

# Using Eye-Tracking to Decode Spelling Challenges for Iranian EFL Learners in Malaysia

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**Abstract**—Spelling remains one of the most challenging aspects of English language learning for Iranian English as a Foreign Language (EFL) learners, largely due to the fundamental orthographic differences between the English and Persian writing systems. This study aims to examine the effect of applying Tabrizi et al.'s (2013) spelling methods on the eye movements of Iranian EFL students in Malaysia during English word memorization. To identify high-frequency errors, preliminary spelling tests were administered, and Tabrizi's classification was used to categorize participants. Eye-tracking technology (EyeNTNU-120) was employed to record and analyze the eye movements of 14 participants (9 female, 5 male), stratified into high- and low-proficiency groups. The analysis focused on fixation counts, saccade numbers, and "Hot Zones" to reveal differences in visual attention patterns. Findings indicated a significant relationship between eye movement patterns and spelling proficiency ( $p < 0.05$ ). Specifically, high-proficiency spellers demonstrated more frequent saccades, increased regressions, and longer fixation durations, reflecting active cognitive processing and self-monitoring strategies. Conversely, low-proficiency spellers exhibited fewer and shorter fixations, suggesting shallower processing and difficulty in attending to orthographic details. These results provide valuable insights into the cognitive mechanisms of spelling acquisition and highlight the potential of eye-tracking as an effective diagnostic tool for identifying and addressing spelling difficulties among EFL learners.

**Index Terms**—eye-tracking, EFL learners, spelling acquisition, visual attention, cognitive processing

## I. INTRODUCTION

Writing is widely recognized as the most complex of the four language skills and is typically the last to be fully mastered (Jamaluddin et al., 2024). It serves as a critical medium, allowing individuals to communicate ideas, thoughts, and information with clarity and effectiveness. Central to writing proficiency is the mastery of spelling; successful text production requires students to transcribe letters automatically and legibly while accurately matching sounds to their associated spelling patterns (Ritchey, 2008; Salehuddin & Jaafar, 2024). However, achieving this competence is a formidable task. English spelling proves difficult not only for English as a Foreign Language (EFL) and English as a Second Language (ESL) learners but also poses significant challenges for first-language speakers (McNeill et al., 2023).

Research consistently indicates that the complexity of English spelling stems from a multifaceted interplay of historical, phonetic, and linguistic influences (Hernández-Campoy & García-Vidal, 2024; Ünal Gezer, 2024). Unlike languages with transparent orthographies, English is often described as "opaque" due to its deep orthographic depth. Specifically, seven primary factors contribute to this difficulty: 1) inconsistent pronunciations, where sound-symbol correspondence is unpredictable (e.g., Crystal, 2012); 2) a vast lexicon of borrowed words from multiple languages which retain foreign spelling patterns (e.g., Seidenberg, 2017); 3) historical spellings and linguistic shifts that have preserved archaic forms (e.g., Baugh & Cable, 1993); 4) phonetic ambiguity and a general lack of phonetic consistency (e.g., Cook & Bassetti, 2005); 5) the prevalence of homophones and homographs which confuse meaning and spelling

(Yule, 2014); 6) regional differences in spelling conventions, such as those between British and American English (e.g., Crystal, 2018); and 7) a high volume of irregular rules and exceptions that defy standard generalizations (Bryson, 1990).

Furthermore, studies investigating spelling difficulties in Second Language (L2) or Foreign Language (FL) contexts suggest that errors are not merely random but can often be traced to the linguistic distance or differences between the learner's First Language (L1) and the target language (Genesee et al., 2006; Sparks et al., 2009; Barjesteh et al., 2025). The cognitive frameworks and orthographic knowledge of the L1 play a pivotal role during the early stages of acquiring the L2 (Genesee et al., 2006; Abas et al., 2025). Consequently, to navigate the specific spelling patterns of the English language, learners in an FL context face unique and varied difficulties (Niolaki & Masterson, 2012; Ford et al., 2014). This mastery is not optional; as Hildreth (1962, p. 2) notes, without the ability to spell correctly, "the load of work in writing cannot be done easily." In essence, spelling acts as the gatekeeper to written expression; without it, effective written communication becomes impractical and the cognitive load of writing becomes unmanageable.

## II. LITERATURE REVIEW

### A. *The Cognitive Gap in Iranian EFL Spelling Research*

Previous studies on spelling among Iranian EFL students have predominantly focused on two crucial topics: the patterns of spelling difficulties and the categorization of spelling error types. A significant body of research (Arab-Moghaddam & Senechal, 2001; Solati et al., 2011; Nezami & Najafi, 2012; Solati, 2013; Ghahremanian & Bahrami, 2023) has rigorously investigated these errors, providing robust evidence of massive spelling difficulties within this demographic. However, while these studies successfully identify *what* the errors are, they fail to provide a clear explanation as to *how* these difficulties occur at a processing level.

Spelling difficulties are rarely superficial; they are often symptomatic of underlying cognitive deficits. Specifically, in the context of orthographic learning, spelling errors are usually considered an effect of a word's "weak orthographic indication"—or unstable representation—in an individual's mind (Mehlhase et al., 2019; Wang et al., 2014). Crucially, the strength of these mental representations can be measured through eye tracking (Baron et al., 2024). Visual processing, or the optical behavioral processes of learners while performing tasks such as reading, can indicate the precise cognitive patterns and related changes that occur within milliseconds.

### B. *Visual Attention and Proficiency*

The link between spelling proficiency and visual attention is distinct. High-proficiency spellers progress rapidly; they develop audio-visual knowledge of words while gradually adding meaning to the logic of the spelling, allowing them to monitor spelling as a systemic, rule-based structure. According to Whitford et al. (2016), high-proficiency spellers can easily identify misspellings and immediately generate possible replacements. They view editing as an intrinsic responsibility and employ effective, internalized strategies to do so.

Conversely, proficiency levels are intrinsically linked to the mechanics of visual attention. It is established that a reader's visual attention is typically shifted marginally ahead of the eye position—approximately 100 to 250 milliseconds before the eye physically moves (Hoffman, 1998). However, the eyes inevitably intend to pursue immediately after the reader's attention shifts to another position (Deubel & Schneider, 1996; Qi & Hemchua, 2022; Mohammad et al., 2025; Zhao et al., 2025).

### C. *The Mechanics of Eye Movements*

Biologically, eye movements are rapid orienting behaviors designed to bring visually interesting displays into the fovea—the specialized, tiny region in the center of the macula lutea in the retina responsible for sharp vision.

These movements provide critical clues regarding which components of a visual demonstration we focus on, how much time is allocated to them, and how attention is transmitted between components. Consequently, the eyes serve as indicators of "higher-level cognitive processing," such as comprehension, memory, and problem solving (Grant & Spivey, 2003, p. 1).

Eye tracking serves as the methodological tool to evaluate these movements, measuring where users look, what they overlook, when they blink, and how pupils respond to stimuli. Historically used to examine behavioral nuances among professional readers (Radach et al., 2003), this technology is particularly vital for spelling research. By tracking the eye movements of spellers, researchers can analyze how they focus on individual letters or distinct morphological areas. This granular data reveals the importance of specific word areas for each speller.

A recent systematic review of eye-tracking in educational contexts confirms that fixation and saccade metrics are widely used to infer tasks and cognitive states (Liu & Cui, 2025). This is supported by Henderson et al. (2013), who investigated whether eye movements encode enough information "about the viewing task that the task can be consistently understood from eye movements." Using multivariate pattern classification during tasks like scene search, memorization, and reading, their findings robustly indicated that eye movements are precisely affected by the task a person is dealing with, and likely by their cognitive state.

### D. *Interpreting Cognitive States Through Eye Metrics*

Henderson et al. (2013) suggested four ways eye movements reflect cognitive states:

1. **Processing Depth:** Longer fixations often indicate greater cognitive processing, as participants spend time interpreting difficult sections. Shorter fixations and faster saccades indicate easier information retrieval.
2. **Cognitive Load:** When information is hard to recall or requires deeper processing, participants tend to re-read or regress to specific points. This indicates high cognitive load or a need to re-check details.
3. **Expectation Violation:** Eye movements reveal surprise. Fixation duration increases when participants encounter unexpected words or images that do not fit an anticipated pattern.
4. **Decision Making:** Frequent switching between options (e.g., weighing two spellings) indicates an internal decision-making conflict.

All of the above can be applied to the current study. The cognitive processes involved in memorizing English spelling can be quantified through specific metrics:

Fixations refer to the distinct positions of an eye when looking at a visual display. By dividing the visual stimulus into a Region of Interest (ROI), fixations can be assessed locally. Gazes classify consecutive fixations on one particular ROI (Holmqvist et al., 2011). It is noted that "visual information is only acquired during periods of relative gaze stability (fixations) due to saccadic suppression" (Henderson et al., 2013). Saccades (NOS) are ballistic, rapid movements between fixations (150-200 ms). Because the eye is effectively "blind" during a saccade, the sequence of fixations is vital. Saccades enable the eyes to assemble information from different segments to form a larger image in the brain (McConkie & Dyre, 2000). Heatmaps, according to Smith (2012), take into account the number and duration of eye fixations on a particular part of the computer screen relative to the length of the eye gaze recording. Using a color gradient (red to green), they visualize the distribution of gaze points, differentiating areas of high intensity focus.

#### *E. Linguistic Awareness and Spelling Challenges*

Understanding these mechanics is vital because, as Phoenix (2021) categorizes, spelling difficulties stem from two primary types: linguistic challenges (inherent to the language) and personal challenges (developmental stages). Alipour et al. (2019) highlight that the complexity of the English spelling system creates substantial hurdles for EFL learners, and even native speakers. The intricate rules and exceptions can overwhelm learners, increasing cognitive load and leading to errors.

In a related study on Iranian EFL students in Malaysia, Alipour et al. (2020) found a significant correlation between linguistic awareness and spelling proficiency. Their study suggests that as learners develop deeper linguistic awareness, their proficiency improves, potentially mitigating spelling challenges. Furthermore, Coronado (2024) shows that L2 students (specifically in the Philippines) often write based on pronunciation patterns, omitting silent letters. This highlights the need for targeted phonics instruction.

However, Baron et al. (2024) argue that while phonological processing is crucial, it does not account for all reading capabilities. Developing orthographic knowledge—understanding letter-sound relationships—is essential. Children facing spelling challenges often struggle to integrate these skills, underscoring the need for comprehensive instruction.

#### *F. Technological Interventions in Spelling*

In the contemporary landscape of English language education, spelling difficulties remain a significant challenge due to cognitive load, linguistic complexity, and emotional factors like anxiety. Technological interventions have offered promising support for learners struggling with the opacity of spelling systems (e.g., Salehuddin & Jaafar, 2024). The integration of eye-tracking technology has enabled educators to gain insights into how learners process written language and the cognitive mechanisms at play (Hu & Aryadoust, 2024). By leveraging these advancements, educators can develop strategies to promote literacy development.

Hu and Aryadoust (2024) reviewed 111 eye-tracking studies in L2 research, showing that understanding cognitive mechanisms in reading can help educators tailor interventions. Eye-tracking allows for real-time observation of how L1 influences L2 processing and the challenges bilingual learners face when navigating different spelling rules (e.g., Quiñonez-Beltran et al., 2024). Furthermore, the eye-tracker helps educators understand how children engage with materials and track cognitive development (Donmez, 2022).

According to Weber (2024), children tend to spend more time on objects semantically linked to spoken language rather than phonological ones, suggesting a struggle to connect phonological cues with semantic meanings. This interplay between cognitive load and linguistic awareness underscores the multifaceted nature of the problem.

#### *G. The Research Gap and Current Study*

Ideally, eye movement patterns can inform us how high and low proficiency spellers read words they must spell. However, currently, recent studies have only focused on the differences between L1 and L2 and/or L3 readers. For instance, Mlakar et al. (2024) examine cognitive processes across languages, highlighting bilingual challenges. Additionally, Xue et al. (2022) investigate the impact of bilingual experience on learning novel words.

There remains a specific gap regarding the real-time processing differences within a single EFL population based on proficiency. The objective of the current study was to investigate the relationship between the eye movement of high and low proficiency Iranian EFL spellers in Malaysia. Therefore, the following research question and hypothesis were formulated:

Q1. Is there any significant difference between the eye movement of the high and low proficiency of Iranian EFL spellers in Malaysia?

H1: There is a significant difference between the eye movement of the high and low proficiency of Iranian EFL spellers in Malaysia.

### III. METHODOLOGY

This study employs a quantitative research design with a correlational focus to investigate the relationship between spelling proficiency and eye movement patterns among Iranian EFL learners. Specifically, it examines the effect of using Tabrizi's spelling instruction methods on the visual processing strategies of high- and low-proficiency spellers. By integrating pedagogical intervention with physiological data, the design seeks to link cognitive processing—as revealed by eye-tracking—with spelling performance outcomes. The data was collected at the Eye-tracking Lab, Centre for Research in Language and Linguistics, Universiti Kebangsaan Malaysia (UKM). The participants consisted of fourteen Iranian students (9 female and 5 male) currently enrolled at the Educational Complex of Imam Khomani in Kuala Lumpur. A convenience sampling method was employed due to logistical constraints, specifically regarding feasibility, parental consent, and student availability during the project timeline.

The participants were homogeneous in terms of age (14–15 years old) and educational background. All subjects were in the second grade of secondary school and were taking English as a compulsory subject for their second year, indicating they possessed approximately one year of formal English language learning experience prior to the study. Two primary instruments were utilized in this study: pedagogical materials adapted for intervention and eye-tracking hardware for data collection.

#### A. Pedagogical Instrument: Tabrizi's Spelling Methods

For the instructional intervention, a set of spelling methods was adapted from Tabrizi et al. (2013). This source is widely utilized in Iranian textbooks for teaching Persian spelling at primary and secondary levels. Tabrizi initially focused on students struggling with spelling, aiming to replace traditional approaches—which often lacked direct instruction—with targeted strategies. In his seminal work, *Diagnosis and Treatment for Persian Dictation* (اختلالات دیکته (نویسی), Tabrizi introduced eight distinct spelling strategies designed to help teachers diagnose strengths and weaknesses.

It is worth noting that Tabrizi redefines the theoretical approach to difficulties, preferring the term “learning disorder” over “learning incapability.” He conceptualizes learning through four neurological stages: Rich Environment, Nervous Receivers, Neural Network Processing, and Brain Coordination (Tabrizi et al., 2013). These methods are designed to be inclusive, suitable for both typically developing children and those with specific language disorders.

#### B. Eye-Tracking Apparatus: EyeNTNU-120

Visual data was captured using the EyeNTNU-120 eye-tracking device. This instrument tracked the participants' eye movements while they read to memorize words displayed on a computer screen. The technical specifications included a pupil camera sampling rate of 120Hz, ensuring high temporal resolution. The distance between the participant's eyes and the screen was maintained at 50 cm, with a calibrated error rate of less than 0.3 degrees.

The device recorded specific metrics to analyze "Hot Zones" (or heat maps). In eye-tracking research, Hot Zones are essential for gaining insights into complex cognitive processes. These zones utilize a color-coded gradient to visualize areas attracting the most visual attention (fixations) versus areas neglected by the viewer. By comparing these zones, the study assessed the efficiency of the visual stimuli. Biologically, the eyes act as the source of visual information, following the direction of the gaze; therefore, the significance of the relationship between eye movement and spelling difficulties relies heavily on analyzing these Hot Zones to determine exactly which parts of a word attracted the speller's gaze. The Statistical Package for the Social Sciences (SPSS) version 18.0 was employed for all statistical analyses, including descriptive statistics, correlation analysis, and regression analysis.

The selection of stimuli followed a rigorous pre-test and intervention process. Initially, a pre-test comprising 40 words selected from the participants' first-year English textbook was administered. The students' performance was analyzed for accuracy, and misspelled words were categorized to identify the appropriate instructional needs. Based on this analysis, 9 out of the 11 methods proposed by Tabrizi et al. (2013) were deemed relevant for English spelling instruction.

Following a six-month intervention period using Tabrizi et al.'s methods, a post-test was conducted using the same set of words from the pre-test. From the post-test results, the six most frequently misspelled words were selected for the eye-tracking experiment. This selection quantity aligns with Tabrizi et al. (2013), who suggest that for this age group, the appropriate number of words for memorization tasks starts from four and can increase to ten. For this study, six words were chosen as the baseline for correct spelling performance across the student cohort. The selected words are presented in Table 1.

TABLE 1  
SIX SPELLING WORDS

Tests	English Words
Word 1	Thirsty
Word 2	Mechanic
Word 3	Nurse
Word 4	Aunt
Word 5	Excuse
Word 6	Favorite

### C. Stimuli Design

Before the eye-tracking session, the six selected words were designed as individual image files using Microsoft Paint. The images were set to a resolution of 1280 pixels (horizontal) by 800 pixels (vertical), utilizing "Arial Rounded MT Bold" font at size 72 to ensure legibility.

### D. Data Collection Protocol

During the experiment, participants were seated with their posture adjusted to maintain the required 50 cm distance from the monitor. The words were presented in a random order to prevent order effects. Prior to the test, each student received the following individual instructions:

1. Put your finger on the "Z" key.
2. Do not move your head.
3. Do not talk.
4. Read and memorize the spelling of each word silently, then press "Z".
5. There is no time limit to read and memorize the word.
6. You cannot go back to a previous word.
7. After memorizing all words, write them down on the provided paper.

### E. Measured Variables

The EyeNTNU-120 recorded the eye movements during the memorization phase. The study investigated the following dependent variables:

1. Total contact time
2. Hot zone (Area of Interest distribution)
3. Number of fixations
4. Latency of first fixation
5. Duration of first fixation
6. Total time of memorizing all words
7. Duration of memorizing each word

## IV. RESULTS AND DISCUSSION

The primary purpose of this study was to investigate the effect of Tabrizi et al.'s (2013) methods on English spelling memorization among Iranian EFL students, specifically through the analysis of eye movements. This section presents and discusses the findings derived from that investigation. The eye-tracking experiment was conducted to investigate participants' fixation points through the analysis of 'Hot Zones.' The software recorded the eye movements of all students as they viewed the target words, and saccades were quantified for six specific words per participant. Data from all 14 participants were aggregated for comparative analysis. For this study, Regions of Interest (ROIs) were defined at the character level, corresponding to the number of letters in each word. For instance, the word 'Thirsty' was assigned seven ROIs, reflecting its seven constituent letters (see Figure 1).



Figure 1. ROIs of Word Thirsty

TABLE 2  
EYE TRACKING TESTS

Tests	English Words	Number of ROIs
Word 1	Thirsty	7
Word 2	Mechanic	8
Word 3	Nurse	5
Word 4	Aunt	4
Word 5	Excuse	6
Word 6	Favorite	8

### A. Hot Zones

The NOS was measured from the rapid eye movements between fixation points.

TABLE 3  
NOS-THIRSTY WITH 7 ROIS

	ROI 1	ROI 2	ROI 3	ROI 4	ROI 5	ROI 6	ROI 7
ROI 1	182	28	1	0	0	0	0
ROI 2	15	176	14	6	4	0	0
ROI 3	1	9	31	7	1	0	1
ROI 4	1	5	3	49	13	3	2
ROI 5	0	3	0	10	84	5	0
ROI 6	0	0	1	2	3	33	11
ROI 7	2	3	0	0	0	11	45

ROI 2 and ROI 1 recorded 28 fixations, suggesting that these regions presented greater processing difficulty compared to others. Additionally, the value of 182 for the 'ROI 1 to ROI 1' transition represents eye movements that began and ended within the same region. While saccades typically involve rapid movement between distinct points, this value likely indicates refixations or micro-saccades within ROI 1 rather than a transition between different regions. A value of 0 denotes that no saccades occurred within the same ROI, as saccades were only recorded when movement occurred between two distinct ROIs.

All participants were analyzed based on the following metrics: Duration of First Fixation (DFF), Latency of First Fixation (LFF), Number of Fixations (NOF), Total Contact Time (TCT), Duration of Memorizing Each Word (DMEW), and the final SCORE for each word. The following section presents a sample analysis of Participant 1 (P1) for the word 'Thirsty,' revealing the data detailed below.

TABLE 4  
THIRSTY

	T ROI 1	h ROI 2	i ROI 3	r ROI 4	s ROI 5	t ROI 6	y ROI 7	Other ROI
DFF	33	12	10	33	10	0	0	12
LFF	933	11	612	2094	1987	0	0	186
NOF	6	20	3	3	7	0	0	20
TCT	158	449	88	93	201	0	0	346

The analysis identified an 'Other ROI,' defined as a region outside the word boundaries on the heat map where Participant 1 (P1) frequently directed their gaze, independent of the text. For the word 'Thirsty,' the Duration of First Fixation (DFF) ranged from a minimum of 10 ms on letters 'i' (ROI 3) and 's' (ROI 5) to a maximum of 33 ms on 'T' (ROI 1) and 'r' (ROI 4). Latency of First Fixation (LFF) data revealed the participant's gaze sequence: 'h' (ROI 2) → Other ROI → 'i' (ROI 3) → 'T' (ROI 1) → 's' (ROI 5) → 'r' (ROI 4). The letter 'h' (ROI 2) received the highest Number of Fixations (NOF) at 20, with Total Contact Time (TCT) across fixated regions ranging from 88 to 449 ms. Notably, across all these metrics, P1 consistently ignored the final letters 't' (ROI 6) and 'y' (ROI 7).

Table 5 presents the Duration of Memorizing Each Word (DMEW) for P1. The total duration for all words was 13,277 ms. The longest memorization time was recorded for the word 'Excuse' (3,123 ms), while the shortest was for 'Thirsty' (1,335 ms).

TABLE 5  
DMEW

Thirsty Word 1	Mechanic Word 2	Nurse Word 3	Aunt Word 4	Excuse Word 5	Favorite Word 6	TDT	Max	Min
1335	1919	2363	2602	3123	1935	13277	3123	1335

To classify the results of the spelling test, the framework proposed by Tabrizi et al. (2013) was adopted. According to this classification, proficiency levels are categorized by the number of correct words: Low (<3), Average (3), High (4–5), and Excellent (6). Consequently, Participant 1 (P1) was identified as an 'Excellent' speller, having spelled all six words correctly.

### B. Heat-Maps

Eye-tracking data for all participants were analyzed using heat maps. As illustrated in Figure 2, Participant 1 (P1) exhibited distinct gaze patterns during each test. In these visualizations, transparent areas indicate regions with no fixations, while the color spectrum represents fixation density ranging from low (purple/blue) to high (red). It should be noted that in Figure 2, specific lower-intensity colors (such as purple and blue) are not visible, as the participant's fixation data did not fall within those specific ranges. The heat map representing the word 'Thirsty' is presented below.



Figure 2. Heat-Map of P1

C. Summary of the Results

A Chi-Square test was conducted to examine the association between spelling proficiency (high vs. low) and spelling errors, specifically to identify significant differences between the two groups. The analysis utilized error scores derived from the six eye-tracking tests. The final sample size for the eye-tracking analysis consisted of 14 participants (nine females and five males).

TABLE 6  
HIGH AND LOW PROFICIENCY SPELLERS' CORRECT SPELLING CROSS TABULATION

		Correct spelling						Total	
		1.00	2.00	3.00	4.00	5.00	6.00		
Group	Low proficiency	Count	1	3	1	0	1	0	6
		Expected Count	.4	1.3	.9	.9	1.3	1.3	6.0
	High proficiency	Count	0	0	1	2	2	3	8
		Expected Count	.6	1.7	1.1	1.1	1.7	1.7	8.0
Total		Count	1	3	2	2	3	3	14
		Expected Count	1.0	3.0	2.0	2.0	3.0	3.0	14.0

Initial analysis using the Pearson Chi-square test did not demonstrate a significant relationship between speller proficiency (high vs. low) and spelling errors ( $X^2 = 9.23, p = 0.10$ ). However, a subsequent analysis using Spearman's rank correlation revealed a significant relationship between the groups and error frequency ( $r = 0.709, p = 0.005$ ).

TABLE 7  
SYMMETRIC MEASURES

		Value	Asymp. Std. Error <sup>a</sup>	Approx. T <sup>b</sup>	Approx. Sig.
Nominal by Nominal	Phi	.812			.100
	Cramer's V	.812			.100
Interval by Interval	Pearson's R	.716	.138	3.554	.004 <sup>c</sup>
Ordinal by Ordinal	Spearman Correlation	.709	.144	3.485	.005 <sup>c</sup>
N of Valid Cases		14			

- a. Not assuming the null hypothesis.
- b. Using the asymptotic standard error assuming the null hypothesis.
- c. Based on normal approximation.

The bar chart illustrates the spelling statistics for both high and low proficiency spellers. The vertical axis represents the number of spelling errors, while the six tested words are distinguished by color. The data is stratified into two sections based on participant proficiency. Among low proficiency spellers, the lowest recorded value was 0. While the majority of this group encountered difficulty with the word 'Excuse,' the highest numerical value was recorded for the word 'Thirsty.' Conversely, for high proficiency spellers, the lowest recorded score was 3.00. For this group, the most difficult word was 'Favorite,' while the easiest words were 'Thirsty,' 'Nurse,' and 'Aunt.'

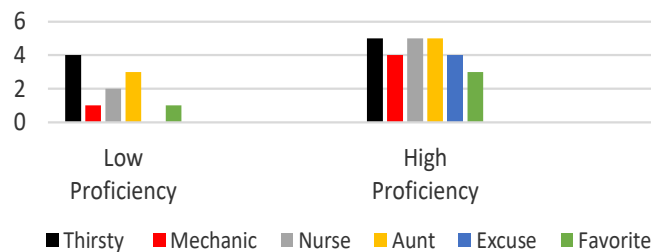


Figure 3. Frequency of Spelling Results

D. Time of Memorizing Effects

The Chi-square test was conducted separately for high and low proficiency spellers. The sample consisted of eight high-proficiency spellers and six low-proficiency spellers. Total Duration Time (TDT) was stratified into six groups. With a minimum TDT of 4,778 milliseconds and a maximum of 36,706 milliseconds, the calculated range was 31,928 milliseconds. Consequently, the TDT values were categorized into intervals spanning 4,000 to 40,000 milliseconds, as detailed in Table 8.

TABLE 8  
TOTAL DURATION TIME

TDTs	Group
4000-10000	1
10001-16000	2
16001-22000	3
22001-28000	4
28001-34000	5
34001-40000	6

#### E. Low Proficiency Spellers

The Pearson Chi-square test revealed no significant relationship between Total Duration Time (TDT) and spelling errors ( $X^2 = 14.00$ ,  $p = 0.30$ ). Although the effect size appeared large (Cramer's  $V = 0.882$ ), the result was not statistically significant. Similarly, the Spearman correlation test yielded insignificant results ( $r = -0.031$ ). This suggests a negligible negative trend, indicating that TDT had no substantial impact on the frequency of spelling errors for low proficiency spellers.

#### F. High Proficiency Spellers

Conversely, the Pearson Chi-square test confirmed a significant relationship between TDT and spelling errors for high proficiency spellers ( $X^2 = 17.33$ ,  $p = 0.044$ ). The strength of this association was substantial (Cramer's  $V = 0.85$ ). However, the Spearman correlation was not statistically significant ( $r = -0.159$ ), suggesting the relationship is non-linear. Based on these findings, the hypothesis positing a significant relationship between eye movement and proficiency among Iranian EFL spellers was accepted.

#### G. Discussion

The analysis of eye movements among Iranian EFL spellers in Malaysia revealed a significant positive relationship between eye movement patterns and spelling proficiency ( $r=0.709$ ,  $p=0.005$ ). Unlike low-proficiency spellers, high-proficiency spellers exhibited more frequent saccades, increased regressions, and prolonged fixation durations. This aligns with the "Hot Zone" analysis, suggesting that high-proficiency learners engage in a more active cognitive process, dedicating greater focus to specific letters to verify accuracy. In contrast, low-proficiency spellers demonstrated fewer and shorter fixations. While fewer fixations typically imply ease of processing in reading, in the context of this spelling task, it appears to indicate shallow processing or a failure to detect errors. This finding supports previous studies indicating that eye movement factors are consistently associated with English literacy skills (Rayner et al., 2010).

The present study drew upon implications stated by Henderson et al. (2013) regarding the prediction of cognitive states—specifically memorization—from eye movements. These findings assist in identifying visual scanning patterns and understanding the morphological processing of spellers. Although the transfer of linguistic knowledge discussed earlier may help Persian spellers spell English words, the fundamental orthographic difference between Persian (right-to-left) and English (left-to-right) creates cognitive conflict. Consequently, Persian spellers may exhibit irregular eye movements, leading to misspelled words or increased processing time. This resonates with Arab-Moghaddam and Senechal (2001), who found that learners' right-to-left eye movement habits cause them to misread alphabets within words, such as confusing *form* for *from*.

Since the sequence of eye fixations is of paramount importance, whereby fixations tend to fall on locations with the most informative patterns (McConkie & Dyre, 2000), tracking spellers' eye movements allows researchers to analyze how learners focus on individual letters (Regions of Interest). For instance, as observed in the analysis of the word 'Thirsty,' specific letters were often ignored by learners, leading to errors. Identifying these neglected areas could help instructors mitigate difficulties by focusing on problematic zones, as suggested by Holmqvist et al. (2011). For this reason, the findings of the present study encourage researchers in psycholinguistics, applied linguistics, and second language acquisition to utilize eye-tracking technology in spelling research.

Furthermore, the significant relationship between proficiency and eye movement has implications for teaching spelling to EFL learners. The study highlights differences in how students learn to spell in English while benefiting from the experimental methodologies of earlier studies, such as Rayner et al. (2010). Another empirical implication is the utility of eye tracking in analyzing morphological processing, as suggested by Deubel and Schneider (1996). By distinguishing the movement patterns of learners' eyes, studies can identify the "hardest" letters of a word. In other words, researchers can gain valuable insights into how spellers focus on individual letters and specific areas of words, as demonstrated by Grant and Spivey (2003, p. 1). Recognizing these individual differences offers a crucial educational implication, potentially guiding more personalized teaching strategies.

Finally, as mentioned in Whitford et al. (2016), high-proficiency spellers are able to progress faster in spelling words, developing audio-visual knowledge while monitoring the logical system of spelling. By using the strategies suggested by Tabrizi et al. (2013) and effectively transferring spelling knowledge from Persian to English, high-proficiency spellers were able to analyze misspelled words more easily. The data suggests that high-proficiency spellers viewed editing and verification as part of their responsibility, employing distinct strategies—manifested as increased regressions and fixations—to ensure accuracy.

## V. CONCLUSION

The current study utilized eye-tracking technology to examine the relationship between high and low-proficiency spellers' eye movements by measuring fixations—the periods of relative stability where information acquisition occurs. The eye-tracking method offers distinct advantages over traditional methods. Crucially, it serves as a technology in which eyes "open a window" into the mind of the speller, enabling researchers to observe natural processing without the interference of secondary tasks, thus offering insightful data.

Differentiating high and low-proficiency spellers through eye movement analysis allows educators to identify the successful strategies of proficient spellers and recognize the specific cognitive hurdles encountered by low-proficiency learners. The results suggest spellers need to pay more attention to specific morphological zones within words. Providing guidelines for teachers based on these visual attention patterns could play a vital role in teaching spelling to Iranian EFL learners.

The analysis indicated that students often faced difficulty with the spelling of initial letters or specific morphological components due to a lack of correspondence between letters and sounds. Therefore, fostering morphological awareness through this knowledge could contribute significantly to writing and reading accomplishment.

This study has several limitations. First, it focused exclusively on English spelling difficulties among specific EFL learners. Second, only the nine methods of learning Persian spelling by Tabrizi et al. (2013) were applied to the context of English spelling. Additionally, the results were drawn from a small sample size of 14 students (aged 14) from an Iranian school in Malaysia. Consequently, gender differences could not be statistically analyzed due to the limited number of participants.

To further advance the understanding of spelling and cognitive processes, promising areas for future research should be explored. For instance, future studies could investigate the correlation between reading proficiency and eye movement efficiency during spelling tasks to understand how general cognitive abilities influence the mechanics of spelling. Additionally, research should examine how the use of autocorrect or predictive text influences both cognitive strategies and eye movement behaviors, providing insight into the intersection of technology, literacy, and cognitive processing.

### APPENDIX. HEAT-MAP OF HIGH AND LOW PROFICIENCY SPELLERS

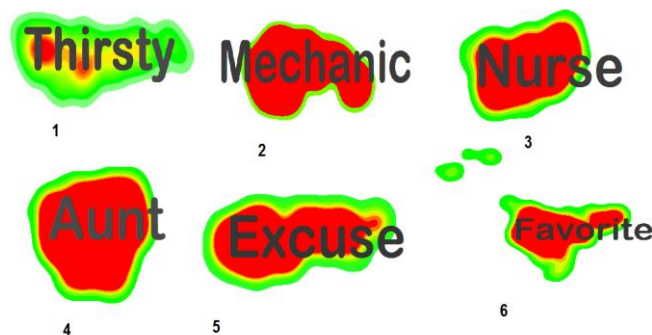


Figure 4. Heat-Map of High Proficiency Speller

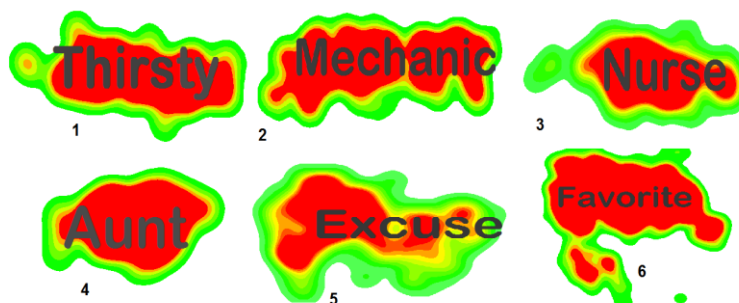


Figure 5. Heat-Map of Low Proficiency Speller

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