications that hinder practical application of the findings. The nature of this research is often conflicting due to the lack of consensus about how to measure PA and what constitutes PA. Some research only focuses on one or two aspects of PA, which limits the value of predictive relationships (Parrila et al., 2004). Goswami (2003) states that there are a wide variety of tasks that can be considered phonological awareness measures, all with different cognitive demands such as phoneme segmentation, initial sound deletion, rhyming, and reading nonsense words. Longitudinal studies of phonological awareness have the added difficulty of finding a task that young children can understand and perform. Some phonological awareness tasks like producing a blended word or non-word require more short-term memory capacity than other tasks such as identifying pictures that contain alike/different sounds. Since young children are still developing their short-term memory abilities, those tasks may not give a true picture of what children can do (Anthony et al., 2007). As a result, there are very few longitudinal studies of PA that begin before formalized reading instruction commences.

**Alphabetic/Orthographic knowledge.** Along with PA, children’s knowledge of letter names is one of the strongest predictors of reading ability (Adlof, Catts, & Lee, 2010; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Orthographic knowledge is the understanding of the regularities in the visual aspects of written language and the sounds represented by written language, which is also very strongly related to latter reading (Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009). Schatschneider et al., investigated the amount of variance kindergarten letter knowledge
explained in first and second grade. They found it contributed 25 percent of variance in first grade and slightly less in second grade. Letter knowledge is more predictive of early reading, but the relationship holds over time. For example, Adlof and colleagues (2010) found that letter identification correlated strongly with second grade reading comprehension (.61) but also demonstrated a moderate correlation with eighth grade reading comprehension (.36). Other researchers have found that letter knowledge actually shares some of its predictive value with PA, and could be measuring an aspect of PA rather than contributing unique variance to prediction models (Parrila et al., 2004).

Roman and associates (2009) found that orthographic knowledge was a reliable and stable predictor for word reading at grades four, six, and eight with a standardized regression coefficient of .41. When reviewing results on the predictive validity of orthographic knowledge, it is important to take into account the language of the children under study. Regular or shallow orthographies like Finnish or Italian have a much stronger relationship between sounds and letters than deep orthographies like English or French.

**Executive functioning.** Executive functioning and other neurocognitive abilities such as rapid automatic naming (RAN) and short-term memory have been researched as possible early predictors of later reading difficulty. Executive functioning refers to a related group of abilities that work to direct attention, inhibit impulses, shift task orientation, and plan actions. Working memory is also considered a part of executive functioning. These skills appear to be particularly important in the early and developing stages of academic achievement, so that children may benefit from critical instruction in this period (Bull, Espy & Wiebe, 2008). For example, Blair and Raza (2007) found that
preschool measures of inhibitory control were modestly related to kindergarten measures of phonemic awareness. Deficits in working memory appear to be related to poor recall of verbal information, leading to difficulties in word reading and comprehension (Perfetti et al., 2005). Berninger, Abbott, Nagy and Carlisle (2010) suggest “phonological working memory underlies the development of phonological awareness: Children need to store spoken words in working memory while they analyze and reflect on them” (p.154). As with the construct of phonological awareness, the measurement of executive functioning has been defined in different ways by different researchers, leading to a lack of clarity of the relationship between executive functioning and reading (Booth, Boyle, & Kelly, 2010). There is also some question as to how much these abilities might overlap with general cognitive abilities (Blair & Razza, 2007). However, research has shown an independent contribution of memory skills in explaining response to intervention with reading disabled students (Frijters et al., 2011). Verbal memory tasks such as sentence imitation also were found to be highly predictive of reading skills from kindergarten to middle school (Adlof et al., 2010).

**RAN.** Rapid automatic naming (RAN) is the ability to quickly label visual symbols such as letters, numbers, objects, or colors. Frijters and colleagues (2011) found that RAN, along with PA, predicted which children would respond to reading intervention. “Non-responders” were consistently lower on both measures. They suggest RAN may be of more utility when trying to separate poor readers from average or good readers. In a study on the longitudinal stability of reading related skills, researchers found RAN to be only modestly correlated with later reading outcomes (.29) (Huslander et al., 2010). However, other researchers found that adding RAN to kindergarten predictors of
PA, sentence imitation and maternal education improved prediction of second and eight grade reading comprehension (Adlof et al., 2010). The type of RAN measured may influence the findings. Schatschneider and associates (2004) found that a RAN measure of letters was more predictive of second grade reading than a RAN measure of objects. Since letter knowledge itself is predictive of reading outcomes, this raises the question about how much unique variance RAN is actually adding to the prediction model.

**Family and SES.** Genetic and environmental influences both contribute to reading abilities and disabilities (Petrill et al., 2010). Children with disabilities and typically developing children from lower socio-economic status (SES) environments experience a negative effect on oral language skills including vocabulary development and phonological processing when compared to children from higher SES backgrounds (Whitehurst & Lonigan, 2002). The vocabulary gap between low SES and high SES students begins early and generally does not close over time (Stanovich, 1986). In a longitudinal analysis by Roberts, Mohammed and Vaughn (2010), data from the Early Childhood Longitudinal Survey was analyzed to compare the reading development of groups of children from low to high SES. They surmised that SES played a major role in lack of quality early language experience, which led to poor literacy outcomes.

Hypothetically, SES can restrict or enhance one’s life experiences upon which oral language facility is built. Similarly, Aikens and Barbarin (2008) found that early family experiences with literacy, number of books in the home, and access to quality child care significantly predicted growth and achievement in reading during school.

Therefore, in order to identify children who need extra support at the earliest possible time point, research suggests certain skills can be measured that are relatively
reliable predictors of later literacy. Phonological awareness is central to developing reading. Alphabetic knowledge, orthographic knowledge and executive functioning are also key predictors. A child’s family background and experience with books before school has a powerfully strong relationship to later reading ability. These predictors can then become targets for intervention.

**Longitudinal Studies of Interventions**

Research suggests early identification and intervention is the most effective way to prevent reading difficulties (Snow et al., 1998; Torgesen, 2002; Menzies, Mahdavi & Lewis, 2008. The justification for early literacy intervention is that children who are at-risk for academic difficulty can receive exposure to the essential elements of learning to read in the same way in which typically developing children receive them (O’Connor, Fulmer, Harty, & Bell, 2005).

Although longitudinal studies of intervention would help policy makers, educators and parents to provide appropriate intervention, not many intervention studies extend beyond one year (NRP, 2000). In general, intervention studies concentrate on the time period between kindergarten and first grade, and few provide follow-up results post-intervention (O’Connor et al., 2005). Interventions vary in intensity, duration, setting, and mode of implementation, so it is difficult to compare studies for effectiveness. Most interventions focus on explicit teaching of print awareness, letter recognition, letter-sound mapping, phonological awareness, sight-word learning, shared and guided reading, and print concepts to children in small group settings, based on research that shows these are foundational skills for learning to read (McMaster et al., 2005; NRP, 2000; Vellutino et al, 2006). Torgesen (2002, 2005) suggested that in addition to these skills, children who
are at-risk for academic failure require more emotional support and scaffolding of instruction, with specific feedback and error correction. However, these latter elements were not explicitly tested as a part of any interventions reviewed here.

**Comparison of type of approach.** In a study comparing a phonological intervention with a meaning-based (Reading Recovery) intervention for children in the bottom 20 percent of readers at age six, Hurry and Slyva (2007) found no significant long-term effects of intervention at age ten. The students in the Reading Recovery intervention made large gains in the short-term, but had no long-term gains. On the other hand, the students in the phonological intervention did not experience short-term improvement, but did perform better on spelling measures at age ten. For the lowest students who were non-readers at age six, Reading Recovery was more effective than phonological training at every time point. However, these students never caught up to typically reading peers.

In another study by researchers in Norway (Helland, Tjus, Hovden, Ofte, & Heimann, 2011), a bottom-up intervention approach was compared to a top-down approach for children considered at-risk for reading disability for children aged five until eight. A bottom-up approach starts with the smallest unit of processing (phonemes) and builds up to word reading, and last, meaning of the text. A top-down approach starts with meaning-based reading of text, emphasizing context and background knowledge to access meaning. The interventions were delivered through teacher-led computer programs, and were implemented in the spring of their primary through second grade year. Results indicate that both interventions resulted in gains in literacy, but in different ways. The bottom-up approach improved in phonological awareness and short-term
memory tasks, while the top-down intervention group scored higher on final word reading and spelling. Helland and colleagues suggest a combination of both interventions is appropriate for young at-risk children.

A longitudinal study carried out with 857 pupils in France compared groups of children who received extra intervention in literacy skills. One group received the intervention for one semester in both the kindergarten and first grade year, another received only the kindergarten semester of intervention, and a control group received only regular instruction. The groups were further divided into three different intervention types. One was a strictly phonological intervention. The others were two different types of comprehension training, one involving explicit teaching of comprehension strategies, and one using a more implicit shared book reading strategy (Bianco et al., 2010).

Researchers wanted to know if focusing on systematic instruction of language skills would affect reading development. Students were followed from kindergarten to third grade, and attended schools that were assigned to the intervention conditions. Children who received the phonological intervention did better in measures of phonics and single word reading, and children who received the comprehension intervention did better on measures of reading comprehension. Researchers found the effect of the interventions faded over time, with only the group who had received the longer, explicit training in comprehension strategies keeping their gain in reading comprehension after the conclusion of the study. This study demonstrated that language interventions can be begun early, but must be long-lasting to impact children’s reading abilities. This study was limited because it did not have random assignment, or fidelity checks for the interventions.
**Comparison of curriculum.** Early literacy intervention curriculums were compared for groups of students at-risk for reading difficulty, in a study investigating the effects of a school-wide RTI model (Kamps et al., 2008). Each curriculum was research based, and followed the principles of explicit teaching of reading skills. These direct instruction curriculums were compared to small group instruction in guided reading with less structured lessons. Researchers found that 41 percent of students in the direct instruction interventions reached grade level benchmarks by second grade. Students in the guided reading comparison group also made gains in reading, but not to the extent of the direct instruction group. Kamps et al. concluded that the less structured phonics teaching and larger group size were factors in the differences between groups. A strength of this study was that interventions were provided by teachers, not researchers, increasing the applicability of the findings.

**Providing professional development.** Another approach to early intervention is to provide teachers with professional development in research-based teaching practices, with the premise that it will improve instruction for all students. O’Connor and collaborators (2005) provided primary teachers with extensive professional development and additionally offered direct intervention to students who did not meet grade-level benchmarks. They found the combination of these two approaches met the needs of the majority of the children at risk for reading difficulty. At the end of third grade, only nine students identified in kindergarten continued to need intervention.

In summary, longitudinal research on intervention strategies suggests early and sustained intervention has the longest-lasting effects. A combination of approaches that target the core phonological weakness, executive functioning, and also support
continuing language development may be the most useful to the widest number of children. However, the strongest approaches may be ones that adapt interventions to a child’s individual characteristics. Lastly, teachers must be trained to implement research-based teaching strategies, and schools should select curriculums that support these strategies.

Conclusion

Although longitudinal studies are complex and difficult to implement, longitudinal research aids in the understanding of development, prediction and intervention in the area of literacy. The majority of longitudinal research in reading has been with typical and learning disabled readers. Longitudinal research with children who may have other disabilities is non-existent. Foorman, Arndt, and Crawford (2011) state that thinking about and describing intraindividual differences in students who struggle with reading for a variety of reasons is critical for the timely identification and intervention of these students.

In addition, most studies on reading development examine relatively short-term outcomes, one to three years after initial testing. While these important studies have added to the evidence of reading etiology, Fischer and Bidell (2006) assert that when assessments are repeated at close developmental ages, scores tend to cluster around the mean and not give a true picture of the variability in the population. Reading ability is theorized to change at a non-linear rate and eventually become stable (Francis et al., 1996). Since reading skills are likely to be different for early and later reading, a long-term bigger picture of the course of reading development would add to the existing body
of knowledge about the necessary components of early intervention and reading instruction (Shanahan & Lonigan, 2010).
References:


prospective controlled follow-up study of grown up boys with persistent and remitting course. *Psychiatry Research, 30*(170), 177-182.


Dickinson, D.K., & McCabe, A. (2001). Bringing it all together: The multiple origins,


Herring, W.L., McGrath, D.J., & Buckley, J.A. (2007). *Demographic and school*
characteristics of students receiving special education in the elementary grades.


Judge, S., & Bell, S.M. (2011). Reading achievement trajectories for students with learning disabilities during the elementary school years. Reading and Writing Quarterly, 27, 153-178.


Noble, K.G., & McCandliss, B.D. (2005). Reading development and impairment:


Leadership, 61(6) 6-11.


vehicle for distinguishing between children with and without reading disabilities:


