

## The Studies about Phonological Deficit Theory in Children with Developmental Dyslexia: Review

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**Abstract: Problem statement:** Developmental Dyslexia (DD) or Reading Disability (RD) that was part of a larger heterogeneous group of learning disorders and characterized by unexpected problems in academic performance, despite average intelligence. **Approach:** Current opinions on the biological basis of dyslexia pointed to problems with phonological processing deficits with resulting poor phonemic awareness. Though there was much support for this hypothesis in the scientific literature, there remained an ongoing debate as to whether the core deficit was in fact a more general information processing problem that involves phonological awareness, phonological short-term memory, phonological re/de-coding (Rapid Automatized Naming, RAN). **Results:** Also double deficit hypothesis proposed that the dyslexic children impaired in word-identification accuracy or exhibiting slowly word decoding profile. **Conclusion/Recommendations:** The aim of this review was to present some of the most exciting researches on DD in the domains of phonological deficit theory that those will help future studies to follow.

**Key words:** Developmental dyslexia, phonological deficit theory, phonological awareness, phonological short-term memory, phonological re/de-coding (Rapid Automatized Naming, RAN), double deficit theory

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### INTRODUCTION

The reading process is a highly composite cognitive task, which relies on brain systems that were originally devoted to other functions. Reading involves the decoding and comprehension of printed materials. Word decoding implies the activation of different brain entities such as the visual and auditory modalities and the orthographic, phonological and semantic systems. The learning disabilities in reading (dyslexia), writing (dysgraphia) or mathematical (dyscalculia) abilities affects the children by unexpected problems in academic performance despite normal intelligence.

One of the most common and well-recognized learning disability, Reading Disability (RD) or developmental dyslexia (DD) is diagnosed in the school age children (4 and 7%). Twin and family studies have shown a substantial genetic component to the disorder, with heritable variation estimated at 50-70% (Caylak, 2007; DeFries *et al.*, 1987; Snowling, 2002). Given the importance of language and the ability to read, DD is considered a major social, educational and mental health problem. In the ICD-10 manual, dyslexia is coded as Specific Reading Disorder emphasizes problems with poor learning to read, spell and write

despite adequate intellectual capacity, educational resources and social background by the inclusion of sensory acuity deficits, neurological and psychiatric diseases (ICD-10). According to the DSM-IV, dyslexia is coded as Reading Disorder, similarly emphasizing poor reading skills by the exclusion of extraneous factors. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities (omissions (e.g., “ply” instead of “play”), substitutions (e.g., “arm” for “hand”), inversions (e.g., “aks” instead of “ask”), or additions (e.g., “of” and “to”) of words or fragments of words) (DSM-IV).

Poor readers are characterized by slow and inaccurate word recognition and many researchers agreed that dyslexia is based on deficits in the phonological system. Recently, considerable progress has been made in understanding the biological and psychosocial aspects of phonological disabilities. However, this body of knowledge is fractured and difficult to conceptualize as a whole. Toward this goal, this review will discuss phonological disabilities from methodological and developmental perspectives and highlight research on the mechanisms of phonological processing deficit theory. In this study, I will present a multilevel approach for organizing the phonological

deficit theory found in the psychological, neuropsychological and biological literature.

I will start a brief of the studies of phonological deficits commonly associated with RD and then discuss findings from the current theory of DD in particular.

**The phonological deficit theory:** The most unifying hypothesis about the core deficit of DD is that these individuals have specific impairments in the representation, storage and/or retrieval of speech sounds (Ramus, 2003; Snowling, 2001). Reading acquisition requires a child to learn the mapping between written letters (orthography) and their corresponding sounds (phonology) (Jorm *et al.*, 1984; Share, 1995). Over time, competent readers expand their linguistic repertoire by integrating two different neurolinguistic processes kinds (Castles *et al.*, 1999; Ellis, 1984; Manis *et al.*, 1997; Morton, 1969; Seidenburg, 1993). The first process is orthographic mastery; the ability to process the visual form of words in terms of shapes, letters and their order in words. Through orthographic mastery, words are processed as a whole unit rather than their component sounds to yield meaning. The second process is phonologic mastery, the ability to translate letters into the sounds (i.e., phonemes) for unfamiliar words. Because all words are unfamiliar when a child is learning to read, a problem in the representation and use of phonological information inevitably hampers the acquisition of reading (Brady *et al.*, 1987; Bryant *et al.*, 1990; Goswami, 2000). Converging lines of evidence suggests that DD can be characterized by one of several phenotypic manifestations of a phonological deficit (e.g., phonological awareness, Phonological Short-term Memory (PSM), phonological re/de-coding [i.e., Rapid Automatized Naming (RAN)]) (Brady and Shankweiler, 1991; Rack *et al.*, 1992).

Although the phonological awareness and RAN deficits have been presented here separately, the researchers now agree these deficits in dyslexia are part of a more general double deficit theory (Wolf *et al.*, 2000; Wolf and Bowers, 1999; Wolf *et al.*, 2002). I will therefore discuss it under the headline of the phonological deficit theory.

**Phonological awareness:** Phonological awareness refers to the conscious ability to access and manipulate the phonemic level of speech (Stanovich, 1986). Early research indicated that children with dyslexia performed poorly on rhyming tasks and word-onset awareness (Bradley and Bryant, 1978). Subsequent research indicated that individuals with dyslexia were

impaired on a variety of phonological awareness skills (Bruck and Treiman, 1990; Joanisse *et al.*, 2000; Olson *et al.*, 1990; Swan and Goswami, 1997). Bruck and Treiman (Bruck and Treiman, 1990) investigated phonological awareness and spelling skills among controls and dyslexics. They found that children with dyslexia performed significantly worse on tasks of phonological awareness and spelling.

Poor phonological awareness may or may not be associated with deficits in speech perception. Joanisse *et al.*, (2000) examined performance on reading and language tasks given to children with reading problems. They used three dyslexic groups identified as Phonological Dyslexics (PD), developmentally Language Impaired (LI) and globally delayed (delay-type dyslexics). They indicated a similar patterns of reading impairment, attributed to low phonological skills in the LI and PD groups exhibited similar patterns of reading impairment, attributed to low phonological skills. However, they only showed clear speech perception deficits, suggesting that such deficits affect only a subset of dyslexics, in the LI group. Their results also indicated phonological impairments in children whose speech perception was normal. They reported inflectional morphology difficulties in both of the LI and the PD groups whereas the impairment being more severe in the LI group. They concluded that the delay group's reading and language skills closely matched those of younger normal readers, suggesting these children had a general delay in reading and language skills, rather than a specific phonological impairment.

Chiappe *et al.* (2001) examined the interaction between speech perception and lexical information among a group of 7-year-old children. They tested the performance of children with tasks, which were reading skill, phonological awareness, pseudoword repetition and phoneme identification. They determined that clearly defined categorical perception in the phoneme identification task for both the /bif/-/pif/ and the /bis/-/pis/ continua in controls while the category boundary for /bif/-/pif/ was at longer Voice Onset Times (VOTs) than the boundary for /bis/-/pis/, which characterizes the classic lexicality effect. Poor readers showed less sharply defined categorical perception on both continua. On the other hand, they showed that abnormal lexicality effect in dyslexics, lexicality did affect the overall rate with which phonemes were identified as /b/ or /p/ at each VOT. Their findings suggested that the lexicon might operate as a compensatory mechanism for resolving ambiguities in speech perception. Furthermore, they concluded that statistical correction for group differences in phoneme identification made group differences in phoneme deletion disappear,

suggesting that deficits in speech perception might play a causal role in the phonological core deficit associated with reading failure.

Elbro and Jensen (2005) examined the quality of phonological representations of lexical items in dyslexic children with learning pseudonyms or known words. They reported that the individuals with dyslexia were significantly outperformed by the reading-age controls in non-word reading and in phoneme awareness. The authors determined long time to learn to associate a set of pseudonyms with pictures of persons in the dyslexics compared to controls, whereas the dyslexics gained same time to learn to associate familiar names with pictures according to controls did. The investigators studied the acquisition of new phonological representations of words in an imitation task with maximally distinct pronunciations of long, familiar words. They found that the learning period of dyslexics less than the controls in this task and phoneme substitution task with the same words as in the distinctness task. They suggested that poorly specified phonological representations might be an underlying problem in dyslexia.

Boada and Pennington (2006) tested the segmentation hypothesis of dyslexia by measuring implicit phonological representations in reading-disabled 11-13 year-old. Their implicit measures included lexical gating, priming and syllable similarity tasks designed to reduce metalinguistic demands. They found that children with dyslexia performed consistently worse than controls when more segmental representations were required across all three tasks. They reported a correlation between phonological representations and measures of speech perception, phoneme awareness and PSM, but not correlate RAN and accounted for unique variance with reading ability. Their results provided strong support for less mature implicit phonological representations in children with dyslexia.

Gathercole *et al.* (2006) investigated reading and mathematics abilities in children with dyslexia. They found significant association severity of reading difficulties within the sample with complex memory, language and phonological awareness abilities, whereas link between poor mathematics abilities and complex memory, PSM and phonological awareness scores. Their findings suggested that working memory skills indexed by complex memory tasks represented an important constraint on the acquisition of skill and knowledge in reading and mathematics.

In test study of the auditory processing in relation to phonological skills in dyslexia, Boets *et al.*, (2006) examined two contrasting groups of 5-year-old

preschool children, a familial high risk and a familial low risk group. They estimated phonological skills by phonological awareness, verbal short-term memory and RAN using tasks. They determined a significant group differences between the groups for phonological awareness and letter knowledge whereas none of the auditory tasks differentiated significantly between both groups. However, they reported significant relation between frequency modulation or tone-in-noise detection and phonological awareness. They suggested that identifying deviant subjects in auditory spectral processing in order to predict deficiencies in phonological skills and subsequent reading development did not yet seem to be a viable option and at the level of individual subjects the relation between auditory and phonological skills seemed to be much less straightforward. Recently, Boets *et al.*, (2007) investigated whether the core bottleneck of literacy-impairment should be situated at the phonological level or at a more basic sensory level. The researchers assessed the phonological ability, speech perception and low-level auditory processing in previous groups. The children both increased family risk and literacy-impairment at the end of first grade, presented significant pre-school deficits in phonological awareness, RAN, speech-in-noise perception and frequency modulation detection. They suggested that the concurrent presence of those deficits before receiving any formal reading instruction might be causal relation with problematic literacy development. When they inspected the individual data, they indicated that the core of the literacy problem was situated at the level of higher-order phonological processing. They reported that the results were interpreted as evidence for dysfunctional processing along the auditory-to-articulation stream that was implied in phonological processing, in combination with a relatively intact or inconsistently impaired functioning of the auditory-to-meaning stream that subserved auditory processing and speech perception.

**Phonological short-term memory:** Phonological Short-term Memory (PSM) is assumed as forming sound-based representations of written symbols being stored transiently in the left posterior parietal cortex of brain. Efficient phonetic recoding in Broca's area of brain appears to be an important tool for the early reader. Learning to read requires an awareness that spoken words can be decomposed into the phonologic constituents that the alphabetic characters represent. Such phonologic awareness is characteristically lacking in dyslexic readers who, therefore, have difficulty mapping the alphabetic characters onto the spoken

word. Normal readers typically surpass dyslexics in memory for linguistic material such as syllables, words and sentences (Liberman *et al.*, 1982; Shankweiler *et al.*, 1995). Unlike the able reader, the beginner reader devotes the maximum amount of cognitive resources possible to the process of blending phonemes to generate words. Serial recall of diverse speech materials, digit and word span and verbal repetition of words, pseudowords, or sentences exemplify measures of PSM (Wagner and Torgesen, 1987).

Further evidence shows that dyslexic children have difficulty in simple rhyme judgments (Rack, 1985). In the study, he investigated memory coding in dyslexic readers and reading-age-matched controls, using cued recall. Firstly, he tested subjects with rhyme judgments about pairs of words. Then, he used one member of each pair (the cue) to cue recall of the other member of the pair (the target). He found that dyslexics were as accurate at detecting rhyme compared to the reading-age-matched controls; however, they were slower and were subject to a greater orthography effect. He did not determine any difference in memory performance between the two groups. However, he reported that individuals with dyslexia made more use of an orthographic code with both visual and auditory presentation whereas they were found to make less use of a phonetic code in the visual but not the auditory condition. Their results supported the view that dyslexics had less easy access to a phonological code in memory, but they were able to compensate for that by increased use of a visual/orthographic code.

The PSM deficit predicted that early word recognition problems should precede the emergence of reading problems and a series of experiments by Shankweiler *et al.*, (1979) in spoken letter names; Brady, Mann and Schmidt (1987) in consonant-vowel syllables and Mann, Liberman and Shankweiler (1980) in words. In addition, dyslexics were found to show a reduced or even absent phonological similarity effect (i.e., superior recall performance for phonemically dissimilar versus rhyming items) that is evident in normal individuals even at early reading stages (Mann, Liberman and Shankweiler, 1980; Shankweiler *et al.*, 1979). Furthermore, early instruction in phonemic segmentation seems to allow the children to progress at a more normal rate through the early stages of reading, thus mitigating the effects of the underlying deficit. This provides strong evidence that phonological segmentation performs a key role in learning to read.

It was demonstrated that dyslexics showed a phonological similarity effect comparable to normal controls when they were compared or equated on memory span by the researchers (Irausquin and Gelder,

1997; Johnston *et al.*, 1987). Johnston *et al.* (1987) examined two dyslexic children with immediate memory task, recalling strings of similar- and dissimilar-sounding letters. They found a close association and a highly significant correlation between memory span and reading age in dyslexics relative to age-matched controls. They concluded that the founded relationship could not be primarily due to a substantial immediate memory component in word recognition as the below average intelligence dyslexics had poorer memory spans than the brighter dyslexics, yet they had very similar reading ages. The authors hypothesized that recognition difficulties might be the primary problem underlying both poor word recognition and immediate memory impairments in dyslexic children.

Irausquin and de Gelder (1997) analyzed immediate ordered memory (auditory-spoken words or visually-their corresponding drawings) for words in individuals with RD compared with normal readers. They found equality for basal memory capacity in all groups whereas phonological similarity and word length were simultaneously manipulated. Their results purposed that when having to recall a restricted set of items and when verbal output was eliminated, phonological coding and rehearsal occurred to the same extent in dyslexics and normal readers, with auditory as well as visual presentation. They concluded that irrespective of presentation modality, absolute performance of the dyslexics was still worse than controls matched chronological age.

Many studies have used pseudoword repetition to investigate the PSM in DD. Limitations in pseudoword repetition frequently have been shown in dyslexia (Brady *et al.*, 1989; Snowling *et al.*, 1986). For instance, Snowling *et al.*, (1986) reported specific decrements in performance of dyslexics compared to reading-level-matched controls, as a function of the number of syllables contained in pseudowords. From a theoretical perspective, Gathercole and Baddeley, (1995) conjectured as to the role of phonological memory as a common factor affecting acquisition of vocabulary and grammar. Moreover, ability on pseudoword repetition predicts literacy achievement later in life.

Multisyllabic nonsense-word repetition tasks have been used to provide evidence on the phonological processing operations of children with language impairment, independent of their lexical knowledge (Brady *et al.*, 1989; Dollaghan *et al.*, 1993). Brady *et al.* (1989) investigated the dyslexics using a word repetition task with monosyllabic, multisyllabic and pseudoword stimuli. They did not find differences on speed of responding and the lack of reaction time

differences between reading groups was corroborated on a control task, which measured verbal response time to non-speech stimuli. However, the authors demonstrated significantly less accurate in individuals with below performance at repeating the multisyllabic and pseudoword stimuli. They concluded that the findings of the study suggesting, encoding difficulties contribute to the memory deficits characteristic of poor readers. Dollaghan *et al.* (1993) investigated the effect on repetition performance of one previously uncontrolled characteristic of multisyllabic nonsense words: the lexical status (word or non-word) of their stressed syllables. They demonstrated significantly more accurately repeating of the nonsense words with lexical stressed syllables as nonsense words with non-lexical stressed syllables in normally achieving school-age boys. Their results suggested the need to control, at a minimum, the lexical status of constituent syllables in constructing nonsense-word stimuli.

Fowler and Swainson (2004) sought to investigate how the phonological representations of words in children's oral lexicons might differ for dyslexic and normal readers at the outset of schooling and after several years of reading instruction. They selected first or fourth graders dyslexics and Normal Readers (NR). They determined higher performance on the tests of naming pictured objects, making acceptability judgments and imitating/correcting naming errors on words for older than younger students and for better NR than dyslexics. In both the first and fourth grades, dyslexics made more expressive naming errors and were more often "tolerant" of variation in their judgments of the acceptability of various renditions of a word, especially for long words. When more than one version was deemed acceptable, however, the authors reported that all individuals were usually quite accurate and about equally so, at deciding which was the correct pronunciation whereas imitating and correcting another speaker's naming errors were less accurately accomplished by first than fourth graders and by dyslexics than NR at both ages. Their results indicated that for all readers, imprecised phonological knowledge, especially about long words, contributed to children's difficulties on all naming tasks. They proposed that the difficulties of dyslexics on the tasks were evident both at the outset of learning to read and after several years of reading instruction and practice. They suggested that the differences between better and poorer readers were quite similar in magnitude at both grades on the judgment, imitation and correction measures.

**Phonological re/de-coding (retrieval):** Phonological re/de-coding (retrieval) can be conceived as the ability to access the lexicon by utilizing sound-based representations and it assessed through measures of naming accuracy and speed. It seems to be especially important that the classic Rapid Automatized Naming (RAN) task in dyslexia studies entails the naming of familiar items under timed conditions. It was found that the dyslexic children performed more slowly on series of digits, letters, colors and objects compared to both age controls (Wolf *et al.*, 2000).

Trauzettel-Klosinski *et al.* (2006) sought to examine picture naming and word reading in dyslexic and control children. They investigated time course of brain activation by magnetoencephalography during word reading and picture naming in them. They reported a combination of normal picture retrieval times and severe reading impairments in dyslexics. They only found differences during reading between the groups, which a delayed response in temporal superior and angular gyri at 235-285 m sec and absence of activation in anterior temporal and inferior frontal regions at 430-530 m sec for dyslexics. They suggested that the problems in phonological processing of children with RD reflected in delay of early activity and absence of late activity in language related brain regions. For explanation of the lack of group differences during picture naming, they concluded the presence of two pathways: a phonological/orthographic one for word reading, which was disturbed in dyslexics and a visual one for picture naming, which could be unaffected in dyslexics.

It is assumed that dyslexics had phonological processes/phonemic awareness deficits in reading. These problems were achieved by phonemic awareness and decoding training, but not all students had responded favorably to this education and might be unable to retrieve phonological codes quickly from long-term memory. Allor *et al.* (2001) sought to examine whether such a deficiency, which the authors referred to as lexical retrieval weakness, blunted the effectiveness of combined phonemic awareness and decoding training. They compared the effectiveness of phonemic awareness and decoding training for readers with and without severe lexical retrieval weaknesses. All individuals in both groups demonstrated poor phonemic awareness. It has been suggested that the individuals with relatively strong lexical retrieval skill responded more favorably to beginning reading instruction than did they with weak lexical retrieval skill. The authors recommended that lexical retrieval weakness might influence reading development independently of the effects of phonemic awareness.

Swanson (2000) sought to investigate whether changes in the working memory performance of Readers with Learning Disabilities (RLD) was related to a general or domain-specific system. He examined the working memory performance for phonological, visual-spatial and semantic information under initial, gain and maintenance conditions in RLD and normal readers. He indicated that RLD were inferior in performance to normal readers across initial, gain and maintenance conditions; however RLD exhibited less change on both visual-spatial and verbal (phonological and semantic) working memory performance tasks across gain and maintenance conditions than the normal readers. He found that the performance of RLD was superior to the normal readers' performance on initial conditions, but inferior on gain and maintenance conditions. In conclusion, his results suggested that a general system moderated the changes in retrieval of phonological, visual-spatial and semantic information in RLD.

Plaza *et al.* (2002) investigated the relationships among language processing (word-and sentence-level), working memory and verbal/nonverbal linguistic output. They compared French-speaking dyslexic children, normally developing age-matched or developing younger children for oral language abilities. Their participant carried out the tasks involving auditory memory skills (digit span, unfamiliar word repetition, sentence repetition), word retrieval (with semantic, phonological and grammatical criteria) and sentence processing (with verbal and act-out production). They found a significant deficit affecting all task in the children with RD compared with controls. Their results were consistent with the processing limitation hypothesis and suggested that the core deficit was the formulation of cognitive plans from auditory input to verbal output.

Mayringer and Wimmer (2000) sought to examine pseudoname learning by German-speaking children with dyslexia for a phonological learning deficit. In their study, these major findings revealed that: (1) the children with RD displayed impaired learning of new phonological forms (pseudonames) in a variety of visual-verbal learning tasks; (2) the dyslexic deficit appeared when phonological retrieval cues were provided and when the to-be-learned pseudonames were presented in spoken as well as printed form and (3) that name-learning deficit was not shown when short, familiar words were used and they also had no difficulty with immediate repetition of the pseudowords. They found an association between the dyslexic children's difficulty in learning new phonological forms and pseudoword-repetition and

naming-speed deficits assessed at the beginning of school, but not with phonological awareness and visual-motor impairments. They suggested that the difficulty in learning new phonological forms might affect reading and spelling acquisition via impaired storage of new phonological forms, which serve as phonological underpinnings of the letter patterns of words or parts of words.

The researchers claimed that using of the phonological awareness tasks might arise from deficits in the accuracy and the segmental organization of the phonological representations of words in dyslexic children's mental lexicons. Swan and Goswami (1997) investigated by using a picture naming task and a battery of phonological measures at three linguistic levels (syllable, onset-rime, phoneme). They used the picture naming task to identify words for which dyslexic and control children had accurate or inaccurate phonological representations and performance in the phonological awareness tasks was then compared for the words which had precise or imprecise representations. They reported that frequency effects in the phonological awareness tasks at all levels disappeared for dyslexic and control children once representational quality was taken into account and that the availability of sublexical units for analysis appeared to differ according to the accuracy and retrieval of the phonological representation and the linguistic level tapped by the phonological awareness task.

Snyder and Downey (2001) sought to examine the word retrieval, phonological awareness, sentence completion skills in poor readers and controls. They indicated significant differences between the subjects with dyslexia and controls on the time and accuracy of word retrieval, dyslexics' ability to produce a syntactically appropriate structure in a sentence completion task. They found the best variance in the younger dyslexic children's reading comprehension scores accounted for by their performance on the sentence completion and word retrieval measures whereas the best variance in controls' reading for by their sentence completion and word retrieval scores for by their reading comprehension. By contrast, they determined the best variance in older controls' phonological awareness score for by their reading scores. They proposed that the oral language skills of poor reading children and controls might relate differently to their reading comprehension at different age levels.

**Double deficit theory (phonological awareness and RAN):** Wolf *et al.* (2000, 2002) have suggested that deficits in phonological awareness and RAN reflected a

general impairment in automatizing low-level subprocesses involved in reading. Wolf and Bowers (1999) proposed that problems in double deficit hypothesis predicted three subtypes of RD: the dyslexic children with phonological-deficit, who impaired in word-identification accuracy (poor phonological awareness); the individuals with rate-deficit, exhibiting slowly word decoding profile and the double deficit reader, showing a general dysfunction on all decoding measures. Further, they suggested that the presence of deficits in both phonological processing and RAN had an additive negative influence on reading performance above and beyond that of a single deficit. Wolf *et al.* (2000) reported that the relationship of speeded naming to reading is mediated by the subject's age and stimulus type. They indicated that naming rate for graphological symbols as letters and digits, continued their predictive power whereas non-graphological RAN symbols as colors and objects, lost to predict word reading scores power at the beginning of children elementary school. Similarly, Semrud-Clikeman *et al.*, (2000) compared 71 children in three groups (RD, ADHD without RD and normal controls) were compared on their ability to RAN of colors, letters, numbers and objects (RAN tasks) and alternating letters/numbers and letters/numbers/colors (RAS tasks). They found that children with RD were found to be slower on letter- and number-naming tasks and made more errors on all tasks than controls. There was an age effect for the RAN/RAS tasks, with younger children with RD performing more poorly on all tasks, while the older children with RD showed poorer performance only on the letter- and number-naming tasks. Goswami *et al.* (2002) measured phonological awareness (using the rhyme oddity task), RAN of letters and pictures and phonological short-term memory in dyslexic children group and controls. In RAN task, the children had to name familiar pictures and letters under timed conditions. Dyslexic children exhibited deficiencies to their Chronological Age (CA) or Reading Level (RL) controls. RAN mean speed of dyslexic children was found 36.7 sec ( $\pm 7.5$  SD) while 29.1 sec ( $\pm 3.6$  SD) in CA group and 34.6 sec ( $\pm 5.6$  SD) in RL group.

In addition, the theorists suggested that RAN speed might be significantly associated with reading abilities in dyslexic and control subjects and demonstrating an increase with maturation (especially the ages of 4 and 8 years) (Watson and Willows, 1995; Wolf *et al.*, 1986). Catts (1993) sought to investigate the predictive value of preschool RAN performance for early reading achievement. He identified a group of children with Speech-Language Impairments (SLI) in kindergarten and tested their phonological awareness and RAN

abilities with a battery of speech-language tests. He found that the children with SLI performed less well on reading tests than a non-impaired comparison group. He observed that the subjects' performance on standardized measures of language ability in kindergarten was closely related to reading outcome, especially reading comprehension. On the other hand, he found that measuring of phonological awareness and RAN was the best predictors of written word recognition in his study. In 2002, Catts *et al.*, (2002) investigated the role of speed of processing, RAN and phonological awareness in reading achievement. They measured RAN, phonological awareness and reading achievement in second and fourth grades. In reading group comparisons, they indicated that poor readers were proportionally slower than good readers across response time measures and on the RAN task. They suggested that some poor readers had a general deficit in speed of processing and that their problems in RAN were in part a reflection of this deficit. In hierarchical regression analyses, they further showed that when considered along with IQ and phonological awareness, speed of processing explained unique variance in reading achievement. They also suggested that a speed of processing deficit might be an extra phonological factor in some reading disabilities.

Manis *et al.* (2000) investigated concurrent relationships among measures of naming speed, phonological awareness, orthographic skill and other reading subskills in a representative sample of second graders. In hierarchical regression analyses, they revealed that naming speed, as measured by the RAN task, accounted for a sizable amount of unique variance in reading with vocabulary and phonemic awareness partialled out. They found that the unique contribution of naming speed to reading was relatively stronger for orthographic skills, whereas the contribution of phonemic skills was stronger for non-word decoding. When they analyzed further, marked difficulties on a range of reading tasks, including orthographic processing, were seen in a subgroup with a double deficit (slow naming speed and low phonemic awareness) but not in groups with only a single deficit. Their findings were broadly consistent with Wolf and Bowers' double deficit hypothesis of RD.

On the other hand, Compton *et al.*, (2001) examined the additive nature of phonological awareness and RAN deficits on written language skill in children with RD. They performed the concurrent relationships between phonological awareness, RAN and written language skills in children with RD. They revealed that phonological awareness and RAN skill had an additive effect on a majority of the reading and spelling

measures in hierarchical regression analysis. Firstly, they classified participants into three deficit subtypes based on the double deficit model (i.e., phonological-, rate- and double-deficit) and compared across the subtypes confirmed that individuals with double deficits performed below the single deficit groups on both subtyping variables (phonological awareness and RAN) and all measures of written language. When they matched all the groups on the subtyping variable (i.e., double- and rate-deficit groups matched on RAN or phonological awareness), they found the differences between those groups in non-word reading, whereas the differences between those groups in timed word recognition and reading comprehension. They supported with those results an additive model in which RAN-deficits primarily affected tasks that require speeded/fluent response and phonological awareness deficits primarily affected tasks that emphasize phonological processing skill. Their results were also presented that illustrate several statistical problems associated with the formation of deficit groups by dichotomizing the phonological awareness and RAN variables.

### **CONCLUSION**

There is substantial evidence that dyslexics are affected by phonological processing deficits in the representation, storage and/or retrieval of speech sounds. As a result of that, there are considerable impairments in the learning of grapheme and phoneme correspondences or the foundation of reading for alphabetic systems (Bradley and Bryant, 1978; Brady and Shankweiler, 1991; Snowling, 1981). The deficits of phonological abilities on word decoding, letter-name knowledge exerted a moderate effect on phonological skills. The authors agree on the underlying mechanism of phonological impairments as a congenital dysfunction of left hemisphere perisylvian brain areas underlying phonological representations, or connecting between phonological and orthographic representations. Support for the phonological theory comes from evidence that dyslexic individuals perform particularly poorly on tasks requiring phonological awareness (i.e., conscious segmentation and manipulation of speech sounds). An integrating account derived from developmental theories of spoken word recognition maintains that language difficulties arise from poorly on tasks requiring phonological awareness, poor verbal STM, slowly RAN and poorly specified phonological representations (Goswami, 2000; Snowling, 2001; 2002).

The most obvious way to challenge the specificity of the phonological deficit is to postulate that it is secondary to a more basic auditory deficit. The auditory rate processing deficit hypothesis postulates that DD may result from a general, nonspecific defect in perceiving rapidly changing auditory signals is a current subject of debate (Tallal *et al.*, 1993). Tallal and colleagues' model (Tallal, 1980; Tallal and Piercy, 1973; 1974) emphasizes the role of timing in the auditory system, is considered essential for encoding brief and rapidly changing or rapidly occurring successive events. Furthermore, these auditory problems may be present and associated with phonological deficits in a significant proportion of dyslexics. Findings provided from adults with dyslexia on auditory perception seem to be less conflicting than those in the child population. Prospective longitudinal studies including dyslexic children and adults are needed for revealing its causal relevance. According to a recent version of the dyslexia hypotheses, the deficit is not limited to the auditory modality.

There is substantial evidence that many developmental dyslexics complain of visual symptoms, of letters blurring and appearing to move over each other that might explain their visual impairment giving rise to difficulties with the processing of letters and words on a page of text. The visual theory postulates that the magnocellular pathway is selectively disrupted in certain dyslexics, leading to deficits in visual processing and, via the posterior parietal cortex (Hari *et al.*, 2001; Stein and Walsh, 1997).

It is widely accepted that dyslexics have phonological, auditory or visual deficits in reading but there is increasing evidence that the magnocellular theory includes visual, auditory, as well as tactile deficits in dyslexics. The magnocellular theory (Stein and Walsh, 1997) postulates that magnocellular abnormalities in the medial and lateral geniculate nucleus of dyslexics' brains (Galaburda *et al.*, 1994; Livingstone *et al.*, 1991), low performance in dyslexics' tactile domain (Grant *et al.*, 1999; Stoodley *et al.*, 2000) and the co-occurrence of visual and auditory problems in dyslexics (Van Ingelghem *et al.*, 2001; Witton *et al.*, 1998). Furthermore, a significant proportions of dyslexics show a comorbidity with motor disorders which, hypothesized with an automaticity deficit or a cerebellar dysfunction. The automaticity/cerebellar deficit theory postulated in individuals with dyslexia that the cerebellum was then unable to regulate motor control and therefore in speech articulation, which would lead to deficient phonological representations and/or to automate of over learned tasks in reading,



would affect the learning of grapheme and phoneme correspondences.

Especially, the phonological and magnocellular theory have inability to explain the sensory and motor disorders that occur in a significant proportion of dyslexics, while the cerebellar theory presents an explanation for sensory and motor deficits in those dyslexics. Of course, it is possible that the five theories are true of different individuals. For instance, there could be five partially subtypes of reading difficulties: Phonological, auditory rate processing, visual, magnocellular and automaticity/cerebellar and the researchers need to be able to diagnose for every subtypes or cases of dyslexia using the different deficit theories. The continuous investigations have to make to clarify the dissociations or associations between certain deficits.

Accounting for the major neurofunctional deficits in dyslexia and assessing the various subtypes of dyslexia through the all deficit theory would be the ideal strategy for efficient investigation of the etiology of dyslexia. In light of the current research of the all deficit theories in conjunction with these dominant theoretical models, however, may be useful in obtaining a more holistic understanding of the true nature of the disorder.

In conclusion, a model, which works to incorporate these five facets of investigation, could potential advance the research and treatment of dyslexia, by broadening the current diagnostic spectrum of dyslexics with neuroimaging (Caylak, 2009) and evoking varying styles of intervention, which work to target the multitude a dyslexic symptoms and subtypes.

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