READING IN KANNADA-ENGLISH BILITERATE CHILDREN WITH DEVELOPMENTAL DYSLEXIA: A STUDY THROUGH EYE-TRACKING METHOD

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CERTIFICATE

This is to certify that this dissertation entitled **"Reading in Kannada-English Biliterate Children With Developmental Dyslexia: A Study Through Eye-Tracking Method"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech-Language Pathology) of the student bearing the Registration Number: 17SLP006. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled **"Reading in Kannada-English Biliterate Children with Developmental Dyslexia: A Study Through Eye-Tracking Method"** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "**Reading in Kannada-English Biliterate Children with Developmental Dyslexia: A Study Through Eye-Tracking Method"** is the result of my own study under the guidance of Dr. Jayashree C. Shanbal, Associate Professor in Language Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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CHAPTER 1: Introduction

India is a multilingual country. As per the constitutional provision of Eighth Schedule, 22 languages are officially recognized by Ministry of Human Resource Development, Government of India, (2008). The intellectual flexibility that is inherent in such a multicultural nation opportune children to speak more than two languages and to read and write British-American literature that is bound from early classroom and environmental exposure. Most of children learn to speak in their native language (L1- i.e, either Indo-Aryan like Hindi, Punjabi, Marathi, Gujrathi or Dravidian like Kannada, Tamil, Telugu, Malayalam, etc.) and also learn to read in both native languages as well as in vernacular and/or foreign language (L2). In such a diverse country, importance of acquiring literacy skills in English language is prevailing nationwide, for English is one of the compound languages in India that is treated as 'bridging language' for communication as well as a 'passport' to gain access to worldwide knowledge. This is why it is mostly used as L2 and majorly practiced medium of instruction in elite schools and universities. Therefore, multilingual India has acknowledged the importance of English as a privileged language for medium of instruction and brought conspicuous amendments in education system by implementing tri-language formula (TLF), by the Secondary Education Commission (1953), Government of India. According to TLF, children should be educated in three languages. Where in Hindi Speaking states, combination of: (a) Hindi; (b) Any one south-Indian regional language; (c) English or any other modern European language. In non-Hindi speaking state: (a) Regional language; (b) Hindi and (c) English or any other modern European languages was recommended. Further, Native languages of India have a transparency in grapheme to phoneme correspondence (GPC).

In Kannada language, the prospects of eye tracking research on reading alphasyllabary scripts has included the following inspections: the identification of the minimum segmentation unit on reading, which is the visual recognition of vowels and consonants with in syllable composite, the application of the orthographic principles while decoding the compound (CCV) and complex (CCCV) alphasyllables (Winskel, Padakannaya & Pandey, 2014). This study is on typically developed population and it reported that TDC apply the principle of segmentation of the syllable in words and decode the vowel sound as the function of the head bar in the script.

According to Lyon, Shaywitz, and Shaywitz (2003), dyslexia is referred to as children having specific learning disabilities due to neurobiological origin and characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge. Developmental Dyslexia (DD) with the underling core deficits in phonological processing, auditory processing(Bradley & Bryant, 1978; Breznitz & Misra, 2003), visual processing (Cestnick & Coltheart1999), cerebellar (Nicolson, Fawcett & Dean, 2001)and general sensory-motor functioning(Jones, Obregón, Louise Kelly, & Branigan, 2008; Ramus, 2003). Amongst all, accounts on phonological processing deficit and visual processing deficits are evident in DD (Lobier, Zoubrinetzky & Valdois, 2012; Pan, Yan, Laubrock, Shu & Kliegl, 2014; Ramus, 2003; Snowling, 2001; Stanovich & Siegel, 1994; Trauzettel-Klosinski et al., 2010; Wolf et al., 2002; Ziegler & Goswami, 2005). Evidence on causal route of DD links phonological deficit

(in task such as verbal working memory, rhyme oddity, rapid naming and non-word repetition) with cognitive impairment that is more central (Nag & Snowling, 2011; Snowling, 2001; Van den Broeck, Geudens, & van den Bos, 2010).

Visual processing deficit is a peripheral deficit and its role is linked to disturbances in orthographic representation to process and decode text material. Most of the studies have confined this peripheral deficit to phoneme grapheme correspondence, an operational deficit and have indirectly related to phonological processing and thus linked to a central processing (Jarodzka & Brand-Gruwel, 2017; Marshall, Snowling& Bailey, 2001; Rayner & Duffy, 1986; Sereno & Rayner, 2003; Shaywitz et al., 2002).In contrast another set of researches propose that visual processing deficit are the primary cause of DD (Lobier et al., 2012; Vidyasagar & Pammer, 2010). The early deficits of the visual perception (poor visual attention span and disturbances in fixation) lead to poor phonological representation and orthographical coding, consequently developmental dyslexia (DD) shows error in retrieval and are less efficient in learning higher operational literacy skills. Yet, most of the learning happens in the school age in an academic context via reading and comprehension of text. Therefore, the academic achievements are correlated to reading comprehension skills (Cromley & Snyder-hogan, 2010). This marks the importance of visual processing and its deficits in developing children.

There are studies in the recent decade that report on the influence of nature of orthography, its transparency and form of representation on the pattern of reading development in biliterate children (Durgunoglu & Oney, 2000; Veii, 2006; Veii & Everatt, 2005; Ziegler & Goswami, 2005). Many hypothesis and assumptions are put forth by researchers on reading and its relation to the processing of different writing systems existing in the world. Geva and colleagues (Gholamain & Geva, 1999; Geva

& Siegel, 2000) proposed that the main theoretical positions to understand processing mechanisms in bilingual literacy, can be reduced to two competing perspectives as the *script dependent hypothesis* (Snowling, 2000) where difficulty could be specific to a particular orthography and *central processing hypothesis* (Geva, Wade-Wooley & Shany, 1997) where difficulty in reading is attributed to deficits in cognitive processes.

Need for the study

Nearly all the studies on eye tracking in DD (vs. typically developing children-TDC) so far have revealed the eye movement deficits for reading in their native language and some studies have drawn comparison of these eye movement measures with that of English readers with dyslexia. To the best of our knowledge, there is no study with the data on eye-movements in sequential bilinguals-biliterates for whom their literacy skills are acquired in the non-dominant language (L2). For the most part, children in India will have native language as their dominant language (L1) and acquire literacy skills in non-dominant language (L2-English).Where, their exposure to English is mostly in school via English medium of instruction. This is true for children in south Indian state, Karnataka, where children are largely exposed to native language 'Kannada' (L1) and acquire most of their literacy skills in English (L2). The speaking and reading exposure to Kannada that is alphasyllabary- akshara involve the Grapheme to phoneme (GPC) processes where each phone can be visualized orthographically and most importantly phone of the consonant in akshara is invariant of vowel context and adhere to one particular GPC and there is not much irregularity in the print to sound form while reading. Unlike non transparent English (consist of irregular words, eg; talk where letter 'l' is considered to be silent while

reading and includes context depended phoneme to grapheme variance), where in the phone changes in the context of vowel (eg; C in the context of vowel /a/, /o/ and /u/ is pronounced as /k/ where as in context of vowel /i/ and /e/ is pronounced as /s/). Not all can acquire these principles and excel in academic performance.

Having known the fact that children with DD exhibit deficits to allocate higher mental process for reading the low frequent, irregular words and non-words (Hristova et al., 2004),it is speculated that sequential bi-literate [Kannada (L1) and English (L2)] DD may by and large apply L1 reading principle in operating and decoding the orthographic principles of English text material or their routes to decode the L2 text may be deviant from that of TDC. There is dearth of empirical evidences on sequential bilingual-biliterate DD children to substantiate the reading difficulty demonstrated in either or both the languages and specifically in a non-transparent language. The strategy for visual processing during reading on transparent language in TDC and DD may be similar or different that can be investigated using eye-tracking method. To our knowledge, understanding the visual processing for reading skills via eye tracking method, in Indian biliterate children is first of its kind and this procedure might facilitate to explore the unseen challenges faced by biliterate children with developmental dyslexia in acquiring reading skills.

Aim of the study

To explore the mechanism in reading words and non-words in Kannada-English biliterate older children with Developmental dyslexia, using eye-tracking method.

Objectives of the study: The study included the following three objectives

i. To investigate reading Words and Non-words in Kannada and English biliterate children in the age range of (11-14years) with DD and TDC on eye-tracking durational measures.
ii. To investigate the effect of syllabic length for reading words and non words in Kannada and English on eye tracking accuracy measures in DD and TDC.
iii. To compare the performance (accuracy and reading duration) of children with DD and TDC for syllabic length on reading words and non-words in Kannada and English across the eye tracking measures.

Hypotheses of the study: The study included the following three null hypotheses.

$H_0$1 There is no significant difference for eye tracking durational measures for reading in Kannada and English biliterate children with DD and TDC.

$H_0$2 There is no significant difference for eye tracking accuracy measures for reading in Kannada and English biliterate children with DD and TDC.

$H_0$3 There is no significant syllabic length effect in reading words and non-words in Kannada and English biliterate children with DD and TDC.

CHAPTER 2: Review of Literature

Good literacy skills are vital for better position and placement in life. Acquisition of these skills starts as early as 3-4 years of age. There are many intrinsic factors (such as developmental conditions, neuro-biological organization, perception, sensory-motor integration, processing skills, language proficiency) and extrinsic factors (such as socio-economic status, early exposure, intensive stimulation and medium of instruction) that influence acquisition of literacy skills. Language is one of the important factors that play a crucial role in literacy development. Exposure to different languages from early age can module the cognitive processing skills require for decoding and encoding skills of the child. Despite having adequate intelligence, sensory abilities, reading-writing instructions and socio-cultural opportunities, some children fail to develop literacy skills. These children exhibit specific difficulties in reading, spelling and writing manifesting difficulty to decode and extract meaning from text. To explore the underlying deficits in children with reading difficulties using eye-tracking methodology has growing evidence elucidating the better understanding of peripheral reading mechanisms that can interact with higher cognitive skill involved in reading.

2.1 Bilingual-Biliteracy[1]

India is a multilingual country. As per the constitutional provision of Eighth Schedule, 22 languages are officially recognized by Ministry of Human Resource Development, Government of India, (2008). The intellectual flexibility that is inherent in such a multicultural nation opportune children to speak more than two languages

[1] Operational Definition of 'Biliteracy' adapted for the present study:
Biliteracy or Bilingual Literacy refers to sequential acquisition of languages to learn literacy skills at home and in schools. Here, the first acquired language i.e. L1 is the native language of the child and the language the child acquires after that at school is considered second language or L2. In the context of the present study, biliteracy refers to literacy skills in Kannada becomes L1 and English becomes L2.

and to read and write British-American literature that is bound from early classroom and environmental exposure. Most of children learn to speak in their native language (L1- i.e, either Indo-Aryan like Hindi, Punjabi, Marathi, Gujrathi or Dravidian like Kannada, Tamil, Telugu, Malayalam etc,.) and also learn to read in both native language as well as in vernacular and/or foreign language (L2). In such a diverse country, importance of acquiring literacy skills in English language is prevailing nationwide, for English is one of the compound languages in India that is treated as 'bridging language' for communication as well as a 'passport' to gain access to worldwide knowledge. This is why it is mostly used as L2 and majorly practiced medium of instruction in elite schools and universities. Therefore, multilingual India has acknowledged the importance of English as a privileged language for medium of instruction and brought conspicuous amendments in education system by implementing tri-language formula (TLF), by the Secondary Education Commission (1953), Government of India. According to TLF, children should be educated in three languages. Where in Hindi Speaking states, combination of: (a) Hindi; (b) Any one south-Indian regional language; (c) English or any other modern European language. In non-Hindi speaking state: (a) Regional language; (b) Hindi and (c) English or any other modern European languages was recommended.

In this context, the first acquired i.e. L1 is native language of the child and the language that the child acquires after that from school is considered second language or L2. Earlier it was believed that a multilingual represents different languages separately and literacy development is bound to respective language domain. This describes biliteracy as linguistic proficiency that extends to literacy development in two separate languages (Fisherman, 1965; Ferguson, 1959). However, this perspective was questioned with the emergence of parallel phenomenon; development of literacy

in one language mirrors that in a second language (Grosjean, 1989). There was a shift from the traditional "domain construct" hypothesis of bilingualism suggesting 'two seperate monolinguals in one person' to a rather conventional "Common Underlying Proficiency" (CUP) model (Cummins, 1979). CUP explains 'how two structurally different languages interdependent on cognitive proficiency that allows interaction between languages'. Cuminns (1979) argued languaging of bilinguals' (i.e., language practice in particular context) is not just bound to linguistic abilities but has dynamic interrelationship governed by cognitive processes. This lead to dynamic approach towards bilingual education and bilingualism, Williams (1996), coined the term "translanguaging" meaning to receive information from one language and use it in other language. Thus, an active bilingual reader brings all the required skills and knowledge to decode the print by negotiating across languages (Bauer, 2017), indicating that effect of bilingualism on literacy is not restricted to language skills but involves other domains of learning.

2.2 Models for reading

"Reading is considered as a complex cognitive process where the information from the visual input first reaches the letterbox (visual word form area), from where it triggers both Broca's and Wernicke's areas for articulation and meaning respectively. This process is monitored by a top-down attention mechanism" (Dehaene, 2009). It is found that while reading a child takes time to establish connections from visual to auditory decoding processes. With frequent exposure , the child develops a lexicon and then becomes automatic According to Dehaene's model (2009), if a child has a perceptual/attention difficulties at the early stages, the child may not be able to get the concepts of grapheme-phoneme correspondence, and later it becomes difficult for developing

reading and writing skills. Such children would show reading deficits when compared to the typical readers.

2.2.1 Dual Coding Theory

The Pavio's dual coding theory talks about the continuous interaction of different processes for verbal and nonverbal activities with the single knowledge base, among bilinguals it is understood to be processed with separate knowledge in bilinguals.

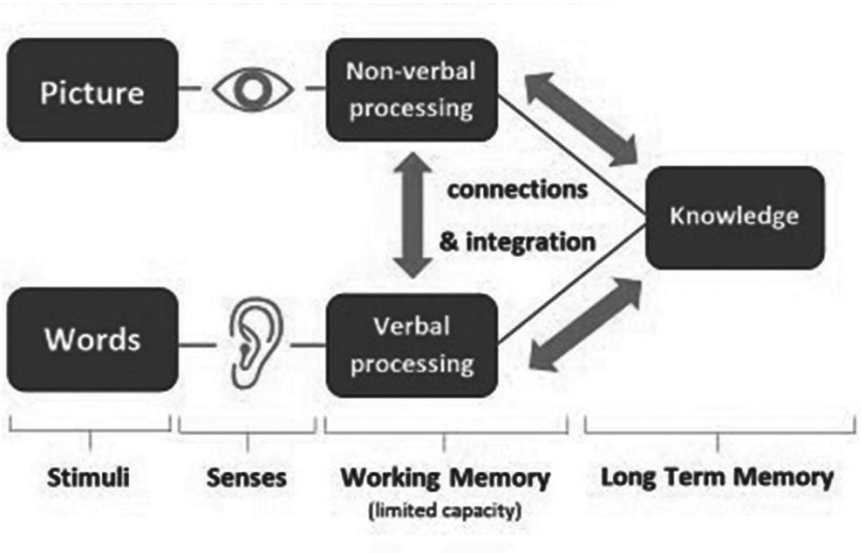

Figure 2.1: "Dual coding theory" by Paivio, A.,1986, *Educational psychology review, 3*(3), 149-210.

Source cited from: *Suvarna, R. C. (2018). Towards understanding dyslexia in a language with transparent orthography: Investigation of perceptual and phonological abilities in Telugu native speakers. Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Cognitive Science, International Institute of Information Technology Hyderabad.*

2.2.2 Dual Route Cascaded model

Popular models on reading include Dual Route Cascaded model (Figure 2.1 below) (Coltheart, 2008) that talks about two route for processing non lexical and lexical routes and these routes gets activated for separately for different word types, one is a serial processing that gets activated for non-lexical word recognition principle

based on grapheme to phoneme correspondence for phonological decoding and the other is the direct lexical route gets activated for retrieving words from mental lexicon for reading irregular words.

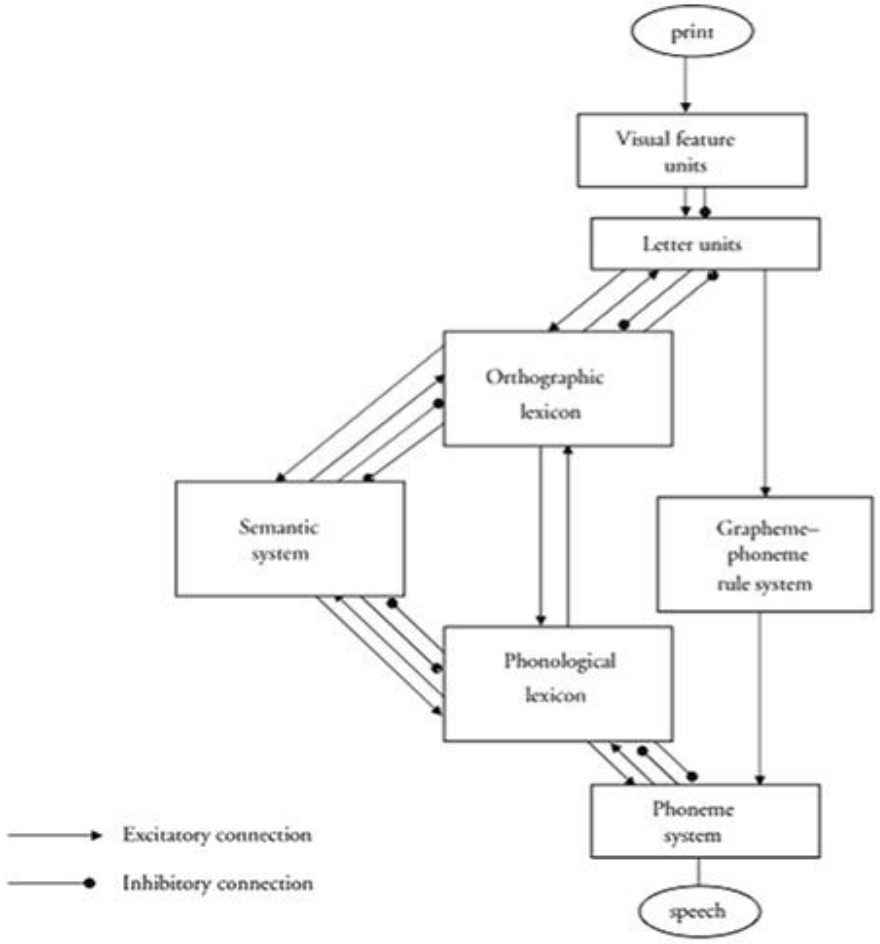

Figure 2.2: *Dual Route Cascaded Model (Coltheart, 2008)*
Source cited from: Adler-grinber, D. L. (1978). Eye movements, Scan paths and Dyslexia.American Journal of Optometry & Physiological Optics, 55(8), 557–570.

2.3 Developmental dyslexia

Individuals with reading disability have significant difficulty in reading despite appropriate educational opportunities, non-verbal intelligence, and or an identifiable disease or disorder that might otherwise account for the problem(American Psychiatric Association, 2000). A common criterion for diagnosing reading disability is decoding abilities (the accuracy or fluency) of

reading aloud greater than 1.5 SD below the standard mean, which results in a prevalence of about 5-10 % (Shaywitz, Shaywitz, Fletcher, & Escobar, 1990) Reading difficulty or developmental dyslexia (DD) is referred to as Specific developmental disorders of scholastic skills(Americans et al., 2013). According to (Lyon, Shaywitz, &Shaywitz, 2003), dyslexia is referred to as children having specific learning disabilities due to neurobiological origin and characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge. And more recently the term Developmental dyslexia (DD) is used alternatively.

2.4 Theories on Deficits in Developmental dyslexia (DD)

The cause of Developmental dyslexia (DD) is long debated. One prominent view is that children with reading difficulties have phonological impairments (e.g., Bishop &Snowling, 2004) that may result in written word recognition and phonological decoding (using letter-sound mapping knowledge to decode novel words) deficits.

2.4.1 Phoneme deficit theory

According to this theory that the reading difficulties in DD arise due to specific impairments in the representation, storage, and retrieval of speech sounds. Reading requires mapping between the letters and constituent of speech sounds of [grapheme to phoneme correspondence (GPC)]. It is believed to be the foundation for

alphabetic system and reading will be affected if there is GPC affected accordingly (Bradley and Bryant, 1978; Vellutino, 1979; Snowling,2000; Fowler, Brady & Shankweiler, 1991).

Visual processing deficits

2.4.2 Cerebellar theory

This theory suggests, cerebellum of dyslexics is mildly dysfunctional in developmental dyslexia and this causes difficulties in automatization of over-learned task, motor control. Motor function (e.g., Nicolson, Fawcett, & Dean, 2001), Szmalec, Loncke, Page, & Duyck, 2011)(Nicolson and Fawcett, 1990; Nicolson et al., 2001)

2.4.3 Auditory processing deficit theory

This theory suggest that individuals with dyslexia perform poorer in auditory perceptual tasks deficit for processing rapid and short sounds (Tallal, 1980; Tallal et al., 1993) including frequency discrimination (Ahissar et al., 2000) and temporal order judgement (Tallal, 1980; Nagarajan et al.,1999).

2.4.4 Magnocellular deficit theory

This theory claims that the abnormality in Magnocellular layers of the Lateral geniculate nucleus, in dyslexics and thereby, binocular and visual perceptual instabilityoccurs resulting in effect the letter stability and can cause letters which is being read can be crossing over each other or to appear to be moving around. According to this theory magnocellular dysfunction is generalized to all modalities for instance visual, auditory and tactile (Stein and Walsh, 1997).

Literature accounts on DD agree on, the multi-modal literacy deficits in processing skills. Several studies have reported the relation between behavior manifestation of children with Developmental Dyslexia (DD) with the underling core

deficits in phonological processing, auditory processing(Bradley & Bryant, 1978; Breznitz & Misra, 2003), visual processing (Cestnick&Coltheart1999), cerebellar (Nicolson, Fawcett & Dean, 2001)and general sensory-motor functioning(Jones, Obregón, Louise Kelly, & Branigan, 2008; Ramus, 2003). Amongst all, accounts on phonological processing deficit and visual processing deficits are evident in DD (Lobier, Zoubrinetzky & Valdois, 2012; Pan, Yan, Laubrock, Shu & Kliegl, 2014; Ramus, 2003; Snowling, 2001; Stanovich & Siegel, 1994; Trauzettel-Klosinski et al., 2010; Wolf et al., 2002; Ziegler & Goswami, 2005). Evidence on causal route of DD links phonological deficit (in task such as verbal working memory, rhyme oddity, rapid naming and non-word repetition) with cognitive impairment that is more central (Nag & Snowling, 2011; Snowling, 2001; Van den Broeck, Geudens, & van den Bos, 2010). With respect to visual processing, as early as 18^{th} century, studies have successfully noted the relation between eye movements and cognitive process (Rayner, 1997). Visual processing deficit is a peripheral deficit and its role is linked to disturbances in orthographic representation to process and decode text material. Most of the studies have confined this peripheral deficit to phoneme grapheme correspondence, an operational deficit and have indirectly related to phonological processing and thus linked to a central processing (Jarodzka & Brand-Gruwel, 2017; Marshall, Snowling& Bailey, 2001; Rayner & Duffy, 1986; Sereno & Rayner, 2003; Shaywitz et al., 2002).In contrast another set of researches propose that visual processing deficit are the primary cause of DD (Lobier et al., 2012; Vidyasagar & Pammer, 2010). The early deficits of the visual perception (poor visual attention span and disturbances in fixation) lead to poor phonological representation and orthographical coding; consequently DD shows error in retrieval and are less efficient

in learning higher operational literacy skills. Yet, most of the learning happens in the school age in an academic context via reading and comprehension of text.

Therefore, the academic achievements are correlated to reading comprehension skills (Cromley & Snyder-hogan, 2010). This marks the importance of visual processing and its deficits in developing children. To examine these deficits, investigators have largely relied on eye-tracking and ERP experimental procedures.

2.5 Script dependent and central processing hypothesis

Researchers who studied literacy in Indian languages believed that transparent orthography may demand different strategies for Indian languages as the basic unit in most of the Indian languages is a syllable and not a phoneme (Karanth, 1998; Prakash & Rekha, 1992).

There are studies in the recent decade that report on the influence of nature of orthography, its transparency and form of representation on the pattern of reading development in biliterate children (Durgunoglu & Oney, 2000; Veii, 2006; Veii & Everatt, 2005; Ziegler & Goswami, 2005). Many hypothesis and assumptions are put forth by researchers on reading and its relation to the processing of different writing systems existing in the world. Geva and colleagues (Gholamain & Geva, 1999: Geva & Siegel, 2000) proposed that the main theoretical positions to understand processing mechanisms in bilingual literacy, can be reduced to two competing perspectives as the *script dependent hypothesis* (Snowling, 2000) and *central processing hypothesis* (Geva, Wade-Wooley & Shany, 1997; Geva & Wang, 2001). The script dependent hypothesis posits that reading acquisition varies across languages. Under this general viewpoint are those theories that propose that reading development should vary with the depth of transparency of a particular orthography (Bialystok, 2002; Prema, 1998;

2000; Shanbal & Prema, 2007; Wang, Koda & Perfetti, 2003; Veii and Everatt, 2005; Suvarna, 2018). Researchers also found similar differences in biliterate children with reading difficulty, who showed deficits in one language and not in the other (Shanbal, 2010; Everatt, Smythe, Ocampo & Veii, 2002); Everatt, Smythe, Ocampo & Gyarmathy, 2004; Karanth, 1992; Miller-Guron & Lundberg, 2000; Smythe, Everatt, Gyarmathy, Ho & Groerger, 2003; Wydell & Butterworth, 1999).

The central processing hypothesis, on the other hand, assumes a *universal approach to literacy acquisition.* It proposes that reading development is not contingent upon the type and the nature of the orthography. Rather, common underlying linguistic and cognitive processes such as working memory, verbal ability, naming and phonological skills influence the development of reading across all languages (Pearson, 2002; Siegel, 2002). Geva (2000) and Gholamain and Geva (1999) found basic reading skills in one language correlated positively and significantly with their reading skills in another language. Such evidence for differential development and commonality of predictors led Geva and Siegel (2000) to conclude that the central processing and script dependant viewpoints are complementary to each other rather than being contradictory. Script dependent and central processing hypothesis explain either script specificity or universality to literacy in children who are biliterate (Shanbal, 2010).

2.6 Eye-tracking studies in children with dyslexia

In the last two decades there is an increase in the quantum of literature that accounts on eye-tracking experiment to understand the peripheral deficits and the effect of abnormal eye movements on visual encoding deficits of DD. While reading a continuous text our eyes glide smoothly across the page, which is composed of following events (a) fixation, the period when the eyes are relatively still while

attending to a part of text and new information is encoded. Fixation for typically developing individual might last for about 200-250ms, (b) saccades, that is the ballistic shift in gaze from word to word or within the syllables of a word, the duration in which one does not perceive the information during eye movement also brings the attended information to the central area of the fovea within the retina, for the greatest visual acuity. On other events like (c) regression, where readers move their eye backwards in text while there is contextual mismatch or difficulty in comprehending the text, (d) pupil dilation, that signifies the emotional context in reading or difficulties while reading (Rayner, 1997). Thus, the eye tracking device can provide the metrics for each of the parameters mentioned above. However, the most essential measures of reading are fixation duration (ms) and saccadic duration (ms) and these parameters are frequently pretentious in the DD.

A study conducted by Luca, Di, Judica, & Spinelli (1999) compared the eye movement patterns for linguistic and non-linguistic tasks in Italian script on 10dyslexics (age range of 10.11 to 17.11 years) with age matched controls (typically developing children, TDC). Results elucidated that children with dyslexia perform on par with control subjects in non-linguistic tasks but contrasted with altered patterns of eye movements for linguistic tasks such as reading short paragraphs. Authors reported that there were increased number of fixations and shorter and more frequent saccadic movements in dyslexics for words with particularly more number of fixations for longer words. This study revealed that dyslexia is not associated with oculomotor dysfunction and assured that their visual processing for reading strongly inclined on grapheme to phoneme correspondence (GPC). These findings were consistent with the other studies reported by Hutzler and Wimmer (2004) and Hyona and Olson (1995). Further, the eye movement in linguistic and non linguistic study was

protracted in order to probe on the visual processing for word length effect on words and non words (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002). This study contemplated the visual processing in reading for non transparent languages such as English, by conceiving the context of irregular words and non words that was created in Italian language. The authors reported the interaction of word length effect on reading words and non-words in 12 DDs with mean age of 13.1 years and 10 age matched controls. The authors reported that TDC showed increased saccadic amplitude for longer word with same no of saccades and more number of saccades only for longer non words whereas DDs showed more of fixations and frequent shorter saccades, for both words and non words irrespective of length effect thus recruiting sequential process. This study leaves the impression that DDs are inefficient to shift from print to sound GPC reading technique (that is slow in real time) to the rapid lexical or global analysis of words in a varied context. Hristova, Gerganov, Todorova, and Georgieva (2004) studied similar interactions of words length and word frequency effects for reading in second and fourth grade children with and without DD. Adding to the previously existing literature account, the main effect of group (dyslexic vs. typical readers) was significant for low frequency words where DD showed extremely slow eye movements, nevertheless, with the normal reading pattern.

Brief review of literature suggests that eye movement data of DDs show significantly long duration measures that are governed by frequency (high vs. low), words (real vs. pseudo) and word length (short vs. long) effects and their eye movement patterns are restricted to grapheme to phoneme correspondence aiding phoneme by phoneme, sequential visual processing. However, performance of DDs on transparent orthography such as Bulgarian (Hristova, Gerganov, Todorova, &

Georgieva (2004), Italian (De Luca et al., 2002) and Kannada (Das, Padakannaya, Kenneth Pugh, & Singh, 2011; Padakannaya & Rao, 2006) shows slow and longer fixation duration (due to complexity of syllabic script) yet less errors and lesser saccadic regression (greater regularity in print to sound forms) compared to English readers with dyslexia.

Native languages of India have a transparency in grapheme to phoneme correspondence (GPC). Kannada is one of the most researched Dravidian language of south India(Nag & Snowling, 2011; Padakannaya, Pandey, Saligram & Ranga Rao, 2016) that follows alphasyllabic system where each symbol in the script is called as*akshara* and it is composed of consonants and a vowel (CV or CCV or CCCV) an open syllable (ending with vowel) where each of the phonemic constituents are visually analyzable (eg; ಕ್ (consonant) + ು (vowel) = ಕು that is /k/ + /u/= /ku/).

In Kannada language, the prospects of eye tracking research on reading alphasyllabary scripts has included the following inspections: the identification of the minimum segmentation unit on reading, which is the visual recognition of vowels and consonants with in syllable composite, the application of the orthographic principles while decoding the compound (CCV) and complex (CCCV) alphasyllables (Winskel, Padakannaya & Pandey, 2014). This study is on typically developed population and it reported that TDC apply the principle of segmentation of the syllable in words and decode the vowel sound as the function of the head bar in the script. Nevertheless, the group of researchers (Padakannaya et al., 2016)have conducted an eye tracking study to compare TDC, RD (children with reading difficulty) and RL (reading level age matched to RD)children in Kannada language, with repeated measure of complexity in akshara(Level 1 (CV) basic letters (/sarala:kshara/), level 2 (CV) with varying vowel ligature as a function of head bar on consonant (/gunitakshara/) and level 3

(CCV or CCCV) combination of consonants conjunction and vowel ligature (/ottakshara/)). They reported that the older TDC proficient readers read Kannada aksharas at three different levels without segmenting them into its phonemic constituents and hence TDC did not show any significant difference between the three levels of akshara complexity. Whereas, the younger readers, RL and the RD groups showed difficulty in decoding the level 3 akshara. However, in Eye tracking measures, there was no significant difference between TD and RL in number of fixations across the akshara complexity levels. Thus, authors claim that the absence of significant difference is not in support of phonemic processing in view of akshara.

In summary, it can be concluded that the literature available for studying eye-tracking measures in children with dyslexia is marked by variations in different orthographies which necessitated the need to investigate whether visual processing could be influencing differently for different languages such as in Indian Kannada-English biliterate children for reading skills via the eye-tracking method.

CHAPTER 3: Method

The aim of the current study was to explore the mechanism in reading words and non-words in Kannada-English bi-literate older children with Developmental dyslexia using the eye-tracking method and to compare their performance on parameters (like saccade, fixation, reading accuracy and word reading duration) with that of age-matched typically developing children. The present study followed a standard group comparison which employed multifactorial mixed design.

The objectives of the study were as follows:

i. To investigate reading Words and Non words in Kannada and English by biliterate children in the age range of (11-14years) with DD and TDC on eye-tracking durational measures.

ii. To investigate the effect of syllabic length for reading words and non words in Kannada and English on eye tracking accuracy measures in DD and TDC.

iii. To compare the performance (accuracy and reading duration) of children with DD and TDC for syllabic length on reading words and non words in Kannada and English across the eye tracking measures.

3.1 Participants

A total of thirty-six (36) children from 6^{th} grade to 8^{th} grade in the age range of $11.0 \leq A \leq 14.0$years (where 'A' being the age of the participants) participated in the study. Group I consisted of 18 children with Developmental Dyslexia (DD) as diagnosed by a Speech-Language Pathologist and a Clinical Psychologist. And group II consisted of 18 age-matched typically developing (TDC) children.

Participants' selection criteria:

a) All the participants were recruited from, Mysore, Karnataka state, India and had Kannada as their first language (L1); and the medium of instruction in school was largely in English (L2) and from an early age. All these children were biliterate with Kannada as L1 and English as L2.

b) The participants were administered language use questionnaire (Shanbal & Prema, 2007) to check for exposure and use of Kannada (L1) and Indian-English (L2) languages and later an informed consent was obtained from their caregivers/parents/teachers as detailed in the AIISH 'Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects''.

c) The WHO 10 disability questionnaire (Singhi, Kumar, Malhi, & Kumar, 2007) was administered to rule-out if participants had any sensory, motor, and/or any notable developmental deficits (such as attention, autism and social disorders).

d) The selected participants were further screened for normal or corrected to normal vision in consultation with an ophthalmologist before inclusion to the study.

e) To measure their L1 ability and to ensure there is no significant language delay in their oral L1 development, Linguistic Profile Test- Kannada (Karanth, 2007) was administered; However, in the present study the participants are sequential bilinguals with L1 proficient Kannada oral language and the literacy training was given in L2, English.

3.2 Eye-tracking Experiment

3.2.1 Stimuli

The stimuli consisted total numbers of 90 words and non-words that included lists of 15 Kannada words (KW) and 15 Kannada non-words (KNW) and lists of 15 English words (EW), 15 English non-words (ENW), 15 English irregular words (EIW) and 15 English irregular non-words (EINW). Each list had five items with a hierarchy of simple bisyllabic to complex trisyllabic words and non-words (Appendix 1).

Words and non-words in the list were selected from Reading acquisition profile in Kannada (Prema, 1998) and also from the doctoral thesis- 'Acquisition of biliteracy in children' at AIISH (Shanbal, 2010) for Kannada stimuli and for English stimuli, words were taken from paragraphs reading stimuli of Gray oral reading tests (Gray & Robinson, 1984) based on the age and grade level (6th to 8th grade) of the typically developing participant. The non-words of English stimuli were formed by substitution of one consonant and one vowel of the words selected in the word list; yet, following the phonotactic of English. For example if the selected word is 'Picnic' the non-word was formed by substituting any one consonant i.e, 'P' with 'L' and a vowel 'i' with 'a' leading to a non-word 'Lacnic' Similarly, irregular non-words were formed. Those of Kannada non-word stimuli were taken from RAP-K and the thesis for the selected words without any changes.

Word lists with seven items in each were subjected to content validation by five Speech-Language Pathologists (SLP). SLPs were requested to rate all the stimuli from each subcategory (bisyllabic, trisyllabic, and polysyllabic) on two-point (1-correct or 0-incorrect) rating scale for the following aspects, for the correct spelling of words, appropriateness of the corresponding age and reading level of the stimuli and

the concept of irregularity (silent letters- e.g.: talk, contextual variations of phoneme to grapheme correspondence- e.g.: geography) in the English irregular word list. Amongst each list that was rated, five most agreed stimuli from all the five SLPs were qualified to be the final target stimuli.

3.2.2 Instrumentation

Experimental software, PsychoPy V1.83.00 (Peirce, 2015) was used to load and present the stimulus trials. Stimuli were presented on a 38.1cm screen Dell Vostro 3550 laptop. Eye tracking measures were recorded by SMI high-speed eye tracker (Senso Motoric Instruments, Germany) with a sampling rate range from 50Hz to 1250 Hz. This recorder has an Eye Tracking Glasses Device (ETG-2.6-1751-190) connected to a removable powerless infrared Eye tracking glasses (ETG) having two mini cameras on the lower edge of the frame and a microphone and also soft retainer cords (for adjusting the proper fit) along the sides of the handle of the frame. The ETG worn by the participant was interfaced with a Lenovo laptop of (15.6" display and 1920 x 1080 px resolution) having licensed i-view ETG eye-tracking experiment software. This software could video record and display eye tracking points across time.

Figure 3.1: *SMI Eye tracking instrument set- up for the experiment*

The analysis of the recorded sample was carried out using the SMI-BeGaze software (version 3.7). With the help of a tool- 'Export metrics' within the SMI-BeGaze software, the raw data output of eye movements (i.e. saccade and visual intake/fixation) was derived for the recorded sample of reading.

3.2.3 Procedure

The reading task was carried out in a well-lit room, with minimal environmental noise. Participants were helped to wear Eye Tracking glasses by tightening the retainer cords for proper fit and they were seated on a height adjustable chair with the head was placed on the chin rest that was mounted to a table. They were requested to stay as still as possible and also to try minimizing eye blinks during the recording. The stimulus presenting laptop was placed at the viewing distance of 60cm from the seating of the participant.

Instruction: The participants were instructed as "Now we will do a reading task in English and Kannada. Look at the laptop screen, you will be shown a plus (+) symbol

that appears at the centre of the screen followed by a text stimulus in many trials. Once the text stimuli appear, you have to read the text as clear as possible and on finishing reading each trial press 'space bar' key to move to the next trial". Similarly, participants were also instructed in Kannada language for a better understanding of the task.

Calibration: Eye movements were first calibrated using a three-point calibration. A picture-animation file with five red dots appearing on the screen (centre and corners) was played in the stimulus laptop screen. Participants were asked to trace the calibration red dots as accurately as possible and the examiner marked these points. The correction factor was obtained for each traced points by the i-view ETG software.

Testing trial: A total of six blocks of stimuli having four blocks of each consisting 5 Words (W), 5 Non- words (NW), 5 Irregular words (IW) and 5 Irregular non-words (INW) stimuli in English language and 2 blocks of 5 Words (KW), 5 Non- words (KNW) stimuli in Kannada language was presented on stimuli laptop screen. All the six blocks had simple monosyllable stimuli to complex trisyllable stimuli and the order of presentation was randomized within each block and between the participants.

On each trial, a small '+' symbol was used as prime at the centre of the screen for 500ms to get the visual fixation of the participant, followed by stimulus was presented in a random order. The target stimuli were presented in a text form with Arial font style and a font size of 72. Participants are expected to read the text in each trial and press 'space bar' key to move to the next trial after reading. The total duration of data recording for each participant was expected to last for around 30 minutes.

3.3. Scoring and data analyses

Audio-video recorded eye movement data of reading was transferred to SMI BeGaze software by selecting 'Export metrics' icon and the recorded sample was processed by the software . The analyzed numerical raw data was obtained in the MS Excel spreadsheet. This raw data was manually segregated by noting the duration of the stimulus read in the original video. The starting point of the duration was noted the appearance of the prime (+) symbol until the end of the acoustic signal of reading. For each subject, manually segregated durational values were further sorted for saccade duration, fixation duration and total duration for each block of Bisyllabic, trisyllabic and polysyllabic words. The examiner cross verified the duration measures in excel sheet with that of the audio-video sample. The durational measures were averaged in each list. For accuracy measures, the data as read by the participants were transcribed orthographically in IPA format and the accurate responses were given a score of one '1' and the inaccurate responses were scored as zero '0'. Ten percent of this data was given to five SLPs other than examiners who had a previous hands-on experience using eye-tracking device to verify the mapping of eye movements with that of the duration measures and accuracy measures of reading, for inter-judge reliability. The durational values and accuracy measures analyzed by the SLPs were found to be synchronous nearly 100% with those of the examiner for. Following the verification, the data was subjected to statistical analysis using SPSS version 20.0 software.

Chapter 4: Results

The aim of the present study was to explore the mechanism in reading words and non-words in Kannada-English bilingual-biliterate older children with Developmental Dyslexia using eye-tracking method. The study mainly focused to compare the durational measures, accuracy measures and syllabic length effect for reading words and non-words in Kannada and English between developmental dyslexia (DD) and typically developing children (TDC) and children with in the age range of 11-14years.

The eye-tracking data obtained from both the groups, i.e. DD and TDC, was subjected to statistical analysis for the durational measures and accuracy scores for reading words and non-words in both Kannada and English languages. The data was subjected to Shapiro- Wilk's test for normality test and the results revealed that the data did not follow the normal distribution ($p < 0.05$) hence; non- parametric tests were carried out. The mean scores of each of the durational values and accuracy scores were computed for each of the word categories in both languages. The data was analyzed using the following statistical procedures:

a) Descriptive statistics was carried out to obtain the mean, median and standard deviation (SD) for durational measures and accuracy scores of DD and TDC groups in Kannada and English words and non words.
b) Mann Whitney U- test was carried out to check if there was significant difference between the DD and TDC groups on the durational measures and accuracy scores for reading Kannada and English words and non-words and for varied syllabic length (bisyllabic, trisyllabic and polysyllabic).

c) Friedman test was carried out to find out if there was significant difference between Kannada and English words and non-words pairs with increasing syllabic length (bisyllabic, trisyllabic and polysyllabic) in DD and TDC groups.

d) Wilcoxon's signed rank test was carried out to find outif there was significant difference between Kannada and English words and non-words pairs and for increasing (bisyllabic, trisyllabic and polysyllabic) syllabic length within the DD and TDC groups.

The results of the study are explained under the following headings:

4.1 Durational measures for reading Kannada and English words and non-words in children with DD and TDC.

4.2 Accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

4.3 Syllabic length effect on durational and accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

4.1 Durational measures for reading regular Kannada and English words and non-words in children with DD and TDC.

The durational measures analyzed in the present study included fixation duration, saccade duration, total duration for reading Kannada and English words and non-words in children with DD and TDC. The results for each of these measures across word categories in the two groups in Kannada and English are explained in the following sections.

4.1.1 Fixation duration for reading Kannada and English in children with DD and TDC

Descriptive statistics showed the Mean, Median and Standard Deviation (SD) for fixation duration obtained for each of the word categories: Kannada words, Kannada non words, English Words and English non words, for both the groups (DD and TDC). Table 4.1 shows mean, median, SD values of fixation duration (F) for Kannada words (FKW), Kannada non words (FKNW), English Words (FEW) and English non words (FENW) in children with DD and TDC.

Table 4.1

Mean, Median, SD values of fixation duration (in ms) for Kannada words, non-words and English words, non-words in children with DD and TDC.

Group	DD				TDC			
Word category	N	Mean	SD	Median	N	Mean	SD	Median
FKW	18	5301.99	1542.85	5258.95	18	4011.14	767.31	3850.70
FKNW	18	5876.19	2190.73	5630.35	18	4748.52	1385.94	767.31
FEW	18	7402.43	3521.15	5837.02	18	3950.76	824.31	3706.88
FENW	18	11193.1	4805.03	11242	18	5083.53	1400.34	4549.96

Note: FKW= Fixation of Kannada Word, FKNW= Fixation of Kannada Non- Words, FEW= Fixation of English Word, FENW= Fixation of English Non- Word.

The analysis of results as in table 4.1 revealed that the fixation durations were longer in children with DD when compared to the TDC for all the word types. As indicated in Table 4.1, overall it was found that children with DD showed longer mean fixation duration {for Kannada words (Mean=5301.99ms, SD=1542.85), Kannada non words (Mean=5876.19ms), English words (Mean=7402.43ms, SD=3521.15) and English non words (Mean=11193.1ms, SD=4805.03)} when compared to TDC {Kannada words (Mean=4011.1416ms, SD=767.31), Kannada non words (Mean=4748.52ms, SD=824.31), English words (Mean=3950.76ms,

SD=2153.53) and English non words (Mean=5083.53ms, SD=1400.34)}. As indicated in figure 4.1, it was observed that children with DD longer fixation duration in comparison to TDC for reading words and non-words in both Kannada and English. [Figure 4.1]

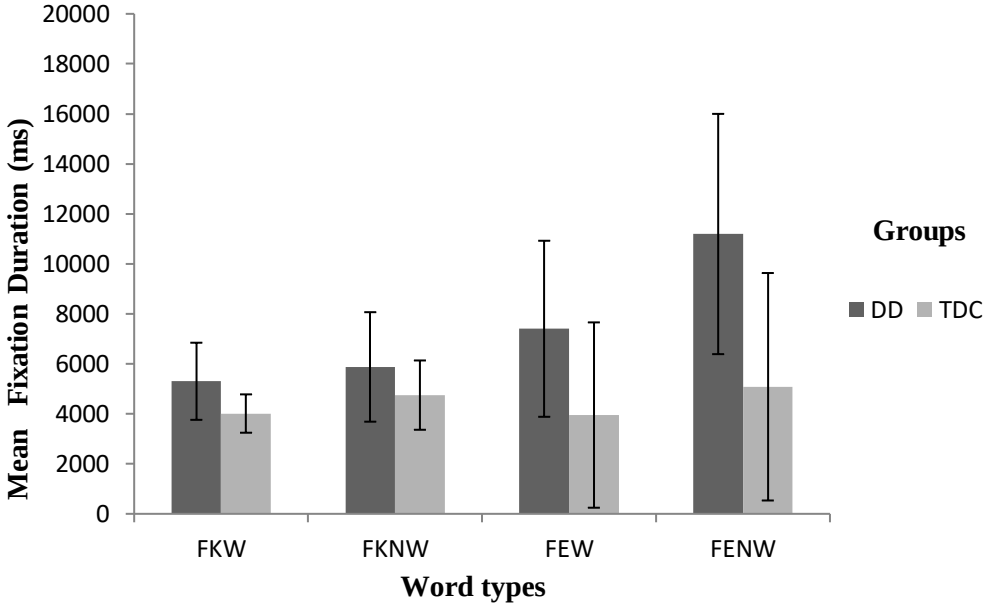

Figure 4.1: *Mean fixation duration values for reading Kannada and English words and non-words in DD and TDC.*
Note: FKW= Fixation of Kannada Word, FKNW= Fixation of Kannada Non- Words, FEW= Fixation of English Word, FENW= Fixation of English Non- Word.

Analysis of the results on Mann Whitney U test revealed that there was no significant difference between DD and TDC for reading Kannada words, (FKW, $|z|=1.866$, $p>0.05$) and non-words, (FKNW, $|z|=1.422$, $p>0.05$). However, the mean scores indicated longer fixation durations for children with DD in comparison to TDC for Kannada words and Kannada non-words. There was a significant difference for fixation duration measures between DD and TDC for reading English words (FEW, $|z|=3.110$, $p<0.05$), English non-words, (FENW, $|z|=2.843$, $p<0.05$). The mean scores as in Table 4.1 indicated that children with DD performed poorer when compared to TDC in English.

Further the data was analyzed separately for the word type (word- non words) and for the language difference (Kannada and English) using the Wilcoxon's Signed ranked test for children with DD and TDC. Analysis of the results in children with DD, indicated that there was no significant difference between reading words and non-words in both Kannada (FKW-FKNW), $|z|=0.178$, $p>0.05$ and English, (FEW-FENW) $|z|=2.100$, $p>0.05$. The results also indicated that there was no significant difference between languages for reading Kannada words when compared to English words (FKW-FEW), $|z|=1.400$, $p>0.05$. However, there was a significant difference found for fixation duration of Kannada non word when compared to English non words, (FKNW-FENW) $|z|=2.701$, $p<0.05$. The analysis of the results in TDC indicated that there was a significant difference for reading words and non words in both Kannada (FKN-FKNW $|z|=2.803$, $p<0.05$, and English FEW-FENW $|z|=2.803$, $p<0.05$, However, there was no significant difference between languages for reading Kannada words when compared to English FKW-FEW, $|z|=0.153$, $p>0.05$, similarly there was no significant difference for reading Kannada non words when compared to English non words for FKNW-FENW $|z|=0.866$, $p>0.05$.However, the mean scores indicated that TDC showed longer fixation duration for reading non-words as compared to words in both languages.

To summarize the results of fixation duration for reading words and non-words in Kannada and English between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for words and non-words in both and Kannada and English. There was a significant difference for fixation duration measures between DD and TDC for reading English words and non-words. There was no significant difference between DD and TDC for reading Kannada words non words.

4.1.2 Saccade duration for reading Kannada and English in children with DD and TDC

Descriptive statistics showed the Mean, Median and Standard Deviation (SD) for saccade duration obtained for each of the word categories: Kannada words, Kannada non words, English Words and English non words, for both the groups (DD and TDC). Table 4.2 shows Mean, Median, SD values of Saccade duration (S) for Kannada words (SKW), Kannada non words (SKNW), English Words (SEW) and English non words (SENW) in children with DD and TDC.

Table 4.2
Mean, Median, SD values of Saccade duration (in ms) for Kannada words, non-words and English words, non-words in children with DD and TDC.

Group	DD				TDC			
Word category	N	Mean	SD	Median	N	Mean	SD	Median
SKW	18	342.47	173.81	318.32	18	261.55	105.47	223.97
SKNW	18	404.43	264.89	286.19	18	392.24	216.48	338.78
SEW	18	1198.09	1392.08	503.16	18	398.38	144.31	360.08
SENW	18	803.74	521.404	715.31	18	536.06	236.40	451.95

Note: SKW= Saccade of Kannada Word, SKNW= Saccade of Kannada Non- Words, SEW= Saccade of English Word, SENW= Saccade of English Non- Word.

The analysis of results as indicated in Table 4.2 revealed that the saccade durations were longer in children with DD when compared to when compared to the TDC for all the word types. As indicated in Table 4.2, overall it was found that children with DD showed longer mean saccade duration {Kannada words (Mean=342.47ms, SD=173.81), Kannada non words (Mean=404.43ms, SD=264.89), English words (Mean=1198.09ms, SD=1392.08) and English non words (Mean=830.74, SD=521.40)} when compared to TDC {Kannada words (Mean=261.55ms, SD=105.47), Kannada non words (Mean=392.24ms, SD=216.48),

English words (Mean=398.38ms, SD=144.31) and English non words (Mean=536.06, SD=236.40)}. As indicated in figure 4.1, it was observed that children with DD longer Saccade duration in comparison to TDC for reading words and non-words in both Kannada and English. [Figure 4.2]

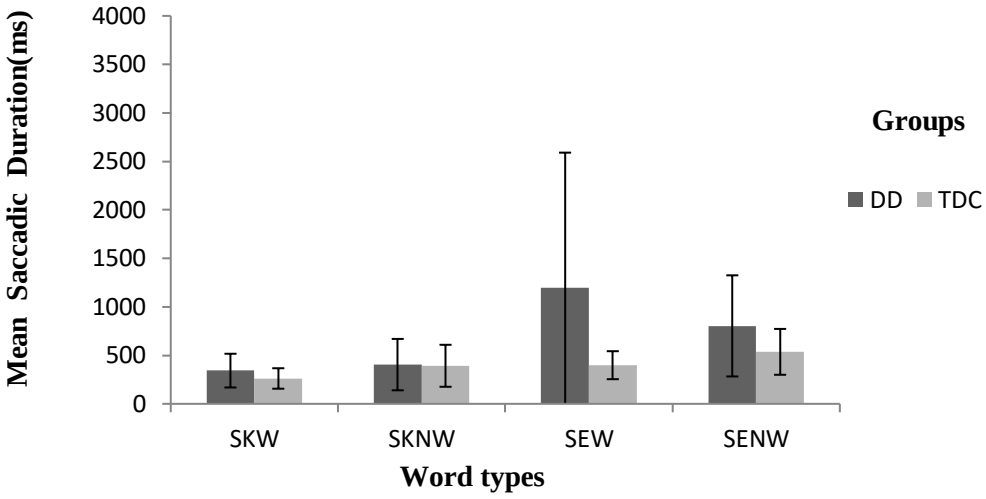

Figure 4.2: *Mean Saccade duration values for reading Kannada and English words and non-words in DD and TDC.*
Note: SKW= Saccade of Kannada Word, SKNW= Saccade of Kannada Non- Words, SEW= Saccade of English Word, SENW= Saccade of English Non- Word.

Analysis of the results on Mann Whitney U test revealed that there was no significant difference between DD and TDC for reading Kannada words SKW, $|z|=1.244$, $p>0.05$, non-words SKNW, $|z|=0.355$, $p>0.05$. However, the mean scores indicated longer saccade durations for children with DD in comparison to TDC for Kannada words, Kannada non words and English non words. There was a significant difference for saccade duration measures between DD and TDC for reading English words SEW, $|z|=2.132$, $p<0.05$. There was no significant difference between DD and TDC for reading English non-words SENW, $|z|=1.155$, $p>0.05$.

The mean scores as in Table 4.1 indicated that children with DD performed poorer when compared to TDC in English.

Further the data was analyzed separately for the word type (word- non words) and for the language difference (Kannada and English) using the Wilcoxon's Signed ranked test for children with DD and TDC. Analysis of the results in children with DD, indicated that there was no significant difference between reading words and non-words in both Kannada (SKW-SKNW) $|z|=1.120$, $p>0.05$ and English, (SEW-SENW) $|z|=1.000$, $p>0.05$. The results also indicated that there was a significant difference between languages for reading Kannada words when compared to English words (SKW-SEW), $|z|=2.521$, $p<0.05$ and for reading Kannada non word when compared to English non words, (SKNW-SENW) $|z|=2.666$, $p<0.05$. The analysis of the results in TDC indicated there was a significant difference for reading words and non-words in both Kannada (SKN-SKNW) $|z|=1.988$, $p<0.05$, and English (SEW-SENW) $|z|=1.988$, $p<0.05$. Also, there was a significant difference between languages for reading Kannada words when compared to English words (SKW-SEW) $|z|=1.988$, $p<0.05$. However, there was no significant difference for reading Kannada non words when compared to English non words for (SKNW-SENW) $|z|=1.580$, $p>0.05$. However, the mean scores indicated that DD showed longer saccade duration for reading non-words as compared to words in both languages and TDC showed longer saccade duration for reading English non words when compared to Kannada non words. (SKNW-SENW).

To summarize the results of saccadic duration for reading words and non-words in Kannada and English between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean saccadic duration for words and non-words in both and Kannada and English. There was a significant

difference for saccadic duration between DD and TDC for reading English words only. There was no significant difference for reading English non-words, Kannada words and non-words between DD and TDC.

4.1.3 Total Gaze duration for reading Kannada and English in children with DD and TDC

Descriptive statistics showed the Mean, Median and Standard Deviation (SD) for total gaze duration obtained for each of the word categories: Kannada words, Kannada non words, English Words and English non words, for both the groups (DD and TDC). Table 4.3 shows mean, median, SD values of total gaze duration (TG) for Kannada words (TGKW), Kannada non words (TGKNW), English Words (TGEW) and English non words (TGENW) in children with DD and TDC.

Table 4.3

Mean, Median, Standard Deviation values of Total Gaze duration for reading Kannada and English words and non-words in children with DD and TDC.

Group	DD				TDC			
Word type	N	Mean	SD	Median	N	Mean	SD	Median
TGKW	18	5644.46	1560.72	5506.96	18	4272.69	791.24	4085.12
TGKNW	18	6280.63	2256.94	5952.29	18	5063.47	1417.4	4378.79
TGEW	18	8600.52	4280.65	6334.47	18	4349.15	901.96	4047.61
TGENW	18	12023.93	5246.73	12201.01	18	5625.05	1618.96	5001.92

*Note:*TGKW= Total Gaze duration Kannada Word, TGKNW= Total Gaze duration Kannada Non words, TGEW= Total Gaze duration of English Word, TGENW= Total Gaze duration of English Non-Word.

The analysis of results as in table 4.3 revealed that the total gaze durations were longer in children with DD when compared to the TDC for all the word types. As indicated in Table 4.3, overall it was found that children with DD showed longer mean fixation duration {for Kannada words (Mean=5644.46ms, SD=1560.72),

Kannada non words (Mean=6280.63ms, SD=2256.94), English words (Mean=8600.52ms, SD=4280.65) and English non words (Mean=12023.93ms, SD=5246.73)} when compared to TDC {Kannada words (Mean=4272.69ms, SD=791.24), Kannada non-words (Mean=5063.47ms, SD=1417.4), English words (Mean=4349.15ms, SD=901.96) and English non words (Mean=5625.05ms, SD=1618.96)}. As indicated in figure 4.3, it was observed that children with DD longer total gaze duration in comparison to TDC for reading words and non-words in both Kannada and English. [Figure 4.3]

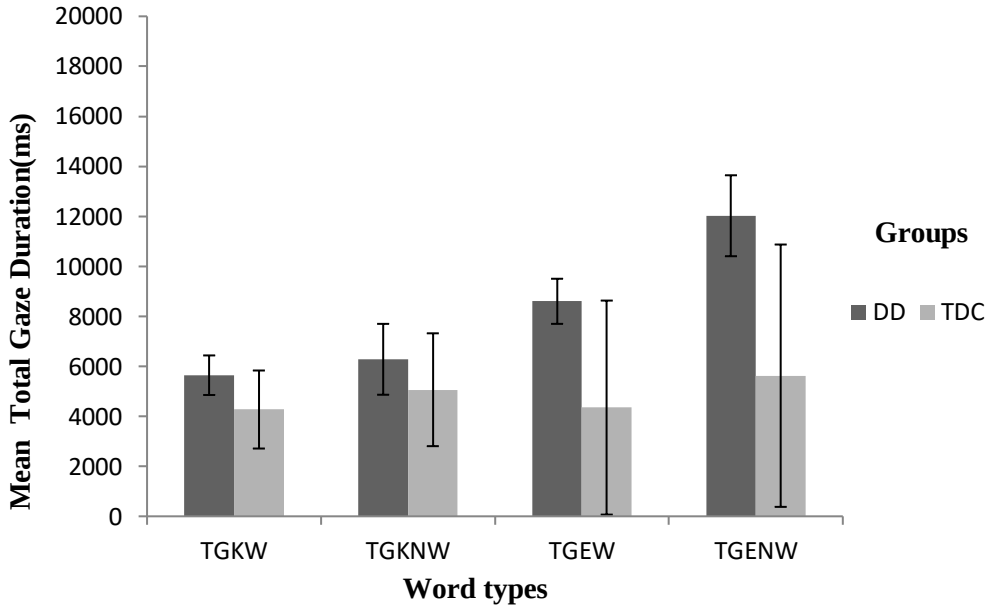

Figure 4.3: *Mean Total gaze duration values for reading Kannada and English words and non-words in DD and TDC.*
Note: TGKW= Total Gaze duration Kannada Word, TGKNW= Total Gaze duration Kannada Non words, TGEW= Total Gaze duration of English Word, TGENW= Total Gaze duration of English Non-Word.

Analysis of the results on Mann Whitney U test revealed that there was a significant difference for total gaze duration measures between DD and TDC for reading Kannada words, $|z|=2.132$, $p<0.05$, English words, $|z|=-3.110$, $p<0.05$ and English non- words $|z|=2.666$, $p<0.05$. The mean scores as in Table 4.3 indicated that children with DD performed poorer when compared to TDC in English. There

was no significant difference between DD and TDC for reading Kannada non words, $|z|=1.333$, $p>0.05$). However, the mean scores indicated longer total gaze durations for children with DD in comparison to TDC for Kannada non words.

Further the data was analyzed separately for the word type (word- non words) and for the language difference (Kannada and English) using the Wilcoxon's Signed ranked test for children with DD and TDC. Analysis of the results in children with DD, indicated that there was a significant difference between reading words and non-words in English, (TGEW-TGENW), $|z|=2.100$, $p<0.05$. However, there was no significant difference for that of Kannada words and non-words (TGKW-TGKNW) $|z|=0.533$, $p<0.05$. The results also indicated that there was no significant difference between languages for reading Kannada words when compared to English words (TGKW-TGEW), $|z|=0.123$, $p>0.05$. However, there was a significant difference for total gaze duration of Kannada non word when compared to English non words, (TGKNW-TGENW) $|z|=2.666$, $p<0.05$. The analysis of the results in TDC indicated that there was a significant difference for reading words and non-words in both Kannada (TGKN-TG KNW $|z|=2.497$, $p<0.05$, and English (TGEW-TGENW) $|z|=2.497$, $p<0.05$, However, there was no significant difference between languages for reading Kannada words when compared to English (TGKW-TGEW) $|z|=0.357$, $p>0.05$, similarly there was no significant difference for reading Kannada non words when compared to English non words for (TGKNW-TGENW) $|z|=0.968$, $p>0.05$. However, the mean scores indicated that DD showed longer total gaze duration for reading Kannada non words when compared to Kannada words and TDC showed longer total gaze duration for reading non-words as compared to words in both languages.

To summarize the results of total gaze duration for reading words and non-words in Kannada and English between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for words and non-words in both and Kannada and English. There was a significant difference for total gaze duration between DD and TDC for reading Kannada words, English words and non-words. There was no significant difference for reading Kannada nonwords between DD and TDC.

4.2 Accuracy scores for reading Kannada and English in children with DD and TDC

The accuracy scores were analyzed in the present study included the accuracy scores for reading Kannada and English words and non-words in children with DD and TDC. The results for each of these measures across word categories in the two groups in Kannada and English are explained in the following sections.

Table 4.4

Mean, Median, SD values of accuracy scores for Kannada words, non-words and English words, non-words in children with DD and TDC.

Group	DD				TDC			
Word type	N	Mean	SD	Median	N	Mean	SD	Median
AKW	18	2.266	1.447	2.666	18	4.666	0.384	4.833
AKNW	18	2.233	1.457	2.233	18	4.300	0.637	4.500
AEW	18	2.766	2.479	2.166	18	7.933	2.423	9.166
AENW	18	2.633	2.196	2.000	18	6.200	2.495	6.500

Note: AKW= Accuracy of Kannada Word, AKNW= Accuracy of Kannada Non- Words, AEW= Accuracy of English Word, AENW= Accuracy of English Non Word.

The analysis of results as indicated in table 4.4 revealed that the accuracy scores were lesser in children with DD when compared to TDC in all the word categories, however, the pattern of the scores were similar. As indicated by Table 4.4,

in children with DD, overall it was found that accuracy scores were similar {Kannada words (Mean=2.266, SD=1.447), Kannada non words (Mean=2.233, SD=1.457), English words (Mean=2.766, SD=2.479) and English non words (Mean=2.633, SD=2.196)} when compared to TDC {Kannada words (Mean=4.666, SD=0.384), Kannada non words (Mean=4.300, SD=0.637), English words (Mean=7.933, SD=2.423) and English non words (Mean=6.200, SD=2.495)}. As indicated in figure 4.1, it was observed that children with DD scored lesser in comparison to TDC for reading words and non words in both Kannada and English [Figure 4.1].

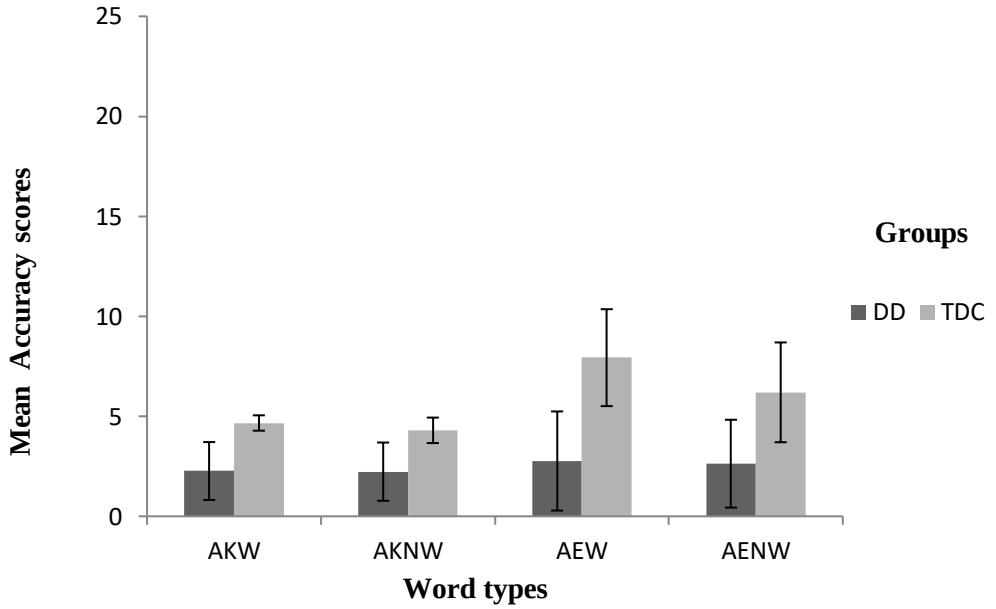

Figure 4.4: *Accuracy scores for Kannada words, non-words and English words, non-words in children with DD and TDC.*

Note: AKW= Accuracy of Kannada Word, AKNW= Accuracy of Kannada Non- Words, AEW= Accuracy of English Word, AENW= Accuracy of English Non Word.

Analysis of the results on Mann Whitney U test revealed that there was a significant difference for accuracy scores between DD and TDC for Kannada words (AKW) $|z|=3.635$, $p<0.05$, Kannada non words (AKNW) $|z|=3.156$, $p<0.05$ as well as for English words (AEW) $|z|=3.635$, $p<0.05$ and for English non words (AENW) $|z|=2.726$, $p<0.05$. The mean scores as in Table 4.1 indicated that children with DD performed poorer when compared to TDC in English.

Further the data was analyzed separately for the word type (word- non words) and for the language difference (Kannada and English) using the Wilcoxon's Signed ranked test for children with DD and TDC. Analysis of the results in children with DD, indicated that there was a significant difference between reading words and non-words in both Kannada (AKW-AKNW) $|z|=1.980$, $p<0.05$ and English, (AEW-AENW) $|z|=2.675$, $p<0.05$. The results also indicated that there was a significant difference for accuracy scores between the languages for reading Kannada words when compared to English words (AKW-AEW), $|z|=2.608$, $p<0.05$ and for reading Kannada non word when compared to English non words, (AKNW-AENW) $|z|=2.091$, $p<0.05$. However, The analysis of the results in TDC indicated there was no significant difference between reading words and non-words in both Kannada (AKW-AKNW) $|z|=0.213$, $p>0.05$ and English, (AEW-AENW) $|z|=0.000$, $p>0.05$. The results also indicated that there was no significant difference for accuracy scores between the languages for reading Kannada words when compared to English words (AKW-AEW), $|z|=0.831$, $p>0.05$ and for reading Kannada non word when compared to English non words, (AKNW-AENW) $|z|=0.953$, $p>0.05$. However, the mean scores indicated that TDC showed better scores for reading words when compared to non-words and also the accuracy scores were better of English words and non-words when compared to Kannada words and non-words.

To summarize the results of accuracy measures DD and TDC, overall it was found that children with DD showed poorer performance when compared to TDC words and non-words in both Kannada and English. There was significant difference between DD and TDC for Kannada words and non-words and English words and non-words.

4.3. Syllabic length effect on durational and accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

The syllabic length effect was analyzed in terms of durational and accuracy measures for reading Kannada and English words and non-words in children with DD and TDC

4.3.1 Fixation duration measures for reading Kannada and English words and non-words on syllabic length in children with DD and TDC

Descriptive statistics with Mean, Median and SD for fixation duration was obtained in each of Kannada and English word and non-word pairs with increasing syllabic length: (bisyllabic, trisyllabic and polysyllabic) in DD and TDC. Table 4.5 shows mean, median, SD values of fixation duration for reading bisyllabic, trisyllabic, polysyllabic words and non-words in Kannada and English in children with DD and TDC groups.

Table 4.5

Mean, Median, SD values of fixation duration (in ms) for Kannada words, non-words and English words, non-words with increasing syllabic length in DD and children with TDC

Word category	DD				TDC			
	N	Mean	SD	Median	N	Mean	SD	Median
Kannada FBKW	18	4503.80	1680.77	3926.90	18	3830.66	634.63	3689.06
FBKNW	18	5350.84	3546.84	4504.08	18	3830.80	706.51	3834.41
FTKW	18	5800.27	2966.21	5535.60	18	4150.40	823.37	3916.75
FTKNW	18	5436.39	2071.19	5159.80	18	5508.19	3559.91	4302.18
FPKW	18	7261.43	2020.43	8187.75	18	4052.36	1126.28	3668.94
FPKNW	18	10604.63	7895.67	7359.30	18	4906.56	1130.96	4522.59
English FBEW	18	6077.80	2677.14	6053.76	18	3592.71	894.17	3354.44
FBENW	18	11598.14	7753.84	8065.33	18	5152.62	3278.37	4138.01
FTEW	18	7174.73	4728.54	5617.56	18	3964.95	876.41	3594.10
FTENW	18	13314.69	4913.52	13544.64	18	4422.01	883.66	4311.51
FPEW	18	9761.40	4546.14	8877.60	18	4294.63	1438.62	3914.41
FPENW	18	17836.57	6062.81	16018.06	18	5536.52	1528.74	5017.45

Note: FBKW= Fixation of Bisyllabic Kannada Words, FBKNW= Fixation of Bisyllabic Kannada Non-Words, FTKW= Fixation of Trisyllabic Kannada Words, FTKNW= Fixation of Trisyllabic Kannada Non-Words, FPKW= Fixation of Polysyllabic Kannada Words, FPKNW= Fixation of Polysyllabic Kannada Non-Words, FBEW= Fixation of Bisyllabic English Words, FBENW= Fixation of Bisyllabic English Non- Words, FTEW= Fixation of Trisyllabic English Words, FTKNW= Fixation of Trisyllabic English Non-Words, FPEW= Fixation of Polysyllabic English Words, FPENW= Fixation of Polysyllabic English Non-Words.

The analysis of results as in table 4.5 revealed that the mean fixation durations were longer in children with DD when compared to the TDC for all the word types. Overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English (mean scores depicted in Table 4.5). Further, Friedman's analysis for Kannada words revealed a significant difference on syllabic length for children with DD (χ^2 (2) =12.286, $p<0.05$), when compared to TDC, (χ^2 (2) =0.800, $p>0.05$). For Kannada words, Wilcoxon's Signed ranked test revealed that there was significant difference between Bisyllabic-Polysyllabic ($|z|=2.366, p<0.05$)

and polysyllabic-trisyllabicwords $|z|=2.366$, $p<0.05$). However, there was no significant difference found between bisyllabic-trisyllabic, $|z|=1.680$, $p>0.05$). For Kannada nonwords, Friedman's results revealed a significant difference on syllabic length in both children with DD (χ^2 (2) =6.000, $p<0.05$), as well as in TDC (χ^2 (2) =12.800, $p<0.05$). Further Wilcoxon's Signed ranked test revealed that there was significant difference between bisyllabic-polysyllabic Kannada non words ($|z|=2.380$, $p<0.05$) in children with DD, whereas, there was no significant difference between bisyllabic-trisyllabic ($|z|=1.690$, $p>0.05$) and trisyllabic-polysyllabic ($|z|=1.352$, $p>0.05$). In TDC, for Kannada nonwords, there was a significant difference between bisyllabic-polysyllabic ($|z|=2.803$, $p<0.05$). There was no significant difference between trisyllabic-polysyllabic nonwords ($|z|=1.352$, $p>0.05$) and. bisyllabic-trisyllabic $|z|=1.690$, $p>0.05$).

Further, results on Friedman's analysis for English words revealed a significant difference on syllabic length for children with DD (χ^2 (2) =8.600, $p<0.05$) when compared to TDC, (χ^2 (2) = 3.71, $p>0.05$). For English words, Wilcoxon's Signed ranked test revealed that there was significant difference between Bisyllabic-Polysyllabic ($|z|=2.701$, $p<0.05$) and there was no significant difference between bisyllabic-trisyllabic ($|z|=1.682$, $p>0.05$) and trisyllabic-polysyllabic ($|z|=1.07$, $p>0.05$). For English nonwords, Friedman's results revealed a significant difference on syllabic length in both children with DD (χ^2 (2) =6.222, $p<0.05$), while there was no significant difference for TDC (χ^2 (2) =1.00, $p>0.05$). Further Wilcoxon's Signed ranked test for DD on English nonwords revealed that there was significant difference between trisyllabic-polysyllabic ($|z|=2.310$, $p<0.05$). There was no significant difference between bisyllabic-polysyllabic English non words ($|z|=1.784$, $p>0.05$), and bisyllabic-trisyllabic ($|z|=0.296$, $p>0.05$) in children with DD.

To summarize the results of syllabic length effect on fixation duration between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English. There was a significant length effect observed for Kannada words and nonwords and English words and nonwords. On the other hand for TDC, there was no significant length effect observed on Kannada words and English words and nonwords. There was a significant length effect observed for Kannada nonwords only, in TDC.

4.3.2 Saccadic duration measures for reading Kannada and English words and non-words on syllabic length in children with DD and TDC

Table 4.5 shows mean, median, SD values of saccadic duration for reading bisyllabic, trisyllabic, polysyllabic words and non-words in Kannada and English in children with DD and TDC groups.

The analysis of results as in table 4.6 revealed that the mean saccadic durations were longer in children with DD when compared to the TDC for all the word types. Overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic no-nwords in DD (mean scores depicted in Table 4.6),

Table 4.6

Mean, Median, SD values of saccadic duration (in ms) for Kannada words, non-words and English words, non-words with increasing syllabic length in DD and children with TDC.

Group		**DD**				**TDC**		
Word category	N	Mean	SD	Median	N	Mean	SD	Median
Kannada								
SBKW	18	247.59	140.93	224.42	18	183.62	69.01	173.3
SBKNW	18	229.44	123.51	212.75	18	223.6	95.69	205.58
STKW	18	257.33	172.35	174.6	18	261.02	110.79	234.21
STKNW	18	288.52	186.10	233.6	18	449.49	454.22	234.20
SPKW	18	684.91	374.06	548.5	18	340.01	159.07	297.61
SPKNW	18	750.56	740.19	405.25	18	309.49	77.55	283.20
English								
SBEW	18	845.81	1063.24	418.6	18	311.25	146.10	244.84
SBENW	18	865.42	737.26	710.2	18	459.50	291.88	383.16
STEW	18	568.45	434.67	445.04	18	379.85	187.38	308.13
STENW	18	1069.38	436.41	1175.16	18	488.42	288.04	394.58
SPEW	18	2517.40	4371.63	873.7	18	504.05	155.14	486.26
SPENW	18	1537.47	994.13	1381.05	18	635.92	229.70	595.01

Note: SBKW= Saccade of Bisyllabic Kannada Words, SBKNW= Saccade of Bisyllabic Kannada Non- Words, STKW= Saccade of Trisyllabic Kannada Words, STKNW= Saccade of Trisyllabic Kannada Non-Words, SPKW= Saccade of Polysyllabic Kannada Words, SPKNW= Saccade of Polysyllabic Kannada Non-Words, SBEW= Saccade of Bisyllabic English Words, SBENW= Saccade of Bisyllabic English Non- Words, STEW= Saccade of Trisyllabic English Words, STKNW= Saccade of Trisyllabic English Non-Words, SPEW= Saccade of Polysyllabic English Words, SPENW= Saccade of Polysyllabic English Non-Words.

Further, Friedman's analysis for Kannada words revealed a significant difference on syllabic length on saccadic duration for children with DD (χ^2 (2) =10.571, $p<0.05$), when compared to TDC, (χ^2 (2) =14.60, $p>0.05$). For Kannada words, Wilcoxon's Signed ranked test revealed that there was a significant difference between Bisyllabic-Polysyllabic ($|z|=2.366, p<0.05$) and polysyllabic-trisyllabicwords $|z|=2.366$, $p<0.05$). However, there was no significant difference found between bisyllabic-trisyllabic, $|z|=0.506$, $p>0.05$). For Kannada nonwords, Friedman's results revealed a significant difference on syllabic length on saccadic duration in children with DD (χ^2 (2) =11.143, $p<0.05$), there was no significant

difference in TDC (χ^2 (2) =2.00, p>0.05). Further Wilcoxon's Signed ranked test revealed that there was significant difference between bisyllabic-polysyllabic Kannada non words ($|z|$=2.380, p<0.05) and trisyllabic-polysyllabic ($|z|$=2.366, p<0.05) in children with DD, whereas, there was no significant difference between bisyllabic-trisyllabic ($|z|$=1.014, p>0.05).

Further, results on Friedman's analysis for English words revealed a significant difference on syllabic length for children with DD (χ^2 (2) =22.800, p<0.05) when compared to TDC which did not reveal any significant difference, (χ^2 (2) = 3.714, p>0.05). For English words in DD, Wilcoxon's Signed ranked test revealed that there was significant difference between trisyllabic-polysyllabic ($|z|$=2.293, p<0.05) and Bisyllabic-Polysyllabic ($|z|$=2.803, p<0.05) and there was no significant difference between bisyllabic-trisyllabic ($|z|$=1.784, p>0.05). For English nonwords, Friedman's results revealed a significant difference on syllabic length in both children with DD (χ^2 (2) =6.222, p<0.05), while there was no significant difference for TDC (χ^2 (2) =2.33, p>0.05). Further Wilcoxon's Signed ranked test for DD on English nonwords revealed that there was significant difference between trisyllabic-polysyllabic ($|z|$=1.362, p<0.05) and bisyllabic-polysyllabic English non words ($|z|$=1.886, p<0.05). There was no significant difference between bisyllabic-trisyllabic ($|z|$=0.770, p>0.05).

To summarize, the results of syllabic length effect on saccadic duration between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean sacaddic duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic nonwords in DD. There was a significant length effect observed for Kannada words and nonwords and English words and nonwords. On the other

hand for TDC, there was no significant length effect observed on Kannada words and English words and nonwords. There was a significant length effect observed for Kannada nonwords only, in TDC.

4.3.3 Total gaze duration for reading Kannada and English words and non-words on syllabic length in children with DD and TDC

Table 4.7 shows mean, median, SD values of total gaze duration for reading bisyllabic, trisyllabic, polysyllabic words and non-words in Kannada and English in children with DD and TDC groups.

The analysis of results as in table 4.7 revealed that the mean total gaze durations were longer in children with DD when compared to the TDC for all the word types. Overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic nonwords in DD (mean scores depicted in Table 4.7), Further, Friedman's analysis for Kannada words revealed a significant difference on syllabic length on saccadic duration for children with DD (χ^2 (2) =12.286, $p<0.05$), when compared to TDC which did not have any significant difference, (χ^2 (2) =3.800, $p>0.05$).

Table 4.7

Mean, Median, SD values of total gaze duration (in ms) for Kannada words, non-words and English words, non-words with increasing syllabic length in DD and children with TDC.

Group		**DD**				**TDC**		
Word category	N	Mean	SD	Median	N	Mean	SD	Median
Kannada								
TDBKW	18	4014.289	644.8189	3828.68	18	4751.393	1729.252	4124.117
TDBKNW	18	4016.679	774.5621	4062.902	18	5580.288	3598.469	4735.154
TDTKW	18	4411.426	815.8659	4251.44	18	6047.606	3127.629	5690.567
TDTKNW	18	5957.682	3701.35	4704.888	18	5724.913	2132.089	5890.6
TDPKW	18	4392.371	1165.507	4002.153	18	7946.34	1897.094	8747.3
TDPKNW	18	5216.054	1183.922	4830.168	18	11355.19	7845.158	8035.31
English								
TDBEW	18	3903.96	976.2149	3716.061	18	6923.581	3255.437	6396.188
TDBENW	18	5612.125	3560.402	4498.142	18	12463.56	8366.375	8833.813
TDTEW	18	4344.806	1046.56	3954.315	18	7743.18	5156.521	6062.6
TDTENW	18	4910.437	1047.324	4669.5	18	12785.84	6899.283	14643.8
TDPEW	18	4798.685	1477.818	4392.304	18	12278.8	7866.639	10008.95
TDPENW	18	6188.803	1700.758	5666.3	18	19374.05	6924.312	17048.58

Note: TDBKW= Total Duration of Bisyllabic Kannada Words, TDBKNW= Total Duration of Bisyllabic Kannada Non- Words, TDTKW= Total Duration of Trisyllabic Kannada Words, TDTKNW= Total Duration of Trisyllabic Kannada Non-Words, TDPKW= Total Duration of Polysyllabic Kannada Words, TDPKNW= Total Duration of Polysyllabic Kannada Non-Words, TDBEW= Total Duration of Bisyllabic English Words, TDBENW= Total Duration of Bisyllabic English Non- Words, TDTEW= Total Duration of Trisyllabic English Words, TDTKNW= Total Duration of Trisyllabic English Non-Words, TDPEW= Total Duration of Polysyllabic English Words, TDPENW= Total Duration of Polysyllabic English Non-Words.

For Kannada words, Wilcoxon's Signed ranked test revealed that there was a significant difference between trisyllabic-polysyllabic words $|z|=2.366$, $p<0.05$) and Bisyllabic-Polysyllabic ($|z|=2.366$, $p<0.05$) and. However, there was no significant difference found between bisyllabic-trisyllabic, $|z|=1.68$, $p>0.05$). For Kannada nonwords, Friedman's results revealed a significant difference on syllabic length on saccadic duration in children with DD ($\chi^2(2)=6.00$, $p<0.05$) and TDC ($\chi^2(2)=11.400$, $p<0.05$). Further Wilcoxon's Signed ranked test revealed that there was significant

difference between bisyllabic-polysyllabic Kannada non words ($|z|$=2.380, $p<0.05$). There was no significant difference between bisyllabic-trisyllabic ($|z|$=1.690, $p>0.05$) and trisyllabic-polysyllabic ($|z|$=1.352, $p>0.05$) in children with DD. In TDC, there was a significant difference found between bisyllabic-polysyllabic ($|z|$=2.380, $p<0.05$) and there was no significant difference between bisyllabic-trisyllabic ($|z|$=1.690, $p>0.05$) and trisyllabic-polysyllabic-($|z|$=1.352, $p>0.05$).

Further, results on Friedman's analysis for English words revealed a significant difference on syllabic length for children with DD (χ^2 (2) =11.40, $p<0.05$) when compared to TDC which did not reveal any significant difference, (χ^2 (2) =3.714, $p>0.05$). For English words in DD, Wilcoxon's Signed ranked test revealed that there was significant difference between bisyllabic-polysyllabic ($|z|$=2.803, $p<0.05$) and there was no significant difference between bisyllabic-trisyllabic ($|z|$=1.68, $p>0.05$) and trisyllabic-polysyllabic ($|z|$=1.478, $p>0.05$). For English non-words, Friedman's results revealed a significant difference on syllabic length in both children with DD (χ^2 (2) =8.22, $p<0.05$), while there was no significant difference for TDC (χ^2 (2) =1.00, $p>0.05$). Further Wilcoxon's Signed ranked test for DD on English nonwords revealed that there was significant difference between trisyllabic-polysyllabic ($|z|$=2.31, $p<0.05$). There was no significant difference between bisyllabic-trisyllabic ($|z|$=0.533, $p>0.05$) and bisyllabic-polysyllabic English non words ($|z|$=1.784, $p>0.05$).

To summarize the results of syllabic length effect on total gaze duration between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean sacaddic duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic non-words in DD. There was a significant length effect observed

for Kannada words and non-words and English words and non-words. On the other hand for TDC, there was no significant length effect observed on Kannada words, English words and non-words. There was a significant length effect observed for Kannada non-words only, in TDC.

4.3.3 Accuracy measure for reading Kannada and English words and non-words on syllabic length in children with DD and TDC

Table 4.8 shows mean, median, SD values for accuracy measure on reading bisyllabic, trisyllabic, polysyllabic words and non-words in Kannada and English in children with DD and TDC groups.

The analysis of results as in table 4.8 revealed that the mean accuracy scores were lesser in children with DD when compared to the TDC for all the word types. Overall it was found that when compared to TDC, children with DD showed lesser accuracy scores for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English (Table 4.8). Further, Friedman's analysis for Kannada words revealed that there was no significant difference on accuracy measure for children with DD (χ^2 (2) =5.250, p>0.05), when compared to TDC which showed that there was a significant difference in TDC, (χ^2 (2) =6.500, p<0.05). For Kannada nonwords, Friedman's results revealed that there was no significant difference on accuracy in children with DD (χ^2 (2) =1.357, p>0.05) and TDC (χ^2 (2) =1.33, p>0.05.

Table 4.8

Mean, Median, SD values of accuracy measures for Kannada words, non-words, and English words and non-words with increasing syllabic length in children with DD and TDC

Group	**DD**				**TDC**			
Word category	N	Mean	SD	Median	N	Mean	SD	Median
ABKW	18	2	1.16	2.5	18	4.9	0.32	5
ABKNW	18	2.4	1.71	3	18	4.6	0.7	5
ATKW	18	2.8	1.69	3	18	4.5	0.53	4.5
ATKNW	18	2.5	1.51	2.5	18	4.2	1.23	4.5
APKW	18	2	1.76	2	18	4.6	0.52	5
APKNW	18	1.8	1.69	1	18	4.1	0.1	4
ABEW	18	8.6	1.9	9.5	18	8.6	1.9	9.5
ABENW	18	6.3	2.36	5.5	18	6.3	2.36	5.5
ATEW	18	8	2.58	9	18	8	2.58	9
ATENW	18	7.2	2.7	8	18	7.2	2.7	8
APEW	18	7.2	2.97	9	18	7.2	2.97	9
APENW	18	5.1	3.25	5.5	18	5.1	3.25	5.5

Note: ABKW= Accuracy of Bisyllabic Kannada Words, ABKNW= Accuracy of Bisyllabic Kannada Non- Words, ATKW= Accuracy of Trisyllabic Kannada Words, ATKNW= Accuracy of Trisyllabic Kannada Non-Words, APKW= Accuracy of Polysyllabic Kannada Words, APKNW= Accuracy of Polysyllabic Kannada Non-Words, ABEW= Accuracy of Bisyllabic English Words, ABENW= Accuracy of Bisyllabic English Non- Words, ATEW= Accuracy of Trisyllabic English Words, ATKNW= Accuracy of Trisyllabic English Non-Words, APEW= Accuracy of Polysyllabic English Words, APENW= Accuracy of Polysyllabic English Non-Words.

The analysis of results as in table 4.8 revealed that the mean accuracy scores were lesser in children with DD when compared to the TDC for all the word types. Overall it was found that when compared to TDC, children with DD showed lesser accuracy scores for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English (Table 4.8). Further, Friedman's analysis for Kannada words revealed that there was no significant difference on accuracy measure for children with DD (χ^2 (2) =5.250, p>0.05), when compared to TDC which showed that there was a significant difference in TDC, (χ^2 (2) =6.500, p<0.05). For Kannada

nonwords, Friedman's results revealed that there was no significant difference on accuracy in children with DD (χ^2 (2) =1.357, p>0.05) and TDC (χ^2 (2) =1.33, p>0.05.

Further, results on Friedman's analysis for English words revealed a significant difference on accuracy for children with DD (χ^2 (2) =13.862, p<0.05) and TDC (χ^2 (2) =9.18, p<0.05). For English words in DD, Wilcoxon's Signed ranked test revealed that there was a significant difference between trisyllabic-polysyllabic ($|z|$=2.53, p>0.05) and bisyllabic-polysyllabic ($|z|$=2.53, p<0.05). There was no significant difference between bisyllabic-trisyllabic ($|z|$=1.49, p>0.05). For English non-words, Friedman's results revealed a significant difference on accuracy in children with DD (χ^2 (2) =6.727, p<0.05) and TDC (χ^2 (2) = 5.886, p<0.05). Further Wilcoxon's Signed ranked test for DD on English non-words revealed that there was significant difference between and bisyllabic-polysyllabic ($|z|$=2.20, p<0.05). There was no significant difference between bisyllabic-trisyllabic ($|z|$=0.420, p>0.05) and trisyllabic-polysyllabic ($|z|$=1.20, p>0.05).

To summarize the results of accuracy measures DD and TDC, overall it was found that children with DD showed poorer performance when compared to TDC, for bisyllabic, trisyllabic and polysyllabic words and non-words in both Kannada and English. The accuracy scores for reading bisyallabic words was better when compared to trisyllabic followed by polysyllabic words in both Kannada and English for DD and TDC. There was significant length effect observed for English words and non-words only. There was no syllabic length effect observed for Kannada words and non-words. For TDC, there was a significant length effect observed for Kannada words, English words and non-words, whereas there was no significant length effect observed for Kannada non-words.

CHAPTER 5: Discussion

The aim of the present study was to explore the mechanism in reading words and non-words in Kannada-English bilingual-biliterate older children with Developmental Dyslexia using eye-tracking method. The study mainly focused to compare the durational measures, accuracy measures and syllabic length effect for reading words and non words in Kannada and English between typically developing children (TDC) and children with developmental dyslexia (DD) in the age range of 11-14years

The findings of the study are explained under the following headings:

5.1 Durational measures for reading Kannada and English words and non-words in children with DD and TDC.

5.2 Accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

5.3 Syllabic length effect on durational and accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

5.1 Durational measures for reading Kannada and English words and non-words in children with DD and TDC.

In the present study the analysis of durational measures included fixation duration, saccade duration, total gaze duration for reading for reading Kannada and English word and non-words in children with DD and TDC.

The results of the present study on fixation duration for reading words and non-words in Kannada and English between DD and TDC, indicated that when compared to TDC, children with DD showed longer mean fixation duration for words

and non-words in both and Kannada and English. There was a significant difference for fixation duration measures between DD and TDC for reading English words and non-words. There was no significant difference between DD and TDC for reading Kannada words and non-words.

Also the results of saccadic duration for reading words and non-words in Kannada and English between DD and TDC, showed that overall when compared to TDC, children with DD showed longer mean saccadic duration for words and non-words in both and Kannada and English. There was a significant difference for saccadic duration between DD and TDC for reading English words only. There was no significant difference for reading English non-words, Kannada words and non-words between DD and TDC.

Further, the results of total gaze duration for reading words and non-words in Kannada and English between DD and TDC, showed that when compared to TDC, children with DD showed longer total gaze duration for words and non-words in both and Kannada and English. There was a significant difference for total gaze duration between DD and TDC for reading Kannada words, English words and non-words. There was no significant difference for reading Kannada non-words between DD and TDC.

Findings of longer fixation duration for children with developmental dyslexia is consistent with the studies that report an altered eye moment durations in children with Developmental Dyslexia (Judica, Luca, Spinelli, &Zoccolotti, 2002, De Luca, Di, Judica, Spinelli, & Zoccolotti, 1999; Olson & Davidson,1983, Creavin, Lingam, Steer, & Williams, 2015; Eden, Stein, Wood, & Wood:, 1994; Howell, 1983; Kim & Lemke, 2016; Martos & Vila, 1990). The literature account on altered fixation

durational measures have attributed it to visual processing deficits in children with DD. (Hutzler, & Wimmer, 2004; Hyona & Olson, 1995). The orthographic processing skills required to encode and decode the print information could take longer time for children with DD and thus can affect the automatic learning of words (Leij&Daal, 1999). This is indicative of lag in automaticity in children with DD. Further, the findings of De Luca, Di, Judica, Spinelli, and Zoccolotti (1999) on the visual processing deficits in twelve DDs (13 years old) using eye tracking for reading linguistic and non-linguistic material suggested that DDs were reported to show inefficient shift from print to sound and these findings were related to the visual processing deficit inclining to the grapheme to phoneme correspondence (GPC) difficulties in DD.

The findings of the present study on durational measures indicated that, children with DD showed significant longer durations for English words and non-words than TDC. On the other hand there was no to least significant difference for reading Kannada words and non-words. The findings of the study are in line with cross-linguistic studies of bilingual children with dyslexia who reported of minimal deficits in transparent orthographies (Davies et al., 2007; Hautala et al., 2013; Landerl et al., 2013, and 1997; Zeigler et al., 2010). In other studies with Indian languages children are found to showed varied deficits in reading of children with dyslexia (Nag and Snowling 2011; Gupta, 2004). It was also observed that children with DD showed non-linear saccadic movements when compared to TDC, which was more linear. Greater fixation durations are often attributed to the time required for the cognitive processing of that word (Just and Carpenter, 1980). From the current study it could be inferred that children with DD are take longer time to process decoding or reading of words in English when compared to Kannada. These findings hint towards, difference

in transparency of orthographies which influences the cognitive processing of words in different languages.

Another explanation for longer fixation duration could also be reasoned to a deficit in the magnocellular layer which could have caused the letters that they are attempting to read to move around (Stein and Walsh, 1997; Livingstone et al., 1991) making the reading task complex and thus increase in the processing time. Also it could be possible that increased gaze duration could imply longer visual attention and automatization deficit in children with DD wherein lack of automatic word recognition processes can lead to slower access to the phonological and orthographic representation of the words. Also, it is often found that children with dyslexia could be doing two tasks at the same time while reading, one is decoding (which requires attention) and the second is comprehension. It has been reported in various studies that typical reader identification of words is automatic and hence children can dedicate time only to comprehension of the word (Perfetti, 2013 and Stanovich, 1999). It is possible that in children with DD since the automatization has not occurred children tend to spend more time on attending while reading and also comprehending the word.

Research supports the notion that phoneme awareness deficits in children with DD could have influenced language difference found in the present study. Poorer performance in English when compared to Kannada in DD is indicative of advantage in reading transparent orthographies such as Kannada. These findings are in support of a study conducted by Suvarna (2018) in Telugu-English bilingual children with dyslexia. Better performance in reading transparent orthographies such as Kannada where the phonological representation is syllabic (i.e. the unit grain size is a syllable),

and the phonological consistency is transparent, one-to-one mapping between grapheme and its constituent phoneme is evident.

Similarly, dyslexic readers delay in word recognition corresponds to gaze fixation difficulty that in turn implies visual- attention and automatization deficit (i.e., lack of automatic word recognition processes, which means very fast accessing to the phonological and orthographic representation of the words). It has been shown that dyslexic readers are always doing two tasks at the same time during reading: one is decoding the word, which takes a lot of attention and second is comprehension. Whereas, in the typical readers the identification of words is so automatic that there is much attention that can be devoted to the comprehension, understanding the text (Perfetti, 2013; Stanovich, 1999).

Research has shown that higher mean fixation duration corresponds to the time required for the cognitive processing (Just and Carpenter, 1980). In a model proposed by Suvarna (2018), (Fig 5.1) the cognitive processes involved in reading are explained. This framework consists of the features of both the dual route model (Coltheart, 2008) and as well as dual coding model (Paivio, 1981) with a single semantic system. For example the dual route model implies that normal reading can happen in two pathways based on the familiarity/frequency of a word. Models of reading can explain the cognitive process involved in reading, for instance, dual route cascaded model (Fig 2.2). It argued that normal reading can proceed in two pathways based on the familiarity/frequency of a word. The known words are accessed faster from the lexicon through the direct route, while the unknown words take the indirect route applying phoneme to grapheme conversion rules.

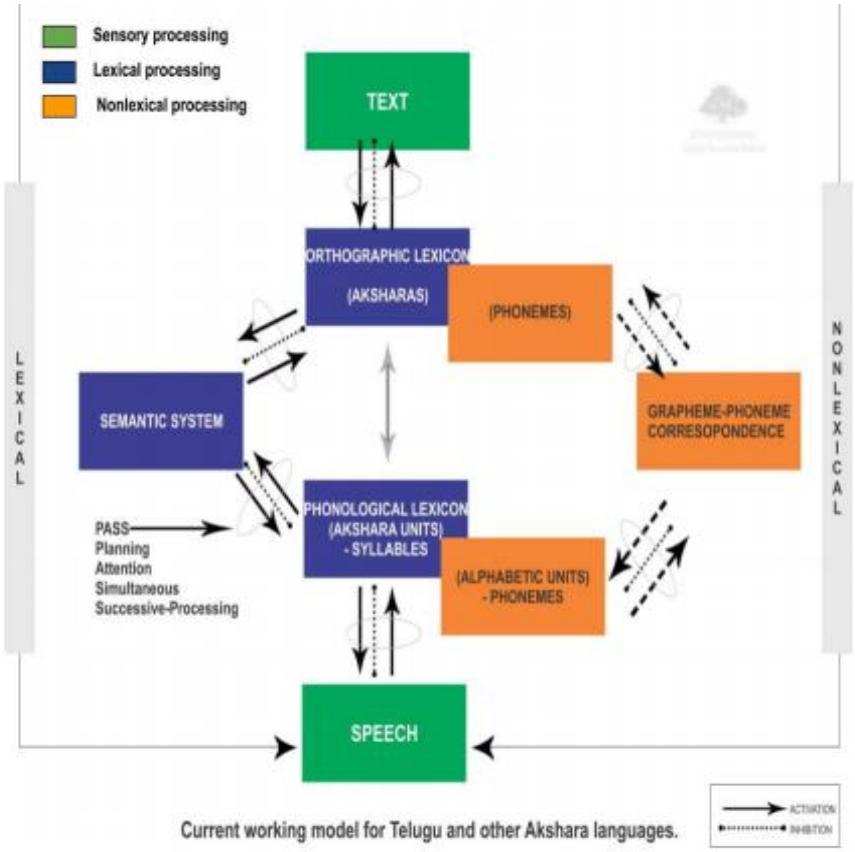

Figure 5.1 Proposed working model for Telugu and other Akshara languages

Source: *Suvarna, R. C. (2018). Towards understanding dyslexia in a language with transparent orthography: Investigation of perceptual and phonological abilities in Telugu native speakers. Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Cognitive Science, International Institute of Information Technology Hyderabad*

The proposed bilingual Akshara framework (Fig 4.1) explains the cognitive process and impairment of reading in bilingual dyslexics. In this context, there are two separate orthographic lexicons one for Akshara (Telugu) and other for Phonemes (English), and two, for the phonological lexicon a syllable for Akshara and phoneme for Alphabets as the unit size. Moreover, there is a continuous interaction between the orthographic and phonological lexicons (i.e. represented by a bi-directional arrow).

In the present study, it was observed that children with DD showed literacy difficulties in both the languages, indicating that if literacy difficulties occur in one language, they are also likely to occur in the other, however, with different degree

consistent with the views of the central processing hypothesis (Gholamain & Geva, 1999: Geva & Siegel, 2000). But the two languages studied here such as Kannada and English vary in their orthographic depth and hence we could expect the patterns of the literacy difficulties in terms of processing while reading to vary accordingly, with more severe literacy difficulties occurring in English, the less transparent orthography than in Kannada, the more transparent orthography (Karanth, 2002; Shanbal, 2010). However, the prevalence of literacy difficulties seen in the present study seems to be similar along the skills in both Kannada and English. For example, difficulty in phonological awareness, rapid naming and written language occur in both Kannada and English. Of great importance here is the observation that the same factors seem to be related to literacy difficulties in both languages. Thus, on the basis of this evidence, and despite the differences in their orthographic depth, Kannada and English seem to place more or less the same degree of demands on children with DD (Shanbal, 2010). In other words, the differences in the orthographic depth of Kannada and English seem to be contributing to differences in processing time reflected in the durational measures in children with DD when compared to TDC.

With the above findings, the null hypothesis stating that, there is no significant difference for eye tracking durational measures for reading in Kannada and English bilingual biliterate children with DD and TDC, is partially accepted. There was a significant difference for fixation duration measures between DD and TDC for reading English words and non-words. There was no significant difference between DD and TDC for reading Kannada words and non-words. There was a significant difference for total gaze duration between DD and TDC for reading Kannada words, English words and non-words. There was no significant difference for reading Kannada non-words between DD and TDC. There was a significant difference for

saccadic duration between DD and TDC for reading English words only. There was no significant difference for reading English non-words, Kannada words and non-words between DD and TDC.

5.2 Accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

The results of accuracy measures between DD and TDC indicated that children with DD showed poorer performance when compared to TDC for words and non-words in both Kannada and English. There was a significant difference found between DD and TDC for Kannada words and non-words and English words and non-words. These results indicated that children with DD have a deficit in reading words and non-words in both Kannada and English. These findings are indicative of a higher level deficit in cognitive processing in children DD. Various studies with Indian languages have also shown deficits at syllable level in Kannada speaking children with poor reading abilities (Nag &Snowling 2011; Shanbal, 2010). Another study of Hindi-speaking children with dyslexia addressed speed and accuracy deficits while reading (Gupta, 2004).

It is possible that in the present study children with DD showed poorer performance than TDC due to deficit in processes that require adequate perception in the earlier stages due to which there are poorer connections from visual to auditory decoding. This can further affect the decoding of words during reading as the process remains a deficit in these children. These findings can be related to reports of a model proposed by (Dehaene, 2009).Some of these deficits are also explained drawing support from deficits in executive functions as reported by Booth et al. (2010), Smith-spark and Fisk, 2007, Menghini et al., 2(011), Varvar et al., (2014). Since children with reading disability are found to show various executive deficits such as working memory, inhibition of irrelevant

information, and accessing material from long-term memory (Booth et al. ,2010), it is possible that children with DD could show reading difficulties due to some or all of these deficits. Overall, the findings of the present study indicated that the reading deficits as such in terms of accuracy are not attributed to any specific languages but to a deficit at the central cognitive processes.

With the above findings, the null hypothesis stating that, there is no significant difference between children with DD and TDC for accuracy measures in reading Kannada and English is rejected. There was a significant difference found between DD and TDC for Kannada words and non-words and English words and non-words on accuracy measure.

5.3 Syllabic length effect on durational and accuracy measures for reading Kannada and English words and non-words in children with DD and TDC.

The results of the study indicated that for syllabic length effect on fixation duration between DD and TDC, overall it was found that when compared to TDC, children with DD showed longer mean fixation duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English. There was a significant length effect observed for Kannada words and non-words and English words and non-words. On the other hand for TDC, there was no significant length effect observed on Kannada words and English words and non-words. There was a significant length effect observed for Kannada non-words only, in TDC. The results of syllabic length effect on saccadic duration between DD and TDC, indicated that when compared to TDC, children with DD showed longer mean saccadic duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic non-words in DD. There was a significant length effect observed for Kannada words and non-

words and English words and non-words. On the other hand for TDC, there was no significant length effect observed on Kannada words and English words and non-words.

There was a significant length effect observed for Kannada non-words only, in TDC. The results of syllabic length effect on total gaze duration between DD and TDC, showed that that when compared to TDC, children with DD showed longer mean total gaze duration for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English, except for Kannada trisyllabic non-words in DD. There was a significant length effect observed for Kannada words and non-words and English words and non-words. On the other hand for TDC, there was no significant length effect observed on Kannada words, English words and non-words. There was a significant length effect observed for Kannada non-words only, in TDC.

The results of accuracy measures between DD and TDC indicated that, children with DD showed poorer performance when compared to TDC, for bisyllabic, trisyllabic and polysyllabic words and non-words in both Kannada and English. The accuracy scores for reading bisyallabic words was better when compared to trisyllabic followed by polysyllabic words in both Kannada and English for DD and TDC. There was significant syllabic length effect observed for English words and non-words only. There was no syllabic length effect observed for Kannada words and non-words. For TDC, there was a significant length effect observed for Kannada words, English words and non-words, whereas there was no significant length effect observed for Kannada non-words.

The results of the present study indicated that there was no difference observed between languages in children with DD. The mean scores indicate that children with DD showed poorer performance on durational and accuracy measures in Kannada than in English. This could be due to a deficit in the underlying cognitive processes such as the

executive deficit theory explained and supported by various researchers (Booth et al., 2010; Varvar et al., 2014). A poor working memory and longer time to access from long term memory could be reflected in poorer performance in children with dyslexia. In similar studies Wimmer (1996) reported that children showed different performance for German and English with better reading in German non-word reading when compared to English.

Further, the eye movement in linguistic and non-linguistic study was protracted in order to probe on the visual processing for word length effect on words and non-words(De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002). This study contemplated the visual processing in reading for non-transparent languages such as English, by conceiving the context of irregular words and non-words that was created in Italian language. The authors reported the interaction of word length effect on reading words and non-words in 12 DDs with mean age of 13.1 years and 10 age matched controls. The authors reported that TDC showed increased saccadic amplitude for longer word with same no of saccades and more number of saccades only for longer non words whereas DDs showed more of fixations and frequent shorter saccades, for both words and non-words irrespective of length effect thus recruiting sequential process. It is possible that, children with DD are inefficient to shift from print to sound GPC reading technique (that is slow in real time) to the rapid lexical or global analysis of words in a varied context. Hristova, Gerganov, Todorova, & Georgieva (2004) studied similar interactions of words length and word frequency effects for reading in second and fourth grade children with and without DD. Adding to the previously existing literature account, the length effect was found to be present in both Kannada and English in children with developmental dyslexia where DD showed extremely slow eye movements, nevertheless, with the some normal reading pattern indicated in accuracy measures.

With the above findings, the null hypothesis stating that, there is no significant syllabic length effect in reading words and non-words in Kannada and English bilingual-biliterate children with DD and TDC is rejected. There was a significant length effect observed for Kannada words and non-words and English words and non-words in children with DD. However, there was significant length effect observed in TDC.

CHAPTER 6: Summary and Conclusions

Eye tracking methodology is one of the objective tools to explore the underlying deficits for reading in children with dyslexia and typically developing children. The present study aimed to explore the mechanisms involved in reading words and non-words in Kannada-English biliterate older children with Developmental Dyslexia (DD) using eye-tracking method. The objectives of this study were to investigate the differences in durational measures, accuracy measures and the effect of syllabic length on these measures between children with Developmental Dyslexia and typically developing children.

In the present study a total of thirty six (36) participants from 6^{th} to 8^{th} grade in the age range of $11.0 \leq A \leq 14.0$ years were included. Group I consisted of 18 children diagnosed with Developmental Dyslexia (DD) and group II consisted of 18 age and gender-matched typically developing children (TDC). Eye movement parameters for reading Kannada and English words and non-words were recorded using the Eye Tracking Glass device (ETG model 2.6). The measures studied (dependent) were inclusive of fixation durations, saccade durations, total gaze duration and reading accuracy.

The findings of the current study indicated that fixation duration, saccadic duration and total gaze duration were longer in children with DD when compared to TDC for reading words and non-words in Kannada as well as English. In case of fixation duration and total gaze duration these differences were statistically significant for Kannada words, English words and non-words. However, there was no statistically significant difference for Kannada non words as compared to the other test stimuli. On the other hand, for saccadic duration, statistically significant difference was obtained only for reading English words. There was no significant difference for reading English non-words, Kannada words and non-words. The reason attributed to longer durational measures in children with DD is

attributed to the longer time these children may require to process the words and non-words at a higher cognitive level. The findings for accuracy measures indicated that children with DD showed poorer performance when compared to TDC for words and non-words in both Kannada and English. There was significant difference between children with DD and TDC for Kannada words and non-words and English words and non-words. Children with DD are found to show a central level processing deficit, due to which despite whatever language is being processed for reading, children with DD are found to show significant deficits. This could also hint at the higher level executive deficit often reported in children with DD controlling mechanisms such as phonological processing required for reading.

The findings on syllabic length effect on durational measures between children with DD and TDC indicated that, children with DD showed longer durational measures for bisyllabic, trisyllabic and polysyllabic words and non-words in both and Kannada and English. However, for saccadic duration and total gaze duration on Kannada trisyllabic non words, longer mean durations were not observed. For all three durational measures, significant length effect was observed for both Kannada words and non-words, and English words and non-words in children with DD. Whereas, for TDC no significant length effect observed for Kannada words and, English words and non-words. A significant length effect was observed only for Kannada non-words in TDC.

The findings for accuracy measures indicated that children with DD showed poorer performance when compared to TDC, for bisyllabic, trisyllabic and polysyllabic words and non-words in both Kannada and English. The accuracy scores for reading bisyallabic words were better when compared to trisyllabic words followed by polysyllabic words, in both Kannada and English for DD and TDC. In children with DD, a significant length effect was observed only for English words and non-words whereas, no syllabic length

effect was observed for Kannada words and non-words. For TDC, there was a significant length effect for Kannada words, English words and non-words, and no significant length effect for Kannada non-words. The results of the present study indicated that there was no difference observed between languages in children with DD. The mean scores indicate that children with DD showed poorer performance on durational and accuracy measures in Kannada than in English. This could be due to a deficit in the underlying cognitive processes such as the executive deficit with a poor working memory and longer time to access from long term memory that could have reflected in poorer performance in children with dyslexia for syllable lengths. As the complexity increased, children with DD were observed to show poorer performance for both durational and accuracy measures on eye-tracking.

Drawing support from studies conducted by Geva and colleagues (Gholamain & Geva, 1999: Geva & Siegel, 2000), Shanbal (2010) it can be concluded that the central processing and script dependant viewpoints are complementary to each other rather than being contradictory in bilingual biliterate children with developmental dyslexia.

Implications of the study

The findings of the present study highlighted the understanding of visual processing in bilingual sequential developmental dyslexic readers (with L1 dominant) for reading a non-dominant language (L2) and thereby helped to differentiate and understand the process allocated (by and large) for reading by typically developing children for reading (L2). The present study also helped to understand different eye tracking mechanisms used by children with DD and by TDC to read a transparent and an opaque script.

The study also highlighted the information on reading process recruited by older children (from the grade 6^{th} to grade 8^{th}) and thereby gave out a yardstick to gauge and

track the reading acquisition abilities in other age groups. The present study also highlighted that studying the peripheral deficits via eye tracking procedures might be a more reliable method which can uncover the hidden visual processing challenges while reading in the children with developmental dyslexia. The high variance showed in the present study could be implicated in terms of the subgroups of dyslexia that could have existed. This makes way for further research in different subgroups of dyslexia in different languages using eye-tracking technology.

Limitations of the study

The present study employed on a small sample size and future studies are required to generalize the findings of the present study to a larger sample.

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Appendix 1

List of stimuli

Stimuli	Kannada Words	Kannada Non words	English words	English Non word	English Irregular word	English Irregular Non word
Bi-syllabic	ಕಟ್ಟು /k^ʈʈU/	ದಟ್ಟು /d^ʈʈu/	Picnic /Pi:kʰni:k/	Lacnic /l ækn:k/	Matching /mæʧIng/	Sutching /suʧIng/
	ತೈಲ /ʈəIl^/	ಕೈಲ /kəIl^/	Defeat /ɖ: f It/	Bofeat /bofi:t/	Column /cɔl^m/	Tilumn /ʈ:l^mɳ/
	ಕಾರು /Ka:Ru/	ಚರು /ʧ^Ru/	Transport /ʈra:nspo:ʈ/	Dranspert /ɖr^ɳspəʈ/	Talking /ʈɔ:ki:ŋ/	Balking /b^ki: ŋ /
	ತಟ್ಟೆ /ʈʈ^ʈʈe/	ಲಟ್ಟೆ /l^ʈʈə/	Hunter /h^ɳʈ^r/	Jinter /ʤinʈ^r/	Biscuit /bi:skəʈ/	Pescuit /pəskəʈ/
	ಕಪ್ಪು /k^ppU/	ನಪ್ಪು /ɳ^ppU/	Begin /bigi:n/	Hogin /hɔ:gi:ɳ/	Trophy /ʈro:fI/	Cruphy /kr^fI/
Tri-syllabic	ಜೀವನ /ʤi:vana/	ಲೀವನ /l̪i:vana/	Gathering /gæɗɛriŋ/	Rothering /ro:ɗɛriŋ/	Descending /ɖ isenɖiŋ/	Foscending /foisenɖiŋ/
	ಚತುರ /ʧ^ʈ̪Ura/	ಜತುರ /ʤ^:ʈ̪Ura/	Different / ɖ i:f^reɳʈ/	Lifferant /l̪if^reɳʈ /	Concentrate /kɔnsəɳʈre:ʈə/	Pincentrate /pi:nsəɳʈre:ʈ/
	ದಾಖಲೆ /ɖ̪a:kʰ^l̪e/	ಬಾಖಲೆ /ba:kʰ^l̪e/	Marvelous /marvəl̪^s/	Purvelous /parv^l̪^s/	Functioning /f^nkʃ^niŋ/	Tanctioning /ʈænkʃ^niŋ/
	ಮುದುಕ /mUɖ̪Uk^/	ನುದುಕ /nUɖ̪Uk^/	Narrative /n^re:ʈi:v/	Serrative /səre:ʈi:v/	Parachute /pær^ʧUʈ/	Gerachute /ger^ʧUʈ/
	ನರ್ತಕಿ /n^rʈ^kI/	ಮರ್ತಕಿ /marʈakʰI/	Minister /ministʈ^r/	Danister /ɗ^n:sʈ^r/	Telephone /ʈeli:fo:n/	Seliphone /seli:fo:n/

Stimuli	Kannada	Kannada	English	English	English	English

	Words	**Non words**	**words**	**Non word**	**Irregular word**	**Irregular Non word**
Poly-syllabic	ಕರ್ನಾಟಕ /karna:ʈ^k^/	ತರ್ನಾಟಕ /ʈarna:ʈ^k^/	Congratulation /kəngrædʒUle:ʃ^n/	Tengratulation /ʈengrədʒUle:ʃ^n/	Geographical /dʒijOgʳ^pfi:k^l/	Feogriphical /fijOgʳ^f:k^l/
	ದೇಶಾದ್ಯಂತ /ɖe:ʃa:ɖjɛnʈə/	ಕೇಶಾದ್ಯಂತ /kɛʃa: ɖjɛnʈə/	Determination /ɖi:ʈərmi:nɛ:ʃ^n/	Biterminationn /bi:ʈərmi:nɛ:ʃ^n/	Partiality /pa:rʃija:liʈI/	Martialety /ma:rʃi:jəl:ʈI/
	ಪಂಚಾಯಿತಿ /p^nʧa:jiʈI/	ಮಂಚಾಯಿತಿ /mənʧa:i:ʈI/	Development /ɖɛv^lopmɛnʈ/	Mavelopment /məv^lopmɛnʈ/	Architecture /a:rkiʈɛkʧ^r/	Oschitecture /ɔ:skiʈekʧ^r/
	ಹಂಚಿಕೊಳ್ಳು /hənʧIkoɭ|U/	ಗಂಚಿಕೊಳ್ಳು /g^nʧIkoɭ|U/	Reproduction /rIprɔ:ɖ^kʃ^n/	Depriductio n /ɖIpʳɔ:ɖ^kʃ^n/	Undoubtedly /ənɖouʈɛɖl:/	Insoubtedly /Insouʈɛɖli:/
	ಪ್ರಧಾನಿಯ /prəɖʰa:nijə/	ಶ್ರಧಾನಿಯ /ʃrəɖʰa:nijə/	Specification /spɛsifikɛ:ʃen/	Stacification /sʈ^si:fikɛ:ʃ^n/	Successfully /səks^sfUɭlI/	Taccessfully /ʈæks^sfUɭ|I/