READING IN CHILDREN WITH AND WITHOUT DYSLEXIA: AN EXPLORATORY STUDY THROUGH EYE-TRACKING METHOD

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MAY 2019

CERTIFICATE

This is to certify that this dissertation entitled "**Reading in children with and without Dyslexia: An exploratory 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 (Registration Number: 17SLP031). 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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May, 2019

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DECLARATION

This is to certify that this dissertation entitled **"Reading in children with and without Dyslexia: An exploratory 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

Reading is a complex cognitive process that demands the smooth back and forth movement of the eyes across words and lines. It involves the integration of various cognitive activities like vision, attention, word recognition, oculomotor control, higher – level language comprehension (Schad, Nuthmann, & Engbert, 2010). Various paradigms have been employed to study the differences in processes involed for reading in children with dylexia when compared to typically developing counterparts . The paradigms range from simple offline procedures like rapid naming (De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002a) to online assesment procedures like eye tracking (Andrews, Miller, & Rayner, 2004; Ehri, 1995; Rayner, 1983; Stanley, 1983).

Considering the eye tracking paradigm, while moving our eyes from one word to another word we briefly stop in order to identify and process the visual word information. The rapid jerky movements across or within words are called as saccades and the short period of steadiness is called as fixations. Saccades are important to locate the new information in the visual field and fixations assist in interpreting the word. Researchers have attempted to infer the underlying cognitive processes with the eye movement behavior. Radach and Kennedy (2004) report that the sequence of eye movements (i.e. saccades) reflect the cognitive process of word processing for either the part of the word or whole word and the focus points (i.e. fixations) reflect the word recognition process.

Studies conducted on readers with dyslexia using eye tracking methodology report the differences between various eye tracking measures (e.g. fixation duration, saccadic durations, regressions, first pass duration, gaze duration, saccadic amplitude etc.) Few common differences highlighted are in terms of longer fixation durations

(Creavin, Lingam, Steer, & Williams, 2015; Eden, Stein, Wood, & Wood:, 1994; Rayner, 1985a, 1985b; Rayner, 1983), shorter saccadic duration (De Luca et al., 2002a), more number of regressions (Feng, 2004; Irwin, 1998; Rayner, 1978) etc.

Literature focusing on eye tracking using the reading paradigm has highlighted the differences in terms of eye movements for reading words and non words (Adler-grinber, 1978; De Luca et al., 2002a; Ehri, 1995; Irwin, 1998; Rayner, 1978, 1983, 1985a; Ziegler, Perry, & Zorzi, 2014). Limited research has been conducted to find the differences for reading regular and irregular words.

Need for the study

Reading development reflects the cognitive development of young children. Pre-literacy skills, consistency of orthographies, and numerous other factors play a key role in the acquisition of the reading skills. The demand on the child to learn and acquire the knowledge of phoneme-grapheme rules varies from individual to individual. The literature in the past predominantly focused on indirect measures (lexical decision tasks, tracking LED lights etc) to account for the reading abilities in typically developing young children and children with developmental dyslexia. However, with the advancement in technology, the focus has shifted to eye tracking equipments that measure and objectify the subtle differences in both the typically developing children and the children with developmental dyslexia. Hence this study is to highlight the differences in eye tracking measures for reading amongst typically developing children and children with developmental dyslexia.

Majority of the eye tracking literature (e.g. De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002b; Ziegler et al., 2014) have highlighted the eye tracking measures for reading words, non-words, pseudowords etc. In comparison to other languages, English relatively constitutes a greater number of irregular words. Studies have indicated that typically developing children as young as in second-grade access the sublexical route to read the words in a regular orthography and with an increase in reading proficiency the lexical route is established (Anne K. Rau, Moeller, & Landerl, 2014). However ,the reading process utilized by young children with developmental dyslexia need to be studied in irregular orthographies such as English which could probably indicate whether they are using lexical processing or sublexical processing for reading.

There emerges a need to assess the reading accuracy and the gaze duration in children with developmental dyslexia for reading. Intervention plans focusing on enhancing the reading abilities of children with developmental dyslexia have reported significant improvement in these eye tracking measures (Judica, De Luca, Spinelli, & Zoccolotti, 2002). Hence an insight into the differences in these measures could assist us to focus on developing intervention strategies.

AIM OF THE STUDY

To investigate reading of Words and Non-Words in English, in children with and without Developmental Dyslexia[1] through the eye tracking method.

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

- To study the differences between children with developmental dyslexia (DD) and typically developing children (TDC) for eye tracking durational measures such as fixation duration, saccadic movements, and total gaze duration on reading regular words, non- words, irregular words and irregular non- words .
- To determine the accuracy in children with DD and TDC on reading regular words, non-words, irregular words and irregular non- words.
- To determine the pattern of eye movements in young children with DD and TDC on reading words, non-words, irregular words and irregular non-words.

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

$H_0$1 There is no statistical significant difference between children with DD and TDC eye tracking durational measures such as fixation duration, saccadic duration and total gaze duration on reading regular words, non-words, irregular words and irregular non- words.

$H_0$2 There is no statistical significant difference between children with DD and TDC for accuracy measure on reading words, non-words, irregular words and irregular non-words.

$H_0$3 There is no significant difference between children with DD and TDC for difference in the patterns of eye movements for reading words, non- words, irregular words and irregular non- words.

[1] In the current study children without developmental dyslexia included the typically developing children (TDC).

CHAPTER 2: Review of Literature

Reading involves the smooth movement of eyes across a text along with the integration of cognitive systems like vision, attention, word recognition, memory, occulo-motor control, and higher level language comprehension. The relationship between reading and the cognitive processes have been vastly studied using the eye tracking technology. It serves as a powerful tool for online assessment of the underlying cognitive subsystems and to identify the developmental reading deficits. Various models have been put forth to explain the developmental sequence of reading and to highlight the deficits in some individuals. Studies incorporating eye tracking measures have aimed to highlight these individualistic variations between proficient readers and children with dyslexia.

2.1 Acquisition of reading

The process of reading comprises the correct identification of the letter features followed by grapheme identification finally leading to the identification of the whole word. Another step to reading is the conversion of the graphic representation to the phonological representation. The process of acquisition of reading requires the children to learn the codes of their culture that represent the visual symbols (Ziegler & Goswami, 2005).The knowledge of phonological awareness across all languages assist in the process of reading.

Landerl (2005) stated that in an alphabetic system, letter or group of letters (graphemes) represent the speech sounds (phonemes). This defines the phonologic and orthographic relationship for a language. Some languages (such as Kannada) are classified as having shallow orthography wherein there is a high consistency between the

graphemes and the phonemes (example /ba:gilu:/). On the other hand, English has a deep orthography that is, it demonstrates highly inconsistent grapheme-phoneme correspondence (example “listen” is read with a silence of‘t’).

Several models have been put forth to accommodate the reading acquisition. One of the most influential models is the Dual Route Cascaded Model (Figure 2.1 below) for reading aloud (Coltheart, 2008). This model states that there exist two parallel routes for reading, a non-lexical and a lexical route. Serial processing along with the rules of grapheme-phoneme-correspondence leads to the activation of the non-lexical route for the word recognition. This process is called phonological decoding (Wise, Ring, Sessions, & Olson, 1997). The non- lexical route is activated for reading irregular words (such as *talk)* and non-words (such as *Kalk*) of English. The lexical route is direct, parallel process, and assist in the efficient and fast retrieval of the word from the mental lexicon. The regular words can be read through both either the lexical or the non-lexical route. However several studies(German: Rau, Moeller, & Landerl, 2014; Italian: Pagliuca, Arduino, Barca, & Burani, 2008; Serbo-Croatian: Katz & Feldman, 1983), and that they start doing so from an early point in reading development (Dutch: Wesseling & Reitsma, 2000; German: Rau et al., 2014; Italian: Burani, Marcolini, & Stella, 2002) have identified the influence of the consistencies of the orthography for the speed of activation of the routes. For example, Anne Katrin Rau (2014) investigated the dysfluent reading pattern in children with dyslexia for German language and concluded that the errors in reading pattern could be due to the overreliance on the sub lexical route while reading.

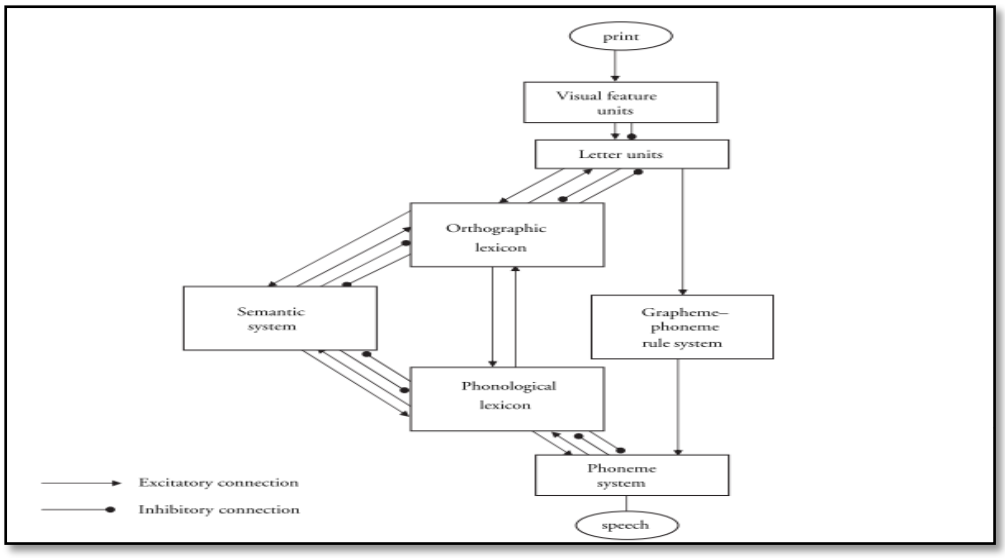

Figure 2.1: *Dual Route Cascaded Model (Coltheart, 2008)*

(Source info: Adler-grinber, D. L. (1978). Eye movemnts, Scanpaths and Dyslexia. *American Journal of Optometry &physilogical Optics*, *55*(8), 557–570.)

A study conducted by Paap and Noel (1991), reports that the activation of the non-lexical route is faster in shallow orthographies. Frequent studies have reported the acquisition of reading skills to be faster in the consistent than in inconsistent orthographies (Wimmer & Goswami, 1994; Ellis & Hooper, 2001; Aro & Wimmer, 2003). To explain the reading acquisition in inconsistent orthographies like English, the Psycholinguistic grain size theory was proposed (Ziegler & Goswami, 2005). This theory considers the lower rate of reading development in inconsistent orthographies and focuses on the need to develop reading strategies that target the psycholinguistic units. It explicates the need to develop the strategies for both whole word recognition for the irregular words and the identification of their rhyme analogies in order to read irregular words which are found to be in a large number in English. In order to read the unknown words yet, another strategy has to be developed for the process of conversion of

graphemes to phonemes. In contrast, children learning to read transparent orthography have to develop only one systematic strategy to convert the grapheme-phoneme correspondence. This model thus suggests for the delay in the reading acquisition of opaque orthographies as the children need to develop a large number of reading strategies for different grain sizes.

2.2 Reading in children with dyslexia

As stated by the International Dyslexia Association (2002), dyslexia can be defined as a "Specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities."

A vast number of studies (Lovegrove et al., 1980; Breitmeyer, 1993; Stein &Walsh, 1997) have been conducted to elucidate the differences in eye movements during reading tasks in children with dyslexia. Some studies conclude as the differences in the perceptual level (Lovegrove et al., 1980) while some state the differences at the cognitive level (Olson et al., 1983).

2.2.1 Perceptual level deficits

The Magnocellular deficit theory (Lovegrove et al., 1980) explains oculomotor and visual perceptual deficits as the underlying cause for dyslexia. This theory hypothesizes that there exist two distinct systems- Magnocellular and Parvocellular, for the process of visual perception. The Magnocellular system is fast acting transient channel, accountable for processing rapidly changing stimuli. Contrariwise, the Parvocellular system is a sustained channel enabling the detection of the stationary detailed patterns. Thus,

coordination of the Magnocellular and the Parvocellular system leads to the perception of the still image during the saccadic movement of the eyes while reading the text or image (Breitmeyer, 1993). This induces to the suppression of the saccade and thereby reducing the blurring effect. Children with dyslexia demonstrate a deficit in the Magnocellular system which leads to diminished binocular vergence during the fixation of the word (Stein &Walsh, 1997).

Studies (Tallal, 1980) have reported deficits at the level of temporal processing in children with dyslexia. The Rapid Temporal Processing Deficit hypothesis (Tallal, 1980), explains that the phonological deficits in children with dyslexia are due to the auditory temporal processing impairments. Tallal, Miller, and Fitch (1993), reported that since children with dyslexia demonstrate impairment in integrating the sensory information at a basic auditory level it would indirectly lead to prevention in the correct temporal analysis at the phoneme level which would, in turn, lead to abnormal phonological development. This as evidenced by Ziegler, Perry, and Zorzi (2013) could have lead to poor phoneme representations or poor phoneme discrimination that in turn could affect the acquisition in reading due to the poor mapping of letters to phonemes in children with dyslexia.

2.2.2 Cognitive level deficits

Olson et al., (1983) reviewed the children with dyslexia based on their verbal IQ and their reading patterns. He concluded that the children with higher verbal IQ demonstrated “explorer” pattern of reading wherein the subjects looked back and forth along the line i.e. they exhibited more frequent regressions and forward skipping of words. Whereas, children with lower verbal IQ scores demonstrated a “plodder” style of

reading, with fewer regressions and skipping of words more within word and word to word movements.

Psycholinguists stated that the children with dyslexia demonstrated two qualitatively different performance patterns. They categorized dyslexic readers into two groups (Castles & Coltheart, 1993). One group of dyslexic readers were impaired in reading pseudowords. These individuals demonstrated impairment in activating the sublexical route of reading. They were grouped under phonological dyslexia. The other group depicted deficits in reading irregular words and or discriminating the homophones. Thus these individuals had impairment in activating the lexical route for those words. They were grouped under surface dyslexia.

2.3 Eye-tracking studies and parameters

Eye tracking and eye movements have been vastly studied using varying instruments ranging from tracking a row of LED lights (Pavlidis, 1981), a typewritten form of text (Huey, 1898), to highly advanced eye-tracking devices. Subjective tasks such as Rapid Automatic Naming (Denckla & Rudel, 1976) have also been used to assess the eye movements. Detection of the eye movements for the reading paradigm using the eye tracking device dates back to the 1970's. Few important parameters identified for the process of reading are fixation pauses, saccades, and regressive eye movements and return sweeps.

Fixations can be defined as the gazing time of fovea alignment for an object that exceeds 100msec, during which the object is fully processed and clearly defined at the fovea. Holsanova, Rahm, & Holmqvist, (2006) reported the duration for fixations to last between 50 and 1500ms. The estimated average gaze time for skilled readers as reported

by Rayner (1978) is 200-250ms. Rayner (1998) reported several factors (type of text, word frequency, word length) that could influence the fixation durations.

Saccades comprise the pursuit of eye movements which occurs when an individual is tracking an object. It estimates up to 10% of the reading time and contributes to bringing a new region of text on the fovea. The saccadic extent for reading is averaged up to 8 to 9 character spaces with duration of 25-30 msec. The saccade distance proportionally influences the saccade duration (Rayner, 1998).

The third important characteristic of eye movement is the regression. Reading the English orthography involves the left to right progressions. A right to left eye movement for reading is identified as the regression. It is interpreted as the skilled reader having difficulty in understanding the text, reader's misinterpretations of the word, and overshooting of the target word. Rayner, Pollatsek, and Starr (2003), reported that skilled reader regresses back 10-20% of the reading time. They concluded that this feature reflects the deep processing of the reader. Return sweep shares the similarity of the right to left progression with the regression feature. However, return sweep is a natural process that occurs between the end of the line and the start of the new word in the next line.

2.3.1 Developmental changes in eye movement for reading

Abundant researches (Buswell, 1922; Judd et al., 1918; McConkie et al., 1991; Rayner, 1986; Taylor, 1965) are available on the developmental patterns in the eye movements for reading. These studies show that with an increase in age and reading proficiency, the efficiency of eye movements also increase.

Mc.Conkie (1991) reported a decrease in the average fixation duration from first grade (304ms) to third grade (262 ms) and then fifth grade (243 ms) and an increase in the mean saccadic length from 3.6 letters to 5.7 and 6.3 letters respectively. He also reported a change in the scanning patterns. Proficient reading was identified as reduction of within word re-fixations and increase in word skipping.

Mc. Conkie (1991) reported that the developmental changes in the aspect of eye movements can be briefed as into three mechanisms. The first being the landing position distribution, i.e. where in the word the eye looks. Whereas, adult readers have efficient word recognition and target the centre of the word, young children, demonstrate almost identical landing position distribution to that of the skilled readers indicating low level of occulo-motor optimization. The second is that the mechanism responsible for controlling fixation duration is less susceptible to developmental changes.

Mc. Conkie (1991) also stated that although with age there is a decline in the means of fixation duration, the modes of the fixation duration remains constant across the distribution of age groups. Yang and Mc. Conkie (2001), found that young typically developing readers have longer fixations which often have been associated with their inhibitory processes and cognitive controls. Finally, the proportion of regressive eye movements has been reported to remain relatively flat throughout the elementary years (Mc. Conkie et al., 1991) in typically developing children. The regression rates vary from around 20% to 33%, depending on the studies. Thus evidencing that, the developmental aspects of occulo-motor system may show different developmental course in typically developing children.

2.3.2 Factors affecting eye tracking measures

The factors affecting the eye tracking measures can be grouped into subject related and stimulus related. Subject related factors include, attention, age of acquisition, IQ, SES, handedness, etc. Eden, Stein, Wood, and Wood (1994) conducted a study on eye movements for a reading task. He included 26 reading disabled children and 39 normal children with the reading age of fifth grade. They attempted to study the effect of subject related factors like gender, handedness and attention on reading performances amongst the reading disabled group and the normal group. Their findings revealed that, there was a significant difference in both the group only for attention.

Liversedge, Paterson, and Pickering (1998) reported few stimulus factors (word class, word length, word familiarity etc) that could have influence the eye tracking measures. They reported that word class and word length could have influenced the saccadic and fixation measures for reading. With respect to the word length; they stated that, proficient readers accommodate and adjust their forward saccades based on the word length. Wherein, larger saccades are produced with longer words when compared to the shorter words with the number of saccades being same. With regard to word class, it has been found that, when words lack the lexical entry (i.e. non-words), there is a significant increase in the saccade duration with a minimal increase in saccadic amplitude. Contrastive findings have been reported for dyslexic readers (Benfatto et al., 2016; Hill, 2006; Irwin, 1998; Olson, Kliegl, & Davidson, 1983; Prado, Dubois, & Valdois, 2007; Anne K. Rau et al., 2014) wherein, they demonstrate regressive patterns of movements and indicate a marked length effect independent of the lexical value of the stimuli.

De Luca, Borrelli, Judica, Spinelli, and Zoccolotti (2002) reported that the type of stimuli could have an influential role on the fixation duration. In children, true words were reported to have shorter fixation duration (about 20 ms) as compared to non words with the same number of letters. On contrast, they reported that children with dyslexia had longer fixation durations (about 40ms) as compared to typically developing children.

2.3.2 Deficits in eye tracking measures in children with dyslexia

The first reports of association of reading disability and irregularity of eye movements dates back to 1920s. Gilbert (1953), reported a linear relationship in the developmental trend between eye movements and reading ability. He concluded that individual with higher reading difficulties demonstrated higher regressive eye movements. Similar findings were reported by Lesevre's (1964, 1968), for reading and non reading paradigms. She attributed the irregularities in the eye movements to the reading habits, poor teaching and environmental factors.

Adler, Grinberg and Stark (1978), attempted to investigate whether children with dyslexia demonstrated deficits in occulo-motor function or visual perception. They explored the dynamic eye movements of 25 children with dyslexia and 19 neurotypicals in the age range of 6- 14 years. A photo electric device connected to the photo transistors was used to track the eye movements for a reading paradigm. They reported children with dyslexia had shorter saccadic spans and longer duration of forward fixations when compared to normal children. They concluded that the deficits in children with dyslexia is beyond visual perception and lies in the area of integration of language acquisition.

In an experiment conducted by Pavlidis (1981), with the task of tracking sequentially placed LED lights he concluded that, children with dyslexia (n=12) in the age range of 10–16 years had erratic eye movements. He reported a higher number of saccades on left to right movement of the stimulus series, higher percentage of regressive saccades (18%) and difficulty in stabilizing fixations in children with dyslexia. He indicated these findings reflected the "sequential disability/ occulo-motor malfunction" which indicated deficits in the perceptual processing of the sequential text.

Contradictory results were reported by Olson, Kliegl, & Davidson, (1983) who replicated Pavlidis (1981) experiment using the same paradigm. They included 34 children with dyslexia and 36 normal subjects. They found no significant differences in the number of fixations, stability of fixations and number of regressions between the dyslexic and normal readers. The authors attributed that the differences in the result might be due to the selection criteria for the dyslexics.

Martos & Vila, (1990) conducted an eye tracking study using the Electro-oculographic technique on dyslexic readers, retarded readers and controls, aged between 7 – 14 years. Their study incorporated two task (i) reading the text of high-level difficulty and low-level difficulty, (ii) ocular tracking task. They found out that the dyslexic readers and the retarded readers show no significant difference in reading text with varying difficulty. However, they highlighted a significant difference among the dyslexic and the controls in terms of longer durations of saccades and regressive and overall total eye movements.

Al Dahhan et al., (2014) conducted a comparative study on dyslexic children (9 - 10 years), using the eye tracking device to assess the reading abilities. Three tasks were

assessed word identification, sight word efficiency and word chain. They reported that the dyslexics had longer pause time, fixation duration and articulation time. Also, dyslexics were less accurate and less efficient in reading when compared to the age and gender-matched controls.

Padakannaya, Pandey, Saligram, and Ranga Rao (2016) reviewed the eye tracking for reading sentences in Kannada English bilinguals. They compared the reading abilities of the typically developing (TD) and the reading disabled (RD) group based on their reading level (Grade III for RD and Grade VI for TD). They recorded the fixation count, first pass reading time and the reading errors for 30 Kannada sentences with increasing level of orthographic complexity. Results indicated that the RD group had lesser number of fixations and poor performance across the complexity. First pass reading time scores were higher for the RD group which reflected the increased encoding time. Reading errors were more for the third level of complexity for the RD group when compared to the TD group.

In summary, literature highlights various findings in the eye tracking parameters in children with dyslexia. A large number of studies reported that the individuals with dyslexia demonstrate differences on eye tracking measures such as erratic eye movements which include longer fixation durations, larger number of saccades, saccadic regressions and saccadic amplitudes. Further, it would be interesting to study how children with and without developmental dyslexia would perform for reading different types of words in English through the eye tracking method, so that the processes involved in reading could be understood.

CHAPTER 3 : Method

The primary aim of the study was to investigate reading of Words and Non-Words in English, in children with and without Developmental Dyslexia through the eye tracking method. A multifactorial mixed group design (2 X 4) was employed to compare the eye tracking measures for reading in typically developing children, TDC, (i.e. control group) and children with Developmental dyslexia, DD, (i.e. clinical group).

The objectives of the study were as follows:

a) To study the differences between children with DD and TDC for eye tracking durational measures such as fixation duration, saccadic movements, and total gaze duration on reading regular words, non- words, irregular words and irregular non- words .
b) To determine the accuracy in children with DD and TDC on reading regular words, non-words, irregular words and irregular non- words.
c) To determine the pattern of eye movements in young children with DD and TDC on reading words, non-words, irregular words and irregular non-words.

3.1 Participants

A total of Thirty (30) participants from 3rd to 5th grade in the age range of $8.0 \leq A \leq 10.0$ years,(where 'A' stands for the age of the child) were included in the study. Group I consisted of 10 children diagnosed withDD and group II consisted of 20 age and gender-matched TDC.

Participants' selection criteria:

The participants were selected based on the following criteria:

(a) Children attending regular school in 3rd and 5th grade with Kannada as their first language (L1) and English as the medium of instruction in school, from grade I.

(b) Children without any sensory, motor and or any notable developmental deficits based on the WHO 10 Disability questionnaire (Singhi, Kumar, Malhi, &Kumar, 2007).

(c) Children without any significant visual deficits as screened by an ophthalmologist.

(d) Children without any significant language delay in their L1 development as screened on the Linguist Profile Test – Kannada (Suchithra & Karanth, 2007).

(e) Children screened for literacy skills in L2, using the Test for Early Reading skills (Loomba, 1995).

3.2 Eye-tracking Experiment

3.2.1 Stimulus

A set of 96 English words were chosen which comprised of 4 blocks of stimuli with 24 regular words (RW), 24 regular non-words (RNW), 24 irregular words (IRW), and 24 irregular non-words (IRNW). These words were chosen based on increasing syllable length, varying from monosyllables to pollysylables. Thus each block of stimuli had 8 monosyllables, 8 bisyllables and 8 pollysylables.

The lists of words were chosen from the Reading Word and Non-Word section of the Dyslexia Assessment Profile for Indian Children (DAPIC); (Kuppuraj, 2009) and the

reading passages from the Test of Early Reading Skills (ERS); (Loomba, 1995). The regular words and irregular words were selected based on the age and grade levels of the TDC. Corresponding non-words were developed for each of the regular and the irregular words respectively. The fabrication of the non-words was based on parameters like syllable length, number of phonemes, number of letters and the phonotactic probability. The property of regularity or irregularities of the words were considered while generating non words. In order to construct the non-words the rule of substitution of phonemes was applied. For example, for a regular word such as 'tree' a non-word like 'pree' was constructed wherein, the't' had been substituted by 'p'. For an irregular word such as 'noble' a non-word 'koble' was constructed by substituting the 'k' sound for the 'n'.

The shortlisted words constituted of 10 words in each block of stimuli across varying word length. These words were then validated by five Speech Language Pathologists for the parameters like regularity principle of the word and appropriateness of the stimuli corresponding to the age and grade levels of the TD children. Post validation of the stimuli, the most appropriate stimuli (Appendix 1) were uploaded to the PsychoPy software (V1.8300) to generate a reading experiment. Arial font style and a font size of 72 were set for the prime and the target stimuli.

3.2.2 Instrumentation

Eye movement parameters for reading were recorded using an Eye Tracking Glass device (ETG model 2.6) with a sampling rate of 60Hz produced by the Sensori Motoric Instruments, Germany. The ETG was connected to an infrared Eye Tracking Glass and thereby to a sLenovo laptop (*15.6" display, 1920 X 1080 px resolution)* installed with the i-view ETG software. The eye tracking glass has an inbuilt camera and

a microphone which is located on the frame and handles respectively. A soft cord extending from the eye glass assured the proper fit for the experiment (Figure 3.1) The points of eye tracking were recorded and displayed in the i–view ETG software.The stimuli were uploaded to the PsychoPy software (V1.8300) and were presented on a flat monitor screen (*19.5" display; 1440 x 900 px resolution*) The analysis of the recorded sample was carried out in the *BeGaze* software (*version 3.7).*

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

3.2.3 Procedure

The experiment was carried out in a well-lit room with minimal noise. Informed consent was taken from the parents prior to the experiment and AIISH Ethics Protocol for Bio-behavioral Sciences was followed. The child was initially screened for language abilities (Linguist Profile Test – Kannada (Suchithra & Karanth, 2007)) and literacy skills (Test for Early Reading skills- (Loomba, 1995)). The child was comfortably seated (adjustable chair) with the head placed on the chin rest (adjustable to height) to minimize the head movements. The participants were requested to stay still and to minimize the

number of eye blinks while reading. The stimulus computer was placed at a distance of 60cm from the participant.

Instruction: The following instruction was provided to each participant: (The medium of instruction was varied based on the language preference of the child).

"You will be seeing some words on the screen. Some words might be familiar and some might be unfamiliar. You will have to read all these words aloud. After you finish reading the word you will have to press the space bar to proceed to the next word."

Calibration: Testing phase began with the calibration of the eye movements wherein 3 point calibration mode was selected and 5 dots were randomly placed over the screen (stimulus computer). The child was asked to trace the calibration points as accurately as possible which was locked by the examiner and the eye movements were automatically calibrated to the point of interest.

Testing trial: The stimuli were presented on a flat monitor screen (details to be mentioned). The hierarchy of block presentation was: 24 regular words, 24 non-words, 24 irregular words and 24 irregular non-words. The presentations of words within the blocks were randomized. On each trial, a prime was followed by the target stimuli. A plus sign (+) was primed at the centre of the screen for 2000 ms to get the visual fixation followed by the target stimuli. Upon reading aloud the participants were asked to press the space bar key to read the next target stimulus. The total duration of the experiment lasted for about 30 minutes.

3.3 Scoring and Analysis

The audio-video recorded eye movements were exported to the SMI BeGaze software to obtain the eye-tracking measures. The measures (dependent) were inclusive of fixation durations, saccade durations, reading accuracy, and total gaze duration for reading words and non-words, irregular words and non words.

Fixation duration was calculated as the duration of steady eye position maintained on the letters or word for the presented word stimuli (Figure 3.2) .Whereas, saccadic duration was calculated as the movement of eyes from one letter to the other within a word (Figure 3.3). Total gaze duration was calculated as the sum of all the fixation durations and the saccadic movements for reading the presented word stimuli. All these raw measures were extracted to an Excel spreadsheet format using the 'Export Metrics' icon.

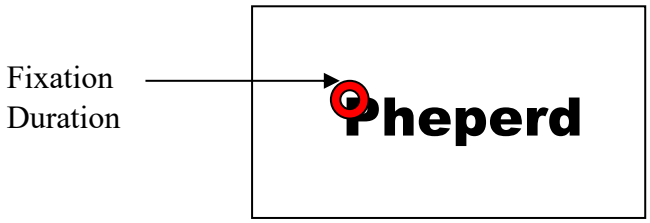

Figure 3.2: *Schematic representation of Fixation duration for the presented word- "Pheperd".*

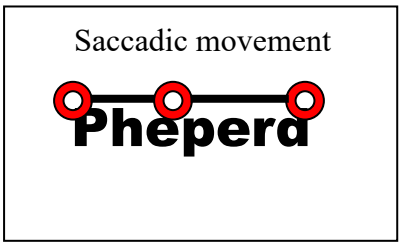

Figure 3.3: *Schematic representation of saccadic movements on reading the presented word ("Pheperd") letter by letter.*

The exported files were uploaded to create an online database to extract the durational measures .The data was manually segregated and duration was listed for each word based on the recorded audio-video samples of each participant. The duration for a word was considered from the point of presentation of the prime stimulus (+) till the vocal response (word read aloud).

These durations were noted for each word across each participant. Ten percent of the data was verified by five SLPs excluding the examiners to validate the identified durational measures. These were found to be synchronous with the values reported by the examiner. After the verification of the durational measures these values were entered manually into the online database (http://203.129.241.88:85/dissertation/). The online database was developed with the provision of manually entering the details like the participant name and time intervals of the words in the hours: minutes: seconds' format. On entering these details, the durational values of the events were displayed on the screen. These numerical values were sorted and systematically entered into the SPSS software for further statistical analysis.

To assess the reading accuracy, the responses from the participants were scored, a score of '1' (one) was given for each accurate response and '0' (zero) for the inaccurate response. These scores were entered into the SPSS software for further analysis.

CHAPTER 4: Results

The aim of the present study was to investigate reading of Words and Non-Words in English, in children with and without Developmental Dyslexia through the eye tracking method. The study also aimed to compare the durational measures, accuracy scores and eye movement patterns for typically developing children (TDC) and children with developmental dyslexia (DD) in the age range of 8.0-9.11 years.

The data obtained from both the groups, i.e. TDC and DD, was subjected to statistical analysis for the durational measures and accuracy scores for reading word categories such as regular words, regular non words, irregular words and irregular non-words. The mean scores of each of the durational values and accuracy scores were computed for each of the word categories. The data was subjected to Shapiro- Wilk's test for normality testing and the results revealed that the data did not follow the normal distribution ($p < 0.05$) hence; Non-parametric tests were carried out. 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 TDC and children with DD on reading of regular words, non- words, irregular words and irregular non- words.
b) Mann Whitney U –test was carried out to check for the significant effect of group on the durational measures and accuracy scores.
c) Wilcoxon's signed rank test was carried out to find the significant difference between words and non words, regular words and irregular words in both TDC and children with DD.

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

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

4.2 Accuracy measures of reading regular words and non-words, irregular words and non words in children with DD and TDC.

4.3 Eye movement patterns for reading regular words and non-words, irregular words and non words in children with DD and TDC.

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

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

4.1.1 Fixation duration for reading 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 (reading regular words and non- words, irregular words and non- words) for both the groups (children with DD and TDC). Table 4.1 shows mean, median, SD values of fixation duration for reading regular words, non-words and irregular words, non-words in TDC and children with DD.

Table 4.1

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

Group		TDC				DD			
Word category	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
FRW	8.0-9.11	20	5082.85	2153.53	4171.76	10	9444.26	9064.6	5553.97
FRNW		20	6933.95	3080.68	6857.33	10	7978.48	7327.75	5374.92
FIRW		20	5552.16	2358.42	3897.83	8	7218.47	5469.21	5960.3
FIRNW		20	5932.02	1982.59	5325.6	5	8091.48	8030.2	3239.21

Note: FRW= Fixation of Regular Word, FRNW= Fixation of Regular Non- Words, FIRW= Fixation of Irregular Word, FIRNW= Fixation of Irregular 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 by Table 4.1 in children with DD, longer mean fixation duration were obtained for regular words (Mean=9444.26ms, SD=9064.6), followed by irregular non words (Mean=8091.48ms, SD=8030.2), regular non words (Mean=7978.48ms, SD=7327.75) and least for irregular words (Mean=7218.47ms, SD=5960.3).Whereas for TDC the mean fixation duration was longer for regular non–words (Mean=6933.95ms, SD=3080.68), followed by irregular non words (Mean=5932.02ms, SD=1982.59), irregular words (Mean=5552.16ms, SD=2358.42) and least for regular words (Mean=5082.86ms, SD=2153.53) [Figure 4.1].

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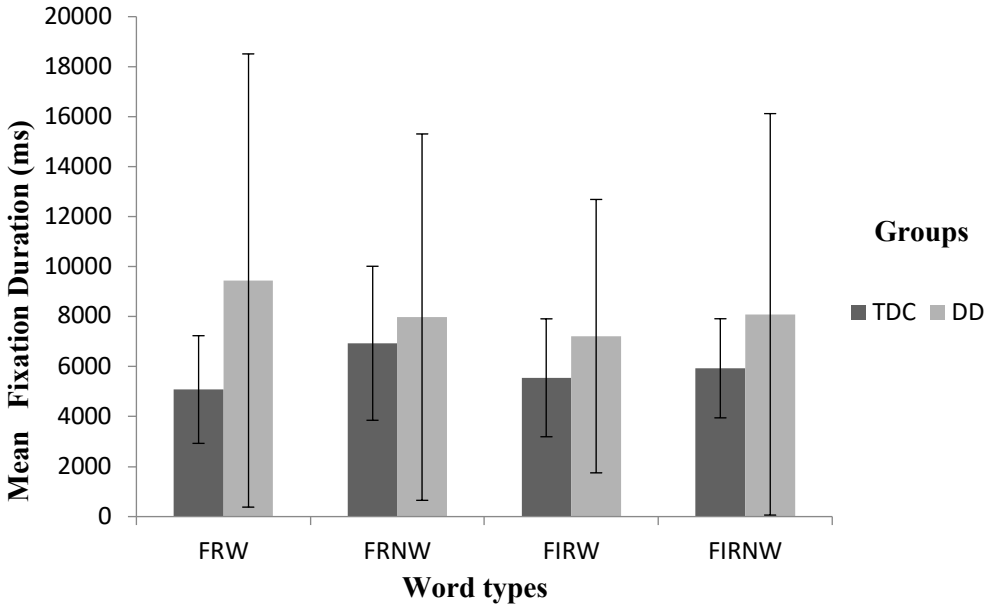

Figure 4.1: *Mean fixation duration values for reading regular words, non- words and irregular words, non-words in TDC and DD.*
Note: FRW= Fixation of Regular Word, FRNW= Fixation of Regular Non- Words, FIRW= Fixation of Irregular Word, FIRNW= Fixation of Irregular Non- Word.

Analysis of the results on Mann Whitney U test revealed no significant difference ($p>0.05$) for fixation duration measures [FRW ($|z|=0.039$, $p>0.05$), FRNW ($|z|=0.176$, $p>0.05$), FIRW ($|z|=0.509$, $p>0.05$), FIRNW ($|z|=0.544$, $p>0.05$)] between children with DD and TDC. However, the mean scores indicated longer fixation durations for children with DD in comparison to TDC for all word categories (FRW, FRNW, FIRW, and FIRNW).

Further the data was analyzed separately for the word type (word- non words) and regularity (regular and irregular words) using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD, indicated no significant difference ($p>0.05$) for reading words as compared to non- words [FRNW-FRW ($|z|=0.051$, $p>0.05$), FIRNW-FIRW ($|z|=0.365$, $p>0.05$)] as well as regular words when compared to irregular words [FIRW-FRW ($|z|=0.140$, $p>0.05$),

FIRNW-FRNW ($|z|$=0.674, p>0.05). Similarly no significant difference (p>0.05) was indicated in TDC for reading words as compared to non-words [FRNW-FRW ($|z|$=2.016, p>0.05), FIRNW-FIRW ($|z|$=1.232, p>0.05)] as well as regular words when compared to irregular words [FIRW-FRW ($|z|$=1.157, p>0.05), FIRNW-FRNW ($|z|$=1.904, p>0.05). However, the mean scores indicated that TDC showed greater fixations for non-words as compared to words but no regularity effect was observed. Whereas for children with DD, similar fixation durations were observed for both words and non-words and longer fixations for regular word as compared to irregular words.

The data was analyzed to see the age-related differences on the fixation duration for both TDC and children with DD across word types. Table 4.2 shows the age-related Mean, Median, SD values of fixation duration for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Table 4.2

Age related Mean, Median, SD values of fixation duration (in ms) for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Group		TDC				DD			
Word type	Age (in years)	N	Mean	SD	Median	N	Mean	SD	Median
FRW	8.0-8.11	10	5196.06	1898.38	4914.55	5	11338.5	10846.8	6277.89
FRNW		10	9364.4	2015.67	10038.4	5	6210.23	2426.43	5557.8
FIRW		10	7575.84	1605.71	8304.6	3	5093.8	2906.12	3915.6
FIRNW		10	7552.76	1279.45	7869.28	3	5263.6	4034.49	3110.4
FRW	9.0-9.11	10	4969.65	2481.6	3325.57	5	7550.05	7632.39	2986.75
FRNW		10	4503.49	1686.96	4089.69	5	9746.73	10349.5	4363.06
FIRW		10	3528.47	251.61	3498.32	5	8493.26	6535.04	8005
FIRNW		10	4311.27	907.56	4642.86	2	12333.3	12860.1	12333.3

Note: FRW= Fixation of Regular Word, FRNW= Fixation of Regular Non- Words, FIRW= Fixation of Irregular Word, FIRNW= Fixation of Irregular Non- Word.

The analysis of results as indicated in Table 4.2 revealed that in the age range of 8.0- 8.11years,fixation durations were shorter in children with DD when compared to TDC for all the word categories except for regular words. As indicated in Table 4.2, in children with DD, longer mean fixation durations were obtained for regular words (Mean=11338.5ms, SD=10846.76), followed by Regular Non Words (Mean=6210.23ms, SD=2426.43), Irregular Non Words (Mean=5263.6ms, SD= 4034.49) and Irregular words (Mean=5093.8ms, SD=2906.12). Whereas, in TDC longer mean fixation durations were obtained for Regular Non Words (Mean=9364.40ms, SD=2015.67), followed by Irregular Words (Mean=7575.84ms, SD=1605.71) and Irregular Non Words (Mean=7552.76ms, SD=1279.45) and least for regular words (Mean= 5196.06ms, SD=1898.38) [Figure 4.2].

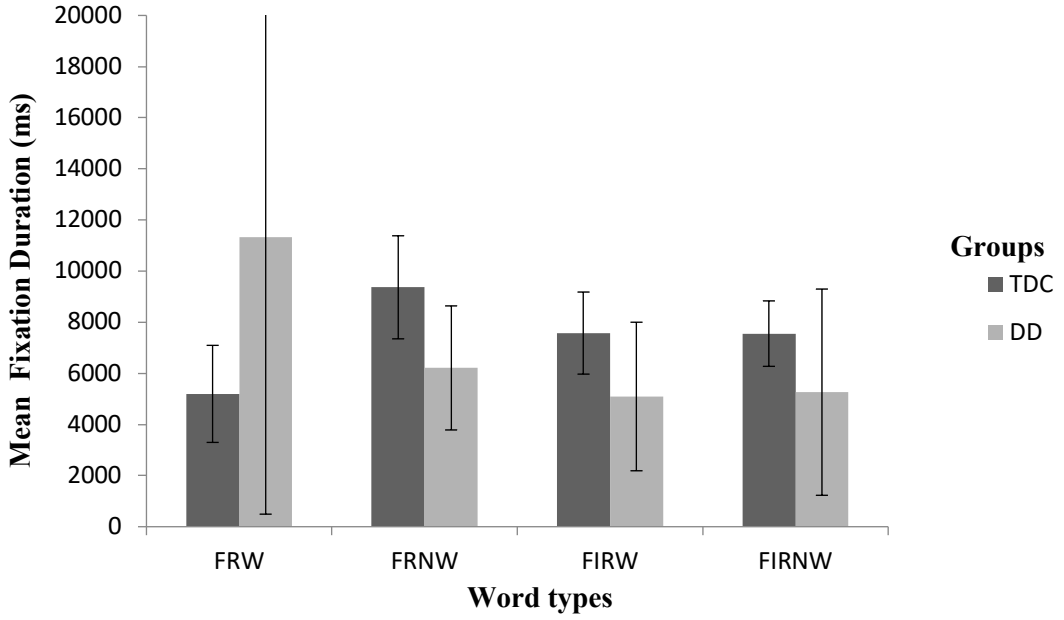

Figure 4.2: *Mean fixation duration in TDC and DD in the age range of 8.0-8.11 years*. *Note:* FRW= Fixation of Regular Word, FRNW= Fixation of Regular Non- Words, FIRW= Fixation of Irregular Word, FIRNW= Fixation of Irregular Non- Word.

Analysis of the results on Mann Whitney U test revealed no significant difference ($p>0.05$) for fixation duration measures [FRW ($|z|=0.735$, $p>0.05$), FRNW ($|z|=2.082$, $p>0.05$), FIRW ($|z|=1.354$, $p>0.05$), FIRNW ($|z|=0.46$, $p>0.05$)]. However, the mean scores indicated shorter fixation duration in younger children with DD when compared to younger TDC for all the word categories (FRW, FRNW, FIRW, and FIRNW).

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD indicated no significant difference for reading words as compared to non- words [FRNW-FRW ($|z|=0.674$, $p>0.05$), FIRNW-FIRW ($|z|=1.342$, $p>0.05$)] as well as Regular Words when compared to Irregular Words [FIRW-FRW($|z|=1.069$, $p>0.05$), FIRNW-FRNW ($|z|=0.00$, $p>0.05$).Similarly no significant difference ($p>0.05$) was obtained for TDC for reading words as compared to non- words [FRNW-FRW ($|z|=2.701$, $p>0.05$), FIRNW-FIRW ($|z|=0.459$, $p>0.05$)] as well Regular Words when compared to Irregular Words [FIRW-FRW ($|z|=2.497$, $p>0.05$), FIRNW-FRNW ($|z|=2.599$, $p>0.05$). However the mean scores indicated that children with DD showed longer fixation duration for words than non-words and for Regular Words than Irregular words. Whereas, TDC showed longer fixation durations for non-words as compared to words and similar fixation durations for Regular and Irregular words.

On the other hand, the fixation durations were longer for children with DD when compared to the TDC in the age range of 9.0-9.11 years for all the word categories. As indicated in Table 4.2, in children with DD, longer mean fixation durations were obtained

for Irregular Non Words (Mean=12333.3ms, SD=1280.1), followed by Regular Non Words (Mean=9746.73ms, SD=10349.46), Irregular Words (Mean=8493.26ms, SD= 6535.04) and least for Regular words (Mean=7550.05ms, SD= 7632.39). Whereas, in TDC longer mean fixation durations were obtained for Regular words (Mean=4969.65ms, SD=2481.6), followed by Regular Non-Words (Mean=4503.49ms, SD=1686.96), Irregular Non Words (Mean= 4311.27ms, SD=907.46) and least for Irregular words (Mean= 3528.47ms, SD=251.61) [Figure 4.3].

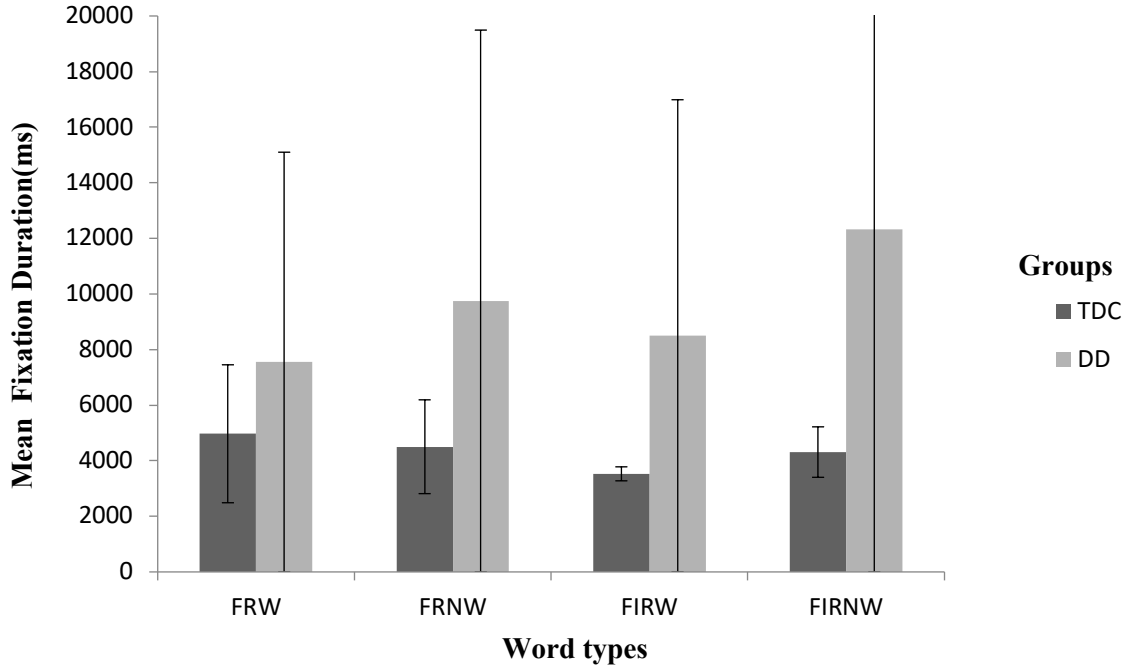

Figure 4.3: *Mean fixation duration in TDC and DD in the age range of 9.0-9.11 years.* *Note:* FRW= Fixation of Regular Word, FRNW= Fixation of Regular Non- Words, FIRW= Fixation of Irregular Word, FIRNW= Fixation of Irregular Non- Word.

Analysis of the results on Mann Whitney U test revealed no significant difference ($p>0.05$) for fixation duration measures [FRW ($|z|=0.903$, $p>0.05$), FRNW ($|z|=0.0903$, $p>0.05$), FIRW ($|z|=0.086$, $p>0.05$), FIRNW ($|z|=0.830$, $p>0.05$)]

between children with DD and TDC. However mean scores indicated longer fixation durations for the older children with DD as compared to TDC.

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in for children with DD showed no significant difference ($p>0.05$) for reading words as compared to non- words [FRNW-FRW ($|z|=0.674$, $p>0.05$), FIRNW-FIRW ($|z|=0.447$, $p>0.05$)] as well as for regular words when compared to irregular words [FIRW-FRW ($|z|=0.405$, $p>0.05$), FIRNW-FRNW ($|z|=0.447$, $p>0.05$). Similarly no significant difference ($p>0.05$) was obtained in TDC for reading words as compared to non- words [FRNW-FRW ($|z|=0.357$, $p>0.05$), FIRNW-FIRW ($|z|=2.191$, $p>0.05$)] as well as for regular words when compared to irregular words [FIRW-FRW ($|z|=0.968$, $p>0.05$), FIRNW-FRNW ($|z|=0.866$, $p>0.05$). However mean scores indicated that in children with DD, fixation durations were longer for non-words as compared to words and irregular words as compared to regular words. The TDC exhibited similar fixation durations for word type (word- non word) and regularity (regular - irregular words).

In summary, the analysis revealed that, there is no statistically significant difference between children with DD and TDC for fixation durations. However, the mean scores indicated that the fixation durations were longer for children with DD when compared to TDC (Table 4.1). In the younger group the fixation durations of the TDC were longer as compared to children with DD whereas, for the older group, the fixation durations of children with DD were longer as compared to the TDC. A decrease in the fixation duration was observed with age for both the groups. Variability in terms of

fixation durations has been observed for words- non-words, regular- irregular words for the younger group in both TDC and children with DD. In the older group of TDC similar fixation durations were observed irrespective of the word type, whereas, in children with DD longer fixation durations were observed with respect to non-words and irregular words.

4.1.2 Saccade duration for reading 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 (reading regular words and non- words, irregular words and non- words) for both the groups (children with DD and TDC) Table 4.4 shows Mean, Median, Standard Deviation values of Saccade duration for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Table 4.3

Mean, Median, SD values of Saccade duration (in ms) for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Group		TDC				DD			
Word type	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
SRW	8.0-9.11	20	629.89	340.17	783.8774	10	623.1	385.23	517.90
SRNW		20	658.73	320.82	641.3657	10	903.27	1092.42	588.81
SIRW		20	513.44	269.72	429.371	8	900.38	1287.57	462.74
SIRNW		20	626.47	311.59	542.0971	5	1038.14	1177.55	535.18

Note: SRW= saccade of Regular Word, SRNW= Saccade of Regular Non- Words, SIRW= Saccade of Irregular Word, SIRNW= Saccade of Irregular Non- Word.

The analysis of results as indicated in table 4.3 revealed that the saccade durations were longer in children with DD when compared to TDC for all the word types except for Regular words where the durations were similar. As indicated by Table 4.3, in children with DD, longer mean saccadic durations were obtained for Irregular Non Words (Mean=

1038.14ms, SD=1177.55), followed by Regular Non Words (Mean=903.27ms, SD=1092.42), Irregular Words (Mean=900.38ms, SD=1287.57) and least for Regular Words (Mean=623.1ms, SD=385.23). Whereas, in TDC mean saccade duration was longer for Regular Non-Words (Mean=658.73ms, SD=320.82), followed by Regular Words (Mean=629.89ms, SD=340.17), Irregular Non- Words (Mean= 636.47ms, SD=311.59) and least for Irregular words (Mean=513.44ms, SD=269.72) [Figure 4.4].

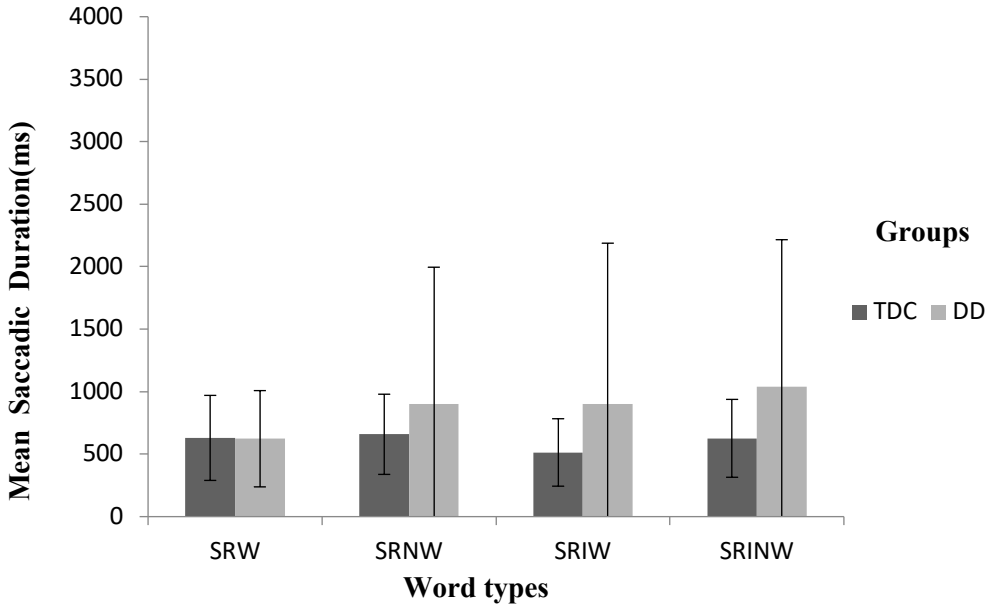

Figure 4.4: *Mean saccadic duration values for reading regular words, non- words and irregular words, non-words in TDC and DD.*
Note: SRW= saccade of Regular Word, SRNW= Saccade of Regular Non- Words, SIRW= Saccade of Irregular Word, SIRNW= Saccade of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for saccade duration measures [SRW ($|z|=0.000$, $p>0.05$), SRNW ($|z|=0.264$, $p>0.05$), SIRW ($|z|=0.203$, $p>0.05$), SIRNW ($|z|=0.272$, $p>0.05$)] between children with DD and TDC. However, it can be inferred from the mean scores that the saccadic duration for children with DD was longer when compared to the TDC.

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD revealed no significant difference for reading words as compared to non- words [SRNW-SRW ($|z|=0.357$, $p>0.05$), SIRNW-SIRW ($|z|=0.730$, $p>0.05$)] as well regular words when compared to irregular words [SIRW-SRW ($|z|=0.140$, $p>0.05$), SIRNW-SRNW ($|z|=0.674$, $p>0.05$). Similarly, no significant difference ($p>0.05$) was obtained in TDC for reading words as compared to non-words [SRNW-SRW ($|z|=0.635$, $p>0.05$), SIRNW-SIRW ($|z|=2.725$, $p>0.05$)] as well regular words when compared to irregular words [SIRW-SRW ($|z|=1.195$, $p>0.05$), SIRNW-SRNW ($|z|=1.157$, $p>0.05$). However mean scores indicated that in children with DD, longer saccadic duration was observed for non-words and irregular words as compared to words and regular words respectively. On the other hand, TDC showed similar saccadic durations with respect to word-non words, and regular–irregular words.

The data was analyzed to see the age related differences on the saccade duration in both children with DD and TDC for word categories. Age related Mean, Median, SD values of fixation duration for reading regular words, non-words and irregular words, non-words in children with DD and TDC are depicted in Table 4.4

Table 4.4

Age related Mean, Median, SD values of saccade duration(in ms) for reading regular words, non-words and irregular words, non-words in children with DD and TDC

Group		TDC				DD			
Word type	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
SRW	8.0-8.11	10	629.42	313.28	783.88	5	679.35	377.21	572.94
SRNW		10	917.22	211.04	989.84	5	1139.05	1530.57	548.2
SIRW		10	731.13	205.89	797.5	3	1610.16	2122.78	437.09
SIRNW		10	884.28	202.53	913.86	3	1292.89	1566.6	535.18
SRW	9.0-9.11	10	630.36	382.27	675.9	5	566.85	428.63	494.74
SRNW		10	400.25	155.82	338.74	5	667.5	451.06	629.42
SIRW		10	295.74	76.71	261.054	5	474.52	208.76	478.38
SIRNW		10	368.75	127.88	351.63	2	656	388.86	656

Note: SRW= saccade of Regular Word, SRNW= Saccade of Regular Non- Words, SIRW= Saccade of Irregular Word, SIRNW= Saccade of Irregular Non- Word.

The analysis of results as indicated in Table 4.4 revealed that saccade durations were longer in the children with DD when compared to the TDC in the age range of 8.0-8.11years for all the word categories. As indicated in Table 4.4, in children with DD, longer mean saccade durations were obtained for Irregular words (Mean=1610.16ms, SD=2122.78), followed by Irregular Non Words (Mean=1292.89 SD=1566.60), Regular non words (Mean=1139.05ms, SD=1530.57) and least for Regular words (Mean=679.35ms, SD=377.21). Whereas, in TDC longer mean saccade durations were obtained for Regular Non words (Mean=917.22ms, SD=205.89), followed by Irregular Non Words (Mean=884.28ms, SD=202.53), irregular Words (Mean=731.13ms, SD=305.89) and least for Regular words (Mean=629.42ms, SD=313.28) [Figure 4.5].

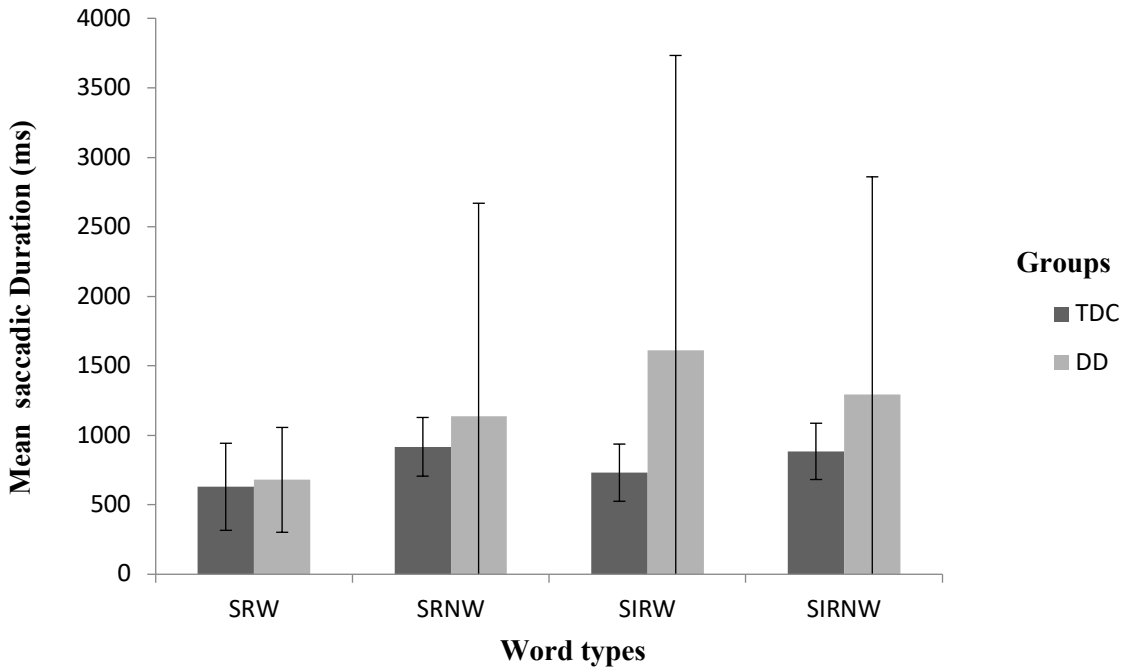

Figure 4.5: *Mean saccadic duration in TDC and DD in the age range of 8.0-8.11 years.* *Note:* SRW= saccade of Regular Word, SRNW= Saccade of Regular Non- Words, SIRW= Saccade of Irregular Word, SIRNW= Saccade of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for saccadic duration measures [SRW ($|z|=0.122$, $p>0.05$), SRNW ($|z|=1.470$, $p>0.05$), SIRW ($|z|=0.508$, $p>0.05$), SIRNW ($|z|=0.677$, $p>0.05$)] in both children with DD and TDC. However, by virtue of the mean scores it is evident that, the saccadic duration was longer in younger children with DD as compared to TDC.

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both TDC and children with DD. Analysis of the results in children with DD revealed no significant difference for reading words as compared to non-words [SRNW-SRW ($|z|=0.135$, $p>0.05$), SIRNW-SIRW ($|z|=0.447$, $p>0.05$)] as well regular words when compared to irregular words [SIRW-SRW ($|z|=0.535$, $p>0.05$), SIRNW-SRNW ($|z|=0.00$, $p>0.05$). Similarly no

significant difference (p>0.05) was obtained for the TDC indicated for reading words as compared to non- words [SRNW- SRW (|z|=2.497, p>0.05), SIRNW-SIRW (|z|=0.561, p>0.05)] as well regular words when compared to irregular words [SIRW-SRW (|z|=0.866, p>0.05), SIRNW-SRNW (|z|=1.904, p>0.05) . However as indicated by mean scores, in children with DD, similar durations were obtained for words- non words and longer durations were obtained for irregular words as compared to regular words. On the other hand, in TDC, longer saccadic durations were obtained for non words as compared to words and similar durations were obtained for regular and irregular words

On the other hand, analysis of results as indicated in Table 4.4 revealed that the saccade durations were longer for the children with DD when compared to the TDC group in the age range of 9.0-9.11 years for all the word types except for Regular words. As indicated in Table 4.4, in children with DD, longer mean saccadic durations were obtained for Regular Non Words (Mean=667.50ms, SD=451.06), followed by Irregular Non Words (Mean=656ms, SD=388.86), Regular Words (Mean=566.85ms, SD= 428.63) and least for Irregular words (Mean=474.52ms, SD= 208.76). Whereas in TDC longer mean saccade durations were obtained for Regular words (Mean=630.36ms, SD= 382.27), followed by Regular Non-Words (Mean= 400.25ms, SD=155.82) Irregular Non Words (Mean= 368.75ms, SD=127.88) and least for Irregular words (Mean= 295.74ms, SD=76.71) [Figure 4.6].

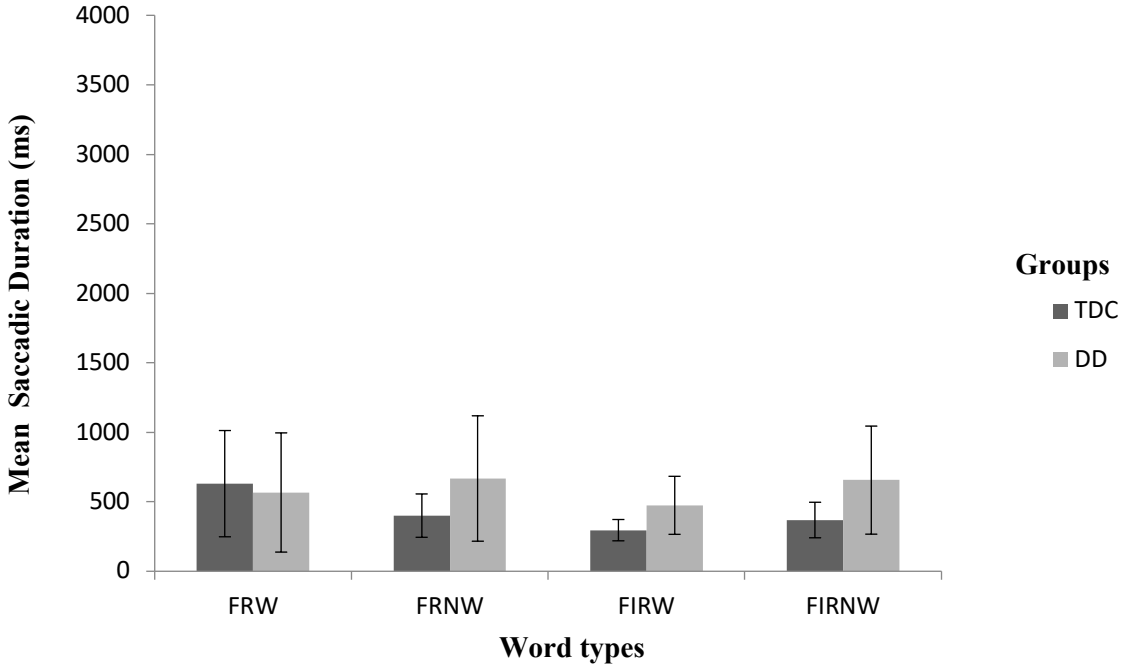

Figure 4.6: *Mean saccadic duration in TDC and DD in the age range of 9.0-9.11 years.* *Note:* SRW= saccade of Regular Word, SRNW= Saccade of Regular Non- Words, SIRW= Saccade of Irregular Word, SIRNW= Saccade of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for saccade duration measures [SRW ($|z|=0.122$, $p>0.05$), SRNW ($|z|=1.225$, $p>0.05$), SIRW ($|z|=1.715$, $p>0.05$), SIRNW ($|z|=1.289$, $p>0.05$)] in both children with DD as compared to TDC. However mean score indicates that saccadic durations were more in older children with DD as compared to TDC.

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both TDC and children with DD. Analysis of the results in children with DD, revealed no significant difference for reading words as compared to non- words [SRNW- SRW ($|z|=0.405$, $p>0.05$), SIRNW-SIRW ($|z|=0.447$, $p>0.05$)] as well regular words when compared to irregular words [SIRW-SRW ($|z|=0.405$, $p>0.05$), SIRNW-SRNW ($|z|=1.342$, $p>0.05$). Similarly no

significant difference (p>0.05) was obtained for TDC for reading words as compared to non- words [SRNW- SRW (|z|=1.682, p>0.05), SIRNW-SIRW (|z|=1.784, p>0.05)] as well as regular words when compared to irregular words [SIRW-SRW (|z|=1.784, p>0.05), SIRNW-SRNW (|z|=0.561, p>0.05). However mean scores indicated that in children with DD, saccadic durations were longer for non-words as compared to words and irregular words as compared to regular words. Whereas, the TDC showed similar saccadic durations for words- non words and longer for irregular words as compared to regular words.

In summary, the analysis revealed that, there was no statistical difference between children with DD and TDC for the saccadic durations. However, the mean scores indicated that children with DD showed longer saccadic durations as compared to the TDC. Specifically, the word- non word and regular irregular effect was more evident in the older children with DD. A decrease in saccadic durations with respect to age was also noted for both the groups (children with DD and TDC).

4.1.3 Total Gaze Duration for reading 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 (reading regular words and non- words, irregular words and non- words) for both the groups (children with DD and TDC). The Mean, Median and Standard Deviation (SD) for Total Gaze Duration was obtained for each of the word type for both TDC and children with DD. Table 4.5 shows Mean, Median, Standard Deviation values of Total Gaze duration for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Table 4.5

Mean, Median, Standard Deviation values of Total Gaze duration (in ms) for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Group		TDC				DD			
Word type	Age (yrs)	N	Mean	SD	Median	N	Mean	SD	Median
TGDRW	8.0-9.11	20	5548.07	2610.39	4427.24	10	9948.02	9450.98	6090.11
TGDRNW		20	7588.81	3389.02	7475.17	10	6992.58	7738.39	4527.15
TGDIRW		20	6073.40	2613.63	4221.54	8	4180.95	6283.68	2404.3
TGDIRNW		20	6558.55	2287.47	5790.57	5	6593.54	8924.07	3620.24

Note: TGDRW= Total Gaze Duration of Regular Word, TGDRNW= Total Gaze Duration of Regular Non-Words, TGDIRW= Total Gaze Duration of Irregular Word, TGDIRNW= Total Gaze Duration of Irregular Non- Word.

The analysis of results as indicated in table 4.5 revealed that the total gaze durations were longer in the children with DD when compared to the TDC for all the word types except for Irregular non word wherein the total gaze durations were similar. As indicated by Table 4.5 in children with DD, longer mean total gaze duration were obtained for Regular Words (Mean=9948.02ms, SD=9450.98), followed by Irregular non words (Mean=659.54ms, SD=8924.07), Regular Non- Words (Mean=6992.58ms, SD=7738.397) and least for Irregular words (Mean=4180.95ms, SD=6283.68). Whereas, in TDC the mean total gaze duration was longer for Regular non-word (Mean=7588.81ms, SD=3389.02), followed by Irregular Non- Words (Mean=6558.55ms, SD=7738.39), Irregular Words (Mean= 6073.40ms, SD=2613.63) and least for Regular word (Mean=5548.07ms, SD=2610.39) [Figure 4.7].

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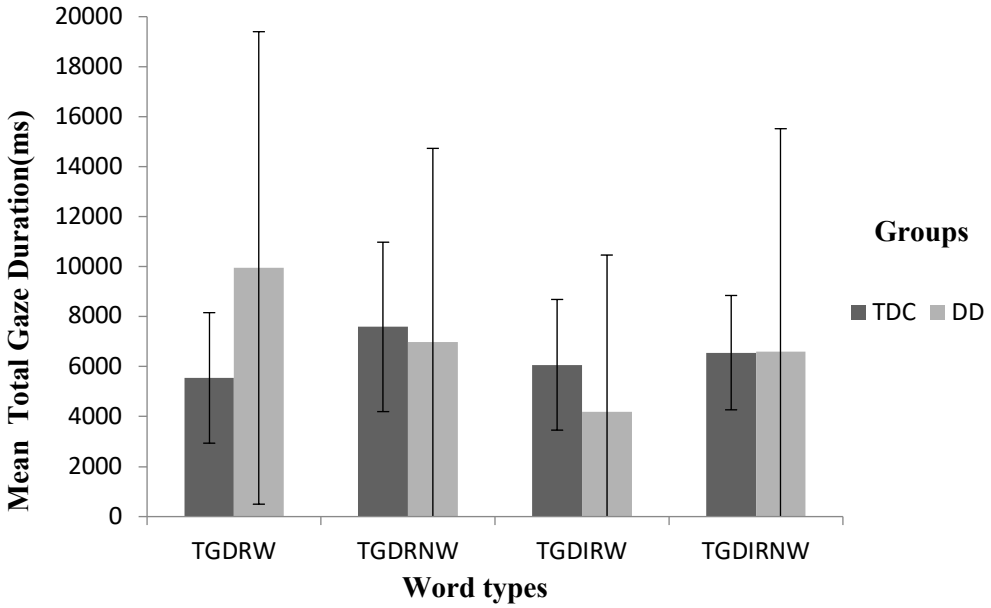

Figure 4.7: *Mean Total Gaze duration values for reading regular words, non- words and irregular words, non-words in TDC and DD.*
Note: TGDRW= Total Gaze Duration of Regular Word, TGDRNW= Total Gaze Duration of Regular Non-Words, TGDIRW= Total Gaze Duration of Irregular Word, TGDIRNW= Total Gaze Duration of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for total gaze duration measure [TGDRW ($|z|=0.660$, $p>0.05$), TGDRNW ($|z|=1.100$, $p>0.05$), TGDIRW ($|z|=1.526$, $p>0.05$), TGDIRNW ($|z|=1.767$, $p>0.05$)] between children with DD and TDC. However, it can be inferred from the mean scores that the total gaze duration for children with DD was longer when compared to the TDC.

Further the data was analyzed separately for words non-word words and regular and irregular words using the Wilcoxon's Signed ranked test for both TDC and children 7with DD. Analysis of the results in children with DD, revealed no significant difference for reading words as compared to non- words [TGDRNW- TGDRW ($|z|=0.561$,

p>0.05), TGDIRNW-TGDIRW (|z|=0.365, p>0.05)] as well regular words when compared to irregular words [TGDIRW-TGDRW (|z|=1.260, p>0.05), TGDIRNW-TGDRNW (|z|=2.023, p>0.05). Similarly, no significant difference (p>0.05) was obtained for reading words as compared to non- words [TGDRNW- TGDRW (|z|=2.016, p>0.05), TGDIRNW-TGDIRW (|z|=1.307, p>0.05)] as well regular words when compared to irregular words [TGDIRW-TGDRW (|z|=1.260, p>0.05), TGDIRNW-TGDRNW (|z|=2.023, p>0.05). However, as evident from mean scores, in children with DD similar total gaze durations was observed for word- non words or regular- irregular words. Whereas, TDC showed longer total gaze duration for words and irregular words as compared to non words and regular words respectively.

The data was analyzed to see the age related differences on the total gaze duration in both TDC and children with DD for word types. Age related Mean, Median, SD values of total gaze duration for reading regular words, non-words and irregular words, non-words in children with DD and TDC depicted in Table 4.6.

Table 4.6

Age related Mean, Median, SD values of total gaze duration(in ms) for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Group		TDC				DD			
Word type	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
TGDRW	8.0-8.11	10	5828.94	2141.92	5422.47	5	12017.8	11217.4	6850.83
TGDRNW		10	10294.2	2187.48	11006.1	5	3946.19	3453.56	4498.06
TGDIRW		10	8306.97	1807.21	9099.36	3	2915.36	2241.33	4060.6
TGDIRNW		10	8447.91	1447.74	8783.25	3	2329.69	1822.72	3094.3
TGDRW	9.0-9.11	10	5267.19	3101.98	3637.28	5	7878.23	8027.02	3178.05
TGDRNW		10	4883.41	1788.05	4596.3	5	10039	9980.36	4556.24
TGDIRW		10	3839.83	262.34	3822.63	5	4940.3	8041.41	748
TGDIRNW		10	4669.18	1008.88	4994.49	2	12989.3	13249.9	12989.3

Note: TGDRW= Total Gaze Duration of Regular Word, TGDRNW= Total Gaze Duration of Regular Non-Words, TGDIRW= Total Gaze Duration of Irregular Word, TGDIRNW= Total Gaze Duration of Irregular Non- Word.

The analysis of results as indicated in Table 4.6 revealed that total gaze durations were shorter in the children with DD when compared to TDC in the age range of 8.0-8.11years for all the word types except for Regular words, wherein mean scores were higher for the children with DD. As indicated in Table 4.6, in children with DD, longer mean total gaze durations were obtained for Regular words (Mean=12017.8ms, SD=11217.37), followed by Regular Non Words (Mean=3946.19 SD=3453.56), Irregular words (Mean=2915.36ms, SD= 2241.33) and least for Irregular Non- Words (Mean=2329.69ms, SD= 1822.72). Whereas in TDC longer mean total gaze durations were obtained for Regular Non words (Mean=10294.21ms, SD= 2187.48), followed by Irregular Non-Words (Mean= 8447.91ms, SD=1447.74), Irregular Words (Mean= 8306.97ms, SD=1807.21) and least for Regular words (Mean=5828.94ms, SD=2141.92) [Figure 4.8].

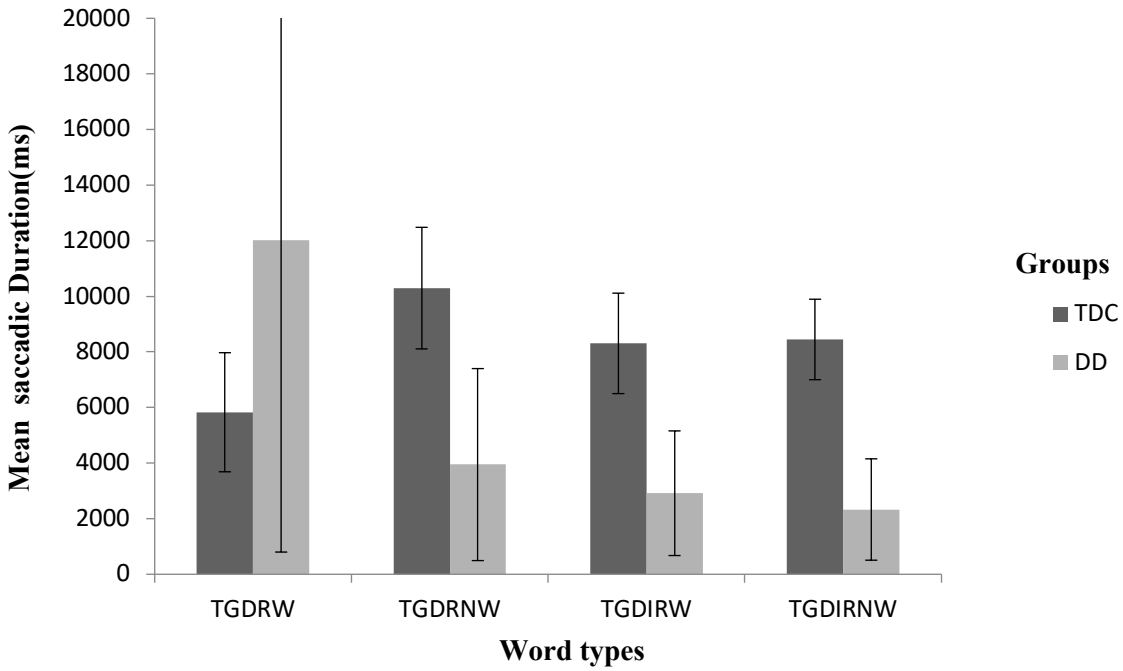

Figure 4.8: *Mean total gaze duration in TDC and DD in the age range of 8.0-8.11 years.* *Note:* TGDRW= Total Gaze Duration of Regular Word, TGDRNW= Total Gaze Duration of Regular Non-Words, TGDIRW= Total Gaze Duration of Irregular Word, TGDIRNW= Total Gaze Duration of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for total gaze duration measures [TGDRW ($|z|=0.735$, $p>0.05$), TGDRNW ($|z|=2.694$, $p>0.05$), TGDIRW ($|z|=2.200$, $p>0.05$), TGDIRNW ($|z|=2.539$, $p>0.05$)] in children with DD as compared to TDC. However, by virtue of the mean scores it is evident that, the total gaze duration was shorter in younger children with DD as compared to younger TDC.

Further the data was analyzed separately for word, non-words and regular - irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD revealed no significant difference ($p>0.05$) for reading words as compared to non-words [TGDRNW- TDGRW ($|z|=1.483$, $p>0.05$), TGDIRNW-TGDIRW ($|z|=1.342$, $p>0.05$)] as well regular

words when compared to irregular words [TGDIRW-TGDRW (|z|=1.069, p>0.05), SIRNW-SRNW (|z|=1.604, p>0.05). Similarly no significant difference (p>0.05) was obtained in TDC indicated for reading words as compared to non-words [TGDRNW-TGDRW (|z|=2.701, p>0.05), TGDIRNW-TGDIRW (|z|=0.459, p>0.05)] as well regular words when compared to irregular words [TGDIRW-TGDRW (|z|=1.157, p>0.05), TGDIRNW-TGDRNW (|z|=1.904, p>0.05). However, mean scores indicated that in children with DD, total gaze duration was longer for words as compared to non-words and for regular words as compared to irregular words. On contrast, TDC showed similar total gaze durations for both word type (word- non words) and regularity (regular and irregular words).

On the other hand, analysis of results as depicted in Table 4.6 revealed that the total gaze durations were longer for children with DD when compared to the TDC in the age range of 9.0-9.11 years for all the word types. As indicated in Table 4.6, in children with DD, longer mean total gaze durations were obtained for Irregular Non Words (Mean=12989.3ms, SD=13249.85), followed by Regular Non Words (Mean=10039ms, SD=9980.36), Regular Words (Mean=7878.23ms, SD= 8027.02) and least for Irregular words (Mean=4940.3ms, SD=8041.41). Whereas in TDC, longer mean total gaze durations were obtained for Regular words (Mean=5267.19ms, SD= 3101.98), followed by Regular Non-Words (Mean= 4883.41ms, SD=1788.05) Irregular Non Words (Mean= 4669.18ms, SD=1008.88) and least for Irregular words (Mean= 3839.83ms, SD=262.34) [Figure 4.9].

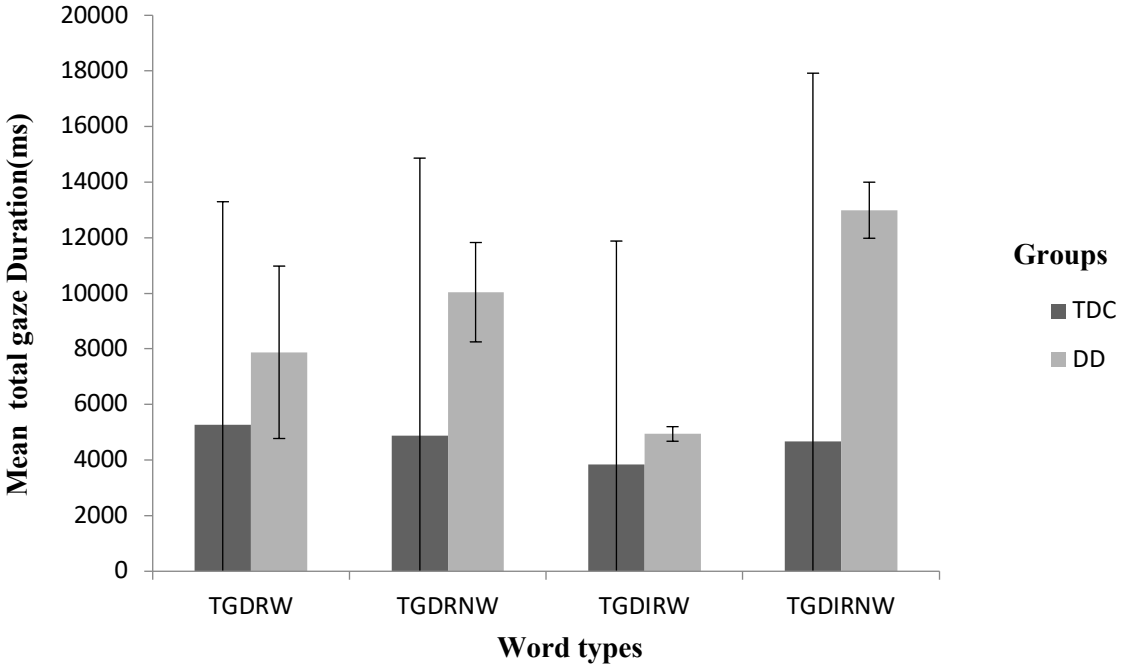

Figure 4.9: *Mean total gaze duration in TDC and DD in the age range of 9.0-9.11 years.* *Note:* TGDRW= Total Gaze Duration of Regular Word, TGDRNW= Total Gaze Duration of Regular Non-Words, TGDIRW= Total Gaze Duration of Irregular Word, TGDIRNW= Total Gaze Duration of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed no significant difference ($p>0.05$) for total gaze duration measures [TGDRW ($|z|=0.367$, $p>0.05$), TGDRNW ($|z|=0.367$, $p>0.05$), TGDIRW ($|z|=0.735$, $p>0.05$), TGDIRNW ($|z|=0.430$, $p>0.05$)] for children with DD as compared to TDC. However mean score indicates that total gaze durations were more in older children with DD as compared to TDC.

Further the data was analyzed separately for words non-word words and regular and irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD revealed no significant difference $p>0.05$) for reading words as compared to non-words [TGDRNW- SRW ($|z|=0.944$,

p>0.05), TGDIRNW-TGDIRW (|z|=0.447, p>0.05)] as well regular words when compared to irregular words [TGDIRW-TGDRW (|z|=0.674, p>0.05), TGDIRNW-TGDRNW (|z|=0.1342, p>0.05). Similarly no significant difference (p>0.05) was obtained in TDC for reading words as compared to non- words [TGDRNW- TGDRW (|z|=1.682, p>0.05), TGDIRNW-TGDIRW (|z|=1.784, p>0.05)] as well regular words when compared to irregular words [TGDIRW-TGDRW (|z|=2.497, p>0.05), TGDIRNW-TGDRNW (|z|=2.497, p>0.05).

However mean scores indicated that in children with DD, longer total gaze durations were obtained for non-words when compared to words and for regular words when compared to irregular words. Whereas, in TDC, similar total gaze duration was seen for reading word- non words and longer durations for regular words as compared to irregular words.

In summary, the analysis revealed that there was no statistically significant difference between children with DD and TDC for total gaze durations. However, mean scores indicated that the total gaze durations were longer in older children with DD when compared to TDC. The effect of word- non word and regularity was observed in both the age groups. An overall decrement in total gaze duration was also seen with respect to age for both the groups (children with DD and TDC).

4.2 Accuracy measures for reading regular words and non-words, irregular words and non-words in children with DD and TDC.

The accuracy scores were analyzed in the present study for all word categories (regular words and non-words, irregular words and non-words). The results across word category in the two groups are explained in the following sections.

Descriptive statistics showed the Mean, Median and Standard Deviation (SD) for accuracy scores for each of the word categories (reading regular words and non- words, irregular words and non- words) for both the groups (children with DD and TDC). Table 4.7 shows Mean, Median, SD values of accuracy scores for reading regular words, non-words and irregular words, non-words in Children with DD and TDC.

Table 4.7

Mean, Median, SD values of accuracy scores for reading regular words, non-words and irregular words, non-words in Children with DD and TDC.

Group		TDC				DD			
Word type	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
ARW	8.0-9.11	20	22.4	2.28	23	10	7.3	5.35	5.5
ARNW		20	20.35	4.54	22.5	10	7.2	7.63	4
AIRW		20	20.15	4.03	21.5	10	3.9	6.50	1
AIRNW		20	13	3.55	14	10	1.5	2.32	0

Note: ARW= Accuracy of Regular Word, ARNW= Accuracy of Regular Non- Words, AIRW= Accuracy of Irregular Word, AIRNW= Accuracy of Irregular Non- Word.

The analysis of results as indicated in table 4.7 revealed that the accuracy scores were lesser in children with DD when compared to TDC all the word categories, however the pattern of the scores were similar. As indicated by Table 4.7, in children with DD, accuracy scores were similar for Regular Words (mean= 7.3, SD=5.35), Regular Non-Words (Mean=7.63, SD=4), and Irregular Words (Mean=6.50, SD=1) and least for

Irregular Non-Words (Mean=1.5, SD=2.32). Whereas, in the TDC group the accuracy scores were similar for Regular words (Mean=22.4, SD=2.28), Regular Non- Words (Mean=20.35, SD=4.54), and Irregular Words (Mean=20.15, SD=4.03) and least for Irregular Non-Words (Mean=13, SD=3.55) [Figure 4.10]

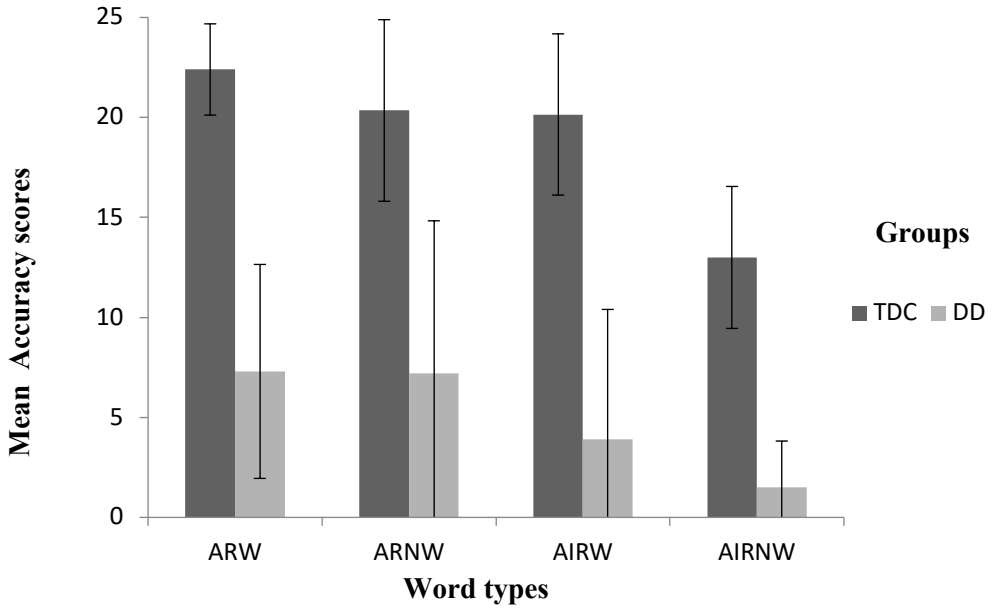

Figure 4.10: *Mean Accuracy scores for reading regular words, non- words and irregular words, non-words in TDC and DD.*

Note: ARW= Accuracy of Regular Word, ARNW= Accuracy of Regular Non- Words, AIRW= Accuracy of Irregular Word, AIRNW= Accuracy of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed significant difference ($p>0.05$) for the accuracy scores [ARW ($|z|=4.375$, $p<0.05$), ARNW ($|z|=3.706$, $p<0.05$), AIRW ($|z|=4.131$, $p<0.05$), AIRNW ($|z|=4.362$, $p<0.05$)] between children with DD and TDC.

Further the data was analyzed separately for words non-word words and regular and irregular words using the Wilcoxon's Signed ranked test for both children with DD and TDC. Analysis of the results in children with DD, indicated that no significant difference ($p>0.05$) was obtained for children with DD for reading words as compared to

non- words [ARNW- ARW (|z|=0.410, p>0.05), AIRNW-AIRW (|z|=2.060, p>0.05)] as well regular words when compared to irregular words [AIRW-ARW (|z|=2.689, p>0.05), AIRNW-ARNW (|z|=2.670, p>0.05). However mean scores indicated that the accuracy scores were higher in children with DD for words when compared to non-words, and for regular words when compared to irregular words.

Contrastively, TDC indicated significant difference (p<0.05) for reading words as compared to non- words [ARNW- ARW (|z|=2.770, p<0.05), AIRNW-AIRW (|z|=3.934, p<0.05)] as well regular words when compared to irregular words [AIRW-ARW (|z|=3.271, p<0.05), AIRNW-ARNW (|z|=3.926, p<0.05).

The data was analyzed to see the age related differences for the accuracy scores in both children with DD and TDC for word types. Age related Mean, Median, SD values of accuracy scores for reading regular words, non-words and irregular words, non-words in children with DD and TDC are depicted in Table 4.8

Table 4.8

Age related Mean, Median, SD values of accuracy scores for reading regular words, non-words and irregular words, non-words in children with DD and TDC.

Group		TDC				DD			
Word type	Age (years)	N	Mean	SD	Median	N	Mean	SD	Median
ARW		10	21.2	2.74	21.5	5	6.6	5.5	4
ARNW	8.0-	10	17.4	4.7	17	5	4.4	7.06	1
AIRW	8.11	10	17.9	4.48	18.5	5	3.2	6.61	0
AIRNW		10	10.7	3.13	11	5	1.4	2.61	0
ARW		10	23.6	0.52	24	5	8	5.74	8
ARNW	9.0-	10	23.3	1.5	24	5	10	7.84	5
AIRW	9.11	10	22.4	1.71	23	5	4.6	7.09	1
AIRNW		10	15.3	2.26	15.5	5	1.6	2.3	0

Note: ARW= Accuracy of Regular Word, ARNW= Accuracy of Regular Non- Words, AIRW= Accuracy of Irregular Word, AIRNW= Accuracy of Irregular Non- Word.

The analysis of results as indicated in Table 4.8 revealed that the accuracy scores were lower in children with DD when compared to TDC in the age range of 8.0-8.11years for all the word types. As indicated in Table 4.8, in children with DD, accuracy scores were highest for Regular Words (mean= 6.6, SD=5.5), followed by Regular Non-Words (Mean=4.4, SD=7.06), and Irregular Words (Mean= 3.2, SD=6.61) and least for Irregular Non-Words (Mean=1.4, SD=2.61). Whereas for TDC higher mean accuracy scores were obtained Regular words (Mean=21.2, SD=2.74), similar for Regular Non-Words (Mean=17.4, SD=4.7), and Irregular Words (Mean= 17.9, SD=4.48) and least for Irregular Non-Words (Mean=10.7, SD=3.13) [Figure 4.11].

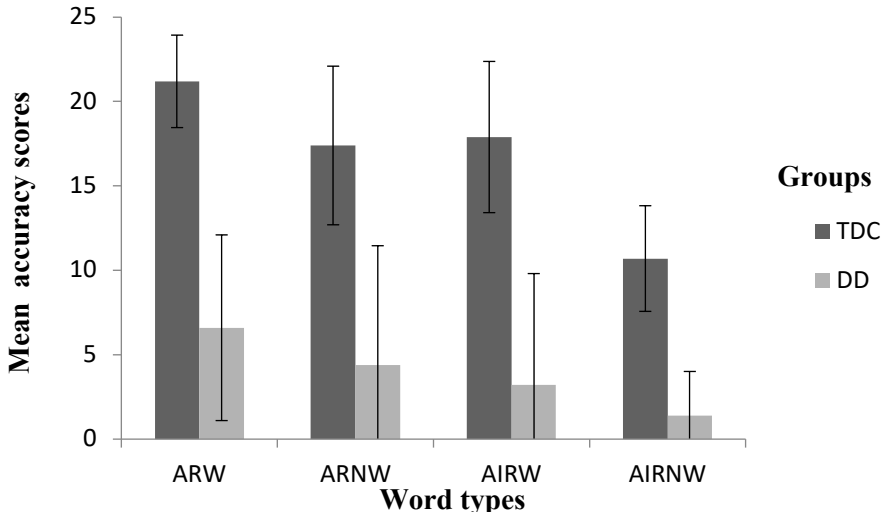

Figure 4.11: *Mean accuracy scores in TDC and DD in the age range of 8.0-8.11 years.* *Note:* ARW= Accuracy of Regular Word, ARNW= Accuracy of Regular Non- Words, AIRW= Accuracy of Irregular Word, AIRNW= Accuracy of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed a significant difference ($p<0.05$) for accuracy scores [ARW ($|z|=2.950$, $p<0.05$), AIRNW ($|z|=2.971$, $p<0.05$)] between children with DD and TDC. Whereas no significant

difference was obtained for ARNW (| z | =2.467, p>0.05), AIRW (| z | =2.704, p>0.05),] between the groups.

Further the data was analyzed separately for words non-word words and regular and irregular words using the Wilcoxon's Signed ranked test for both TDC and children with DD. Analysis of the results in children with DD revealed no significant difference (p>0.05) for reading words as compared to non- words [ARNW- ARW (| z | =1.761, p>0.05), AIRNW-AIRW (| z | =1.00, p>0.05)] as well regular words when compared to irregular words [AIRW-ARW (| z | =2.060, p>0.05), AIRNW-ARNW (| z | =1.841, p>0.05). However mean scores indicated that, accuracy scores were higher for word than non-words and regular words than irregular words in children with DD. Whereas, TDC indicated one significant pair difference (p>0.05) for reading words as compared to non-words [ARNW- ARW (| z | =2.536, p>0.05), AIRNW-AIRW (| z | =2.807, p=0.05)]and was significant for one pair for regular words when compared to irregular words [AIRW-ARW (| z | =2.524, p>0.05), AIRNW-ARNW (| z | =2.807, p=0.05) indicating the effect of regularity on word type.

Similarly, analysis of results as indicated in Table 4.8 revealed that the accuracy scores were reduced in children with DD when compared to TDC in the age range of 9.0-9.11 years for all the word types. As indicated in Table 4.8, in children with DD, higher accuracy scores were obtained for Regular Non-Words (Mean=10, SD=7.84), followed by Regular Words (Mean=8, SD=5.74), Irregular Words (Mean=4.6, SD= 7.09) and least for Irregular Non-Words (Mean=1.6, SD= 2.30). Whereas, in the TDC group similar accuracy scores were obtained for Regular words (Mean=23.6, SD= 0.52), Regular Non-

Words (Mean= 23.3, SD=1.50) Irregular Words (Mean= 22.4, SD=1.71) and least for Irregular Non-Words (Mean= 15.3, SD=2.26) [Figure 4.12].

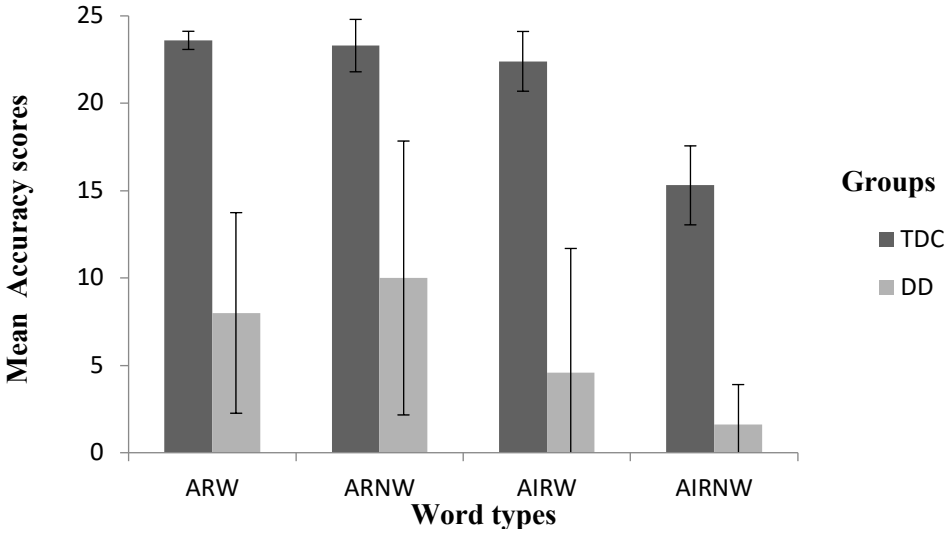

Figure 4.12: *Mean accuracy scores in TDC and DD in the age range of 9.0-9.11 years*. *Note:* ARW= Accuracy of Regular Word, ARNW= Accuracy of Regular Non- Words, AIRW= Accuracy of Irregular Word, AIRNW= Accuracy of Irregular Non- Word.

Analysis of the results using the Mann Whitney U test revealed significant difference ($p<0.05$) for accuracy scores [ARW ($|z|=3.196$, $p<0.05$), ARNW ($|z|=3.261$, $p<0.05$), AIRW ($|z|=3.090$, $p<0.05$), AIRNW ($|z|=3.090$, $p<0.05$)] between children with DD and TDC.

Further the data was analyzed separately for words non-words and regular and irregular words using the Wilcoxon's Signed ranked test for both TDC and children with DD. Analysis of the results revealed that in children with DD, no significant difference ($p>0.05$) was obtained for reading words as compared to non- words [ARNW- ARW ($|z|=0.944$, $p>0.05$), AIRNW-AIRW ($|z|=1.890$, $p>0.05$)] as well as for regular words when compared to irregular words [AIRW-ARW ($|z|=1.826$, $p>0.05$), AIRNW-ARNW ($|z|=2.032$, $p>0.05$). However mean scores indicated that, accuracy scores were

higher for words than non-words and regular words than non-words in children with DD. Whereas, TDC indicated significant difference ($p>0.05$) for reading a pair of word as compared to non- words [ARNW- ARW ($|z|=0.412$, $p>0.05$), AIRNW-AIRW ($|z|=2.825$, $p=0.05$)] as well regular words when compared to irregular words [AIRW-ARW ($|z|=1.897$, $p>0.05$), AIRNW-ARNW ($|z|=2.820$, $p=0.05$) .This indicated the effect of word type and regularity.

In summary, the analysis revealed that there was a statistically significant difference between children with DD and TDC for accuracy scores. Wherein, accuracy scores were higher in TDC when compared to children with DD. A regularity effect was found on the word type for younger TDC and for older TDC both word type and regularity effect was observed for all word categories. With increase in age, the accuracy scores have also shown an increment.

4.3 Eye movement patterns for reading regular words and non-words, irregular words and non-words in children with DD and TDC.

A qualitative analysis was carried out to infer the differences in the patterns of eye movements in children with DD and TDC. The patterns of eye movements include the number of fixations, direction of saccadic movements, regressions, size of the saccades. Differences in the errors in reading between the two groups have also been highlighted.

Overall it was observed that, in comparison to TDC, children with DD had more fixations which were longer in durations along with less efficient saccadic movements of eyes. In children with DD, the saccades movements were clustered up to 2-4 letters in a polysyllabic word and up to 1 letter for monosyllabic words irrespective of the regularity

principle of the word. Contrastively, TDC had saccadic movements and fixations to the important parts within the word (e.g.; focusing on the irregularity of the word) than on each letter. In other words, children with DD demonstrated parceled eye movements i.e. parsing of eye movements into sub- units and TDC had visual scanning i.e reading a word as a single unit. Slowness in reading due to longer fixations and larger saccadic movements led to an increase in the reading time which was predominantly observed in children with DD. Specifically with regard to word categories, longer reading times were observed for Irregular non words, followed by regular non words, irregular words and least for regular words.

With respect to age, the patterns of eye movements in younger (8.0-8.11 years) children with DD and TDC were similar. The performance of the 5 children with DD was in par with that of the 10 TDC, however minute differences were present. They both demonstrated fixations on each letter (letter by letter) irrespective of the word categories (word- non word, regular word- irregular word). Younger Children with DD, and TDC demonstrated parceled eye movement patterns for reading all word types, however only the TDC made an attempt to complete the reading of the word categories. On the other hand, children with DD showed more of back and forth saccadic movements even after individually scanning each letter. The numbers of rightward or forward saccades were lesser in children with DD as compared to TDC which revealed limited sighting ability in children with DD. Thus, increased fixation durations and saccadic movements thereby influenced the reading time wherein, children with DD demonstrated longer reading time as compared to TDCs. The responses as read out aloud by younger children with DD and TDC were of similar features, with both substituting a word for a non-word and

regularizing the irregular words. Younger children with DD and TDC did not attempt to complete the word sets wherein, fewer numbers of words (35/96) were read by DD as compared to TDC (60/96).

In older (9.0-9.11 years) children with DD and TDC, differences in fixation duration, saccadic movements and pattern of reading, types of saccades, and sizes of saccades were evident. While, older children with DD still demonstrated parceled eye movements, the TDC demonstrated a more mature pattern of visual scanning with efficient saccadic movements and shorter fixation durations. The saccadic patterns were more of regressions in children with DD and rightward saccadic movements in TDC. These patterns indicated that the children with DD, when compared to TDC when reading unfamiliar words, demonstrated more time in processing the visual information. The children with DD demonstrated more frequent pauses, frequent right to left regressions as compared to TDC. Children with DD demonstrated less accurate and slower reading responses as compared to TDCs. The size of saccadic movements significantly increased in the older TDC (up to 8 letters) to accommodate the forward saccadic movements for longer or unfamiliar words. The older children with DD demonstrated good performance for the effect of word types (word- non word) when compared to the regularity effect (regular- irregular word).

The older children with DD demonstrated better performance when compared to the younger age. The saccadic regressions, fixation, pauses within word, were comparatively reduced for the older age when compared to the younger age. Similar patterns were observed in the TDC. However, greater maturation of saccadic efficiency, fixations, saccadic sizes, forward saccades were observed for the older TDC when

compared to the younger ones. In both the groups, fixation durations decreased and saccadic movements increased with age. With respect to the pattern of errors, the younger children with DD and TDC demonstrated lexicalization and regularization errors when compared to older children with DD and TDC wherein, 2 older children with DD demonstrated lexicalization errors (e.g. lake- like) and 3 demonstrated regularization errors for all the Irregular words and non-words.

CHAPTER 5: Discussion

The aim of the present study was to investigate reading of Words and Non-Words in English in children with Developmental Dyslexia through eye tracking method. The study also aimed to compare the durational measures (fixation duration, saccadic duration, total gaze duration, accuracy scores and eye movement patterns in children with developmental dyslexia (DD) and typically developing children (TDC) in the age range of 8.0-9.11 years.

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

5.1 Durational measures for reading regular words and non-words, irregular words and non words in children with DD and TDC.

5.2 Accuracy measures of reading regular words and non-words, irregular words and non words in children with DD and TDC.

5.3 Eye movement patterns for reading regular words and non-words, irregular words and non words in children with DD and TDC.

5.1 Durational measures for reading regular words and non-words, irregular words and non words in children with DD and TDC.

The durational measures analyzed in the present study included fixation duration, saccade duration, total gaze duration for reading regular words and non- words, irregular words and non- words in children with DD and TDC. The findings of the study have been explained in both the groups below.

5.1.1 Fixation duration for reading in Children with DD and TDC.

The findings of the present study indicated that, there was no statistical significant difference observed for fixation durations between DD and TDC. However, the mean fixation durations were longer for children with DD when compared to TDC which is in consensus with majority of the studies(Creavin, Lingam, Steer, & Williams, 2015; Eden, Stein, Wood, & Wood:, 1994; Howell, 1983; Kim & Lemke, 2016; Martos & Vila, 1990; Rayner, 1985,etc) focusing on studying eye tracking measures for reading. Fixation durations reflect the time taken by the visual system in processing the visual information from where the eye is fixated on along with some minute peripheral information. Thus longer fixation durations in children with DD are indicative of struggled reading or prolonged processing for graphemes or single words as evidenced (Adler-Grinber, 1978).

In the younger group the fixation durations of the TDC group were longer as compared to children with DD group whereas, for the older group, the fixation durations of children with DD group were longer as compared to the TDC group. These findings are similar to those reported by Yang and Mc. Conkie (2001), who concluded that, longer fixation durations in young typically developing readers could be attributed to their process of inhibiting and preventing the return effect of the saccade and the influence of the occulomotor control. Whereas, for the older children it could be related to the slower processing pattern and time for reading.

A developmental trend was seen for the fixation duration wherein a decrease in the fixation duration was observed with age for both the groups. However, with respect to age, there was no statistical significant difference between the children with DD and TDC for fixation durations. This could be attributed to the maturational process of the visual

system (Stein &Walsh, 1997), i.e. strengthening of the binocular vergence and occulomotor control to enhance more forward accommodations for words and thereby reducing the reading time. These findings are in accord with the study of Mc. Conkie (1991), who reported a decline in the fixation durations for reading for the typically developing children from 1st grade to 5th grade. In the present study, the decrement in the fixation durations for the children with age in DD could be attributed to the familiarity of the words (Rayner et al., 2003; Andrews et al., 2004) or to the process of regularization and lexicalization of non words to words, wherein children make multiple fixations with frequent word skipping. These features are well explained by the Dual Route Cascaded Model (Coltheart, 2008) wherein the authors state that the effortless and fast reading of familiar words reflect the lexical route of processing and the increased durations in reading of unfamiliar words reflect the serial sub lexical processing. This means that the older children are observed to show shorter fixation duration when compared to younger children in both DD and TDC indicating a developmental process. However, the findings indicate that this process is slow and gradual in children with DD when compared to TDC.

The variability in terms of fixation durations has been observed for words non-words, regular- irregular words for the younger group in both TDC and children with DD. However, there was no statistical significant difference for the word type and regularity effect in the children with DD and TDC. In the older group of TDC similar fixation durations were observed irrespective of the word type, whereas, in children with DD longer fixation durations were observed with respect to non words and irregular words. These findings are in support with De Luca, Borrelli, Judica, Spinelli,

and Zoccolotti (2002) who also reported longer fixation durations in children with developmental dyslexia with respect to word type. The findings of the present study indicated that children with DD depended on processing words using the phonological route or the non lexical route which has an increased time of processing when compared to the lexical route. On the other hand, in TDC the processing for the word categories reflect the use of the lexical route irrespective of the word type and regularity.

5.1.2 Saccade duration for reading in Children with DD and TDC

Saccades define the movement of eye within or across the word however no specific information is processed during saccadic movements (Rayner &Pollatsek, 1989). Saccades guide the eyes where to look next while reading the text. Even though new information is not encoded during saccades, the cognitive processing continues during the saccadic movements (Irwin, 1998).

The findings of the present study revealed that, saccadic durations of the children with DD were longer as compared to the TDC group. However, there was no statistical significant difference observed for saccadic durations between DD and TDC. These findings are in contradiction to various studies(e.g. Prado, Dubois, & Valdois, 2007) wherein, they report shorter saccades for reading in children with dyslexia. As affirmed by Breitmeyer (1993), there exists coordination between Magnocellular and Parvocellular system that leads to the perception of the still image during the saccadic movement of the eyes while reading the text or image. This induces to the suppression of the saccade and thereby reducing the blurring effect. The longer duration of saccade could be attributed to

the deficit in the coordination between the Magnocellular and the Parvocellular system in dyslexia.

Reports indicate that proficient readers tend to have shorter saccadic movements when compared to the poor readers (Eden, Stein, Wood, & Wood, 1994). Thus the increase in the saccadic duration in children with DD when compared to TDC could be due to poor reading skills and increased processing duration which is reflected on greater saccadic movements along with regressive movements for reading a word.

With regard to the word type and regularity principle, there was no statistical significant difference for word type and regularity in children with DD and TDC. However, mean score indicated a greater word type and regularity effect in the older children with DD. These findings were similar to Eden, Stein, Wood, and Wood (1994), who reported an increase in the saccadic durations with words that lack the lexical entry (i.e. non words). The regularity effect can be explained by the Psycholinguistic grain size theory (Ziegler &Goswami, 2005), wherein, the authors have explained that the children reading inconsistent orthographies like English, need to develop complex reading strategies that include the whole word recognition and identification of the rhyme analogies while reading irregular words. In order to read the unknown words, yet another strategy has to be developed for the process of conversion of graphemes to phonemes. Thus, it can be concluded that the children with DD demonstrated longer saccadic durations for irregular words due to the need to develop these additional reading strategies.

A decrease in saccadic durations with respect to age was also noted for both the groups (children with DD and TDC). However, with respect to age, for saccadic

durations, there was no statistical significant difference between the children with DD and TDC. The maturational process of the visual system could have played a role in the both children with DD and TDC. However, word length could be another possible factor that could have influenced the saccadic durations. Both younger and older children with DD and TDC demonstrated saccadic movements but the errors greatly differed across the age. Whereas, younger children (both children with DD and TDC) attempted to use the process of simplification of the non words and regular words it was found that they had greater saccade endings or size as compared to the older children with DD and TDC. With development in age, while the younger children read each word letter by letter, the older children with DD and TDC attempted to read the words by forming clusters of letters leading to shorter and faster saccadic movements. Thus, it can be concluded that these differences in the reading patterns amongst age groups could have influenced the saccadic duration.

5.1.3 Total Gaze Duration for reading in Children with DD and TDC

Total gaze duration is considered as the sum of all the fixation duration, and re-fixations for the entire text (Liversedge, Paterson, & Pickering, 1998.). The findings of the study revealed that total gaze durations were longer in children with DD when compared to TDC. However, for total gaze duration, there was no statistical significant difference between the children with DD and TDC. This can be inferred as children with DD had both longer fixations and saccadic duration, naturally it would have led to the increase in the gaze durations. Since gaze durations are majorly influenced by the fixation durations, the longer fixation duration in children with DD has lead to such a finding in

this study. Since, the word categories varied with respect to word length, it would have influenced the gaze durations. These finding are in line with Padakannaya, Pandey, Saligram, and Ranga Rao (2016) who reported longer fixation duration, fixation pauses and first pass time (gaze duration) for reading in children with dyslexia.

Similarly, the effect of word- non word and regularity was observed in both the age groups of children with DD and TDC. However, there was no statistical significant for word type and regularity effect in children with DD and TDC. By virtue of the mean scores, the effect of word type (i.e. longer durations of non word) was greater in children with DD and regularity effect was greater for TDC. Gaze durations also reflect the ease of processing the information across various texts. Thus in both the groups, longer gaze duration for non words (in children with DD) and regular words (in TDC) reflected the increased processing time for the word categories. An overall decrement in total gaze duration was also seen with respect to age for both the groups (children with DD and TDC). However, with respect to age, for total gaze durations there was no statistical significant difference between the children with DD and TDC. These findings can be inferred from the decrease in fixations and saccades with development. The variability in terms of word type and regularity effect could indicate the presence of sub grouping of the developmental dyslexia (i.e. surface and phonological dyslexia) which could have lead to variance.

With the above mentioned findings, the null hypothesis stating that, there is no statistical difference between children with DD and TDC for durational measures such as fixation duration, saccadic duration and total gaze duration, is accepted. However, the

mean scores indicated that there exist differences in children with DD and TDC for the durational measures while reading different word categories.

5.2 Accuracy measures for reading regular words and non-words, irregular words and non-words in children with DD and TDC.

Literature focusing on eye tracking using the reading paradigm has highlighted the differences in terms of eye movements for silent reading and reading aloud. The modality of reading out loud reflects the cognitive processes like the phonological representation of the phonemes(Geranmayeh, 2016), episodic buffer (Rayner, McConkie, & Zola, 1980) and long term memory(Ericsson & Kintsch, 1995). Reading aloud requires a reader to produce each grapheme and thereby avoiding the discrepancy caused by the eye- voice lag phenomenon. Thus to account for the accuracy scores, reading aloud task was chosen.

The findings of the study revealed that accuracy scores were lower in children with DD when compared to TDC and specifically for words when compared to non words and for regular words when compared to irregular words. These findings were statistically significant between children with DD and TDC for the accuracy scores. These finding are in consonance with the previous studies on word reading (Al Dahhan et al., 2014; Padakannaya et al., 2016) where the children with dyslexia demonstrated atypical durational measures and were less accurate and less efficient in reading when compared to the age and gender-matched controls. The lower accuracy scores can be also explained by the Rapid Temporal Processing Deficit hypothesis (Tallal, 1980), wherein it explains that the phonological deficits in children with dyslexia are due to the auditory

temporal processing impairments. Since children with dyslexia demonstrate impairment in integrating the sensory information it would indirectly lead to a prevention in the correct temporal analysis at the phoneme level which would, in turn, lead to abnormal phonological development (Tallal, Miller,&Fitch, 1993).This leads to poor phoneme representations or poor phoneme discrimination in children with dyslexia that is reported to affect the acquisition in reading due to the poor mapping of letters to phonemes in these children (Ziegler, Perry, & Zorzi, 2013).

The findings of the present study also highlighted that with increase in age, the accuracy scores have also shown an increment in TDC. However, with respect to age, statistical significant difference was observed for younger TDC for the regularity effect whereas, for the older TDC statistical significance was obtained for both word type and regularity effect. As evidenced in literature, with increase in age , the eye movements also increased (i.e. decrease in durational measures) thereby reflecting an increase in reading proficiency in children (Buswell, 1922; Judd et al., 1918; McConkie et al., 1991; Rayner, 1986; Taylor, 1965). Thus, a developmental trend can be noted with respect to the durational measures and the accuracy scores. Hence, the findings of the present study highlighted that the increase in accuracy scores could be attributed to the increase in reading proficiency for both the groups.

With the above mentioned findings, the null hypothesis stating that, there is no statistical difference between children with DD and TDC for accuracy measures is rejected. In the present study, there exists an effect of word type and regularity in the older TDC when compared to the children with DD.

5.3 Eye movement patterns for reading regular words and non-words, irregular words and non words in children with DD and TDC.

The findings in the present study revealed that, in comparison to TDC, children with DD had greater fixations which were longer in duration along with less efficient saccadic movements of eyes. These findings on durational differences and saccadic movements are in consonance with the literature (Creavin, Lingam, Steer, & Williams, 2015; Eden, Stein, Wood, & Wood:, 1994; Howell, 1983; Kim & Lemke, 2016; Martos & Vila, 1990; Rayner, 1985,etc).

In children with DD, the saccadic movements were clustered up to 2-4 letters in a polysyllabic word and up to 1 letter for monosyllabic words irrespective of the regularity principle of the word. On contrast, TDC had saccadic movements and fixations to the important parts within the word (e.g.; focusing on the irregularity of the word) than on each letter. In other words, children with DD demonstrated parceled eye movements i.e. parsing of eye movements into sub-units, while TDC showed visual scanning i.e., reading a word as a whole unit. These findings are parallel to the findings of De Luca et al., (2002), who reported that children with dyslexia fragmented the 8-10 letter words into smaller subunits of 4. They inferred that while reading word lists the process of fragmenting words into subunits indicated the dependence on the sub lexical route of processing.

Slowness in reading due to longer fixations and larger saccadic movements led to an increase in the reading time which was predominantly observed in children with DD. These findings are similar to the findings reported by Adler, Grinberg and Stark (1978) that concluded that the longer fixations and saccadic durations reflected that the deficit in

children with dyslexia is not limited only to visual perception and can be insightful to the process of language integration.

Specifically with regard to word categories, longer reading times were observed for Irregular non words, followed by regular non words, irregular words and least for regular words. Increased fixation durations and saccadic movements influenced the reading time wherein, children with DD demonstrated longer reading time as compared to TDCs. Similar findings have been reported by Pavlidis (1981), who concluded that the higher regressive movements and fewer rightward saccades lead to the increase in the reading time and indicate the deficit in the duration of sequential processing and occulomotor malfunction.

With respect to age, the patterns of eye movements in younger (8.0-8.11 years) children with DD and TDC were similar. The performance of the 5 children with DD was in par with that of the 10 TDCs, however minute differences were present. They both demonstrated fixations on each letter (letter by letter) irrespective of the word categories (word-non word, regular word-irregular word). Younger Children with DD, and TDC demonstrated parceled eye movement patterns for reading all word types, however only the TDC made an attempt to complete the reading of the word categories. On the other hand, children with DD showed more of back and forth saccadic movements even after individually scanning each letter. The numbers of rightward or forward saccades were lesser in children with DD as compared to TDC which revealed limited sighting ability in children with DD. These findings are comparable to that of De Luca et al., in (2002), wherein children with DD demonstrated higher percentage of forwards saccades (40%)

and parceled eye movements. They concluded that these features reflected the cognitive processing and these perturbations in the eye movements reflected the linguistic deficits.

The responses as read out aloud by younger children with DD and TDC were of similar features, with both substituting a word for a non-word and regularizing the irregular words. This indicates the strategies and route of processing used by these groups of children for reading word categories. Wherein, the process of regularization and lexicalization of a non-word to word reflected the utilization of non lexical route.

With the above mentioned findings, the null hypothesis stating that, there is no significant difference between children with DD and TDC for the pattern of eye movements for reading is rejected. In the present study, the pattern of eye movements for reading in DD was different when compared to that of TDC.

CHAPTER 6: Summary and Conclusions

The studies using eye tracking measures are reported to objectify the subtle differences of reading in both the typically developing children and the children with developmental dyslexia. The present study aimed to investigate reading of Words and Non-Words in English, in children with and without Developmental Dyslexia through the eye tracking method. The objectives included were to study the differences between the children with DD and TDC for eye tracking durational measures such as fixation duration, saccadic movements, and total gaze duration; to determine the accuracy and the pattern of eye movement in reading regular words, non-words, irregular words and irregular non- words.

In the present study a total of thirty (30) participants from 3rd to 5th grade in the age range of $8.0 \leq A \leq 10.0$ years were included in the study. Group I consisted of 10 children diagnosed with Developmental Dyslexia (DD) and group II consisted of 20 age and gender-matched typically developing (TD) children. Eye movement parameters for reading regular words and non-words, irregular words and non words were recorded using an Eye Tracking Glass device (ETG model 2.6). The measures studied (dependent) were inclusive of fixation durations, saccade durations, reading accuracy, and total gaze duration for reading.

The findings of the current study indicated that the durational measures like fixation duration, saccade duration and total gaze duration were longer in children with DD than TDC. However, these differences were not statistically significant. Age wise comparisons were also made for these measures. The findings revealed that there exists a developmental pattern for these measures, wherein, fixation duration, saccadic duration

and total gaze duration decreased with age in both the groups. However, these findings were not statistically significant. The decrease in these durational parameters could be attributed to the maturational process of the visual system, the word length effect, the underlying cognitive process etc. With increase in fixation duration, saccadic movements the total gaze duration also increased in children with DD as compared to TDC. However, no statistically significant difference was obtained.

Statistically significant difference was obtained only for the accuracy scores between children with DD and TDC. These findings could be attributed to the increase in proficiency in reading. With increase in age, the accuracy scores have also shown an increment in TDC and statistically significant difference was observed for younger TDC for the regularity effect whereas, for the older TDC statistical significance was obtained for both word type and regularity effect.

The differences have also been highlighted in terms of eye movement patterns with parceled eye movements in children with DD and visual scanning patterns in TDC. The greater number of regressions and fewer numbers of forward saccades have also been observed in children with DD as compared to TDC. Greater number of fixations and word skipping in children with DD for reading could have attributed to regularization and lexicalization errors. The reading errors in children with DD indicated the reliance on the non lexical route for reading. However, in TDC with increase in age the lexical route had been established leading to fewer inaccurate responses.

Implications of the study

The findings of the current study highlighted the differences in the eye tracking durational measure between children with DD and TDC. This is a preliminary study on eye tracking measures for reading irregular orthography like English, in Indian children. The findings of the present study with respect to the differences in the duration measures, accuracy and eye movement patterns could be used to objectively screen and assist in early identification of children with dyslexia.

The study also highlights the differences in the reading strategies used by children with developmental dyslexia and typically developing children. The knowledge of the eye tracking measures for reading irregular words will assist in developing effective intervention strategies to assist in reading these words for children with developmental dyslexia. The intervention strategies can be implied for training from single words to sentences. The eye movement patterns can be monitored for these strategies. However, further research needs to be conducted to see the reading patterns for phrases and sentences. The effectiveness of the intervention strategies can also be assessed by objectively measuring the reading accuracy and gaze duration in children with developmental dyslexia.

Limitations of the study

The present study was employed on a small sample size and future studies are required to generalize the findings of the present study to a larger sample. The selection criteria for children with dyslexia did not include the sub grouping of dyslexia like phonological dyslexia and surface dyslexia. These subgroups could have influenced for

the variation seen in the findings for the present study especially in the group of children with developmental dyslexia. Word length effect was not studied in the present study which could have attributed to the differences in the findings for the durational measures.

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APPENDIX 1

1. Monosyllables:

Regular words	**Regular nonwords**
Tree	Pree
Lake	Nake
Flew	Plew
World	Jorld
Born	Korn
Large	Carge
Please	Blease
Friends	Briends

Irregular words	**Irregular non-words**
High	Figh
Tore	Vore
Right	Dight
Tight	Jight
Sewed	Kewed
Heard	Geard
Flight	Dlight
Thrown	Phrown
Thought	Ghought

2. Bisyllables:

Regular words	**Regular non words**
Modern	Bodern
Travel	Pravel
Summer	Jummer
Sister	Tister
Bandage	Randage
Shepherd	Pheperd
Nearby	Kearby
Brothers	Drothers

Irregular words	**Irregular non words**
Noble	Koble
People	Geople
Pieces	Sieces
Gentle	Ventle
Future	Muture
Flower	Clower
Consent	Wonsent
Picture	Zicture

3. Polysyllables:

Regular words

Italy

Society

Everyday

Covering

Tremendous

September

Beautiful

Wonderful

Regular non-words

Otaly

Dociety

Overyday

Rovering

Vremendous

Beptember

Leautiful

Tonderful

Irregular words

December

Decision

Imagine

Orchestra

Disposal

Natural

Organise

Principles

Irregular non- words

Gecember

Jecision

Umagine

Irchestra

Hisposal

Latural

Erganise

Frinciples