Investigating the applicability of the neurodevelopmental framework to enhance learning for all students, especially those with mild to moderate disabilities

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INVESTIGATING THE APPLICABILITY OF THE NEURODEVELOPMENTAL FRAMEWORK TO ENHANCE LEARNING FOR ALL STUDENTS, ESPECIALLY THOSE WITH MILD TO MODERATE DISABILITIES

By
Lisa B. Kline

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Masters of Arts in Education

The College of Professional Studies School of Education
California State University, Monterey Bay
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INVESTIGATING THE APPLICABILITY OF THE NEURODEVELOPMENTAL FRAMEWORK TO ENHANCE LEARNING FOR ALL STUDENTS, ESPECIALLY THOSE WITH MILD TO MODERATE DISABILITIES

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Abstract

The overall focus of this study was to investigate the applicability of the neurodevelopmental framework to enhance learning for all students. The present study sought to provide educators with a sufficient foundation for how movement influences neurodevelopmental maturation for learning, with possible implications for reading, by creating a handbook to assist educators to become comfortable incorporating developmental movement patterns into lessons. One goal was to bring attention to primary reflex persistence interfering with typical movement development, leg length inequality (LLI) connected to primary reflex persistence, and the possible use of LLI assessment to be used as a screening tool for students at-risk for reading. The handbook was submitted for review to two groups with considerable knowledge of the research topic; a national group (n – 6) for content validity and an educator group (n – 6) for social-use validity. The three research questions centered on their responses to the five survey questions regarding content and social validity, and generalizations on developmental movement instruction. Survey data were compared examining interests in and among groups. There was substantial agreement with national experts from various fields such as adapted physical education, physical therapy, movement science, and medicine regarding the relevance, usefulness, and validity of handbook content. However, the national expert in reading strongly disagreed with the premise of the handbook. The educator group reported high agreement for acknowledging handbook relevance and strengths, but lower for usefulness. On a scale from 1-5, with 5 as the most, a mean score of 3 for the educator group indicated that the handbook would be helpful for teaching PE. The national experts suggested audiences that would benefit from the handbook, including APE specialists, general PE teachers, OTs and PTs, and early intervention/resource specialists. Both groups suggested revisions to clarify the introduction; to separate content for the neurology and practical applications components; and to describe a step-by-step intervention program. Insufficient feedback was received for LLI assessment, so this topic might be further investigated.
Chapter II

Literature Review

Due to the complexity of this topic, the overall literature review is comprised of several categories of smaller sub-reviews according to a variety of disciplines that were necessary to examine the research questions, and that were useful in connecting the concepts. The literature review examined in the fields of special education, neuroscience (including neurological cognitive research, psychology, biology, physiology, auditory and vision), kinesiology and motor development science (including adapted physical education, occupational therapy and physiotherapy, and physical therapy), osteopathy and surgery, orthopaedics and pediatric orthopaedics, neuro-developmental medicine (including rehabilitation), behavioral science, and upper cervical research. Frequently, evidence demonstrated a cross-over among disciplines, especially incorporating the departments of medicine and psychology, although it was necessary to search in these varied perspectives because of a lack of specific material from the educational field relating to physical neurology connected to strengthening children’s abilities to read.

Systematic searches for specific articles, book chapters, and books were conducted through computerized databases, including: Science Direct-Elsevier; Academic Press; Academic Search Elite (Ebsco); CINAHL; PsychARTICLES; PsychINFO; Hotwire Press; Google; JSTOR Retrospective Journals; Sage Journals; Science Direct-Elsevier; SpringerLink; and Wiley Interscience Journal Backfiles. The following key words were used: (a) dyslexia, (b) postural instability, (c) primary reflex persistence, (d) eye saccades, (e) atlas subluxation, (f) leg length inequality. These descriptors were either used alone or in combinations of words.
Sources were used if (a) the procedures and data-based results are marked as published between 1896 - 2012, and (b) the topics were relevant to connecting the concepts of dyslexia, atypical movement, head tilt, and leg length disparity; related to learning to read.

This review of the literature was organized into seven sections according to the following content areas: Special Education for LD; Multifactorial Hypothesis; Neurological Foundations for Human Movement (including Sensory Motor Development from Earlier- to Later-Maturing Systems); Visual Deficits and Reading; Posture, Ocular Motor Control, and Balance; Atypical Posture and Movement, Body Asymmetry, and LLI; and Upper Cervical, Correction.

Special Education for LD

Examining historical perspectives provides opportunities to notice trends. Almost fifty years ago, in 1963, a series of task forces were established to “study the status and needs of children with minimal brain dysfunction (MBD) and/or learning disabilities” (Haring & Bateman, 1969, p. 1). Clements, Cole, Gallagher, and Kunstadter (1969a), from the medical field in the area of neurological disease and blindness, introduced the focus:

No concern has higher priority in the national interest than does that of providing for every child the fullest opportunity for physical and intellectual development. Yet, for one group of children, those now being spoken of as suffering minimal brain dysfunction, or learning disabilities, the special resources required to permit the effective exploitation of latest abilities appear to be lacking in our society. (p. iii)

Haring and Bateman (1969) reported that agencies from both of the medical and educational fields were included in a collaborative effort. The co-sponsors included:

1) The National Institute on Neurological Disease and Blindness, U.S. Department of Health, Education and Welfare; 2) the Easter Seal Research Foundation, National Society
for Crippled Children and Adults; 3) the U.S. Office of Education, Department of Health, Education, and Welfare, and 4) the Neurological and Sensory Disease Control Program, Division of Chronic Diseases, U. S. Public Health Service. (p. i)

Haring and Bateman (1969) stated that the committee of Task Force I included mostly personnel from the medical field, and Task Force II focused their investigation on “areas of educational identification and assessment, educational practices, teacher training, and legislation” (p. 1). Haring and Bateman (1969) described some initial “important areas of agreement” between the two Task Forces:

Task Force II agreed with Task Force I that multidisciplinary communication, requiring precise, descriptive nomenclature, is essential for effective identification, assessment, and total management of these children. Secondly, it was agreed that both medical and educational assessment are essential for complete diagnosis. (p. 1)

Additionally, “Medical evaluation may also further our basic knowledge of the existence and nature of relationships between brain and behavior” (Haring & Bateman, 1969, p. 1).

Furthermore, the Haring and Bateman (1969) acknowledged some complexity regarding the scope of this multidisciplinary effort, with concerns regarding defining terms among professions:

Problems in terminology arise when two different disciplines attempt a common description of the child to accommodate different purposes for obtaining diagnostic information. Viewing the child from the medical vantage point provides the physician the kind of diagnostic information relevant to ameliorating or preventing causative factors from disease or injury. For the educator who must approach the problem of identification from the purpose of child management in the classroom however, a more functional and hence more behavioral definition is essential. The educator requires identification and
assessment of learning disabilities which can be incorporated functionally into educational services, training and evaluation. (p. 1)

The specific outcomes for Task Force I dealt with the terminology, definition and symptomatology (Haring & Bateman, 1969). Clements (1966) defined the children in question as “near average, average, or above average in general intelligence with certain learning or behavioral disabilities ranging from mild to severe, which are associated with deviations of function of the central nervous system” (p. 9). Haring and Bateman (1969) summarized that with the recognition of the construct of Task Force I by Task Force II, when considering the definition provided for children with learning disabilities, the educators from Task Force II arrived to four conclusions (Table 1).

Table 1

*Four Conclusions by Task Force II Regarding the Definition of LD by Task Force I*

<table>
<thead>
<tr>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) To “formulate realistic recommendations,” the children in question would have to be considered as “an educationally heterogeneous group.”</td>
</tr>
<tr>
<td>2) “Because special educators in the field of learning disabilities must base educational management and teaching strategies on functional diagnostic information, a redefinition of this group of children for educational purposes was required.”</td>
</tr>
<tr>
<td>3) Intelligence scores should be broadened to reach a larger number of children in the average range, and educational identification here should not have the “unrealistic burden required of making estimates of potential.”</td>
</tr>
<tr>
<td>4) “Effective educational identification and specification of remediation of learning disabilities are functional without any reference to associations with functional deviations of the central nervous system. Identification of an educational deficiency is adequate for remediation plans with or without positive neurological signs. Further, requirements of positive neurological signs might preclude or delay necessary remediation.”</td>
</tr>
</tbody>
</table>

*Note.* From Haring and Bateman (1969, p. 2).

Clements, et al. (1969b) recognized that understanding the compromise of life adjustments and achievement for children with learning disabilities might be imperfect, and they indicated for individuals providing services to children to be committed to making “optimum use of the best
understandings available to intervene in what may be a difficult and pernicious developmental process. Availability of appropriate services during developmental years may well be the factor most decisive for optimal functioning in later years” (p. 53). Clements, et al. (1969b) responded to the educators’ analysis with definitions including more extensive symptomatology:

The previous report defined minimal brain dysfunction as a state descriptive of… children of near average, average, or above average general intelligence with certain learning and/or behavioral disabilities ranging from mild to severe, which are associated with deviations of function of the central nervous system. These deviations may manifest themselves by various combinations of impairment in perception, conceptualization, language, memory, and control of attention, impulse, or motor function. These aberrations may arise from genetic variations, biochemical irregularities, perinatal brain insults or other illnesses or injuries sustained during the years which are critical for the development and maturation of the central nervous system, or other unknown organic causes. (p. 53)

Additionally, Clements, et al. (1969b) suggested individualizing services for children with LD, “The diversity of problems among these children emphasizes the need for highly individualized considerations. Different kinds of services will be paramount at different ages and for different children” (p. 53). Clements, et al. (1969b) clarified the prior report’s findings that described influential conditions in the developmental progression for a child with LD; to address the relevance for an early neurological intervention need for each child:

The definition allows for the possibility that early severe sensory deprivation can result in manifestations of the central nervous system that can be permanent. It further states
that, during the school years, a variety of learning disabilities is the most prominent manifestation of the condition. (p. 53)

Diagnostic attention focuses on the years of early childhood, when subtle deviations in development may precede symptoms more obviously related to minimal brain dysfunction. Even then, except for a few rare conditions events productive of minimal brain dysfunction have usually ceased in activity, so that the basis for therapy no longer rests on a traditional disease-specific curative approach. Concern focuses instead on the plasticity of the developing nervous system which may allow compensation for loss of circumscribed functions either in the natural course of development by means of training, special educational techniques, and attenuation of emotional stress. Against this background, and in the interest of preventing neglect or mismanagement of children with minimal brain dysfunction, the following approach to medical and health-related services is set forth. (p. 53)

Conventional neurological examination is heavily weighted in testing noncortical regions, i.e., spinal cord, brain stem, cerebellum, basal ganglia, primary motor and sensory pathways and peripheral nerves. Since it is important in minimal brain dysfunction to have more information concerning behavioral and cognitive function, the examination (Rabe, 1969, pp. 69 - 71; Appendix A) has been appropriately modified. Appendix A contains an outline describing a neurological examination devised for children ranging in age from 3 to 12 years and containing modifications which are especially applicable to children suspected of having minimal brain dysfunction. (p. 55)

Examination of children with minimal brain dysfunction usually will reveal one or more of the following signs of abnormal neurological function after taking into account
the patient’s age: Hyperactivity, short attention span, abnormalities of resting muscle

tone, clumsiness of gross or fine motor movements, hyperactive deep tendon reflexes,
extensor plantar responses, abnormal extraocular movements, apraxia of face or tongue,
abnormalities of position sense or simultagnosia, choreiform movement of fingers,
abnormal resting postures reflecting the persistence of a dominant avoiding reaction,
synkinesias, mild ataxia, minimal gait abnormalities with asymmetries of associated
movement, right-left confusion, abnormalities of visual motor skills, perceptual
abnormalities, dysphasia, finger agnosia and dyslexia. (p. 56)

Many physical symptoms of LD had been identified, even before education law came into
place. Clements, et al. (1969b) proposed three purposes regarding the importance for educators
to include an early neurological examination for a child with LD (Table 2).

| Table 2 |
| Three Purposes for Neurological Examination of the Child with Minimal Brain Dysfunction |
|______________________________________________________________________________|
| 1) It assists in identifying the child with organic brain disease who may require further  |
| diagnostic procedure and specific therapy.                                      |
| 2) It helps to clarify reasons why the child may not perform up to his expected level as judged |
| from scores on intelligence tests.                                              |
| 3) Finally, it helps to allay suspicion of organic brain disease in children with adjustment |
| reactions of childhood whose overactivity and other symptoms may have endogeneous  |
| cerebral dysfunction.                                                          |

*Note. From Clements, et al. (1969b, p. 56).*

Haring (1968) concluded with the need to investigate educational readiness assessment tools.
Assessment can be used as an *indicator of readiness* for instructional programs, as Haring stated:

*From this survey it is evident that education still has its major contribution to make in educational assessment. Further, a high probability exists that this advancement will be*
made both through instructional programming and through the assessment of entering responses to these programs. (p. vii)

So, in the grand transition to formulate special education law for providing additional support for individuals with disabilities, the language to describe LD definitions was ultimately drafted with an educational emphasis. “Because the [medical] definition did not include [educational] criteria by which practitioners could identify children with LD, the federal government proposed regulations to operationalize it” (Fuchs, Fuchs, Mathes, Lipsey, & Roberts, 2002, p. 738).

Lawmakers' enduring and inclusive efforts still have resulted in holding educators to a discrepancy model which is insufficient for addressing each individual student's earliest intervention needs; despite controversial research for over thirty years, the comparison between the IQ test and achievement scores is still used to qualify or not qualify students with LD for special education services (Francis, et al., 2005). There have been numerous efforts to create tools to measure this discrepancy, including IQ and standardized achievement tests, but research and practice have demonstrated the inefficiency of these methods for children with reading disabilities (Siegel, 2009). Semrud-Clikeman (2005) described IQ testing deficiency:

An evaluation that centers solely on the simple process of subtracting, or regressing IQ from achievement, is a narrow one that misses many of the difficulties frequently seen in these children. The processing of information is a complex and distributed operation. To evaluate the child’s learning skills, one must understand the child’s ability to process language, to understand what he or she hears, and to organize information; the speed with which the child processes information; and the child’s attention, ability to hold information in mind while solving a problem, and ability to self-monitor the reading process. (p. 564)
The typical problem is that children have to wait a few years until a discrepancy becomes apparent, and then their best learning opportunity has passed; by that time they do not typically catch up to their peers (Stuebing, et al., 2002). Stuebing, et al. (2002) focused on a meta-analysis of 46 studies regarding the validity of methods used to classify poor readers, behavior, achievement, and cognitive ability, and found little evidence supporting the validity of the IQ discrepancy classification of children with LD, and poor achievers. "The two groups have been proposed to differ on several dimensions, including instructional needs, response to intervention, neurological integrity, cognitive characteristics, prognosis, gender, and the heritability of LD" (Stuebing, et al., 2002, p. 474). Stuebing, et al. (2002) described a hypothetical classic example for the process to identify a struggling reader:

Remember that the child was not referred for special education until Grade 2 and was not found to be eligible. In Grade 4, as the child’s actual reading level had shown little change, the norm-referenced reading quotient decreased because the child’s peers had continued to grow at a faster rate, so that the discrepancy was obtained. The child’s reading difficulties were apparent in Grade 1, but placement did not occur until Grade 4. (p. 476)

Furthermore, Stuebing, et al. (2002) stated:

From a psychometric perspective, it takes time for a child to move beyond the floor of an achievement test. The types of pre-reading items used to assess early reading skills on achievement tests (e.g., letter matching) are not necessarily difficult for many children at risk for reading problems. More important, the number of items used to discriminate levels of performance in kindergarten and Grade 1 may not be adequate to reliably differentiate these young students. So, the problem is that the emerging research
knowledge is not the basis for classifications of LD in federal regulations. The overlap between poor readers identified as LD and those not so identified is substantial, and little external validity exists for the differentiation of reading disabilities (RD) on the basis of IQ-discrepancy. (pp. 509 - 511)

Francis, et al. (2005) explained an apparent convenience for IQ testing as, “students are often placed in special education on the basis of a single assessment” (p. 105). Differences between longitudinal groups of poor readers were examined, where cut-off points for identifying LD, either by discrepancy or low-achievement definitions, were found to be unstable (Francis, et al.). The margin of error associated with psychometric IQ and achievement testing demonstrated that insufficient scores strongly influenced the validity of decisions determined by the scores, so the need was acknowledged to develop “more robust procedures for employing assessments in the process of identifying students with LD” (Francis, et al., p. 105). Francis, et al. compared the educational model for identifying LD with the medical model for identifying hypertension; contrasting the inaccuracies of static testing measures for LD with ongoing examination for determining patterns for hypertension:

Approaches to the identification of children as having LD based solely on individual test scores not linked to specific behavioral criteria lead to invalid decisions about individual children. Low-achievement definitions are not a viable alternative to IQ-discrepancy definitions in the absence of other criteria, such as the traditional exclusions and response to quality intervention. If we accept the premise of multiple classes of low achievers, then we must develop identification systems that are valid and abandon systems whose only merits are their historical precedence and convenience. (p. 98)
Francis (2005) continued by explaining:

The Individuals with Disabilities Education Act (IDEA; 1997) has flexibility that permits interdisciplinary teams to go beyond test scores. It encourages the use of clinical judgment, which is necessary because of these psychometric issues. Although the basis for clinical judgment should include performance on psychometric tests that at least involve achievement levels, even these types of test scores should not be the sole basis for identifying children as having LD. If there were a natural discontinuity in the score distribution, setting cut points [i.e., cut scores or identification markers] would be straightforward. But such natural discontinuities are not apparent in the achievement distribution and, thus, do not help us in the identification of children with LD. (pp. 99, 104)

Furthermore, Francis (2005) described an example from medicine:

There are dimensional disorders, such as hypertension, where there is an absence of true pathological markers. The attribute (i.e., blood pressure) is normally distributed in the population. In contrast to LD, cut-points for hypertension can be set because studies have been done that help establish where on the distribution of blood pressure some form of treatment is indicated to prevent heart attacks and strokes. It is recognized that blood pressure assessments are not completely reliable and that the decision to treat hypertension is a clinical decision that is not completely dependent on whether one particular blood pressure measurement falls above or below the cut-point. To get around the problems associated with unreliability in the measurement of blood pressure and normal fluctuations in blood pressure due to a variety of factors, the diagnosis of hypertension requires a pattern of blood pressure readings consistently meeting the criteria for hypertension. One reason why blood pressure is measured at each doctor’s visit is to establish a historical
record of blood pressure against which to judge any changes that might be observed over time. Because blood pressure rises during physical activity and then returns to normal afterward, the diagnosis of hypertension is typically made when an individual suspected of hypertension is subjected to a cardiac stress test and their blood pressure remains high for an extended time following the physical stressor. This process has been established through research on human physiology, but also through studies that confirmed the predictive validity of these signs and associated symptoms of hypertension. Unfortunately, we do not have studies of this sort in LD, partly because the idea that definitions should be evaluated in relation to response to intervention or long-term outcome in the absence of intervention is inconsistent with the focus on static assessments of eligibility that dominates the field. The example is highly relevant, as hypertension, like LD, is normally distributed in the population. Any establishment of a cut-point for IQ discrepancy or low achievement is inherently arbitrary in the absence of criterion-related research that attempts to establish its validity. Decision making about performance around that cut-point should also incorporate confidence intervals in an effort to address measurement issues that lead to inaccurate classifications, but even a confidence interval will not be adequate.

(pp. 104 – 105)

Stuebing, et al. (2009) evaluated the relationship of different IQ and intervention response assessments in a meta-analysis of 22 studies. Based on reviews from Fletcher, Lyon, Fuchs, and Barnes (2007), and Fuchs and Young (2006), the validity of IQ as a useful predictor for early reading intervention was found to be negligible. Stuebing, et al. (2009) explored the impact of IQ-achievement discrepancy testing, stating that IQ can be correlated with achievement, but does not determine a cause of achievement. Much evidence is associated with the reduction of IQ and
cognitive problems that minimize achievement (e.g., language), and in time, declining IQ scores become apparent for students who do not learn to read (Stuebing, et al., 2009). According to Stuebing, et al. (2009), if indicators of reading success such as phonological awareness and rapid naming were included on IQ tests, students with reading problems would receive lower IQ scores.


Table 3
Some problems with the discrepancy model for identifying SLD

<p>| |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1) Uniform discrepancy application is insensitive to developmental differences in cognition and achievement</td>
</tr>
<tr>
<td>2) Unclear which IQ score should be used to establish “ability” for discrepancy calculation</td>
</tr>
<tr>
<td>3) Difficulty with distinguishing between children with SLD and low achievers</td>
</tr>
<tr>
<td>4) Inconsistent application of the approach across schools, districts, and states</td>
</tr>
<tr>
<td>5) Over-identification of students from diverse backgrounds</td>
</tr>
<tr>
<td>6) Measurement problems that result in poor decision-making</td>
</tr>
<tr>
<td>7) Early identification is unlikely although it is critical for ameliorating problems (a “wait-to-fail” model)</td>
</tr>
<tr>
<td>8) Encourages “test and place” practices which are neither an accurate nor an effective use of resources.</td>
</tr>
</tbody>
</table>

*Note.* From Hale, et al. (2010, p. 227).
So, regulations for the 2004 reauthorization of IDEA (USDOE, 2006) were changed based on research investigating a lack of validity for using IQ to define aspects associated with learning disabilities; now states cannot require school districts to use IQ tests (Stuebing, et al., 2009). For the first time, the 2004 reauthorization of IDEA brought an alternative for using the IQ-achievement discrepancy model by incorporating the early identification Response to Intervention (RTI) model; allowing practitioners in the general and special education fields to address students' varying needs on multitiered proficiency levels, with the intent to minimize students' awareness of failure (Grimes, 2002; Stuebing, et al., 2009). Fuchs and Young (2006) defined RTI:

regulations to accompany the law and specify RTI have not yet been published.

According to proponents, RTI starts with the teacher providing scientifically validated, or "generally effective," instruction; identifying at-risk students; and monitoring their academic progress. Those who do not respond to classroom instruction get something else or something more from the teacher, reading coach, or someone else. Again, progress is monitored. Children responsive to the more intensive instruction are returned to the classroom where practitioners continue to monitor their performance. Students still unresponsive either qualify for special education by virtue of their unresponsiveness or are provided a comprehensive evaluation to determine special education eligibility, depending on the version of RTI. (p. 9)

Versions of RTI are still being formulated. The RTI model relies on “formative assessment,” that is still currently in the theoretical process of acquiring a definition (Black & Wiliam, 2009). Chech (2008) described “formative assessments” in the testing industry:
Formative assessments, also known as “classroom assessments,” are in some ways easier to define by what they are not. They're not like the long, year-end, state-administered, standardized…required exams that testing professionals call “summative.” Nor are they like the shorter, middle-of-the-year assessments referred to as “benchmark” or “interim” assessments. Or they shouldn't be, at least according to experts inside and outside the testing industry, who believe that truly "formative" assessments must blend seamlessly into classroom instruction itself. (p. 1)

The inefficiency of the IQ discrepancy model has been addressed by multi-tiered levels of RTI, through providing more immediate and specific individualized instruction to students (Grimes, 2002) during gradual levels of intervention. Even with this attempt to refine the instructional process, still there is not a standard RTI model (Berkeley, Bender, Peaster, & Saunders, 2009); one that still is essentially based on discrepancy of achievement.

It is acknowledged that “screening for early reading problems is a critical step in early intervention and prevention of later reading difficulties” (Johnson, et al., 2009, p. 174). Although efforts to standardize reading assessments through informed instruction, which takes into account the many educational and social considerations influencing a child's ability to read, no agreement related to the reliability of the widely used screening tools for reading intervention has been made (Johnson, et al., 2009).

Johnson, et al. (2009), examined the effectiveness of commonly used early reading intervention screening tools. The purpose was to: a) identify a state standardized reading measure in 1st grade that best predicted performance at the end of 3rd grade; b) to test the usefulness of commonly used screening measures, as the predictor for 1st grade outcomes; c) to examine whether false negatives would be reduced by combining screening measures;
and d) to establish whether subgroups of at-risk students of English Language Learner (ELL), non-ELL, Free or Reduced Lunch (FLR), and non-FRL categories would be required to have different cut scores to reflect screening results identified with 90% accuracy. The measures used consisted of five quick tests. Classroom teachers did not do the testing; only trained school or district-based testing teams administered the tests over a 4-year period at varying times. Only the students in the progress monitoring database who had scores for all of the test variables were included for this study. In Figure 1, the distribution of student participants for Johnson, et al. is demonstrated.

Figure 1

![Progress Monitoring for 12,055 students in 309 Florida State Public Schools, K-3rd Grade (2003-2007)](image)

The outcomes of Johnson, et al. (2009) showed: a) the state standardized test indicated the best predictor for future reading in the third grade, b) nonsense word fluency was found to be the most accurate kindergarten screening tool; nonsense word oral reading fluency the most accurate 1st grade screening tool; 254 false negatives, 611 false positives, and 5,219 students were found in the "some risk" category according to the published screening tool cut scores, c) the greatest improvement indicated a 2% specificity when combing two or more screening tools for
Kindergarten and 1st grade, and d) with obtaining 90% sensitivity for ELL and FRL subgroups, it was necessary to lower the cut scores for Kindergarten nonsense word fluency (4 points), and Grade 1 oral reading fluency (5 points) (Johnson, et al., pp. 182 - 183). Due to the high number of false positives for children at risk, including for ELLs, Johnson, et al. demonstrated a good indicator for the need to improve reading screening tools. Johnson, et al. investigated the screening process, and not progress monitoring.

In contrast, Boscardin, Muthén, Francis, and Baker (2008) identified phonological awareness and rapid naming as being substantially predictive of word reading (word recognition) with “developmental profiles formed in kindergarten…directly associated with development in Grades 1 and 2” (Boscardin, et al., p. 192). In an RTI meta-analysis, classification measures for students at-risk for reading were considered by Tran, et al. (2011) (Table 4).

Table 4  
Classification Measures for Students At-Risk for Reading

<table>
<thead>
<tr>
<th>1. Real word reading.</th>
<th>Word recognition was the focus.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Rapid naming speed.</td>
<td>Speed (timed trials) related to the overt verbalizing of letters, sounds, words, objects, or colors, including color naming, digit naming, picture naming, number naming, letter naming, object naming, and naming of words (e.g., nonwords [ pseudowords ], regular words).</td>
</tr>
<tr>
<td>3. Phonological awareness.</td>
<td>Oral tasks were the focus that required dividing spoken words into segments of sounds smaller than a syllable or learning about individual phonemes (e.g., blending sounds, naming letter sounds, phoneme deletion, phoneme elision, phoneme segmentation, phonemic blending, phonological awareness, phonological oddity, phonological skills, rhyme, rhyme judgment, rhyming letter naming, sound categorization, syllable deletion, and phoneme detection).</td>
</tr>
<tr>
<td>4. Pseudo word reading (word attack).</td>
<td>Word attack skills, considered as a separate entity of phonological processing, required the reading of printed nonwords (e.g., reading of nonwords or sounding out of nonwords of increasing complexity).</td>
</tr>
<tr>
<td>5. Vocabulary.</td>
<td>Word meaning considered receptive vocabulary.</td>
</tr>
<tr>
<td>6. Reading comprehension.</td>
<td>General reading measures were used for text comprehension.</td>
</tr>
<tr>
<td>7. Reading fluency.</td>
<td>Oral reading fluency was the focus.</td>
</tr>
<tr>
<td>8. General intelligence.</td>
<td>Standardized general intelligence measures were considered.</td>
</tr>
</tbody>
</table>
9. Verbal intelligence. Vocabulary for verbal IQ was considered as a separate category.
11. Behavior. Behavior was determined thorough behavior ratings.

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*Note. From Tran, et al. (2011, p. 286).*

The most important factors in predicting posttest outcomes were connected to “initial level of real word reading, word attack, passage comprehension and rapid naming speed” (Tran, et al., p. 293). There were no significant distinguishing effects for number of sessions, length of intervention, or types of methods used to identify responsive students (Tran, et al., p. 291), with a pretest and posttest achievement gap between responding and low responding students remaining consistent. Inconsistencies persist for defining the most influential classification measures for reading success (Tran, et al., 2011).

So far, according to Reynolds & Shaywitz (2009) there is not consensus for an effective standard RTI model. Some of the problems involving accurate diagnosis and appropriate intervention for students with SLD in the RTI system include:

a) RTI fails to identify bright, albeit, struggling readers who require and would benefit from intervention and accommodation; (b) RTI delineates neither which specific components of, for example, reading (phonological awareness, fluency, vocabulary, orthographic processing, attention or other) require intervention, nor which specific strengths can assist in bootstrapping weaker areas; (c) how is RTI best implemented: intensity and duration of intervention are currently unknown, and, of course; (d) what constitutes the R in RTI? (p. 140)

Hallahan, et al. (2007) found there is no consistent manner to differentiate students among special education categories, and comparisons between states and their prevalence rates have been “radically different” (p. 136), with RTI criteria ranging “from few criteria to very stringent”
(Semrud-Clikeman, 2005, p. 565). The lack of consistency for the eligibility process among states, districts, schools, including grade levels has demonstrated concern for both discrepancy and RTI models (Berkeley, et al., 2009, p. 94).

Ysseldyke (2005) described a systemic inaccuracy with identifying LD in the RTI system. The author contrasted the occurrence of identification decisions based on fact vs. opinion:

“RTI resistance” is here now, and will get serious when too many students are identified as LD using RTI approaches. And, then we will do what we always have done and what government agencies like welfare agencies and departments of natural resources always have done: We will put upper limits and/or “slot limits” on conditions to control eligibility. Departments of natural resources use “slot limits” (e.g., one may keep only fish between 16-24 inches) to define “keepers.” When the harvest gets too high, they modify the slot (say from 16-24 to 20-24) and redefine “keepers.” As in the classification decisions we make, definitions and numbers are more politically than scientifically determined. (Ysseldyke, 2005, p. 127)

During the years, there have been contributions from parent and professional groups interested in defining learning disabilities, as well as those from varying fields (e.g., language, education, psychology, and medicine) that have considered ideas related to processing disorders, neurological impairment, perceptual handicaps, cognitive deficits, discrepancy, exclusion factors, and academic deficiencies (Mercer, Jordan, Allsop, & Mercer, 1996). The academic field appears to be lacking consistency for identifying the needs for individuals with LD or reading disability, so perhaps it would be beneficial to further investigate broader disciplinary views that might contribute to a common consensus among educators regarding the necessity for more specific reading ability indicators.
The education field relies on academic and observational tests to inform instruction, and now with non-invasive medical tools such as functional magnetic resonance imaging, functional transcranial Doppler ultrasound, positron emission tomography, Voxel Based Morphometry, magnetic source imaging, and magnetic resonance spectroscopy, by tracking blood flow, there is the advantage to visually document physical properties of neurological learning and dyslexia. “The resolution is excellent and sufficient so that precise measurements of brain structure can be completed” (Vellutino, Fletcher, Snowling, & Scanlon, 2004, p. 19). Continuing progress has been evident for discoveries regarding the learning process, “Advances in our knowledge of the neuroanatomical and physiological foundations of higher-order cognitive functions are occurring faster than diagnostic criteria can accommodate this knowledge” (Hughes, 2008, p. 124).

Hillman, Erikson, and Kramer (2008) located activation for specific cognitive processes in particular brain regions; the frontoparietal network was activated for learning traditional academic areas such as mathematics and reading. Semrud-Clikeman (2005) emphasized the necessity for a comprehensive learning approach for students with learning challenges, aside from the traditional areas of learning: “An evaluation of children with learning problems must consider measures of working memory, attention, executive function, and comprehension (listening and written), particularly for children who do not respond to intervention” (p. 563).

The essential neurological foundation for students with LD must include evaluation of movement disparities. Although medical and educational diagnoses for “conditions seem to indicate different levels and types of disability, the motor development issues among them are…similar” (Cheatum & Hammond, 2000, p. 3). Henderson and Hall (1982) found that children identified as “clumsy” showed significantly poor scores on several motor performance measures, in comparison to a control group, including showing a “higher incidence of other
educational and social problems” (p. 459). It was previously recommended by educators to treat LD as “an educationally heterogeneous group” (Haring & Bateman, 1969, p. 2). Evidence has shown that clumsiness is heterogeneous (Gubbay, 1975, 1985; Henderson & Hall, 1982), and, Henderson and Hall (1982) stated that “clumsy children do not form a single group but vary widely in their characteristics” (p. 459). There is evidence to suggest “a higher incidence of reading difficulties in the clumsy children” (Gubbay, 1975, p. 235).

The central nervous system influences learning to read. Cause of the “learning disability is a known or presumed dysfunction in the central nervous system…by-products of traumatic damage to tissues, inherited factors, biochemical insufficiencies or imbalances, or other similar conditions that affect the central nervous system…intrinsic to the individual” (Hammill, 1981, p. 340).

Atypical shapes and sizes of anatomical brain structures, including the for cerebellum, have been evident for dyslexia (Rae, et al., 2002; Eckert, et al., 2003; Kronhichler, et al., 2008; Vlachos, Papathanasiou, & Andreou, 2007). Rumsey, et al. (1999) found a connection between a functional lesion in the left angular gyrus with severity of dyslexia. The malfunction of cortical structures strongly influences individuals with dyslexia (Punt, DeJong, DeGroot, & Hadders-Algra, 2010), with evidence showing that atypical cerebral lateralization persists into adulthood (Illingsworth & Bishop, 2009).

The field of special education has relied on significant contributions from authors in the areas of medicine, neurology, pediatrics, psychology. These areas, in addition to others, have provided scientific inquiry regarding issues related to special education, and learning to read.

**Multifactorial Hypothesis**

Researchers have been addressing varying symptoms for individuals with reading deficiencies, and by now there have been studies to support previous findings relating to multifaceted deficits
for dyslexia (Habib, 2000; Nicolson & Fawcett, 2009). Kibby, et al. (2009) found correlations between the shape and length of the pars triangularis brain region relating to the function of language, including for children with attention-deficit hyperactivity disorder (ADHD). Within the search to understand Autism Spectrum Disorder (ASD), children have demonstrated considerable deficits associated with those for ADHD (Allen & Courchesne, 2001; Corbett & Constantine, 2006). Evidence has shown children with dyslexia experience both phonological coding and visual deficits (Eden, Stein, & Wood, 1993; Valdois, Bosse, & Tainturier, 2004), when tested for nonsense words (Lovegrove, Martin, & Slaghuis, 1986). Menghini, et al. (2010) recognized wider implications for defining and treating developmental dyslexia (DD):

[DD is] a composite disorder in which other competencies besides linguistic ones are compromised…a diagnostic system that collects only linguistic symptoms of dyslexics is not sufficient for understanding their reading difficulties, making a correct diagnosis and, consequently, developing a consistent program of treatment. (p. 870)

Menghini, et al. (2010) investigated the multifactorial hypothesis of DD by simultaneously testing several neurocognitive functions with 125 children and adolescents with dyslexia (n = 60), and normal readers (n = 65). Students were selected according to speed accuracy on reading words and non-words with at least 2 standard deviations below the mean for their chronological age. Instruments included assessments for phonological fluency, for phonological awareness, repetition of a non-word task, and spoonerisms. In testing spoonerisms, “the examiner pronounced two words aloud and participants had to swap the initial phonemes to form two new real words. They were asked to transpose the beginning sounds of the two words as quickly as possible,” (Menghini, et al., 2010, p. 865). Two tests were used to assess general intelligence. Additional measures evaluated visual-spatial perception, motion coherence, and selective visual-
spatial attention by distinguishing color and size. Sustained auditory attention, executive function, and implicit memory abilities were also investigated. None of the children with DD had “intensive or specific reading training” (Menghini, et al., 2010, p. 865). “None of the children in our sample with DD showed co-morbidity with ADHD” (Menghini, et al., 2010, p. 865).

Testing children for dyslexia took place at the Children's Hospital Bambino Gesù in Santa Marinella (Rome, Italy), and the control group was individually tested at their schools. Chronological age and scoring in the normal range for the word and non-reading tests were matched for the control group. The testing occurred in 3 to 4 sessions, for around an hour and a half at a time on separate days. The intelligence and reading tests were administered during the first sessions, and then the other tasks in the later sessions. Tests were administered randomly.

It was presumed that these tests required activating many abilities at once, rather than one domain at a time. The general linear analysis was to compare the group differences, although interaction among the cognitive domains was considered. In addition, participants were selected from a large group of children in different stages of development with DD. An additional goal was to examine if non-phonological cognitive functions would predict word and non-word reading in children with dyslexia, even with controls for age, IQ, and phonological skills.

Results indicated, of the largest group of children with DD had phonological deficits with spoonerisms and non-word repetition task, almost half also had deficits on an attentional task, and a third on executive function tests. Aside from a test to see how many words could be articulated beginning with a particular phoneme, nearly 20% of the children with DD had deficits in visual-spatial tasks, and with the test of categories completed on an executive function task. Menghini, et al. (2010) reported:
to support this interpretation we conducted also a deviance analysis, which confirmed the high presence of phonological impairments in our children with DD as well as more diffused cognitive impairments in attentional, executive function and visual-spatial tasks. In fact, the frequency of occurrence of children with DD who only exhibited a phonological deficit was 18.3% while the most of the children with DD (76.6%) showed other deficits in addition to phonological deficit. For instance, 16.6% displayed executive deficits, 13.3% visual-spatial perception deficits, attention and executive deficits, 8.3% attention and perceptual deficits and 8.3% attention and executive deficits. (p. 869)

Results confirmed in our children with DD the presence of deficits on phonological awareness and processing tasks, as well as more diffused cognitive impairments on tasks assessing auditory sustained attention, executive function and category fluency, and visual-spatial abilities. Our findings are consistent with the hypothesis that individual with DD may show multiple impairments in different cognitive domains, thus suggesting that DD may result from multifactorial impairments. (p. 870)

Furthermore, Menghini et al., (2010) examined dyslexia by emphasizing the "developmental" aspect of learning, and addressed the possibility that reading difficulty might have broader systemic-neurocognitive influences extending beyond the linguistic brain area. For example, memory has been investigated.

Students with reading difficulty have gained additional support with further evidence of a specific working memory deficit (Beneventi, Tonnessen, Ersland, & Hugdahl, 2010). Wolf, et al. (2010) identified specific brain regions showing the working memory deficit for DD:

Within an “executive” neural network, dyslexics exhibited decreased connectivity in key regions associated with executive function during working memory (WM), but
also increased functional connectivity in parietal, hippocampal and thalamic regions.

The relationship between task accuracy at high load levels of manipulation demand and connectivity indices in parietal and hippocampal areas suggests the presence of alternative neural pathways in dyslexics in order to compensate for deficient executive neural processing. (p. 317)

DeLuca, Borrelli, Judica, Spinelli, and Zoccolotti (2002) demonstrated a close relationship between motor and cognitive development, and the cerebellar and pre-frontal cortex. To better understand the importance of recognizing specific brain regions relating to dyslexia, it is necessary to have a basic knowledge of neurological functions relating to movement.

Neurological Foundations for Human Movement

Seaman, et al., (2007) described the basic foundation of the central nervous system (CNS), starting with the neuron (the body and processes of the cell), made of axons (pathways from the cell) and dendrites (branchlike receptors transferring stimuli to the cell). Seaman, et al., (2007) described the process for CNS growth and development:

CNS maturation depends on several factors: axonal growth, maturation of neuronal dendritic systems, maturation of the synapses, and myelination. The maturation of the synapses is interdependent on axonal growth and the functioning of the dendritic systems. Myelination occurs as a separate process and is considered a measure of the maturity of the individual cell and its ability to transmit impulses efficiently. Not all nerve cells become myelinated, nor does all myelination occur at the same time. In general, myelination begins before birth and continues for nearly 30 years of life. (p. 45)
Seaman, et al. (2007) explained the structure and function of the CNS as “hierarchical” (p. 45), although it is important to also recognize and understand the CNS functioning “as a whole” (p. 44). They specified the comparison between the “old” and “new”:

The evolutionary older structures are found at the anatomically lowest level (i.e., spinal cord) and are the least functionally complex…the newer structures are found in the highest anatomical position (i.e., telencephalon or cerebral cortex) and have the most complex functions. For optimum functioning, the higher levels of the brain depend on adequate lower-level function. The following general concepts apply:

1. Growth, development, and maturation begin in the spinal cord and end in the cortex.
2. Hierarchy of control and complexity of function increase with higher CNS structures.
3. Inhibitory centers tend to predominate over excitatory centers.
4. Reflexes and feedback loops become progressively more complex with higher structures.

The spinal cord is at the lowest anatomical level and is structurally and functionally the simplest in the CNS…Its importance lies in its mediation of spinal cord reflexes and conduction of neural impulses. Located anatomically higher, the brain stem receives sensory input from many sources, handles significant and massive integration, and has widespread influence over the rest of the brain. Within the brain stem is housed, at least in part, the reticular formation, considered to be the master control mechanism in the CNS. The reticular formation serves a general arousal and alerting function, as well as a central integrative role (e.g., inhibition, facilitation, augmentation, synthesis). It is also a selective network that decides which information is to be perceived and focused on.

(Seaman, et al., 2007, pp. 45 - 46)
Seaman, et al. (2007) also defined the cerebellum as “a huge integration center, the primary functions of which are integration and regulation...its function has been linked most frequently to motor output, smoothing and coordinating action and influencing muscle tone” (p. 46). The cerebellum coordinate motor function, influence long-term memory, spatial perception, impulse control, attention, and cognitive function (Sousa, 2006).

The higher brain centers are more diverse and numerable than the lower ones. Seaman, et al. (2007) identified some of the higher brain centers:

The diencephalon and telencephalon, respectively, are the next to highest and highest levels of the CNS. Their functions are more complex. The diencephalon (thalamus, hypothalamus, and other structures) serves as a relay station for sensation and movement. The telencephalon includes the basal ganglia, limbic lobe system, and the cerebral cortex. The basal ganglia assist with the initiation and execution of purposeful movement. The limbic lobe system, or “old cortex,” is the primary memory storage area of the brain. The cortex consists of two hemispheres (right and left) and five lobes (two temporals, occipital, parietal, and frontal). The two hemispheres are connected through a bundle of fibers known as the corpus collosum, which transmits impulses between hemispheres. These higher centers organize sensory activity at their respective levels and influence integration at the lower levels. Processing at the cortical (cortex) level depends on subcortical (levels below the cortex) processes. As the level of function increases, behavior becomes less stereotyped and more individualized. As the level of sensory organization decreases, more emphasis is placed on sensorimotor integration. (Seaman, et al., 2007, p. 46)
Appropriate development relies on essential sensory and environmental factors, regardless of innate potential (Haywood & Getchell, 2009; Seaman, et al., 2007). Seaman, et al. (2007) emphasized that the strength of the higher CNS relies on the lower CNS:

Sensory input (e.g., tactile, vestibular, proprioceptive, visual, and auditory) continually impinges upon the human organism, placing demands that help foster the growth of the nervous system…The process begins with enhancing development in the lower, less complex levels of structure and response that, in turn, enables the individual to become more competent at the higher, more complex levels. (p. 46)

Seaman, et al. (2007) summarized the process of sensory input to sensory motor output response (e.g., movement, writing, speaking). Furthermore, the authors included the importance of the feedback loop for refining future motor responses or movement:

In order for a person to move, sensory stimuli must be received (reception) and attended to (selective attention). Following neurological arousal and attention, the sensory information is available to be modulated, analyzed and integrated. The result is the perception or image of the desired and appropriate motor response. This is matched with memory and then translated into the motor program. The actual motor response is influenced by selected motor control mechanisms of the brain (e.g., basal ganglia, cerebellum). Once neural impulses are sent to the muscles, the motor response occurs. (Seaman, et al., 2007, pp. 49 - 50)

According to Ayres (2005), directing one’s own movements provides internal feedback by “record[ing] the motor command…before it is completely executed” (p.96). “When the body is moved passively, the brain does not send out a motor command, and so there is no internal feedback…self-directed movement is one of the keys to developing better motor planning” (p. 96).
Sensory Motor Development from Earlier- to Later-Maturing Systems

The growth process takes place according to particular physical directions of development. Horvat, et al. (2011) explained the process of growth and motor development:

Motor skills develop in a predictable sequence from basic to more complex movement patterns beginning at the head and proceeding to the feet [cephalo-caudal], and beginning from the midline of the body and proceeding to the extremities [proximo-distal]. The head develops initially and has the greatest degree of control in the upper extremities. During the process of maturation, the arms will develop in mass and control before the lower extremities. Similarly, control of the large muscles of the trunk and shoulder girdle develops before control of the hands and fingers...the sequence of motor development and postural control is orderly, although not all abilities will be mastered at a specific age. (Horvat, et al., 2011, p. 69)

In the developmental model “it is generally accepted that each developmental step depends on a certain degree of maturation at previous steps...early developmental stages serve as building blocks for later stages” (Seaman, et al., 2007, p. 58). The developmental pyramid model (Figure 2) demonstrates the progression of development for the three lower systems; initially, for the innate neural capacity or reflexes; secondly, for the earlier-maturing systems, including the tactile, vestibular, and proprioceptive; then, for the later-maturing systems, the visual and auditory systems (Seaman, et al., 2007, p. 59; M. Karwas, personal communication, 2006, 2007). The development of movement sequences within each of the later stages of motor-sensory responses, motor patterns, and motor skills are dependent on the sophistication of the previous stages. The sensory systems interrelate. The most refined movements, and higher level functioning are at the top of the pyramid.
Figure 2
Developmental Pyramid for Motor Development

Motor Skills – culturally determined
running while bouncing balls, walking on the balance beam, dancing

Motor Patterns – common to all humans
rolling over, hand raising, walking, running, creeping, crawling, sliding, throwing, jumping, hopping,
skipping (combination of hopping and walking), leaping, kicking, striking, galloping

Motor-Sensory Responses – planning and executing purposeful movement
twisting, bending, lifting head, eye-hand coordination, eye-foot coordination; ability to use both sides of
the body independently from each other, isolate one body part, cross midline, and maintain balance

Functioning of Later-Maturing System – visual, auditory
hand-eye and eye-hand coordination; most closely linked to the vestibular

Functioning of Early-Maturing System – vestibular, tactile, proprioceptive
understanding right from left, memory playing an important role; the same anatomic age

Innate Neural Capacity – reflexes; according to survival behavior; gene pool

Note. From Seaman & DePauw (1989, p. 31) “The Developmental Model” [above]; adapted from
Seaman & DePauw (1989) by Karwas (2006, 2007), used with permission by Seaman (M. Karwas,
personal communication, October 10, 2012) [below].
The astonishing accuracy with which normal human subjects can estimate their straight ahead body orientation under normal conditions argues for a stable body-centred [sic] reference frame for the evaluation of body orientation in space and further shows that under normal conditions the sensory systems [visual, vestibular, and proprioceptive] tested act together in a very precise manner, supplying us with a close to optimal estimate of body orientation. (Karnath, Sievering, & Fetter, 1994, p. 145)

Seaman, et al. (2007) indicated, “reflex development and inhibition occur along a continuum rather than an ‘all or nothing’ manner” (p. 54). Horvat, et al. (2011) explained the function of reflexes that are typically present to assist infants:

Reflexes are automatic responses of the nervous system that are present at birth and controlled by the primitive regions of the nervous system, spinal cord, labyrinth of the inner ear, and brain stem. They are responsible for changes in muscle tone and movement and gradually become integrated into voluntary movements as the higher center of the brain develops. Reflexes also aid children in assuming postures and controlling movement. During infancy reflexes will dominate movement until 6 months of age. (p. 207)

The following represents a glimpse of the individual sensory systems. Each system, intricate on its own, typically integrates with the others.

Spoor, Wood, and Zonneveld (1994) examined the dimensions of the inner ear's bony labyrinth vestibular system, the oldest evolutionary and developmental sense, among hominid fossils as “a major component of the mechanism for the unconscious perception of movement” (p. 645). The study explored the question of why "the upright posture and obligatory bipedalism of modern humans are unique among living primates" (Spoor, et al., 1994, p. 645). "Among the
fossil hominids investigated, the earliest species to demonstrate the modern human semicircular canal morphology is *Homo erectus*” (Spoor, et al., 1994, p. 647). An advantage to studying the bony labyrinth is that it develops to its "adult shape and size long before birth" (Spoor, et al., 1994, p. 648).

The vestibular sense regulates sensory processing by coordinating the visual, auditory, proprioceptive, and tactile senses (Ayres, 2005; Cheatum & Hammond, 2000), with neuroplasticity (Ayres, 2005; Sousa, 2006). Seaman, et al. (2007) described the vestibular:

> It functions to maintain equilibrium, muscle tone, position of the head in space, and an awareness of motion. It exerts widespread influence throughout the CNS and contributes to the coordination and timing of all sensory input for the enhancement of perception… and chiefly acts through the vestibular-spinal tracts and the vestibular-oculomotor pathways, sending impulses to the rest of the CNS…via the cerebellum. (p. 52)

Grasso, et al. (2011) investigated the responses of the vestibular system according to leg rotation and head position. Grasso, et al. (2011) found evidence that the labyrinthine apparatus responds to positions of the legs and the entire body:

> In particular, within the cerebellar cortex, the direction of animal tilt giving rise to the best response of the neurons tend to rotate by the same angle and in the same direction as the body under the head, so that labyrinthine responses become dependent on the direction of body displacement, rather than head displacement…(p. 312)

We postulate that the cerebellum integrates somatosensory information from the whole body and adapts the voluntary and reflex movements to the orientation assumed by the body in space and to the relative position of the different body segments…(p. 312)
The results of the present experiments support the hypothesis that somatosensory signals related to leg rotation and/or copies of the corresponding voluntary motor commands modify the pattern of VS [vestibulospinal] reflexes and, thus, maintain this postural response appropriate to counteract body sway in the direction inferred by labyrinthine signals. (p. 312)

The tactile system receptors respond to touch, pressure, temperature and pain, and are located in layers of the skin; most sensitive in the mouth, lips, tongue, fingers, and hands (Cheatum & Hammond, 2000, pp. 223, 225). Seaman, et al. (2007) stated, “Touch refers to the primary sense, characterized by the reception of nondiscriminating, nonlocalized, and generalized information... tactile is the later-developing sense able to discriminate among and localize tactile information” (p. 53). “Spaces in the sensory cortex created by impulses [from the fingers, thumbs and lips] are larger than the combined space reserved for impulses for all the other body parts” (Cheatum & Hammond, 2000, pp. 226 - 227). “One of the most important functions of the tactile system is to enable the brain to suppress or ignore a vast amount of information it receives through the skin” (Cheatum & Hammond, 2000, p. 230).

Body schema coordination understands how body parts are in relation to each other, including the concept of laterality or lateral preferences for favoring one eye, hand, and foot, and movements crossing the midline, so directional discrimination can be learned (Cheatum & Hammond, 2000). Cheatum and Hammond (2000) explained that proprioceptive receptors detect: relationships of the body parts and joints to each other in both stationary (static) and moving (dynamic) positions...at any time, the proprioceptive system sends information to the brain concerning the (a) location of the joints and body parts; (b) movement of
the joints and muscles; (c) pressure on the skin and underlying tissue; (d) pain [or relief from pain] felt in the joints, tissue, or muscles; and (e) temperature (p. 187).

Seaman, et al. (2007) stated, developmentally, the proprioceptive sense has three main objectives: “1) it helps to maintain normal muscle contraction; 2) it influences muscle tone; and (3) it aides in space perception…regarding size and shape of the environment” (p. 52).

The auditory system detects vibration that creates sounds. Seaman, et al. (2007) described the auditory system as:

a very intricate and complex system. The stimuli enter at the ear and are routed bilaterally almost as soon as they enter. As input passes through the nervous system, it makes many different connections and travels directly or indirectly to the cortex. The direct path leads through brain structures that contribute to the general arousal and inhibition of the CNS at the cerebellar level. As impulses travel through integrative brain structures, the auditory system becomes closely associated with the visual system. The auditory system also has a close association with the vestibular system because the receptors are in proximity to one another in the inner ear and share the same cranial nerve. (p. 53)

“The visual system is the most complex of all the sensory systems. The auditory nerve contains about 30,000 fibers, but the optic nerve contains one million, more than all the dorsal root fibers entering the entire spinal cord!” (Mason & Kendel, 1991, p. 420). According to Porter, Porter, Baker, Ragusa, and Brueckner (1995) "Eye muscles can execute pursuit and vergence movements to maintain fixation upon smoothly moving targets at velocities at which motion is barely perceptible, yet also are capable of saccadic peak velocities of as high as 600 [degrees]/second" (p. 454). Regarding oxidative capacity, the extra-ocular eye muscle fiber “[is likely] the most fatigue resistant mammalian skeletal muscle fiber type” (Porter, et al., 1995,
In humans, "extraocular muscle blood flow, and thus potential oxidative capacity, is the highest of any skeletal muscle" (Porter, et al., 1995, p. 466). "The eye movement reflexes, vestibulo-ocular and optokinetic, represent phylo-genetically old systems that provide a baseline ocular stability that is vital for clear vision and thereby provide a platform from which to execute voluntary movements" (Porter, et al., 1995, pp. 453 - 454).

Muri (2006) found evidence that eye movement control or oculomotor processes and visuospatial attention are closely integrated in a common neural network. Cheatum and Hammond (2000) stated that the visual system is composed of “several visual skills: binocular vision, accommodation (convergence and divergence) fixation, visual pursuit (pursuit fixation), depth perception (stereopsis), visual memory, and visual sequential memory” (p. 267). Ocular motor control is described as “the ability…to use the six eye muscles…[to] allow the eyes to move in all directions for tracking” (Cheatum & Hammond, 2000, p. 269). Stoffregen, Pagulayan, Bardy, Hettinger, and Hettinger (2000) explained how eyes typically move together, “binocular convergence…is controlled by rotating the eyes relative to one another” (p. 208). Kirkby, Webster, Blythe, and Liversedge, (2008) described functional binocular control, as each eye adjusts its position to the other:

An important implication of this conclusion is that the traditional description of the human binocular system in which the two lines of sight adhere to a tight, rigid trigonometric, angular arrangement in relation to the fixated stimulus is untrue. This description is frequently depicted in undergraduate text books, and it may be time to revise it. The two eyes are coordinated such that each eye fixates within a degree of proximity to the other in order to allow fusion to occur. Thus, the oculomotor control system subserves a visual system that is efficient in constructing a clear and
unified perceptual representation from retinal inputs that can differ to a substantial degree. Arguably, this may be the most important implication to emerge from our review. (p. 759)

Kulkarni, Chandy, and Babu (2001) studied human fetuses, post-mortem from stillborn, to find a very high muscle spindle (sensory receptors) content in the suboccipital muscle triangle, compared to other muscles. “The complex integrative mechanisms involved in head-eye coordination probably demands complex proprioceptive inputs from the neck muscles which probably is the reason for their high spindle content” (p. 358). Kulkarni, et al. indicated the importance of the cervical muscles for postural and eye movement control, and found evidence that suboccipital muscles move according to length changes, instead of muscle contractions.

Edwards, et al. (2007) stated that increased blood flow would influence the cervico-sympathetic reflex for suboccipital muscles. Additional blood flow “would result in altering the length of fibers in the suboccipital muscle group” (Edwards, et al., p. 8331).

Bringing together the senses; internal and external neurological feedback shapes an individual’s motor planning while motor skills are learned through repetition, via hypo- and hyper-sensory input responses, as they avoid and seek stimuli toward a balanced homeostasis (Cheatum & Hammond, 2000; Horvat, et al., 2011; Seaman, et al., 2007) (Figure 3). “As stimuli enter the sensory systems, they act as stressors and disturb homeostasis, which must then be gained anew by means of a respective, appropriate motor response” (Seaman, et al., 2007, p. 50).

Figure 3
The Responsivity Continuum

<table>
<thead>
<tr>
<th>Hypo(--------------------------------------------------------------X-----------------------------)Hyper</th>
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<tr>
<td>gets little/seeks stimulation</td>
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*Note. Adapted from Seaman, et al. (2007, p. 74) by Karwas (2006, 2007), used with permission by Seaman (M. Karwas, personal communication, August 14, 2012).*
“An unknown amount of sensory input, unique to each individual, is necessary for adequate functioning” (Seaman, et al., 2007, p. 59), while “a process disorder of responsivity may manifest itself in one of three ways: hyperresponsivity, hyporesponsivity, or vacillating responsivity” (Seaman, et al., 2007, p. 74). Integrating the concepts of the developmental pyramid with those of the responsivity continuum results in combinations of sensory responses (e.g., hypo/hyper vestibular, hypo/hyper tactile, hypo/hyper proprioceptive, hypo/hyper auditory, and hypo/hyper visual) (Cheatum & Hammond, 2000). Seaman, et al. (2007) described compensating behaviors according to sensory system responses for the vestibular, tactile, proprioceptive, auditory, visual, including integrating lateral sides of the body (Appendix B). Horvat, et al. (2011) stated the importance of addressing individualized movement development:

programming for special needs must be implemented at the appropriate functioning level, with age providing a general guideline of expected skill development. If children can overcome or compensate for deficiencies, they will attain similar levels of functional ability. For children with movement disorders, the more completely we understand the stages of development and underlying mechanisms of disease or injury, the more likely we can develop an instructional program based on individual needs. (p. 69)

Visual Deficits and Reading

As early as 1896, visual deficits were examined for individuals learning to read; comparing the recognition of whole words and smaller components of letters comprising words (Hinshelwood, 1896). “Inappropriate use of vision only adds to the child’s literacy problems; he is likely to keep losing his place and to scan poorly” (Baker, 1981, p. 360). Children with reading disability have performed significantly worse than children without disabilities on several eye-movement and visual tasks, in addition to testing poorly with verbal indicators (Eden,
Investigators studying dyslexia have suggested the presence of a serious spatial orientation problem or a visual-spatial deficit resulting in taking longer to read than normal readers, by using additional longer fixations, poor saccadic control due to shorter or increased saccades (Prado, DuBois, & Valdols, 2007), and more regressions (Biscaldi, et al., 1998; Miles & Segel, 1929; Rayner, 1998). A reduction in saccadic eye movement frequency relates to gaining better control over fixation and tracking (Ayres, 2005; Cheatum & Hammond, 2000; McPhillips, Hepper, & Mulhern, 2000). Scores have been significantly lower on tracking, binocular depth perception, and focusing difficulty for students who were academically and behaviorally at-risk (Johnson, Nottingham, Stratton, & Zaba, 1996). Pavlidis (1981) documented an ocular motor disability for individuals with DD regarding inability to follow a sequentially illuminated light, and proposed using the light as a pre-reading diagnostic tool.

Facoetti, et al. (2000) investigated abilities for focusing and orienting visual attention using a simple detection task, and found a visuospacial automatic attention deficit while orienting the peripheral vision, with slower eye movement planning for children with DD. According to Van der Heijden, (1992) (as cited by Facoetti et al., 2000, p. 112) “a simple detection task allows the investigation of the simple allocation of spatial attention involved in orienting and focusing, excluding other attentional factors such as ‘expectation’ and ‘intention’, which would be otherwise present in a choice reaction task.”

For experiments #1 and #2, participants included 10 adults and 20 children with normal or corrected vision. The adults worked at the Neuropsychiatry Department in Bergamo, Italy (5 females, 5 males, average age of 30). The 10 children identified with dyslexia (3 females, 7 males, average age of 10), scored 2 standard deviations below normal on a reading test, were not taking medication, nor had any known sensory, neurological or emotional impairment. The
other 10 children (3 females, 7 males, average age of 9.4 years) were proficient readers. Children were matched with controls for IQ and age. Experiments #1 and #2 consisted of 144 trials arranged into two sections of 72 trials each, including 32 valid trials, 8 invalid trials, 20 neutral trials, and 12 catch trials (where there was no cue given, and it wasn’t necessary to respond), while the cue was only valid on 80% of the trials.

The first experiment wanted to address the automatic orienting of attention for children with dyslexia, proficient readers, and adults, for deficiency with the transient or magnocellular pathway. In a dimly lit room, participants were shown a cue (a white dot) in the visual peripheral field on a fixation point in the center of a monitor screen that was placed 40cm from their eyes, as their heads were on a headrest. Participants were asked to press a spacebar on computer to register their quickest responses, while the computer recorded their reaction times. There was a one second maximum time to respond.

The results for experiment #1 showed the reaction time for children with dyslexia to be slower than the normal readers and adults, and a cue in the peripheral area for the children with dyslexia did not attract attention. Experiment #2 was designed to investigate whether the group with dyslexic was generally unable to process the cue information, or if it was because the visual cue was shown in the periphery. Additionally, the conditions for experiment #2 were the same as experiment #1, except that the cue was an arrow shown above the central fixation point.

For experiments #1 and #2 the children with dyslexia generally responded slower than the adults and proficient readers, but showed evidence of voluntarily directing attention following the cue. The study suggested to question the hypothesis that children with dyslexia are not able to use the spatial information from a cue, or that a general attention disorder exists (Facoetti, et
The results support evidence for a specific automatic orienting deficit, most likely due to a dysfunction in the processing mechanism of peripheral signals.

Participants for experiment #3 were the same twenty children as in the previous experiments. For experiment #3 there were 152 trials in two sections of 76 trials each, with 30 trials including a small cue, 30 with a large cue and 16 catch trials. A pre-cue (a green dot) oriented the participants’ attention to the exact point where the cue (two white circles of different sizes) was shown “to orient subjects’ gaze to the precise point of the visual field where the cue would appear” (Facoetti, et al., 2000, p. 118), so then only focus had to be adjusted later for size. Findings for experiment #3 confirmed that the children with dyslexia generally read slower than proficient readers, and when presented a peripheral cue that they were unable to automatically shift their attention.

The authors suggested that the automatic orienting mechanism deficit could be due to impairment in the “1) a selective impairment of the ability to process peripheral visual onset stimuli, and/or 2) a reduced speed in the elementary operation of moving of attention...affect[ing] the planning of ocular movements that are essential for reading” (Facoetti, et al., 2000; p. 121). In addition, the children with dyslexia maintained focused attention for shorter time periods than normal readers, perhaps affecting the processing of visual information, and possibly affecting higher cognitive processing. Facoetti, et al. (2000) suggested that dyslexia might be an ocular fixation disorder, where laterally-distracting information is not ignored, so is distracting to the reading process.

Lateral visual disparities have been evident for dyslexia. “Without visual information, human subjects are not able to maintain displacement in a straight line” (Boyadjian, Marin, & Danion, 1999, p. 21). The results from Boyadjian, et al. (1999) suggested that “veering was the result of
a peripheral mechanism linked to an imbalance between the two sides of the body” (p. 23). For dyslexia, Facetti, Turatto, Lorusso, and Mascetti (2001) found “significantly slower reaction times in the left visual field than in the right visual field…[possibly] due to an asymmetric control of visual spatial attention” (p. 46).

It is critical to better understand interrelated neurological processes necessary for following the physical reading process. Brenner and Gillman (1966) stated, of the children surveyed, that visuomotor and visuospatial deficiency is associated with behavior disorders, and “clumsiness either in gait or movement, or in fine motor control, or both” (p. 700). Dare and Gordon (1970) emphasized, “children with visuo-motor disabilities are often in need of special help…and are often classified as having minimal cerebral dysfunction, minimal brain damage” (p. 178).

Posture, Ocular Motor Control, and Balance

The majority of sensory integration takes place in the brain stem where primitive postural reflexes change the effects of muscle tone in the entire body (Fiorentino, 1981). Horvat, et al. (2011) stated that the righting reflexes emerge from the brain stem, through the input of sensory information into the vestibular apparatus, for posture and vision. “Tilting (equilibrium) reactions…righting reactions and primitive reflexes are considered evoked responses” (Stuberg, Dehne, Miedaner, & Romero, 2010, p. 2). “Sensory information is…sent to the brain stem, which controls contraction of the appropriate postural muscles necessary to obtain upright posture. The brain stem also controls the visual muscles that fixate eyes while the head is moving” (Horvat, et al., 2011, p. 70). Horizontal eye movements are controlled by nerves in the brain stem (Martin, 1996). Results from Karnath, Reich, Rorden, Fetter, and Driver (2002) showed that when determining the “subjective straight ahead” some visual memory integrates with proprioceptive inputs, “and that this integration is sensitive to the delay over which the
visual memory must be held” (p. 357). Stoffregen, Bardy, Bonnet, Hove, and Oullier (2007) explained the relationship between posture and the visual: “overall results are not consistent with the view that eye movements and postural control compete for limited central processing resources. The results are consistent with the thesis of a functional integration of postural control with visual performance” (p. 86).

Reflex-based coordination assists infants at first with hand-eye coordination (ocular reflex), and then develops later with eye-hand coordination (Seaman, et al., 2007), possibly to facilitate reaching toward and ultimately touching an object they can see (Holt, 1991). The asymmetrical tonic neck reflex (ATNR) is closely connected to the early balancing system (Ayres, 2005; Cheatum & Hammond, 2000; McPhillips & Jordan-Black, 2007), with visuomotor responses for close-up vision occurring around the same developmental time. Horvat, et al. (2011) described the ATNR: “in a supine position [the ATNR] is elicited by rotation or lateral flexion (tilt) of the head leading to increased extension of the limbs on the chin side with accompanying flexion of limbs on the head side” (p. 73). The ATNR is typically inhibited, or incorporated into more sophisticated movement patterns by the second half year of life (Peiper, 1963). Initiating voluntary movement control includes inhibiting primitive postural reflexes (Horvat, et al., 2011).


Development of skilled, goal-directed movements requires complex and subtle postural adjustments involving the head, trunk, and limbs so as to maintain the body over its center of gravity…functions of postural control occur because of multisensory inputs regulating orientation and stabilization body segments, flexible postural reactions for balance recovery after disturbances, and anticipatory body segment positioning during
voluntary movements. The development and application of postural control mechanisms is dependent on spinal reflex activity…higher order adaptive mechanisms involving vestibular, visual, and somatosensory (proprioceptive and touch/pressure) systems as well as information processing in the cerebral cortex. Postural control development can be best described as a discontinuous, step-like process of integrating multiple sensory and motor systems, and the ability to incorporate new strategies into the repertoire for postural control. Hence, postural control development involves three components—perception (integrating sensory information); cognition (attention, motivation, information processing, and developing appropriate movement strategies); and action (generating muscular forces to control body position). The ability to modify both sensory and motor strategies to change task and environmental conditions develops in late childhood, thereby reducing the child’s ability to the environment until this time. (pp. 78 - 79).

In the developmental progression of muscle growth for the proximo-distal manner, or “from the center of the body outward” (Seaman, et al., 2007, p. 55), later-developing “distal muscles are generally used to produce finer gradations of force and are more difficult to control; thus, the use of distal muscle activity to regulate balance may represent a more refined and effective level of motor control” (Williams & Castro, 1997, p. 48). The postural control system for children with normal motor development in Williams and Castro (1997) demonstrated both proximal and distal leg muscle force activated when balance was perturbed, but distal muscles responded with additional force. Furthermore, the effects of vision influenced the order of muscle activation: “when the sensory framework for postural control is modified by removing vision….then] children with normal motor development continue to maintain a pattern of disto-proximal muscle activation” (Williams & Castro, 1997, p. 50).
The erector spinae (ES) muscles act to stabilize the trunk against gravity (Floyd & Silver, 1951). Comparing sitting and standing, Clair, Okuma, Misiaszek, and Collins (2009) examined the ES for regulating posture and balance, and found that ES muscles in the lower back responded through reflex pathways connected to the lower leg.

The neck is critical for considering the strength of the postural and balancing systems, including for vision. Haywood and Getchell (2009) explained balance as “refined control of degrees of freedom of movement in the neck” (p. 227). Karnath, et al. (1994) found “strong experimental evidence that neck afferent activity plays an important role in maintenance of posture, in ocular motor control, and in the perception of body orientation in space” (p. 144). Stoffregen, et al. (2000) recognized the effects of posture on vision: “Postural control can be used to improve visual performance” (p. 203).

Blood flow influences posture. Confirming results from their prior study, Vaitl, Mittelstaedt, and Baisch (1997), Vaitl, Mittelstaedt, Saborowski, Stark, and Baisch (2002) demonstrated that shifts in posture perception, with upward and downward shifts in head tilt, are influenced by shifts in blood volume distribution in the lower body; according to positive and negative blood pressure in the lower body traveling in and out of the thoracic cavity.

Boyd, Blincoe, and Hayner (1965) found evidence for the quadratus lumborum (QL) muscle, working in conjunction with the diaphragm, to support the breathing system. “The quadratus exerts a braking action to oppose the normal elastic recoil of the lungs during expiration” (Boyd, et al., 1965, p. 579). Chung, et al. (2004) found evidence that visuospatial performance improved with breathing additional 30% oxygen. The functional quality of the QL, influencing respiration, might also influence eye movement for reading.
Atypical Posture, Eye Coordination, and Movement; Body Asymmetry and LLI

Posture and movement influences have been examined for DD in relation to control groups. Pozzo, et al. (2006) identified postural and muscle tone impairment, with or without vision, for boys with DD. Balance deficits for children with DD (Moe-Nilssen, Helbostad, Talcott, & Toennessen, 2003) and adults with DD (Brookes, Tinkler, Nicolson, & Fawcett, 2010), including deficits in gait (Moe-Nilssen, et al., 2003), have been evident. Wolff (1990) found bimanual timing deficits for adolescents and young adults with DD, and Geuze and Kalverboer (1994) for children with DD and DCD.

Interference in the brain stem reaches to structural deficiencies. “Without an appropriate balance or postural framework, any number of action patterns could be expected to deteriorate” (Williams & Woollacott, 1997, p. 9). Seaman, et al. (2007) described the “structural interdependence” of the brain stem in relation to motor performance:

When the brain stem—the master control area for muscular activity—is performing its function adequately, performing on tasks such as moving through an obstacle course is controlled automatically, and the attention of the cortex can be directed to the planning, processing, and adapting required to complete the obstacle course successfully. If the brain stem is not doing its job, then the cortex or the conscious attention must be focused on the muscular activity rather than on planning how to get through the obstacle course, thus deterring or interfering with motor performance. (p. 155)

Integrating the function of the vestibular, tactile, proprioceptive, and visual sensory systems results in “praxis…the ability to plan and execute purposeful movement…for the necessary input and appropriate motor output” (Seaman, et al., 2007, p. 83). Furthermore, Seaman, et al. (2007) described “disorders in interpretation, assimilation, organization, and transmission of
sensorimotor information” can be demonstrated in some of the following characteristics of disordered praxis:

1) Clumsiness; 2) Messy handwriting; 3) Difficulty imitating movements; 4) Lack of body awareness; 5) Observable slow, deliberately sequenced (calculated) movements; 6) Poor fine motor coordination; 7) Poor gross motor coordination; 8) Poor eye-hand or eye-foot coordination; 9) Uneven or hesitant gait (p. 83)

Gubbay (1985) defined “clumsiness” as “a child whose ability to perform skilled, purposeful movement is impaired, yet whose motor coordination is virtually normal by the standards of routine, conventional neurological assessment, and who also has normal bodily habitus, intellect, physical strength and sensory function” (p. 159). Authors have compared children with “clumsiness” to similar characteristics of DCD (Dare & Gordon, 1970; Geuze, 2005; Gubbay, 1975; Huh, Williams, & Burke, 1998; Johnston, Burns, Brauer, & Richardson, 2002; Williams & Woollacott, 1988). Williams, Fischer, and Tritschler (1983) stated that muscular control did not show “a clearcut pattern of age-related development” for slowly developing children (p. 25). Delayed muscle timing responses for DCD have been evident (Williams & Castro, 1997; Williams, Woollacott, & Ivry, 1992). A distinguishing factor for the “clumsy child” is poor cocontraction for muscles, or “the inability to contract antagonistic muscle groups simultaneously” (Seaman, et al., 2007, p. 79). Geuze (2005) identified the most significant characteristics of poor control for DCD as “an inconsistent timing of muscle activation sequences, co-contraction, a lack of automatization, and slowness of response” (p. 194). In contrast to children with normal development, muscle activation for children with DCD demonstrated more frequent occurrence of a proximo-distal pattern when testing balance (Williams & Castro, 1997; Williams & Woollacott, 1997), and children with DCD sometimes
seemed “to need visual information and were unable to shift control from vision to other sources of sensory information when needed. This often resulted in postural responses that were either developmentally inappropriate or characteristics of central nervous dysfunction, or both” (Williams & Castro, 1997, p. 51).

Shoulder girdle, pelvic girdle, and trunk instabilities have been observed in “clumsy children” (Baker, 1981, p. 357). Johnston, et al. (2002) observed conditions for muscle activation in DCD:

Poor upper-limb coordination is a common difficulty…One hypothesis is that deviant muscle timing in proximal muscle groups results in poor postural and movement control…significantly [taking] longer to respond to visual signals and longer to complete the goal-directed movement…shoulder muscles, except for serratus anterior, and posterior trunk muscles demonstrated early activation. Further, anterior trunk muscles demonstrated delayed activation…anticipatory function was not present in three of the four anterior trunk muscles. These differences support the hypothesis that in children with DCD, altered postural muscle activity may contribute to poor proximal stability and consequently poor arm movement control when performing goal directed movement. These results have educational and functional implications for children at school and during activities of daily living and leisure activities and for clinicians assessing and treating children with DCD. (p. 583)

The oldest evolutionary animal reflex behaviors, usually present and necessary shortly after birth, do not always integrate into motor development to allow the emergence of volitional movement against gravity (Ayres, 2005; Horvat, et al., 2011; Milani-Comparetti & Gidoni, 1967; Seaman, et al., 2007; Silver, 1952; Stuberg, et al., 2010). Seaman, et al. (2007) indicated, “reflex inhibition, not disappearance, is accomplished in stages: not discretely designated, but
individually, developmentally sequenced” (p. 55). The primal brain stem reflexes that are most-likely to interfere with developmental motor learning, but if not inhibited, include: the tonic labyrinthine; asymmetric tonic neck [ATNR]; and symmetric tonic neck (Cheatum & Hammond, 2000; Horvat et al., 2011; Levine & Kliebhan, 1981). Horvat, et al. (2011) described conditions for persistent righting reflexes:

unable to run, change directions, and maintain body alignment in movement requiring proper head control. Without the persistence of these reflexes or any maturational delays, the reflex movements are replaced by equilibrium reactions. Reactions are automatic responses that proceed from reflexes as the individual’s central nervous system matures. These reactions allow individuals to maintain body support and to develop posture and balance control. Problems encountered in this stage of development include the inability to establish basic stability, body positioning, and muscle tone necessary for movement. (p. 72)

Additionally, the protective extension reflex might be lacking. Interference with the appropriate amount of movement development typically occurs with lacking of the protective extension due to a child’s propensity for getting hurt, and by avoiding movement to be “safe” (Seaman, et al., 2007, p. 78).

signals could delay development of muscular control of the eyes” (p. 159). Horvat, et al. (2011) explained some of the influences of a persistent ATNR on posture and eye movement:

Persistence of the reflex will cause difficulty in rolling, because the extended arm impedes rolling...the ATNR interferes with holding the head in the midline, resulting in visual perceptual problems commonly associated with tracking or fixating on objects. (p. 73)

Silver (1952) documented developmental postural and neck righting responses, connected to the occipital-sided arm extremity activated by left and right head rotation for children with organic brain disturbances and maturational lags. Rider (1972) studied early motor development and found a correlation between children with early primitive reflex integration deficits and poor academic achievement. Morrison (1985) observed the “extension of arm and leg on face side…and flexion of limbs on the occiput-side” (p. 49) when assessing for ATNR presence in children with LD. Overactive reflexes can interfere with refined movement needs such as reading and writing (Ayres, 2005; Cheatum & Hammond, 2000).

McPhillips and Jordan-Black (2007) compared core literacy skills in dyslexic and non-dyslexic poor readers with ATNR persistence in the general education setting from thirteen primary schools. ATNR persistence was also compared among groups of males and females, and in groups with social advantages compared to the socially disadvantaged. Participants were 739 children between the ages of 7 - 9 years (363 of 7 year olds, and 376 of 9 year olds).

At the end of school year, students were tested by experienced psychological educational testers for spelling, reading, and non-word reading, verbal IQ, and were videotaped for accuracy while assessed during clinical diagnosis for ATNR persistence. Results indicated that ATNR persistence was a strong predictor of reading, spelling, non-word reading, and of verbal IQ attainments, with 62% of the students showing high levels of reflex persistence in the bottom
10% of reading level. No differences were determined between students with dyslexia and poor readers. In addition, results revealed males with higher levels of persistent ATNR than females, and socially disadvantaged children exhibited higher levels of persistent ATNR than without social disadvantages.

McPhillips and Jordan-Black (2007) proposed that many students in general education settings might be influenced by a "brainstem mediated reflex system that should have been inhibited in the first year after birth" (p. 748), and they suggested that the term *dyslexia* is not a specific category of poor readers based on IQ scores, but perhaps it is best to use the term *dyslexia* to describe poor readers. “Reflex persistence…may be viewed as an early developmental risk factor for some children where subsequent effects are dependent on the interplay of a range of cognitive, environmental, and biological factors” (McPhillips & Jordan-Black, 2007, p. 753).

Shaheen (2010) stated that persistent ATNR, and apraxia tests were predictors of dyslexia. Teitelbaum, et al. (2004) found evidence to suggest that persistent ATNR evaluation can be used as an early pre-language indicator for autism.

Typically, in the ATNR response for children with cerebral palsy the arm and leg contract on the opposite side of the direction the head is turned (Goddard, 2002; Haywood & Getchell, 2009; Hoskins & Squires, 1973). “Some ['clumsy children'] demonstrate patterns of movement or balance responses suggestive of a minimal cerebral palsy” (Baker, 1981, p. 357). Dare and Gordon (1970) stated that the study of “‘clumsy’ children with visuo-motor disabilities confirms that…some may show evidence of minimal cerebral palsy, while others may present a specific disability, apparently affecting only the acquisition of skilled movement” (p. 181). Gubbay (1985) recognized mild symptoms of cerebral palsy that might influence learning:
Although anoxic birth injury has been implicated as the fundamental aetiology [sic] in most patients with cerebral palsy, there must be many which are due alternatively to cerebral maldevelopment. Very mild degrees of cerebral palsy without overt evidence of the hallmarks of weakness, spasticity and involuntary movements may result in ungainly motor activity possible partly due to impairment of perceptual abilities. Paradoxically, the child with no conventional neurological signs of cerebral palsy may manifest defects of motor functioning of greater personal impact than cerebral palsy and which interfere more profoundly with function of learning and performance. (pp. 162 - 163)

Some researchers have concluded that balance deficiencies for “clumsy children are more related to dysfunction of the motor control system than to a delay in the development of the system” (Williams & Woollacott, 1997, p. 20). Bilateral motor coordination seemed to be evident for children with and without DCD around the age of six, although only children with DCD demonstrated balance control problems showing significant inefficiency in organizing bilateral muscular activation responses, temporal inconsistencies, and use of “different motor-control strategies” than normal children (Huh, Williams, & Burke, 1998, p. 483). Williams and Woollacott (1997) found that only selected deficits of neuromuscular postural responses for “clumsy children” were evident when studying leg muscle responses (p. 21). So, the authors stated that they could not conclude that “the motor control deficits of these children lie solely within the postural control system…[but, perhaps] could be related to a more general problem of timing of all movement sequences” (Williams & Woollacott, 1997, p. 21). Larger amounts of muscular activity for leg and trunk muscles were evident for children with DCD attempting to hold a quiet stance, than the control group (Williams, et al., 1983). In Williams (1999), as cited in Cermak & Larkin (2002) control children activated postural control in the order of:
ankle, upper leg, trunk, and neck; whereas children with DCD activated postural control in the order of: upper leg muscles, ankle muscles, trunk and neck (pp. 132 - 133).

Bove, Diverio, Pozzo, and Schieppati (2001) described, “Neck muscle vibration disrupts steering of locomotion” when human neck muscle vibration was used to examine the influences of atypical neck proprioceptive input for the organization and execution of gait (p. 581). Muscle length of ES, and leg length have been investigated for analyzing and comparing gait in children to quantify “physical handicap” (Butler, et al., 1984, p. 607). In contrast to children without DCD, children with DCD displayed varied ES muscle timing when responding to visual prompts for postural muscles (Johnston, et al., 2002). There has been a comparison between LLI and the endurance of the ES and the QL (Knutson, 2005).

Head tilt, shoulder and hip imbalances, and leg length disparities have been investigated for muscle strength discrepancies (Kendall, Kendall-McCreary, Provance, Rodgers, & Romani 2005), and according to Lasko and Aufsesser (n.d.) (as cited in Horvat, Block, & Kelly, 2007), for postural instability. Problems with postural control can be influenced by musculoskeletal limitations of strength or range of motion in joints of the upper or lower extremities and trunk, and can negatively impact cognition (e.g., memory, attention, spatial relations, body schema, and praxis) (Horvat, et al., 2011).

The dysfunction resulting in leg length equality might be strongly connected to structural and postural impairment for individuals with LD. Boyadjian, Marin, and Danion (1999) studied the properties of correcting body orientation, and found, “systematic deviations occurring in two-limb displacements originate from a peripheral mechanism (slight different properties of the right and left limbs) rather than a central mechanism (systematic bias in the perceived body trajectory)” (p. 21). “The spine, pelvis, and lower extremities are all involved in the
compensation of limb-length asymmetry. The symptoms associated with limb-length discrepancies are often due to the mechanisms involved in trying to equilibrate functionally the asymmetry” (Kaufman, Miller, & Sutherland, 1996, p. 149). When participants were walking blindfolded, Lund (1930) observed a correlation between the structural and functional strength of a shorter or longer leg, and the tendency to veer in the opposite direction as the shorter leg. Kaufman, et al. (1996) found a connection with LLI and gait: “as the limb-length inequality increased, the degree of gait asymmetry also increased” (p. 146).

Anatomical leg length inequalities have been addressed by orthopedic surgeons for many years (Carpenter & Kirk, 1952), and differences between anatomical and functional leg length disparities have been examined (Eichler, 1977; Gurney, 2002; McCaw & Bates, 1991; Reid & Smith, 1984). Eichler (1977) defined “functional length” as “leg shortening or lengthening caused by joint contractures or by axial malalignment” (p. 30). Injury or compromise to central nervous system pathways can result, as muscles on one side of the body tighten, creating leg length disparity (Bakris, et al., 2007; Knutson, 2001; Rochester, 2009); referred to as a functional, opposed to anatomical, leg length inequality (Eriksen, 2004; Thomas, 1991).

Methods for assessing LLI have been investigated (McCaw & Bates, 1991; Sabharwal & Kumar, 2008). Measuring pelvic crest height alignment has been implemented for establishing leg length discrepancy (Petrone, et al., 2003), with heel comparison (Gregory, 1979). Lateral pelvic imbalances have been evident for school children to distinguish asymmetries in leg length inequality (Klein & Buckley, 1968; Pearson, 1951). “Femur head lowness, commonly termed ‘leg shortness’…[was] visualized in 80 per cent of rural school children between the ages of 5 and 13” (Pearson, 1951, p. 166). According to Lasko and Aufsesser (n.d.) (as cited in Horvat, et al., 2007; P. Aufsesser, personal communication, October 4, 2010; M. Horvat, personal communication,
September 28, 2010), the San Diego State University Adapted Physical Education Posture Evaluation checks a short leg according to the evenness of popliteal creases [in the back of knees] (Horvat, et al., 2007, p. 145). In Fong, Mak, Swartz, Walsh, and Delgado-Escueta (2003), brain imaging was used for differentiating body asymmetry, and found that evaluating popliteal crease levels for shorter or longer legs to be useful for examining possible origins of seizures. Reinhart, et al. (2006) examined leg length, and atypical gait patterns in children with autism:

Spatiotemporal gait data for children with autism were compatible with findings from patients with cerebellar ataxia: specifically, greater difficulty walking along a straight line, and the coexistence of variable stride length and duration. Children with autism were also less coordinated and rated as more variable and inconsistent (i.e. reduced smoothness) relative to the comparison group. Postural abnormalities in the head and trunk suggest additional involvement of the fronto-striatal basal ganglia region.

Abnormal gait features are stable across key developmental periods and are, therefore, promising for use in clinical screening for autism. (p. 819)

Esposito, Venuti, Maestro, and Muratori (2009) detected lower levels of symmetry (LLS) for infants with ASD lying in a supine position, and suggested that LLS might be used to define subgroups of ASD in the early months of life.  de Quirós (1976) described the usefulness for connecting symptoms for infants related to atypical vestibular function, with LD later in life: equal or different arm abduction, homo- or heterolateral raising of arms or legs, sternocleimastoid contraction, tonus modification, trunk position, need for visual support…can provide extremely valuable medical data. This information is particularly helpful in the diagnosis of some learning disorders, especially those in vestibular disabled children. (p. 44)
Upper Cervical: Correction

Upper cervical research has been connected to brainstem responses. It is suggested that positive effects from chiropractic care for individuals with dyslexia, speech disorder, learning disabilities, and correcting vertebral subluxation have improved cognitive functioning (Lerner & Lerner, 2009; Pauli, 2007).

Since the 1940s, investigators have used physics and mathematical measurements in increments of degrees to examine the upper cervical placement of the atlas bone, or 1st cervical vertebra (Eriksen, 2004). The atlas encircles the spinal cord under the medulla, the lowest part of the brain stem (Martin, 1996). The atlas, in its central position, relative to the gravitational vertical, orients the central axis, balance and weight of the skull, including the spine, shoulders, and pelvis below. The atlas relies on soft tissue for support, so it can be displaced or subluxated from its central position, as the head tilts and the brain stem becomes compressed (Bakris, et al., 2007). “Persistent tilt of the head is abnormal at any age” (Rabe, 1969, p. 70). The visceral sense is located in the brain stem for regulating blood flow (Ayres, 2005; Edwards, et al., 2007; Knutson, 2001). Martin (1996) described that “occlusion of the vertebral artery can produce discrete set of limb and sensory motor signs” (p. 401). According to Kendall, et al. (2005), “Pelvic rotation or lateral tilt will change the relationship of the pelvis to the extremities enough to make a considerable difference in measurement” (p. 438).

There are some that support the fact that contracted reflex muscles occurring on one side of the body for an atlas displacement are associated with a rotated or torqued atlas activating the ATNR (Knutson, 1997; Knutson & Owens, 2005); influencing differences in lateral awareness and reduced blood flow. Bakris, et al. (2007) stated, “Anatomical abnormalities of the cervical spine at the level of the atlas vertebra are associated with relative ischaemia of the brainstem circulation.
and increased blood pressure. Manual correction of this malalignment has been associated with reduced arterial pressure” (p. 1). Presently, there has been investigation showing good interexaminer reliability in discriminating LLI for upper cervical structural instability (Woodfield, et. al, 2011; C. Woodfield, personal communications, October 15, October 16, November 5, November 19, November 25, November 29, 2009, January 16, October 25, November 25, and December 20, 2010).

Bakris, et al. (2007) proposed that correcting misalignment of the atlas, reduces and maintains lower blood pressure, increases blood flow, and lengthens a functional short leg; by assessing alignment of the pelvic iliac crests with a heel position comparison for leg length disparity (Gregory, 1979). Bakris, et al. examined 50 patients (26 drug naïve, and 24 with washed out systems) who were: a) between 21 and 75 years; b) positive for a preliminary screening of atlas misalignment (with comprehensive X-ray analysis determining head tilt [based on three dimensional physics and mathematical calculations relative to the center of gravity axis of the skull; S.N. MacDonald, personal communication, November 12, 2009]), and a supine contracted leg length check (comparing heel positions when patients turned their heads to the far right and left); and c) documented with a history of Stage 1 hypertension. Participants were excluded if there was: a) no evidence of atlas subluxation; b) stage 2 or higher hypertension, and/or with prescription for two or more antihypertensive medications; c) not with the capacity or willingness to suspend anti-hypertension treatments for the duration of the screening; d) with a second or third degree heart block; and e) with history of a recent stroke or cardiovascular surgery in the last 12 months. The selection process was random, and double blind with a placebo controlled group. Participants took part in an official blood pressure check, and NUCCA [including UCRF] X-ray analysis, and all 50 finished the study.
The participants were manually adjusted for a difference in both a rotational and lateral central atlas positioning on a low adjusting table. For 8 weeks, patients showed the atlas holding position, and a reduction in blood pressure with no detrimental effects. The conclusion indicated that the restoration of an atlas misalignment related to substantial and ongoing reductions of blood pressure; similar to using a two-drug combination therapy (Bakris, et al., 2007).

The atlas, in its central position, relative to the gravitational vertical, orients the central axis, balance and weight of the skull, including the spine, shoulders, and pelvis below. McKnight and DeBoer (1988) found evidence for blood pressure changes, and Scott, Kaufman, and Dengal (2007) for blood flow, with chiropractic manipulations of the atlas. Knutson (2001) studied the effect of a vectored atlas correction affecting an abrupt drop in blood pressure, perhaps due to a cervico-sympathetic reflex stimulation, relaxing muscle tone, and the releasing of pressor reflex effects.

Ahmetoğlu, et al. (2003) investigated the effects of an antihypertensive drug for extraocular muscles in patients with hypertension. "These findings suggest that blood flow in the extraocular vessels decreased due to increased peripheral resistance in hypertensive patients" (Ahmetoğlu, et al., 2003, p. 182). Relieving hypertension might coordinate peripheral vision for extraocular muscles.

Relaxing lateral muscles typically result in lengthening the shorter leg of a LLI. Aligning the skeletal system might have beneficial effects by reducing brainstem compression for improved sensory organization, and increasing blood flow for strengthening the vulnerability of postural and eye movement systems for reading.
Summary

The U.S. civil rights history in the past fifty years was influential for upholding important basic human rights for individuals with disabilities, with the idea of addressing special needs by formulating special education law (Friend & Bursuck, 2002). The medical and educational fields were initially consulted in the beginning efforts to identify LD, and even though the medical field identified children with LD as having minimal neurological dysfunction or MBD, special education law was formulated according to the recommendations by educators to base identification of individuals with LD on functional educational diagnostic information, as a heterogeneous group, and without considerations regarding neurological conditions (Haring & Bateman, 1969). Visser (2003) stated, “In later years, the terminology used to describe these children changed from MBD into ‘Deficits in Attention, Motor Control and Perception’ (DAMP)” (p. 486), attributable to brain dysfunction involving an “automatization deficit” (p. 489).

Historically, varied disciplines have outlined neurological symptoms for individuals with LD or reading difficulties (Ayres, 1980; Brodney & Kehoe, 2006; Bruininks, 1978; Decker, 2008; de Quirós, 1976; Godfrey & Kephart, 1969; Habib, 2000; Johnson, et al. 1996; Kephart, 1964; MBD Compendium, 1974; Menghini, et al. 2010; Miles & Segel, 1929; Morrison, 1985; Nicholson & Fawcett, 2009; Orbrzut et al., 1983; Punt, et al., 2010; Rider, 1972; Roach & Kephart, 1966; Silver, 1952; Strauss, 1943). Motor coordination deficits are sometimes misinterpreted to mean that a child is not trying hard enough. “Often parents think their child is being naughty or lazy, and this increases the pressures he is already under” (Baker, 1981, p. 356).

To compound the confusion for LD, it has been demonstrated that so far there are no sufficiently reliable academic assessments tools that determine identification for individuals with LD (Reynolds & Shaywitz, 2009; Stuebing, et al., 2009). Current LD identification does
not reflect the developmental continuum, by examining the developmental step progression of the lower CNS influencing the higher CNS cortical structures. By now the perspective of the medical community has been reflected into the fields of physical education and APE (Horvat, et al., 2011; Kovar, et al., 2007; Winnick, 2005). Evidence shows common physical symptoms for children with LD and DCD according to insufficiencies occurring during atypical neurological motor development; persistent primitive reflexes with hypo- or hyper-sensory responsivity affecting poor muscle tone, lateral disparities, balance deficits, postural instability, and eye muscle weakness (Cheatum & Hammond, 2000; Horvat, et al., 2011; Rabe, 1969; Seaman, et al., 2007). Levine and Kliebhan (1981) described, “The posture and movement problems of children with neuromotor handicaps affect their social, perceptual, cognitive, verbal, linguistic, and emotional development” (p. 209).

Pearson (1951) recognized the importance of early intervention: “Problems of structural [postural] nature, serious but not producing symptoms…suggest the need for routine structural examination…during the preschool years or during the first year of school” (p. 166). Cherng (2007) emphasized that poor balance control for children with DCD is “more likely due to a deficit in sensory organization than compromised effectiveness in individual sensory systems. It is important that such deficits be identified at an early stage in a child’s development” (p. 925). Horvat, et al. (2011) described the importance of addressing “soft neurological signs” for children in a timely manner, so that neuroplasticity can be utilized for learning:

The most important thing to remember about neurological dysfunction, or soft neurological signs, is that some damage has occurred to the brain. If teachers can address the specific problem area early in the child’s development, other areas of the brain may take over impaired functions before the process of mylinization takes place. (p. 138)
Understanding the physiology of movement plays an important role for the outcomes of appropriate educational planning (Levine & Kliebhan, 1981). Any therapeutic program to improve balance control should implement a multisensory approach with repeated opportunities for the child to incorporate and refine vestibular and proprioceptive information (Williams & Castro, 1997). Extensive, regular, and systematic opportunities of carefully designed therapeutic activities to strengthen distal muscle control should be given to children with DCD (Williams & Castro, 1997, p. 52; M. Karwas, personal communication, September 15, 2011), including varying “levels of force production (e.g., minimal, mild, moderate, maximal)” (Williams & Castro, 1997, p. 52). Levine and Kliebhan (1981) formulated a prescription to be used to identify developmental motor disparities, including assessing for: 1) postural tone; 2) movement patterns; and 3) primitive, postural, and abnormal qualities for reflexes and reactions (pp. 209 - 210). Additionally, they addressed the significance of recognizing persistent reflexes: “when accompanied by increases in tone and seen in an exaggerated, obligatory form…[they] are again useful for diagnosis” (p. 210).

The importance of motor function deficits are now recognized as “pervasive across diagnoses, thus, a cardinal feature of ASD” (Fournier, Haas, Naik, Lodha, & Cauraugh, 2010, p. 1227), being relevant for psychologists diagnosing autism (Dowd, Rinehart, & McGinley, 2010), and with the strong need for interventions (Bhat, Landa, & Galloway, 2011). Reed (2007) suggested the importance of early detection of persistent primary reflexes for Autism Spectrum Conditions:

If persistent Primary Reflexes [including ATNR] that predict the possible development of ASC-related behaviors, and ASC itself, could be inhibited by approaches that are known to help with the removal of Persistent Primary Reflexes, this might allow the development of a preventative intervention for some aspects of ASC that could be taken long before the
typical point of diagnosis of ASC. That is, the potential precursors of ASC problems may be remediated long before they impede typical development. (p. 22)

It is important to acknowledge the integral learning processes of reading with writing (Cecil, 2003). Assessment for developmental dysgraphia has been investigated (Gubbay, 1995). Impairment to a child’s fine motor control would be influenced by lower CNS structures including, balance disorders and delays in gross motor development (Baker, 1981; Johnson & Williams, 1988). Baker (1981) indicated that children with gross motor disparities might have difficulty copying postures that might translate to “higher perceptual processes of space and form relationships,” including poor ability for copying letters (p. 360). Cermak and Larkin (2002) recognized muscle tone and weak pencil grip for problems with handwriting for children with DCD, “despite meeting early intervention goals in foundation motor skills, most children with DCD encounter serious problems with writing” (p. 257). Johnson and Williams (1988) explained that hand use might be distracted by postural responses:

A child with inadequate postural control may…have difficulty producing the additional muscular activity needed to maintain a stable sitting posture and also use the hands to perform a task skillfully. For such children, sitting unsupported may require conscious attention or even use of the hands to maintain balance. Thus, minimal energy may be available for controlled activity of the distal musculature. (p. 25)

Lee, Yoo, and Lee (2010) studied treatment to improve the ATNR influence on muscle weakness in dominant-hand grip strength, while Ocklenburg, et al. (2010) evaluated detected head tilt for infants, and supported that “increased visual control of the hand during early childhood seems to modulate handedness” (p. 447).
Much emphasis in the academic field has to do with awareness of the quality of articulating sound for the beginning reader (Shaywitz, et al., 2007). Dyslexia has been explored according to brainstem responses affecting central auditory function (Banai, et al., 2009; Banai, Nicol, Zecker, & Kraus, 2005; Billiet & Bellis, 2011). It is possible that “these findings are among the first to establish a direct relationship between subcortical sensory function and a specific cognitive skill (reading)…this cortical-subcortical link could contribute to the phonological processing deficits experienced by poor readers” (Banai, et al., 2009, p. 2699). Roth, Muchnik, Shabtai, Hildesheimer, and Henkin (2012) found first evidence of atypical auditory brainstem responses “already apparent in young children with suspected ASD and language delay” (p. 23). Relieving brainstem compression would be important to investigate for delayed speech-motor articulation; possibly connected to poor muscle tone.

Eye movement disparities have been the focus of research for dyslexia (Biscaldi, 1998; DeLuca, et al., 2002; Facoetti, et al., 2000; Facoetti, et al. 2001), and for autism regarding deficiencies in “broadening the spread of visual attention” (Mann & Walker, 2003). Vogel (1995) presented a review of theory, testing, and therapy for eye saccades by evaluating eye-tracking for reading disabilities and academic success, with suggestions for successful eye muscle strengthening techniques. Brodney and Kehoe (2006) investigated assessing eye movement vulnerabilities with dyslexia, and showed significant potential for elementary school teachers “to identify children at-risk for related vision problems” (p. 13).

Physical fitness has been linked to the prefrontal and parietal cortices brain regions for inhibitory functioning and spatial selection (Colcombe, et al., 2004). Motor development and cognitive development have been correlated with activation of the prefrontal cortex and the cerebellum (Diamond, 2000). Some studies have investigated the possible relationship of
physical exercise on cognitive thinking, but positive results have varied (Hill, et al., 2010; Hillman, et al., 2008; Reynolds & Nicolson, 2007; Tomporowski, et al., 2008; Zagrodnik & Horvat, 2009). Exercise treatments have shown gains for phonology, speech/language fluency, working memory, motor skill, and “highly significant reduction in the incidence of symptoms of inattention” related to DD (Reynolds & Nicholson, 2007, p. 78). Students with ADHD and autism have seen significantly improved focusing ability by implementing movement and other intense sensory experiences (Sousa, 2006).

There have been critics regarding sensory integration through perceptual-motor movement techniques for individuals with LD (Hoehn & Baumeister, 1994; Kavale & Mattson, 1983; Stephenson, Carter, & Wheldall, 2007). Doubt exists regarding some study assessments that might be comparing items that are unrelated. According to Tomporowski, et al. (2008):

> A plausible explanation for researchers’ failure to detect the effects of exercise on children’s intelligence is that IQ tests provide only global measures of functioning, which may not be sensitive enough to detect subtle changes in specific aspects of cognitive functioning brought about by exercise training. (p. 117)

Additionally, there are cross-disciplinary criteria for understanding cognition. “Comprehensive theories have yet to be formulated that address numerous contextual and psycho-social factors that may moderate or mediate the relation between exercise and children’s cognitive function.” (Tomporowski, et al., 2008, p. 126).

Zagrodnik and Horvat (2009) stated that there is a lack of research investigating exercise and cognition for students with developmental disabilities, perhaps due to the lack of control for exercise frequency, type, intensity and duration, and pre-determined heart rate level. “Developing studies where the intensity of exercise is known throughout the intervention is
critical” (Zagrodnik & Horvat, 2009, p. 280), and continued on to address the concern that comorbidity among populations of individuals with disabilities are “major roadblocks for the generalizability of the research findings on, not only the impact of exercise on cognition, but any investigation in these populations” (Zagrodnik & Horvat, 2009, p. 282). Furthermore, Zagrodnik and Horvat (2009) advocated utilizing the influences of nutrition and exercise for understanding the impact of developmental movement on cognition, and the necessity for using double blind studies in the future.

Although there is evidence of pediatric musculoskeletal examination to include LLI (Jandial & Foster, 2007), presently, LLI is not a procedural pediatric assessment (B. Bannon, personal communication, November 7, 2009; Stanford Pediatrics, Los Gatos, California, personal communication, November, 2009), nor for occupational therapy (T. Ammon, personal communication, October 22, 2009). In physical therapy there is LLI assessment measuring from the umbilicus to the medial malleoli (Kendall, et al., 2005; E. Folkins, personal communication, September 23, 2009; R. Croce, personal communications, October 8 and 12, 2010). Aligning the medial malleoli, as a marker for determining functional LLI, has been investigated for the NUCCA/UCRF SLC procedure (S.N. MacDonald, personal communications, November 12, 21, & December 21, 2009, January 18, August 8, & October 8, 2010).

There is evidence to support that a functional LLI is specifically due to an atlas displacement (Bakris, et al., 2007; Eriksen, 2004; Thomas, 1991; Woodfield, et al. 2011) possibly influencing an ATNR (Knutson, 1997, 2005), with this evidence showing that brain stem responses are closely linked to eye movements (Kulkarni, et al, 2001), and eye movement strength (Ayres, 2005; Cheatum & Hammond, 2000; Horvat, et al., 2011; Seaman, et al. 2007). Presently, there is evidence that the most influential vestibular sense relies on leg position (Grasso, et al., 2011).
“It may well be that somatosensory leg afferents act at the cerebellar level by tuning the neuronal responses to vestibular stimulation” (Grasso, et al., 2011, p. 312). It seems plausible that correcting LLI might improve the most influential vestibular response.

Martin (1996) described investigation regarding the influence of the upper cervical nervous system pathways on the legs, and a possible influence for LLI: “Animal experiments…have shown that propriospinal neurons located in the upper cervical spinal cord can transmit control signals from the medial pathways to more caudal levels…thus, pathways terminating in the cervical cord may also influence trunk and lower limbs muscles” (p. 260). Additionally, Martin (1996) stated the importance of lessening the obstruction of cerebral blood flow: “occlusion of the vascular supply to the midbrain produces a complex set of neurological deficits that disrupts eye movement control, facial muscle function, and limb movements” (p. 412). Brownlee, Flatt and Miller (2004) found that “Intraocular pressure was significantly reduced, and pulsatile ocular blood flow was significantly increased, following moderately intense exercise” (p. 44). Areas of “brain blood flow abnormalities” (Burroni, et al., 2008, p. 155) have been apparent for children with autism, especially relating to language and understanding sounds and music (p. 150). The suggestion of a left-hemisphere blood flow anomaly for adults who had DD as children (Flowers, Wood, & Naylor, 1991) might be connected to head tilt associated with an atlas displacement.

Presently, speech and language therapist services have been cut from budgets, so students are not receiving adequate time allotted for sufficient movement outcomes (retired Veteran Speech and Language Pathologist, personal communication, December 20, 2011). Currently, the educational system is not set up to assess for LLI or an atlas displacement, and if an LLI condition were recognized, it would be necessary to be designated on an IEP; ultimately school districts would be responsible for treatment costs. Most likely it will be a long time into the
future before X-ray technology, or a safer alternative, is incorporated into educational assessment, but in the meantime it is relevant to acknowledge the effects of head tilt, pelvic, shoulder and hip imbalances, possibly associated with an atlas displacement. Early LLI screening might provide opportunities for referrals to treatment for an atlas displacement. Perhaps, if LLI were incorporated into the framework for developmental educational screening assessments, classroom learning environments might ultimately reflect the importance of movement by incorporating persistent primitive reflexes into more sophisticated developmental movement patterns, and the overall affects on strengthened muscle tone and increased cerebral blood flow might become more evident. Developmental movement activities for the classroom (Cheatum & Hammond, 2000; Colvin, Markos, & Walker, 2008; Horvat, et al., 2011; Kovar, et al., 2007; Seaman, et al., 2007) might be regularly incorporated into classroom teachers’ lesson plans via identifying LLI.

In the future, educational support teams and parents might be trained to assess the relationship between a persistent ATNR and LLI, as a screening tool for reading success. Perhaps, collecting LLI data eventually might be able to easily document and distinguish relevant neurological patterns for individual struggling readers, eventually resulting in reducing school district costs by averting more expensive and time-intensive identification processes and treatments. Addressing the importance of a sound visual system might reflect a better understanding for more immediate benefits for all students’ reading abilities, and ultimately for their quality of a functionally independent life.
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APPENDIX A

Neurological Evaluation
APPENDICES

Appendix A—Neurological Evaluation
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The examination begins with observation of the general appearance, attitude, affect, and spontaneous activity of the child together with observations of his attention span, distractibility, impulsiveness, and ability to adapt to the examination and to the examiner. It is important to observe not only what tests the child accomplishes but how he accomplishes them.

A standard neurological examination is performed in which the following functions are evaluated: Cranial nerves I through XII; motor system—tone and strength; sensation—vibration, position, touch, pin; cerebellar testing; and reflexes—stretch and cutaneous.

COMMENTS ON SPECIAL PROCEDURES

1. Inattention, distractibility, and failure of eye-head coordination can be elicited by double simultaneous stimulation of the peripheral visual field. By 5 years, the patient should be able to indicate by pointing that both the examiner’s fingers are moving. Abnormal testing occurs when the patient persistently looks to either or both sides as soon as the examiner’s fingers move.

2. Eye movements.
   (a) Extraocular movements during visual pursuit of a 1-centimeter disc are smooth after 18 months of age. Horizontal jerking or saccadic extraocular movements are abnormal if persisting after this time. Visual pursuit associated with persistent head following is abnormal after 6 years of age.

   (b) Optokinetic nystagmus (OK nystagmus)—OK nystagmus is elicitable at any age. Normally the patient follows in the direction of motion of the moving figures with quick eye jerks occurring rhythmically in the opposite direction. The speed of the jerks varies with ability to sustain attention, and with increasing age, becomes faster. Abnormality occurs when the OK nystagmus is absent or when there is a persistent asymmetry of rate when response to movement of the targets towards one side is compared with response of movement toward the opposite side.

   3. Facial apraxia: Blowing out of cheeks can be performed uniformly and alternately after 9 years of age. Facial apraxia is present if the patient is unable to perform this test over the age of 9 years.

   4. Hearing: Weber and Rinne tests are performed using a 1024 and air conduction is tested with a 4096 cycle per second tuning fork.

   5. Pronunciation: Labials, linguals, and gutterals should be well performed by 3 to 4 years. Inability suggests a lingual apraxia.

   6. Simultanagnosia: Double simultaneous stimulation testing is performed with the patient’s eyes closed and stimulation with the examiner’s finger four times on the following sites in variable order: Hand-hand, right hand-left face, left hand-right face. By 5 to 6 years, the normal patient makes no more than one error out of 12 stimuli.

   7. Performance of repetitive motions.
   (a) Serial apposition of thumb and fingers, alternating pronation and supination of the hands, and repetitive heel-shin tapping are normally done slowly and with little or no rhythm at 3 years of age, but deliberately and with slow rhythm by 5 years of age. Abnormal performance is slow, not rhythmic and a quality to note is the persistence of avoiding response predominating over the developing flexion ability as the patient performs the test.

   (b) Clumsiness, tremor, and ataxia can be elicited in patients at 3 years by having the child place marbles in a cylinder, the diameter of which is slightly larger than the marbles. A smooth, fairly rapid performance is normal by 3 years of age.

   (c) Synkinesias.

   (i) With finger tapping, serial apposition of fingers, and alternating supination and pronation in one hand, similar but less marked motions occur in the opposite hand up to 9 years. Such synkinesias persisting after 9 years are abnormal.
ii. Heel tapping on opposite shin associated with persistent motion of the tapped leg of variable degrees occurs normally until 8 years.  

8. Posture and gait.  
(a) Posture.  
(i) Resting, supine: When a child automatically assumes the infantile posture of bilateral symmetrical abduction of the shoulders, partial flexion of arms and forearms, this is abnormal after 2 years of age.  
(ii) Sitting.  
   a. Persistent tilt of the head is abnormal at any age.  
   b. When asked to extend the arms and hands before them, a tendency to pronation of the arms and spooning of the fingers all exaggerated by contact stimulation of the ulnar side of the hand is abnormal over 5 years, although this activity may persist to a mild degree in the nonpreferred hand for many years.  
(b) Gait.  
   (i) The examiner should watch and listen to the patient’s gait noting the symmetry of step, symmetry and quantity of associated movements of both arms, and listen to the sound of each footfall. Asymmetry suggesting minimal hemiparesis can be documented.  
   (ii) Toe walking: When the child walks on his toes for a minute or more, one can bring out sagging of one heel, a sign of weakness not easily elicitable otherwise in younger children. Asymmetry of arm swinging, persistent flexion of arm and forearm, or accentuated extension of arms is abnormal at any age.  
   (iii) Heel walking: This not only brings out weakness of dorsiflexion of the foot but clumsiness and associated movements consisting of shoulder abduction, arm and forearm flection and spooning of the fingers. These postures are abnormal after 5 years, or if exaggerated are abnormal before this time.  

9. Visual-motor skills: The patient is asked to copy the following figures and should do so normally by the stated time.  
   Scribble—18 to 24 months of age.  
   Circle—24 to 36 months of age.  
   Cross straight line, vertical, and horizontal—3 years of age.  
   Square with rounded corners—3½ to 4 years of age.  
   Square—5 years of age.  
   Triangle—5 to 6 years of age.  
   Diamond—7 to 8 years of age.  

10. Conception of spatial relationships.  
(a) Three-dimensional square, circle, triangle (2½” x 2½” x 3½”) are placed on heavy, black-lined tracings made on three separate, standard-sized papers. The normal performance consists of the following: Stacks all figures on one paper after one demonstration, 21 to 28 months; places any form on any figure, 24 to 30 months; places forms on appropriate figures after one demonstration, 30 to 36 months.  
(b) French curve (dimensions 3½” x 5” x 3½”) is to be placed on a heavy black-line tracing of the curve on paper. The traced outline of the curve is presented sequentially in three different positions of orientation, and after each presentation the subject is to place the curve appropriately on the outline. Normal performance consists of the following—after verbal instruction and without prior demonstration: One correct trial of three trials, 48 to 52 months; three correct trials of three trials, 54 to 60 months.  

11. Right-left orientation: The child can name his right and left eye, ear, hand and foot by 7 to 8 years of age.  

12. Auditory and visual word association and language use. Picture naming: test pictures consist of house, cup, leaf, dog, flag, star, basket, clock, shoe, and book. Normal performance: 18 months—names or points to one picture; 24 months—names three points; 24 months—names five, points seven; 36 months—names eight; 40 months—names 10.  

(a) In-between test: With the patient’s eyes closed, one touches the distal phalanges of two fingers of one hand simultaneously and asks how many fingers are in between those touched. A visual demonstration is given first and five trials are made on each hand.  
(b) Two-point test: One touches with two fingers two points simultaneously on either one or separate fingers of one hand. Following a visual demonstration, the subject is to identify whether one or two fingers have been touched. Five trials are made on each hand. Normal standards: 50 percent of children make no errors by 5½ years, 95 percent make no errors by age 7½ years.  

14. Reading ability: This may be roughly assessed by samples from the Gray Oral Reading or Gates Primary Reading Test. Reading performance one or more years below the grade placement should be referred for psychological testing.  

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APPENDIX B

Vestibular, Tactile, Proprioceptive, Auditory, and Visual System Disorders,

including Difficulty Integrating Both Sides of the Body
Vestibular System Disorders

1) *Atypical muscle tone.* **Muscle tone** refers to the elasticity of the muscles and fluidity of associated movements. Some individuals with a disability demonstrate **hypertonicity** (overly tight tone) and others **hypotonicity** (overly flaccid tone). If hypertonicity dominates, the individual tends to have limited range of motion, the muscles appear to be stretched (tight), and the movements appear to be jerky and awkward. If hypotonicity exists, the muscles tend to be flaccid (floppy), with extreme flexibility around the joints. The movements appear labored and lacking precision.

2) **Poor balance and equilibrium responses**

3) **Poor cocontraction.** Poor cocontraction is demonstrated by the inability simultaneously to contract antagonist muscle groups or to “fixate” two or more body parts around a joint (e.g., the inability to hold one’s outstretched arms in a steady position with the addition of weight or force on the arms).

4) **Postural insecurity.** Postural insecurity is demonstrated by an adverse reaction to sudden movements (e.g., flailing arms upon sudden movement of the body).

5) **Poor eye pursuits.** The inability to track visually the movement of an object, when this can negatively affect motor performance (e.g., catching a ball), demonstrates poor eye pursuits.

6) Disorders in arousal state (e.g., excitability, lethargy). Atypical responses to auditory stimuli (e.g., aversive reaction to sound) and visual stimuli may also appear.

7) **Short attention span and distractibility.**

8) **Avoidance of or seeking out swinging, spinning, or twirling activities.** These might include
spinning one’s body or twirling one’s fingers in front of the eyes or active avoidance of these activities (e.g., avoiding merry-go-rounds and swings).

Note: From Seaman, at al. (2007, pp. 79-80).

Tactile System Disorders

1) Tactile defensiveness—demonstrating a negative response to touch or defending oneself from tactile stimuli
2) Tactile-seeking behaviors—a strong desire to touch and feel anything and everything
3) Tactile processing difficulties—a complete lack of response to touch, the inability to discriminate between different tactile sensations, the inability to locate where one has been touched, or the inability to perceive stimuli simultaneously
4) Hyperactivity or distractibility
5) Difficulty in motor planning—difficulty in planning and executing nonhabitual, purposeful movement

Note: From Seaman, at al. (2007, p. 80).

Proprioceptive System Disorders

1) Atypical muscle tone. [See prior definition.]
2) Inadequate muscle contraction for maintenance of posture. [See prior definition.]
3) Poor cocontraction. [See prior definition.]
4) Lack of body awareness. Body awareness is demonstrated through the ability to “know”
where one’s own body parts are based upon internal stimuli (without vision). With a lack of body awareness, one’s ability to use body parts for movement is limited.

5) Difficulty in coordinating movement efficiently and effectively.

6) Difficulty in moving through space, especially around objects.

Note: From Seaman, at al. (2007, p. 79).

Auditory System Disorders

1) Difficulty grasping the meaning of words

2) Difficulty using language creatively by conceptualizing the message, associating the appropriate language symbols for use, and sequencing the motor response (expressive language)

3) Inability to recall and use language structures

4) Difficulty discriminating sounds from one another

5) Difficulty detecting variations in sound, including pitch, volume, direction and rhythm

Note: From Seaman, at al. (2007, p. 82).

Visual System Disorders

1) Limited ability to attend to visual stimuli

2) Difficulty following a visual sequence or fixating on a moving object

3) Difficulty discriminating visual objects in the field of vision

4) Difficulty maintaining spatial orientation either at rest or while in motion
5) Difficulty recalling visual sequences, spatial relations, forms, or other visual features

Note: From Seaman, at al. (2007, pp. 80-81).

Difficulty Integrating Both Sides of the Body

1) Difficulty jumping with both feet simultaneously
2) Unequal stance
3) Difficulty crossing the midline of the body (e.g., a child who hesitates as he or she moves a hand to the opposite side of the body or whose eye movements become “jerky” while visually tracking an object across the midline of the body)
4) Poor performance in rhythmic activities
5) Poor coordination of both sides of the body during symmetrical and asymmetrical movements (difficulty buttoning a shirt blouse [symmetrical], skipping or galloping [asymmetrical], or jumping up and down)
6) Difficulty isolating body parts for use (e.g., a child who is attempting a task with one hand, whose other hand is moving in response)
7) Slow balance reactions

Note: From Seaman, at al. (2007, p. 84).
APPENDIX C

NUCCA/UCRF Supine Leg Check
SLC Procedure

Example of Table centered on a perpendicular line on wall via center marked UC side posture side posture adjusting table 12 inches in height, rear feet placed on 6 inch platform

PATIENT/PRACTITIONER ALIGNMENT

1. Remove all objects from the back pockets of patient's pants, slacks, etc.
   Rationale: Objects in back pockets will cause turning of patient's pelvis into transverse plane, shortening leg.

2. Seat the patient on the body end of the adjusting table, facing away from the headpiece.

3. Guide patient onto his/her back, sliding the body toward the headpiece, aligning the center of the pelvis, the spinal column, and center of the head to a pre-marked line which divides the table into two equal halves.

4. Practitioner checks patient's position while standing at the patient's feet. The glabella, center of chin, episternal notch, and pubic center should lie directly above the table's center or dividing line.

5. The examiner holds and cups the feet in the following manner sling like manner known as
the Arciform.

THE ARCIFORM

Position of Hands Grasping Heels for SLC, The Arciform

The practitioner forms his hands in an arc or bow-like shape, called the Arciform, to hold the patient's shoes. The backstay, or part of the shoe just above the heel, rests in the palm of the hand. The little finger is placed under the heel so that sufficient pressure can be exerted to keep the shoe against the patient's heel. The thumb rests gently along the outside of the shoe and patient's ankle, paralleling the patient's leg and permitting control in squaring the patient's shoes to the baseline of the triangle. Care should be taken that no downward pressure is placed on the patient's shoes; neither should they be lifted but rest, relaxed, on the table.

6. Practitioner aligns his sagittal plane to the patient's sagittal plane.

Rationale: If practitioner's body is not aligned, the lateral displacement will produce greater pressure on patient's shoe on the side of the displacement.

Examiners Position

Proper Position

Improper Position
7. Bending his knees, the practitioner settles down by following his knees forward in the same plane as his feet. The knees flex more rapidly than the hips; the lumbar spine is kept straight. The body weight should be sufficiently forward so that the practitioner cannot maintain his position without holding the table. His hip sockets should be slightly higher than his knees. This position permits the necessary forward pressure of about five pounds against the patient's shoes. In this position, the practitioner can control the pressure against the patient's shoes by bringing his body forward and downward. The practitioner's position should not be too close or too far from the patient's feet. A triangle is formed by the practitioner when he assumes the above position. The apex is at the practitioner's pelvic center and the sides are formed by his thighs. A line (imaginary) across the practitioner's knees forms the base line.

Rationale: The triangle aligns the practitioner further: The base line parallels a line across the patient's heels and the apex lies directly over the mid-center line between his feet, indicating that the practitioner's body is not rotated. The base line, of the triangle is used as a guide and the patient's feet should approximate the base line, being about two or three inches in front of the base line.

Note: The imaginary line bisecting the table should be extended between practitioner's feet and pass directly beneath the center of his pelvis. The practitioner's feet should be equidistant from this line and pointing outward at a 45 degree angle. The width between the feet should approximate the width of the pelvis of the patient.

Examiner alignment

Note: Slight rotation of the examiner that can effect the leg check

8. Positioned in the checking posture, the practitioner again checks his sagittal plane
alignment to the patient's sagittal plane, verifies that the base line of the triangle is parallel to
the line across the patient's heels and confirms that an equal distance exists from the center of
each of his knees to the line across the patient's heels. He then places his fore-arms, elbows
slightly outward, across his thighs at about a 45° angle. Forming his hands in the arciform
position, he secures the patient's shoes, squares them, and pushes downward with his knees
to exert a slight pressure equally against the patient's shoes. He then brings his knees together
to close any distance that may separate the patient's shoes and compares them.

9. The practitioner raises the patient's legs, one at a time, about two inches from the table top
and place each leg in parallel alignment to the table's center line.

   (Do not drag the legs across the table top)

   Rationale: Dragging the legs will pull on the muscular structure at the posterior of the
   leg, causing false shortening.

The practitioner checks for leg resistances by exerting about a ten pound pressure with his
hands against the heel of each patient's shoe, pushing straight up the leg. Inequality to the
resistance exerted indicates spastic contracture. A slight weakening of the resistance signals
an incipient misalignment.

10. The patient's shoes are compared to each other at that point where the heel of each shoe
attaches to the backstay of the shoe. Shoe heels and soles are frequently unequally worn or
warped and unsuitable for checking other than where the heel attaches to the backstay.
Inequality or equality is then noted and distance estimated to be recorded at the end of the
procedure.

11. If the patient's legs are equal in length, his/her head should be rotated as a check against
an impending Atlas misalignment. The patient is asked to rotate their head from center to the
right, back to center and to the left and any disparity in leg length is noted. An Atlas
misalignment that is just forming and is not sufficiently active to cause leg disparity, will register
a contractured or short leg when the head is rotated to one side.

If Atlas misalignment does not exist, rotating the head will not cause a leg deficiency
APPENDIX D

North American Federation for Adapted Physical Activity

Conference Abstract, Fall 2012
A Comprehensive Literature Review: Adapted Physical Education and Related Disciplines, in Neurological Development and Reading

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This project examined usually distinct academic fields, crossing disciplinary boundaries, to create a holistic approach for children who have difficulty learning to read. **PURPOSE:** Atypical readers are at a disadvantage, and although there has been substantial multidisciplinary investigation outlining neurological symptoms for individuals with learning disabilities, including reading problems (Brodney & Kehoe, 2006; Decker, 2008; Habib, 2000; Menghini, et al. 2010; Nicholson & Fawcett, 2009; Punt, et al., 2010), further efforts are necessary to bridge the silos that have been growing for decades through research specialization (Ysseldyke, 2001). Developing appropriate diagnostic and evaluation tools is essential. Literature reviews were conducted and similar themes were identified in: Special Education; Neuroscience (Neurological Cognitive Research, Psychology, Biology, Physiology, Auditory and Vision); Kinesiology and Motor Development Science (Adapted Physical Education, Occupational Therapy and Physiotherapy, and Physical Therapy); Osteopathy and Surgery, Orthopaedics and Pediatric Orthopaedics; Neuro-Developmental Medicine (Rehabilitation); Behavioral Science; and Upper Cervical Research. **METHODS:** Sources were used if 1) procedures and data-based results were published between 1896 - 2012, and 2) topics were relevant to connecting the concepts of atypical movement development, head tilt, leg length disparity, and dyslexia; related to reading instruction. Systematic searches for specific articles/book chapters were conducted through computerized databases: Science Direct-Elsevier; Academic Press; Academic Search Elite (Ebsco); CINAHL; PsychARTICLES; PsychINFO; Hotwire Press; Google; JSTOR Retrospective Journals; Sage Journals; Science Direct-Elsevier; SpringerLink; and Wiley Interscience Journal Backfiles. Key words used: 1) primary reflex persistence; 2) postural instability; 3) eye saccades; 4) atlas subluxation; 5) leg length inequality; and 6) dyslexia. Descriptors were used alone or in word combinations. Some articles were referenced from *Council for Exceptional Children* publications, and many textbooks were examined. Personal communications: P. Aufsesser, R. Croce, K. DePauw, M. Horvat, and J. Rimmer. **RESULTS:** Predominant themes included 1) atypical motor development and muscle strength; 2) atypical neurological blood/oxygen flow; 3) eye muscle weakness; 4) auditory dysfunction; 5) balance deficits; 6) persistent asymmetrical tonic neck reflex, influencing functional leg length inequality; and 7) inconsistency for criteria to identify, and provide services to children with reading disabilities. **CONCLUSIONS:** This review supports that interdisciplinary study might contribute to the overall literature base identifying reading difficulties. This might create a new discipline “Developmental Neurological Education,” so child support teams might further examine the influence of physical neurology on the learning process.