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Eye movement pattern in different orthographies: Evidence from English- Telugu/Hindi Multilingual Children with Dyslexia.

Suvarna Rekha Chinta[1*], Harini Sampath[1] and Bipin Indurkhya[2]

1. *Cognitive Science Lab, International Institute of Information Technology, Hyderabad, India*
2. *Cognitive Science Program, Institute of Philosophy, Jagiellonian University, Cracow, Poland*

Abstract

The present study sought to broaden the empirical basis of eye-movement characteristics of multilingual dyslexic children during reading different orthographies (English with Telugu/ Hindi), and contrast with their peer non-dyslexic children. Two-way ANOVA was used with a group (dyslexic and non-dyslexic) as the between-subject factor and orthographies (English, Hindi, Telugu) as a within-subject factor. The dyslexic group made longer saccades; had longer fixations, more regressions and longer reading times, with highly significant changes in fixation duration. Post-hoc analysis with Bonferroni adjustment found that the fixation duration was highly significant between English-Telugu and English-Hindi orthography, but not-significant between Telugu-Hindi. The qualitative analysis of a dyslexic's eye movement revealed no preprocessing of the next word as in the E-Z reader model. Based on the regression pattern and the saccade movement, we propose a model to explain how dyslexics preprocess English. We conclude that the orthographic properties of a language influence the strategies used by bi/ multilingual children when they read in other languages.

Keywords: Dyslexia, Eye movement, Multilingualism, Orthography, Reading model, Visual processing.

* *Correspondence to:*
Suvarna Rekha, B5-102, Cognitive Science Lab, IIIT-Hyderabad, Gachibowli, Hyderabad, Telangana, India- 500072.
E-mail: suvarna.rekha@research.iiit.ac.in; suvarna.rekha.11@gmail.com.

Considerable research has been done on eye movement and reading in regular and irregular orthographies to suggest that differences in orthography may not alter the fundamental nature of reading (Li et al., 2014; Reichle et al., 2012; Rayner et al., 1986). In contrast, studies on monolinguals demonstrated a significant difference in eye movement while reading regular and irregular orthographies (Krieber et al., 2016; Rodriguez et al., 2016). One recent study on normal bilinguals demonstrated that local and global strategies are used while reading transparent and opaque languages respectively (Rodriguez et al., 2016). Currently no data is available on the eye-movement patterns of bi-/multilingual dyslexics while reading different orthographies. To fill this gap, we conducted a study to compare the eye movements in dyslexic children with multilingual background in three different orthographies: one irregular/ opaque (English) and two regular/ transparent languages (Telugu/ Hindi: we will describe characteristics of these languages in a later section below).

Related Research

It has been suggested that, among the skilled readers, there is a smooth pattern of eye-movement saccades with few fixations and regressions, fixating word N and preprocess N+1 word (Rayner et al., 2010; Reichle et al., 2003; Silva et al., 2015). In contrast, eye movement studies on the dyslexic readers have shown abnormal saccade latencies, poor binocular coordinations, longer fixations, high regressions, and the evidence of oculomotor deficits (Biscaldi et al., 1998; Hawelka et al., 2010; Hutzler and Wimmer, 2004; Jainta and Kapoula 2011; Kapoula et al., 2008; McConkie et al., 1991; Rayner, 1986; Rayner et al., 2010).

Hutzler et al., (2004) conducted eye movement studies on regular orthography and demonstrated slow, laborious reading and fewer errors with longer fixation durations and high regressions among dyslexics. Similarly, other studies found that dyslexic children produced a significantly larger number of saccades and regressions, but did not find any difference in the fixation durations compared with the normal readers (Hawelka et al., 2010; Trauzettel-Klosinski et al., 2010). But studies by Rayner (1998) and Kirkby et al., (2008) on English-speaking monolinguals shown longer fixations and higher regressions compared to the earlier studies. It seems evident from the studies mentioned above that the apparent differences in the dyslexic readers may be a reflection of their different eye-movement patterns. More specifically, what is sometimes described as irregular eye movements in dyslexia suggest oculomotor dysfunction unique to English orthography (Hutzler and Wimmer 2004; Lefton et al., 1979; Lallier et al., 2016).

However, a study by Xuejun et al.,(2008) on Chinese-English bilinguals found that there is a difference in the comprehension in the two languages, but found that significant differences in reading rate, the number of fixations, the number of regressions, were typical for Chinese speakers but not for English speakers. Another bilingual study has shown that the orthographic properties of the language influence the reading strategies (Lallier et al., 2016, and Krieber et al., 2016).

Since the data discussed in this paper deals with the Telugu and Hindi languages, we would like to provide some details about the writing system. Telugu is one of the four South Indian languages spoken by 70 million people. It is an alpha-syllabic or akshara based writing system, which adopts characteristics of both alphabetic and syllabic system. Here the rules of the writing system differ from those of English. In the Telugu script, syllables are regarded as the units of representation, and consist of primary graphemes and secondary graphemes for vowels and consonants respectively. The Telugu script has 56 graphemes and allograph. The language curriculum focuses on mastering these 56 Akshara by rote learning and not on phoneme-based instructions as in English. Another important thing about the Telugu writing system is that the geminates are stacked vertically, and there are many words with consonant clusters (for a comprehensive review of the Telugu language, see Vasanta, 2004). Similarly, Hindi is the dominant language spoken by 180 million people in India, mostly in the North. Hindi is written in the Devanagari script, which is derived from the Brahmi script of ancient India. The Devanagari script is an abugida, written consonants have an inherent vowel, and the basic unit is a syllable (for a comprehensive review of Hindi, see Gupta, 2004).

As there is little existing research on the potential differences among bi-/multilingual reading strategies in different orthographies (regular versus non-regular), we took a novel approach in analyzing the eye-movement patterns in various orthographies (regular -Telugu/Hindi versus irregular-English) among normal multilingual children and those with dyslexia. We investigated the reading strategies across these three languages using the within- subject and between-subject designs. Our goal was to answer the following questions: Do the reading strategies differ for the two groups across languages? Are the eye-movement patterns of the two groups consistent across orthographies? Can we predict the eye-movement pattern, given the language and the group?

Design

In our study, eye movements were recorded for two reading tasks: passage reading and non-word reading. One would expect a non-linear random eye movement in irregular orthographies with high regressions, and a smaller, smooth and linear eye movement in regular orthographies among multilingual children with dyslexia. The non-word reading task is considered to be the best predictor for decoding skills, and it has a significant role in dyslexia studies (Baddeley et al., 1982; Gupta 2004; Holligan and Johnston 1988; Siegel and Ryan 1988; Ziegler and Goswami 2005). For the non-word reading task, we expect longer fixations, indicating a higher cognitive load, and the least differences between the two groups, thereby suggesting similar reading strategies irrespective of the orthographic transparency. We also measure the initial landing position or preferred viewing location (PVL) of a word to evaluate the visual attention process and eye movement pattern.

We performed the text analysis for the reading task using the following global eye- movement measures: words read per minute (wpm), Percentage of regression, and mean fixation time. To investigate the spatial aspects of the eye movement, we also analyzed the initial landing position (location of the initial fixation on a word), which yielded word-specific measures for PVL analysis. Due to small numbers of short and long words in the stimuli, only data for medium-length words (having four to five characters) was included in the analysis. The words were organised into three PVL zones. For four-character words: the first zone is 1.5 and the second zone is 2.5 from the beginning of the word. The respective separation points for the five- character words are 2 and 3.5. This division is justified as the ends of the words receive less initial fixation (Sainio et al., 2007).

Methodology

Participants

Sixteen dyslexic children and sixteen normal children (8-11 years: mean age 11.84, SD 1.27) participated in our study. We obtained informed consent from all the participants as well as from their parents. The participants were enrolled in an integrated school in Hyderabad (India). All the children in the dyslexic group had a documented history of reading difficulties, and were formally diagnosed with developmental dyslexia by a psychologist in the primary school. We first contacted them via the school psychologist and the special education teacher. With the parental consent, their files were made available to us so that we could consider their history and exclude children with autism, ADHD, and seizures. Inclusion criteria were checked after the first testing session. These included IQ within the normal range (≥ 100); reading and spelling age (1.5 SD below the mean); standard visual acuity (all the participants underwent the ophthalmological examination and had normal vision). Moreover, all the participants were native Telugu speakers with a multilingual background; they had been exposed to Telugu, Hindi, and English language instructions from an early age, and could read and write in these three languages. We did a formal assessment based on the norms of NIMH, Hyderabad: IQ tested on the Malin's Intelligence Scale for Indian Children, which is an adaptation of Wechsler Intelligence Scale for Children, Seguin form board (SFB) / CPM (coloured progressive matrices), reading and spelling age with Schonell spelling test. Table 1 shows the statistical profile of the participants.

Procedure

Before the experiment, each participant was familiarized with the apparatus, a Tobii eye tracker X120. Then the participant was seated comfortably on a chair in a quiet room to minimize the distraction, and a regular 9-point calibration was performed, which was repeated until they achieved an average gaze position. After the calibration, the instructions were repeated on the computer screen, and the participant was

Table 1. *Descriptive Statistics of group on Psychometrics. Results reported for Mean, SD and Cohen's d*

Measures	Dyslexic M(SD)	Non-dyslexic M(SD)	Cohen's *d*
Chronological-age	12.01 (1.3)	11.68(1.24)	0.25
Reading-age	9.57(1.02)	11.68(1.24)*	1.85
Spelling-age	9.42(.96)	11.68(1.24)*	2.03
IQ	101 (1.5)	104.7(2.24)	1.94
ADHD	17 (1.5)	16.4 (1.9)	0.35
Language proficiency	68(2.3)	70 (1.9)	0.94

*Note: * statistical significance at .005*

instructed to read aloud the text at a normal speed and as accurately as possible. The reading was self-paced; after reading the text, the participants have to press a button to switch to the next task. While she or he was reading, their eye movements were recorded.

There were two tasks in the experiment: reading aloud a passage and reading aloud non-words in English, Telugu and Hindi. Test stimuli for English consisted of a passage from the children's story book "The hare and the tortoise", which was selected based on its familiarity and frequency of words. The text for reading consisted of 102 words, and the length of the words ranged from 1 - 11 characters per word (CPW). In addition to the experimental text, one practice test was selected with its length similar to the experimental version, which was used to familiarise the participant with the experimental conditions. Thus, each participant read two passages: one practice test and one experimental text. The stimuli were presented on the computer screen in white characters on a black background. The entire passage was displayed on a single screen (17" inch monitor) with a viewing distance of 63 cms. The number of lines was kept constant, and used Arial 24 pt fonts. For the non-word reading task, we adapted ten non-words from Castles and Coltheart (1993). Telugu and Hindi language passages were selected from an Asser board (grade-level reading material). Telugu non-words were created by taking a meaningful word from Ray (2013), and changing one sound or phoneme in it. Hindi non-words were adapted from

Gupta (2004). All the non-word stimuli used in our experiment are included in the Appendix.

At first the participants are presented with the instructions. After reading the instructions, the participant needs to press the "enter key" to start the experimental tasks.

Figure 1 illustrates the task-flow diagram. After the instruction part there was a fixation point for 5 seconds, and then the passage appears. After reading the passage, the participant needs to press the enter key to begin the second task. All the non-words were presented randomly, after reading each word the participants needs to press the enter key to move to the next one. There were ten words and non-words in each language. All these readings were recorded in an MP3 player for assessing reading accuracy analysis.

The audio recordings were processed off-line to study the reading skills. We used three parameters to measure operationally the reading skills: (a) Reading-speed = number of error-free words/reading time; (b) Error free words = number of words – number of mistakes made in reading; (c) Reading duration = Total time for the first utterance – last sentence. These three parameters were combined together to compute the reading ability.

$$\text{Reading Ability} = \frac{\text{Reading Speed} + \text{Error Free Words} + \text{Reading Duration}}{3}$$

Data analysis

Two-way ANOVA was used with the group (dyslexic and non-dyslexic) as the between- subject factor and orthographies (English, Hindi, Telugu) as the within-subject factor. For PVL analysis we employed 2 (group) X 2- word length (4, 5) X 3 (initial, centre, final) design. MANOVA was computed on the parameters as mentioned above.

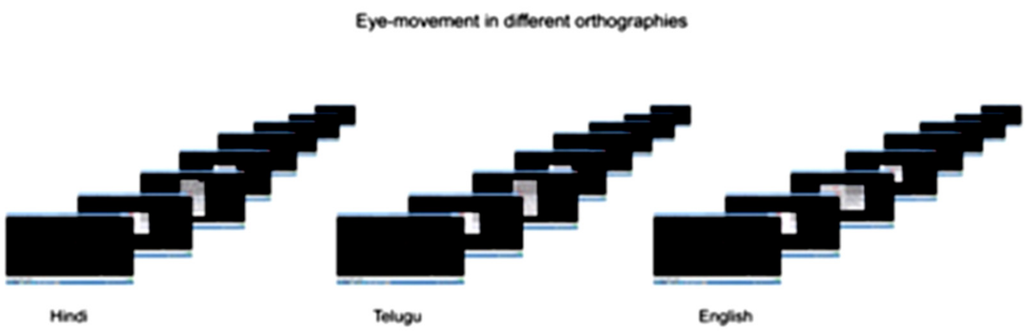

Figure 1 illustrates the work-flow diagram