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A Systematic Review of Eye-Tracking Studies on L1 Persian and Arabic Reading: Implications for L2 English Reading Comprehension

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ABSTRACT

This study examines how first-language (L1) reading processes in Persian and Arabic shape second-language (L2) English reading, with a focus on insights from eye-tracking research. While L2 reading has been widely studied, the role of L1-based cognitive and visual processing patterns remains underexplored, particularly for learners whose orthographic systems differ substantially from English. This study systematically reviews empirical eye-tracking studies on Persian and Arabic reading to identify processing patterns that may influence L2 comprehension. A systematic literature search was conducted using major academic databases, applying defined inclusion and exclusion criteria. A total of 12 empirical eye-tracking studies were selected for analysis. The selected studies were analyzed comparatively, focusing on key eye-movement measures such as fixation duration, regression patterns, and reading time. The findings reveal that L1-specific features, including right-to-left directionality, cursive script structure, and reduced vowel representation, significantly influence reading behavior and increase cognitive load during L2 processing. Recurring patterns such as vowel-related processing difficulties, reliance on visual segmentation cues, and sensitivity to lexical frequency were observed across studies. These findings highlight the importance of considering L1 reading habits in L2 instruction and suggest that targeted pedagogical interventions addressing orthographic and perceptual differences can support more efficient L2 reading development.

Keywords: cross-linguistic transfer; bilingual literacy; visual word recognition; cognitive processing; script directionality

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Introduction

L1 Reading as a Cognitive Foundation for L2 Development

Reading in a second language (L2) is a complex cognitive process that is strongly influenced by first-language (L1) literacy skills. According to Jiang (2011), the L2 reading process involves the interplay of two language systems, and although L1 and L2 reading differ in some critical ways, understanding the role of L1 literacy is essential for explaining the development of second-language reading. Research has shown that literacy skills developed in the first language can provide an important foundation for second-language reading. Readers with stronger L1 literacy are generally better able to transfer cognitive and metalinguistic skills, such as inferencing, comprehension monitoring, and decoding strategies, to L2 reading (Bernhardt & Kamil, 1995). Consequently, an appropriate level of L1 literacy may facilitate successful L2 reading comprehension, although the extent of this transfer depends on linguistic and orthographic differences between the two languages.

When we read, we coordinate rapid and automatic word recognition, syntactic parsing, meaning formation, text comprehension, inference, critical evaluation, and connections to prior knowledge (Grabe, 2009). Eye-tracking provides a valuable method for examining these cognitive processes in real time by capturing fixation patterns, regressions, and attentional allocation during reading, thereby offering insights into lexical access, comprehension monitoring, and processing difficulty. Grabe (2009) argues that L1 and L2 are different in three main areas: linguistic and processing differences, cognitive and educational differences, and sociocultural and institutional differences. Thus, how individuals read, process text, and ultimately interpret what they read can vary considerably across readers and contexts. Researchers have identified many variables that influence L2 reading. Some of these variables include L1-L2 reading proficiency, background knowledge, cultural schemata, and strategy choices (e.g., Bernhardt & Kamil, 1995). Consequently, reading in a second language (L2) is not a monolingual event. In fact, L2 readers draw on their first-language reading skills as they read an L2 text, using them as a strategy to help comprehend it (Upton & Lee-Thompson, 2001). The effect of L1 on the reading of L2 is viewed as a mental translation. As Kern (1994, p. 442) defines, mental translation is the "mental reprocessing of L2 words, phrases, or sentences in L1 forms while reading L2 texts". Research performed on this phenomenon shows that for high school and adult language learners, mental translation is a common cognitive strategy. Cook (1999) suggests that L1 is not effectively switched off during L2 processing. Instead, the L1 remains constantly available and is almost always active in the L2 learner's mind.

Koda (2005) explains how L1 experience embeds habits of mind, instilling specific processing mechanisms. The implication is that proficiency in a second language does not appear as a direct consequence of experience in L2; linguistic knowledge and language processing are separate competencies. Furthermore, people proficient in reading in their first language will not necessarily be good at reading in their second language. According to Goodman (2014), reading is a 'psycholinguistic guessing game' that emphasizes top-down prediction over bottom-up decoding. Even the reading processes of advanced English learners are influenced by their L1 habits. At lower levels, inefficient reading places a heavy burden on short-term memory, making comprehension difficult. It results in significant individual differences, the reasons for which are not always clear to teachers or learners. Hence, learners ideally need ample time to become familiar with new writing systems, discourse structures, and textual conventions.

While much of the research on L2 reading focuses on how learners process second-language input, understanding how they read in their L1 is equally critical. This is especially true for learners whose first languages, such as Persian and Arabic, differ significantly from English in orthographic structure, reading direction, and morphological processing (Koda, 2005). Eye-tracking offers a

unique methodological window into the cognitive processes that L1 readers bring with them when transitioning to an L2. By measuring fixation durations, regressions, and attentional allocation in real time, eye-tracking reveals how deeply embedded L1 processing habits, such as reliance on consonantal roots in Arabic or sensitivity to spacing cues in Persian, persist during L2 reading. In this review, the researcher includes several studies that focus solely on L1 reading tasks, as they provide essential cognitive benchmarks for interpreting L2 eye-movement patterns. This inclusion is not merely a response to the scarcity of L2 data, but reflects a growing recognition that L1 reading behavior, especially when systematically examined through eye-tracking, lays the cognitive groundwork for understanding cross-linguistic transfer, processing difficulties, and reading efficiency in a second language.

Orthography and reading processes

The foundational level of reading is shaped by the orthography of a language, that is, its writing system. To understand how L2 reading develops, it is essential to first examine how readers process written text in their L1 orthography, particularly when that system differs structurally from the target language. Persian orthography, for example, is a cursive, right-to-left script derived from Arabic, but it includes additional letters specific to Persian (Arab et al., 2022; Baluch, 2013). In contrast, English employs the Latin alphabet, which lacks a straightforward one-to-one letter-to-sound correspondence and instead reflects a more complex relationship between phonemes and morphemes (Venezky, 1970). Perfetti and Liu (2005) propose that reading involves transforming visual symbols into linguistic-conceptual representations, such as words and morphemes. Their framework emphasizes that learning to read requires an understanding of how a writing system encodes the spoken language. Two principles form the foundation of this model. The Universal Writing System Constraint suggests that each writing system reflects key features of the language it represents, and the Universal Phonological Principle, which states that proficient readers activate phonological forms across all scripts. These principles, when applied cross-linguistically, reveal that orthographic structure significantly shapes reading processes. Based on these findings, Perfetti and Liu introduce the System Accommodation Hypothesis, which suggests that readers' cognitive and neural systems adjust to meet the structural demands of their L1 script.

While many orthographic challenges have been examined in Latin-based scripts (e.g., Abu-Rabia & Awwad, 2004; Mueller & Weidemann, 2012), cursive systems such as Persian and Arabic remain comparatively underexplored. Recent research highlights that letter recognition in these scripts is influenced by orthographic depth and spelling transparency, which impact decoding efficiency (Baluch & Danaye-Tousi, 2006). These features are particularly important for understanding how Persian and Arabic readers process text in their L1, and how those perceptual and cognitive reading habits may carry over into L2 reading contexts such as English. Studies comparing word recognition in L1 and L2 suggest that readers may transfer cognitive and visual processing habits, such as prioritizing visual cues, focusing on intra-word features, or encountering difficulties with phonological decoding, all of which are rooted in their L1 orthographic experience.

Eye-Tracking in L1 Reading and Its Relevance for L2 Development

Eye-tracking offers a direct window into the cognitive processes underlying reading by measuring fixation durations, regressions, and saccadic patterns in real time. Unlike offline measures such as comprehension tests or reaction time tasks, eye-tracking captures the moment-by-moment allocation of attention, revealing how readers struggle with specific linguistic features as they occur. Eye-tracking technology has significantly advanced our understanding of the cognitive mechanisms involved in both first (L1) and second language (L2) reading. Studies in this field have examined factors such as orthographic transparency, lexical processing, and cognitive load. Eye-tracking research has shown that fixation duration reflects real-time cognitive processing (Abu-Rabia &

Awwad, 2004), and orthographic depth has emerged as a key factor affecting reading efficiency. For bilinguals, especially those with structurally distinct L1s such as Persian and Arabic, the transition to reading in English may involve perceptual, cognitive, and directional challenges**.** For example, Persian-English bilinguals shifting from the semi-transparent orthography of Persian to a language with a deeper orthography, like English, may experience changes in both reading speed and accuracy (Baluch & Danaye-Tousi, 2006). Additionally, word and letter spacing influence reading fluency, especially in cursive scripts like Persian, which differ structurally from Latin-based systems (Hermena, 2021).

Lexical processing has also received considerable attention in eye-tracking research. Studies suggest that efficient word recognition depends not only on lexical familiarity but also on readers' sensitivity to morphological and orthographic information. Morphological awareness plays a crucial role in reading fluency (Abu-Rabia & Awwad, 2004). For Persian-speaking learners, graphemic similarity can make it difficult to distinguish visually similar words and minimal pairs (Arab et al., 2022). Likewise, vowel blindness, a phenomenon observed among Persian and Arabic L1 readers, demonstrates how orthographic processing habits developed in the native language can interfere with accurate word recognition during L2 reading (Alhazmi et al., 2019). Eye-tracking data also reveal that L2 readers allocate cognitive resources differently from native speakers, often relying on mental translation or compensatory strategies (Kern, 1994). Fixation durations and regression patterns suggest increased cognitive load when processing unfamiliar lexical or syntactic structures (Dolgunsöz, 2015; Grabe, 2009). Emotional valence and word frequency further influence recognition times, with high-frequency words typically producing shorter fixations (Amini et al., 2022). Eye-tracking studies have also clarified how L1 reading direction influences perceptual span and attention allocation. Left-to-right readers (e.g., English speakers) exhibit different eye-movement patterns from right-to-left readers (Fernandez et al., 2023). Studies on Incidental vocabulary learning further show that word exposure during natural reading supports implicit learning, reinforcing the value of input frequency (Godfroid et al., 2018).

Although many of the studies discussed in this review are focused on L2 reading tasks, eye-tracking studies of L1 reading are equally valuable for understanding the foundational cognitive and visual strategies that bilingual readers bring to L2 contexts. This review includes both L1 and L1-L2 studies to examine how script-specific processing patterns observed among Persian and Arabic readers may shape later L2 English comprehension and fluency. By analyzing L1 reading behavior through eye-tracking, researchers can gain insight into the deeply embedded strategies that persist across languages and influence second-language literacy development.

Aims

Persian and Arabic remain significantly underrepresented in eye-tracking research on reading, particularly in studies examining cross-orthographic processing. This review addresses that gap by focusing on the unique visual and structural characteristics of these scripts, including cursive connectivity, right-to-left directionality, and morphological complexity, and by examining how these features shape reading behavior. The primary aim of this review is to systematically synthesize empirical eye-tracking studies on Persian and Arabic reading in order to identify recurring cognitive, perceptual, and eye-movement patterns relevant to bilingual literacy development and L2 English reading. By bringing together evidence from an underrepresented group of languages, this review contributes a cross-linguistic perspective on reading processes and provides a foundation for future research and pedagogical practices tailored to Persian and Arabic speaking learners.

Methodology

This study followed a systematic literature search conducted in 2024 to identify empirical research on L2 reading processes investigated through eye-tracking, with a specific focus on Persian and Arabic L1 speakers. The primary search tool was Google Scholar, supplemented by targeted retrieval of peer-reviewed studies from Scopus, Web of Science, and PubMed Central. The search employed combinations of the following keywords: *"L2 reading eye-tracking," "Persian-English bilingual eye-tracking," "eye-tracking metrics in Persian-English reading," "eye-tracking study of Persian-English bilinguals," "L2 reading eye movements in Persian-English bilinguals,"* and *"cognitive processing in English L2 reading"*. Studies were included if they reported empirical eye-movement data and examined reading behavior either in L1 (Persian/Arabic) or in relation to L2 English reading. Despite a growing interest in cross-linguistic eye-tracking research, Persian and Arabic remain underrepresented, particularly due to the limited number of empirical datasets on cursive, right-to-left scripts. As a result, the number of eligible studies was small, reflecting the broader gap in oculomotor research on these languages.

Inclusion Criteria:

Studies were included if they met all the following criteria:

1. Participants were native speakers of Persian or Arabic (L1).
2. The study reported empirical data based on eye-tracking methodology.
3. Studies involving children or participants with known language impairments were excluded.
4. English proficiency levels varied across studies; only studies with clear L2 reading tasks in English were included.

Exclusion criteria

Studies were excluded if they:

1. Did not present original empirical data.
2. Involved children or participants with language or cognitive impairments.

Studies that did not report original empirical eye-tracking data were excluded because they did not allow for direct analysis of eye-movement behavior during reading. Studies involving children or participants with language or cognitive impairments were also excluded in order to reduce developmental and clinical variability that could affect eye-movement patterns and limit comparability across studies. In addition, only studies published in English were considered due to accessibility and consistency considerations. While this research follows a literature review approach, it partially adheres to the PRISMA guidelines, applying a systematic methodology for selecting and analyzing studies, adapted to the scope of this review.

L1 Influence on English L2 Reading: Evidence from Eye-Tracking Studies

The reviewed studies in this paper reveal several recurring patterns that may contribute to English L2 reading among Persian and Arabic speakers. Across both L1 and L1-L2 eye-tracking studies, common themes emerged in relation to visual attention, lexical access, orthographic processing,

and the effects of script-specific features. The following sections synthesize these findings and discuss their potential implications for English L2 reading development.

Study Selection and Overview

To investigate how reading in the first language (L1) may shape second language (L2) reading development, this review synthesized findings from 12 empirical eye-tracking studies involving Persian and Arabic speakers. While some studies directly examined L2 English reading, others focused solely on L1 reading behavior in Persian or Arabic. These L1-focused studies were included due to their relevance in uncovering visual and cognitive processing patterns that can inform our understanding of L2 reading. The study selection followed a systematic review process, with clearly defined inclusion criteria: studies had to be empirical, report eye-tracking data, and involve participants whose first language was Persian or Arabic. Figure 1 illustrates the review process, showing the number of records identified, screened, and ultimately included in the analysis.

Figure 1

Flow Diagram of the Study Selection Process

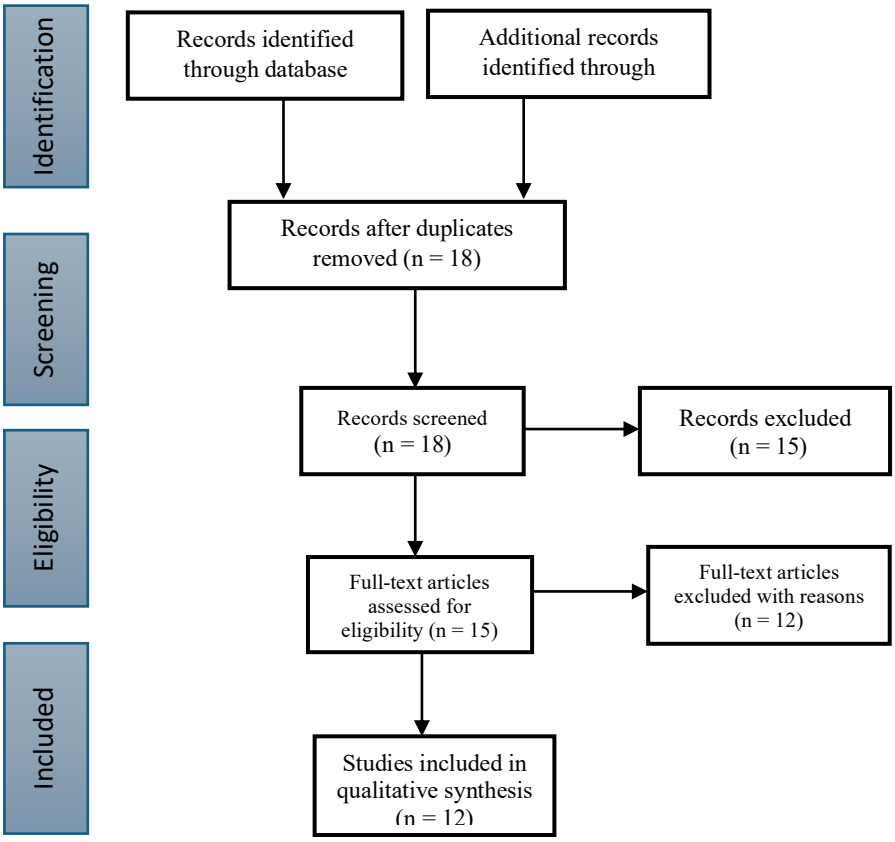

Figure 1 provides an overview of the review process. A total of 31 papers were initially identified, from which 12 studies were included in the qualitative synthesis. Table 1 summarizes the characteristics of these studies, including participants' L1/L2 backgrounds, age, and gender. All studies involved native speakers of Persian or Arabic, with most participants being adults aged 19 to 50. Table 2 outlines the aims, experimental designs, and key findings of each study. Collectively, the reviewed research highlights how linguistic background, orthographic differences, and cognitive processing demands shape reading behavior across L1 and L2 contexts. The methodological diversity, from sentence-level tasks to naturalistic reading, demonstrates the broad applicability of eye-tracking in investigating bilingual literacy development.

Table 1

Characteristics of the reviewed studies

Study	L1	Language of the experiment	Age of the participants	Gender of the participants
El-Dakhs et al. (2025)	Native Arabic	English	L2 speakers: Mean 21.93 (range 18-36) L1 speakers: Mean 36.98 (range 18-64)	L2 speakers: 36 females, 19 males L1 speakers: 27 females, 24 males
El-Dakhs et al. (2024)	Arabic (non-native speakers); English (native speaker baseline)	English	• Non-native speakers: Mean 19.94 (range 18-24) Native speakers: Mean 38.63 (range 18-61)	• Non-native speakers: 23 females, 8 males Native speakers: 26 females, 4 males
Tekbudak et al. (2024)	Native Persian	Persian	Eye-Tracking Participants (Main Study) • Mean age = 29.60 (SD = 4.03) Predictability Test Participants (Cloze Task) • Mean age = 23.66 (SD = 5.03), N = 15 (for final words), Mean age = 25.83 (SD = 1.80)	Eye-Tracking Participants (Main Study) • N = 60 (30 Females) Predictability Test Participants (Cloze Task) • N = 172 (70 females) N = 15 (10 females) Predictability norms were obtained using two separate cloze tasks: one group (N = 172) completed sentence-internal predictions, while a second group (N = 15) provided predictions for sentence-final words.
El-Dakhs et al. (2023)	Native Arabic	English	Experiment 1: Mean 23.52 (range 18-38) Experiment 2: Mean 29.70 (range 18-62)	Experiment 1: 36 females, 8 males Experiment 2: 29 females, 14 males
Amini et al. (2022)	Persian	English	Mean age: 22 years	23 females, 20 males
Hermena (2021)	Native Persian speakers living in the UAE.	Persian	Mean age: 35.7 years (SD = 8.7, range = 18 – 50).	6 males, 22 females
Conklin et al. (2020)	English Arabic, Chinese, Turkish, Hindi, Dutch, German	English	L2 participants' mean age: 25.6 L1 participants' mean age: 20.1	L2 participants : 3 males, 25 females L1 participants : 7 males, 21 females
Alhazmi et al. (2019)	Native Arabic, Native English	For Native Arabic: English	Arabic Speakers: aged 22-42 English Speakers:	Arabic Speakers: 25 males, 5 females English Speakers: 12 males, 8 females

			aged 19-32	
Zahedi & Khoshsaligheh (2019)	Persian	Persian	aged 19-23	16 females and 17 males
Godfroid et al. (2018)	Native speakers: English Non-native speakers: Persian, Dari, Arabic, Hindi, Urdu	English novel containing Dari word	Age Range: 17 to 35 Native speakers: aged 19-23 Non-native speakers: 17-35	Native speakers: 17 females, 2 males Non-native speakers: 23 females, 12 males
Safavi et al. (2016)	Persian	Persian	aged 17-40	Not Specified
Razzaghi Asl (2015)	Persian and Azeri	Persian for the dialogue part	University students	2 males and 8 females

Table 2
Aims, methodology, and major findings

Study	Participants	Methodology	Gap	Aims, findings, and implications
El-Dakhs et al. (2025)	• Groups: Native English speakers (NSs) and Arabic L1 speakers learning English as an L2 (NNSs) • NNSs: 55 adults (36 females, 19 males), ages 18–36 (M = 21.93, SD = 3.50), speakers of the Najdi Arabic dialect studying in Saudi Arabia, good English proficiency (V-YesNo M = 6312.02) • NSs: 51 adults (27 females, 24 males), ages 18–64 (M = 36.98, SD = 14.39), residing in Riyadh with little or no Arabic knowledge, V-YesNo M = 8407.20	• Approach: Eye-tracking study examining online processing of English compound nouns by Arabic-English bilinguals during natural sentence reading, comparing morphologically congruent compounds, morphologically incongruent compounds, and monomorphemic control words. • Procedure: SR Research EyeLink 1000+, sentences presented on a single line, 9-point calibration and drift correction, three counterbalanced lists, comprehension questions after one-third of sentences. • Measurements: Gaze Duration (GD- early processing), Total Reading Time (TRT-late integration), Regression Path Duration (RPD-rereading), V-YesNo vocabulary score as a measure of L2 proficiency.	• Little research has examined the influence of morphological congruence and incongruence on L2 lexical processing, particularly for compound nouns. • Arabic–English bilinguals remain underrepresented in bilingualism and psycholinguistic research despite the distinctive root-and-pattern morphology of Arabic. • Current bilingual lexical processing models (e.g., RHM, BIA+, and Multilink) were not specifically designed to account for cross-language morphological processing of multimorphemic words. • Eye-tracking studies investigating L1 morphological influences on L2 compound-word processing during natural reading remain limited.	• Aim: To investigate whether Arabic-English bilinguals show L1 morphological transfer during the online processing of English compound nouns and to examine whether L2 lexical proficiency moderates this effect. • Results: No significant differences were found between morphologically congruent and morphologically incongruent compounds for either L1 or L2 speakers. Lower-proficiency L2 learners processed compound nouns more slowly than monomorphemic control words, whereas higher-proficiency learners showed no such disadvantage. • Findings: The study found no evidence of L1 morphological transfer in the processing of English compounds by Arabic-English bilinguals. Instead, lexical proficiency influenced processing patterns: lower-proficiency learners relied more on decomposition, whereas higher-proficiency learners processed compounds more holistically, resembling native speakers. • Implications: The findings challenge predictions of strong cross-language morphological transfer and provide limited

				support for the Revised Hierarchical Model (RHM). They support dual-route models of morphological processing, suggesting that proficiency influences whether compound words are processed compositionally or holistically. The study also expands the limited eye-tracking literature on Arabic-English bilingual lexical processing.
El-Dakhs et al. (2024)	• Groups: Native Arabic speakers (L2 English), Native English speakers (baseline, with no or basic Arabic knowledge) • NNS: 31 adults, ages 18-24 (M=19.94), 23 females/8 males, V_YesNo scores M=5501 (good level of English) • NS: 30 adults, ages 18-61 (M=38.63), 26 females/4 males, V_YesNo scores M=8537	• Approach: Eye-tracking study examining real-time processing of L2 collocations during silent sentence reading in a contextualized natural reading setting, rather than decontextualized judgment tasks. • Stimuli: 20 congruent collocations (with Arabic L1 equivalents), 20 incongruent collocations (without Arabic L1 equivalents), and 40 semantically plausible but infrequent non-collocational control pairs adopted from Sonbul and El-Dakhs (2020); included verb–noun and adjective–noun collocations embedded in sentence contexts. • Procedure: Eye movements recorded using the SR Research EyeLink 1000+ eye tracker. Sentences were presented on a single line in Courier New 20-point font. The experiment included 9-point calibration, drift correction before each trial, and re-calibration when necessary. Participants completed one of two counterbalanced experimental lists (Version 1: NS=16, NNS=16; Version 2: NS=14, NNS=15). Comprehension questions followed one-third of the sentences to ensure attentive reading (NS: 89.01%; NNS: 84.23%). • Measurements: First-pass reading time (early lexical access and initial processing) and total	• Previous studies on L2 collocation processing have mainly presented collocations out of context in tasks requiring explicit judgment (e.g., lexical decision or acceptability judgment), which may not reflect actual reading performance. • Research on the real-time processing of collocations during natural reading remains scarce. • Such decontextualized tasks may exaggerate certain processing effects, particularly congruency effects. • To date, few studies have examined how L2 speakers process congruent and incongruent collocations online during contextualized natural reading. • The modulating effects of proficiency and transparency on congruency remain inconclusive due to conflicting findings across previous studies. • Arabic-English bilingual learners remain underrepresented in eye-tracking research on L2 collocation processing.	• Aim: To examine how Arabic-English bilinguals process congruent vs. incongruent L2 collocations during natural reading using eye-tracking, and whether proficiency and transparency affect congruency effects. • Results: Collocations were processed faster than control phrases (NS: d = 0.68; NNS: d = 0.28), but no significant differences were found between congruent and incongruent collocations in either early or late processing measures. Proficiency and transparency did not significantly modulate congruency effects, although transparency benefited lower-proficiency readers. • Findings: The study found that collocational processing advantages persist during natural reading, but contextualized reading may reduce or eliminate congruency effects previously observed in decontextualized tasks, particularly for frequent and familiar collocations. The findings also suggest that sentence context may constrain L1 transfer effects during online processing. • Implications: The findings challenge assumptions derived from decontextualized collocation studies and provide greater support for the BIA+ model than for the Revised Hierarchical Model (RHM) or L2 Multilingual Lexicon Model (L2 MLM) in explaining collocation processing. The study also contributes to theories of bilingual lexical processing and highlights the need for more

		reading time (later integration and reanalysis processes).		contextualized eye-tracking research involving Arabic-English bilinguals, particularly studies examining wider transparency variation and productive collocation knowledge.
Tekbudak et al. (2024)	Eye-Tracking Participants (Main Study) • N = 60 native Persian speakers (30 Females) • Mean age = 29.60 (SD = 4.03) Predictability Test Participants (Cloze Task) • N = 172 (for internal words), M = 23.66 (SD = 5.03), 70 females • N = 15 (for final words), M = 25.83 (SD = 1.80) (10 females)	• Silent reading of 99 Persian sentences (Bijankhan Corpus: dbrg.ut.ac.ir/Bijankhan/), displayed in 18 pt Courier New • Eye movements recorded with EyeLink 1000 Plus (1000 Hz) • 9-point calibration with chin/forehead rest; 5 randomized blocks • 20 pseudo-random comprehension questions to maintain attention • Low-quality and regressive trials excluded • Single fixation durations analyzed using linear mixed models • An additional 172 participants completed a Persian cloze test to predict middle words • 15 participants predicted final words • Predictability scores from cloze task used as corpus variables in the analysis	• Despite a growing interest in cross-linguistic eye-tracking research, Persian remains underrepresented, especially in terms of empirical datasets and analyzes of oculomotor behavior during sentence reading. This limits our understanding of how script direction, morphology, and lexical characteristics shape reading patterns in non-Latin orthographies.	• Aim: The study aimed to create and analyze a large-scale eye-tracking corpus of Persian sentence reading to examine how word-level characteristics (e.g., frequency, predictability, length) influence oculomotor control during reading. • Results: The authors conducted a linear mixed model (LMM) analysis on single fixation durations (SFDs) using multiple word-level and oculomotor predictors. The model included foveal (word n), preceding (n−1), and following (n+1) word characteristics like frequency, length, and predictability. The model-building process followed standard practices, including model comparisons and principal component analysis for random effects structure. • Findings: Fixation durations were shorter for frequent, predictable, and short words (the effect of shorter *preceding* words was significant, not all short words in general.)/ A parafoveal preview effect was observed via predictability of word n+1. / The study confirmed the inverted optimal viewing position effect and showed that eye movement patterns in Persian align with cross-linguistic findings. • Implications: Confirms that Persian eye movement patterns align with cross-linguistic findings (e.g., German, English)/ Provides a new corpus to support computational modeling and reading research in underrepresented languages/ Shows that oculomotor control mechanisms are robust across different scripts and reading directions/ Enables future comparative studies on

				right-to-left orthographies like Persian and Arabic
El-Dakhs et al. (2023)	• Groups: Native Arabic speakers (L1 Arabic, L2 English) • Experiment 1: 44 adults, ages 18-38 (M=23.52), 36 females/8 males Experiment 2: 43 adults, ages 18-62 (M=29.70), 29 females/14 males • Proficiency: Good-to-high (V_YesNo vocabulary test scores 4159-8966) • Experiment 1: Participants demonstrated good-to-high English proficiency, with a mean self-reported skill rating of 4.32/5 and an average vocabulary score of 6543.75/10,000 (V_YesNo online vocabulary test Mearaand Miralpeix 2017) Experiment 2: Participants reported a mean self-reported skill rating of 4.34/5 and an average vocabulary score of 6492.37/10,000 (V_YesNo online vocabulary test Mearaand Miralpeix 2017)	• Approach: Eye-tracking during silent reading of sentences • Stimuli: 21 positive/neutral pairs (Exp1), 21 negative/neutral pairs (Exp2), from Knickerbocker et al. (2015) • Procedure: SR Research EyeLink 1000+, sentences presented across one line • Measurements: First fixation duration, single fixation duration, first pass reading time, landing position, skipping rate, total time, regressions in, second pass time, spillover, regressions out	• Prior research on emotion word processing has largely relied on decontextualized tasks with isolated words, primarily focusing on native speakers. Few eye-tracking studies have examined emotion word processing during natural silent reading, and bilingual populations, particularly Arabic-English learners, remain critically underrepresented in this area.	• Aim: To extend Knickerbocker et al. (2015) to Arab EFL learners by examining L2 processing of positive vs. neutral (Exp 1) and negative vs. neutral (Exp 2) emotion words using 13 eye-tracking measures, and to test the modulating effects of frequency, arousal, length, and proficiency. • Results: No main effect for word type across 13 eye-tracking measures/ Positive words were processed faster under certain conditions, particularly when associated with high frequency and lower arousal. / Negative words: skipped less (especially short words) and faster when low-arousal • Finding: L2 emotion processing differs fundamentally from L1 processing/ L2 remains emotionally distant for late instructional bilinguals/ Processing modulated by frequency, arousal, and word length/Negative words trigger automatic vigilance and prolonged attention during reading. • Implications: (Theoretical) Supports RHM (Revised Hierarchical Model) & L2 MLM (Mental Lexicon Model); calls for integrating affect into bilingual models/ (Pedagogical) Explicit teaching of emotion vocabulary needed; create emotionally engaging L2 experiences/ • (Methodological) Eye-tracking is valuable for capturing real-time bilingual emotional processing
Amini (2022)	• Participants: 43 total • Gender: 23 females, 20 males	• EFL learners read 36 sentences in a coherent text for comprehension while their eye movements were recorded by eye-tracker.	• Focus: Emotional word processing in intermediate EFL learners • Previous Studies: L1 and high-proficiency L2 readers, valence-centric	• Aim: To investigate the emotional valence and frequency and gender impact on L2 word recognition • Key Findings: No emotional word advantage in

	• Age: Mean 22 years • Background: Undergraduate, late Persian-English bilinguals • Selection: PET scores • Conditions: No neurological disorders, normal vision	• Approach: Mixed-methods • Words: Emotional words (positive, negative, neutral) from ANEW • Device: Tobii Eye Tracker 4C • Procedure: Read sentences with emotional words, rate valence and arousal • Design: Repeated measures (valence, frequency, gender) • Measurements: Eye fixation time, number of fixations, total reading time	• Objective: Emotional valence, frequency, gender effects on word recognition	L2/ Contextual learning boosts retention/ Effects vary by word/learner factors/ Loanwords process faster • Implications: Language teaching insights, new word acquisition strategies • Theoretical Context: Emotional Context of Learning Theory • Considerations: Individual differences, learning environments
Hermena (2021)	• 28 participants (6 males), native Persian speakers living in the UAE. • Regularly read Persian on daily or weekly basis. • Mean age: 35.7 years (SD = 8.7, range = 18 – 50). • Normal or corrected-to-normal vision confirmed by Bailey-Lovie chart.	• Eye-Tracking (ET): EyeLink 1000+ (1000Hz)/ Binocular viewing, right-eye recording/ 3-point calibration (≤0.25° error) • Design: Within-participants (N=28) • Three conditions: Spaced (baseline), Pixel-Spaced (Exp. 1+2), Connected (Exp. 2 only) • Variables: *Independent*: Spacing manipulation (inter-word spacing reduction + inter-letter ligature extension; Connected = ligature-replaced spacing)/ *Dependent*: Fixation duration, count, saccade amplitude, total reading time, comprehension accuracy Controls: Randomized sentence order/ Counterbalanced condition presentation/ Stimuli norming (grammaticality ratings by 5 native speakers) • Stimuli: 40 (Exp. 1) + 60 (Exp. 2) Persian sentences/ Arial 14pt font (proportional)/ Non-connecting final letters (except sentence-final words) to isolate boundary effects	• Prior studies focus mainly on Latin scripts; Persian's cursive script is underexplored. • Persian's ligatures and variable spacing pose unique challenges for word segmentation. • Effects of spacing manipulations on eye movements in Persian remain unclear. • No study has tested both interword and interletter spacing using a within-participant ET design. • Current study addresses these gaps with controlled spacing manipulations in Persian text.	• Aim: Examine how spacing manipulations (inter-word and inter-letter) impact Persian reading, and test if non-connecting letters mark word boundaries. • Results: Pixel-Spaced: Increased fixation durations (17-20%) and reading times (35-40%) due to crowding effects. Connected: Severe disruption (180% more fixations) from altered letter forms. • Findings: Standard spacing is essential, reductions impair segmentation./ Non-connecting letters alone cannot compensate for spacing loss./ Letter form preservation matters as much as spacing. • Implications: Practical: Maintain conventional spacing in Persian texts. Theoretical: Update reading models to account for cursive script features. Future: Test cross-script L1 transfer and expand to other cursive orthographies.

Conklin et al. (2020)	• Total: 56 participants 28 L2 English speakers (3 males; 25 females; mean age: 25.6) 28 L1 English speakers (7 males; 21 females; mean age: 20.1) • L2 Speakers: Advanced learners of English, various L1s (Arabic, Chinese, Turkish, Hindi, Dutch, German) • L1 Speakers: Native English speakers • University: Students at the University of Nottingham	• Design: Comparative study on reading-only vs. reading-while-listening • Measures: Total reading time, first fixation duration, first-pass reading time, total fixation count, regression count, skipping probability • Analysis: Linear mixed-effects models, generalized linear mixed-effects models • Software: R, Version 3.4.4 • Conditions: Reading-only, reading-while-listening • Materials: Two stories • Alignment: Reading and listening alignment analysis • Assessments: Vocabulary size test, language-background questionnaire, self-rated proficiency (7-point scale)	• Focus: Effects of reading-while-listening (RWL) on reading behavior in L1 and L2 speakers • Variables: Word frequency, word length, part of speech, vocabulary scores, reading and listening alignment	• Aim: Compare reading patterns (fixations, regressions, alignment) in L1/L2 speakers during reading-only vs. reading-while-listening. • Results: L1: Slower reading with audio (longer/more fixations, fewer skips). / L2: No added slowdown with audio; longer fixations in reading-only mode. / Both groups fixated ahead of audio (L1: 89%, L2: 79%), but L2 aligned more (33% vs. L1's 17%)./ Word frequency/length affected fixation duration (shorter/high-frequency words = faster). • Findings: Similar eye-movement patterns in reading-while-listening for L1/L2./ Audio helped L2 readers synchronize but may overload L1 (competing visual/auditory input). • Implications: Audio supports L2 word segmentation but requires proficiency-matched pacing. • Caution: Misalignment risks cognitive strain; optimal design needs further research.
Alhazmi et al. (2019)	• Groups: Native Arabic speakers, Native English speakers • Arabic Speakers: 30 adults, aged 22-42, 25 males/ 5 female, IELTS 6-6.5, upper-intermediate to advanced, 10-week program • English Speakers: 20 adults, aged 19-32, 12 males/ 8 females, undergraduate/postgraduate students	• Approach: Eye-tracking reading 'context-free' words • Words: 100 BNC-based, lemmatized • Word Length: 5-10 letters • Procedure: Computer screen reading, eye movements recorded • Measurements: Fixation duration, fixation count, total reading time	• Focus: L1 Arabic speakers' English word processing under 'vowel blindness' literature • Comparison: Arabic vs. English speakers, eye-tracking • Specifics: Word-level processing difficulties, Arabic learners	• Aim: To investigate whether Arabic EFL learners exhibit vowel blindness • Investigation: Comparing native Arabic speakers' eye movement patterns to native English speakers during English word reading • Theory: Vowel blindness in Arabic learners • Objective: Arabic learners' English word recognition • Reading Strategies: Tri-consonantal root focus, vowel neglect • Slower reading rate for native Arabic speakers were recorded based on the results
Zahedi–Khoshsaligheh (2019)	• 33 random participants (aged 19-23 (Mean 19), 16 males and 17 Females) were included in the data analysis. All	• Scene from *Elle* chosen as the experimental stimulus. • Subtitles created using Subtitle Edit Software.	• Limited research on eye movements during reading of Persian subtitles within the context of translation studies. Lack of studies investigating how viewers process different types of information presented in Persian subtitles.	• Aim: To investigate how viewers process grammatical and lexical words in Persian subtitles using eye-tracking. • Results: Data from 33 participants were analyzed.

	were native Persian speakers. • Participants had normal vision or used contact lenses. • Excluded those familiar with French language or the film shown. • Written consent was obtained from all participants	• Eye-tracking data collected using SMI device with 60 Hz sampling rate. • Three-point calibration performed on the eye-tracking device. • Areas of interest (AOIs) determined for analysis. • Data extraction conducted using BeGaze software. • Eye-tracking data analyzed in SPSS software.		/ Viewers paid more attention to grammatical words than lexical words. / Significant differences in fixation time, fixation count, first fixation time, and pass rate were found. / Lexical words had higher fixation times and counts, while grammatical words had higher no-fixation percentages. • Findings: Results align with previous research on subtitle and text reading (Krejtz et al., 2016)./ Grammatical words had fewer fixations (38%) than lexical words (83%)./ Grammatical words are processed more easily due to frequency, length, and structural language rules. / Grammatical words may be processed peripherally or during nearby fixations. • Implications: Increasing grammatical words in subtitles could improve continuity without affecting processing speed./ Omitting grammatical words may hinder comprehension./ This is the first eye-tracking study on Persian subtitles, highlighting a need for more research in Iran to fill the gap in cognitive translation studies.

Godfroid et al. (2018)	• Total: 54 participants • Composition: 19 native speakers (NSs; 17 females) and 35 non-native speakers (NNSs; 23 females) • Institution: Large Midwestern university in the US • NSs: Mostly undergraduate students enrolled in language teaching courses, aged 19-23 • NNSs: Undergraduate or graduate students in various specializations, aged 17-35, excluding native speakers of Persian, Dari, Arabic, Hindi, and Urdu	• Analysis: Longitudinal growth curve of eye-fixation durations • Pre-screening: 14k Vocabulary Size Test for NNSs • Reading Material: A Thousand Splendid Suns • Procedure: Normal-paced reading followed by post-reading questions • Duration: 2 hours for NSs, 3 hours for NNSs • Eye-tracking: EyeLink 1000, 1000 Hz sampling rate for right eye • Text Presentation: Consolas, size 18, double-spaced • Navigation: Controller button used for screen transitions	• Existing Literature Gaps: Limited focus on cognitive processes in incidental vocabulary learning during L2 reading, lack of representation in naturalistic contexts with prolonged exposure, need for a comprehensive approach to measuring vocabulary knowledge	• Aim**:** Study incidental vocabulary learning during novel reading using eye-tracking. • Results**:** Reading speeds improved non-linearly (S-curve) with repeated exposures/ More exposures → better form recognition; longer reading time → better meaning recall/ Intentional learners outperformed incidental learners on meaning tests • Findings**:** Words need 8-10+ exposures for reliable learning/ Eye movements reveal implicit learning missed by tests/ Form and meaning are acquired differently • Implications**:** Combine extensive reading with vocabulary focus/ Use eye-tracking to study implicit learning/ Teach noticing strategies for L2 learners
Safavi et al. (2016)	• Experiments 1: 42 Persian-speaking participants aged 17-40 in Tehran, Iran. All were native-speakers • Experiments 2: 43 Persian-speaking participants aged 17-40 in Tehran, Iran. All native-speakers • Experiments 3: 40 Persian-speaking participants in Golm campus, University of Potsdam, Germany. • Experiments 4: The same criteria as experiment 3 The study complied with the Declaration of Helsinki, and informed	• Manipulated Predictability (Strong/Weak) and Distance (Short/Long). • Focused on Persian separable complex predicates (CPs). • Used self-paced reading (SPR) and eye-tracking (Experiments 1–4). • Analyzed reading via FPRT and RPD at verb region. • Applied Bayesian hierarchical models for analysis. • Included comprehension questions to ensure engagement.	• Persian CP processing is understudied compared to languages like Hindi. • Explores language-specific features (e.g., separability, entropy). Aims to test cross-linguistic generalization of dependency resolution effects.	• **Aim:** Investigate whether locality effects in Persian sentence processing align with memory-based or expectation-based accounts. • **Results:** Locality effect observed consistently (supporting memory-based accounts)./ Predictability facilitated processing, but no expectation-based facilitation with longer distances./ Entropy (uncertainty) increased in long-distance conditions, especially with complex interveners./ Entropy affected reading times only in one experiment (Exp 1). • **Findings:** Predictability consistently improved reading speed./ Complex interveners (RC+PP) showed stronger locality and entropy effects than long PPs./ Forgetting in longer dependencies may increase entropy, reducing grammatical sentence completions./ No evidence that longer distance sharpens

	consent was obtained from all participants.			expectation (contra Konieczny, 2000). • **Implications:** Memory-based accounts better explain locality in Persian. / Entropy (uncertainty) may contribute to locality effects, especially with complex interveners./ Highlights the role of intervening structure and language-specific dependency patterns./ Suggests need for further controlled studies to isolate memory vs. entropy effects.
Razzaghi (2015)	• 5 pairs (10 participants: 2 male, 8 female) from Middle East Technical University. • Native speakers of Farsi (Persian); 8 also spoke Azeri. • No participants had eye disorders (e.g., color blindness) or thick glasses/contact lenses with special filters (one pair was excluded due to this issue). • Most of the participants were master's/PhD, but one was an undergrad (p. 26).	• Mixed methods (quantitative: gaze coordination, RE length; qualitative: pronoun usage). • Dual eye-tracking with Eye Tribe trackers (60 Hz). • Roles: Instructor (director) and operator, switched after each trial. • Conditions: Normal (no cues), Color (uniquely colored Tangram pieces), Gaze (visualization of partner's gaze). • Data collection: Gaze coordinates, screen/audio recordings, transcribed dialogues.	• Limited prior research on Persian Referring Expressions (REs) in situated dialogue. • Existing RE corpora (e.g., English, Japanese, Turkish) lacked cross-linguistic comparison with Persian. Need for studies integrating linguistic analysis (REs) with joint attention (dual eye-tracking).	• Aim: Examine how Persian speakers process text and images with/without audio. /Analyze Persian referring expressions (REs) during a Tangram task with visual cues (color, gaze). /Build a Persian RE corpus and compare it with Turkish, Japanese, and English. • Results: All groups focused more on text than images./ Reading-only → more text focus; reading-while-listening → more image focus./ L2 adults scored highest; children lowest (different test)./ Color → more one-word REs; Gaze → more shape/size terms./ Persian REs closest to Turkish./ Gaze alignment improved over time and predicted task success. • Findings: Text dominance across all groups, even with images./ Audio input helps shift focus to images, supporting multimodal integration. / RE use influenced by visual cues: color = shorter REs; gaze = richer attributes./ Persian differs in RE style (fewer pronouns, more determinatives). Implications: Instructional design: Audio aids visual integration; color supports clarity./ Language learning: L2 adults benefit from both modalities; kids need fluency first./ Corpus work: Persian REs require custom annotation strategies./ Joint attention: Gaze coordination boosts success; visual cues aid communication over time.

Methodology of Eye-Tracking in L1 and L2 Reading Research

Eye-tracking studies investigating L1 influence on L2 reading employ systematic methodologies to capture real-time cognitive processes during reading. This review includes both L2-focused and L1-only studies, as the latter offer critical insight into foundational reading strategies and visual processing patterns that inform L2 development. These studies rely on quantitative metrics such as fixation duration, fixation count, total reading time, and regression frequency to assess cognitive load, attentional allocation, and reading efficiency. By analyzing these metrics, researchers can identify how L1 orthographic, morphological, and syntactic features influence L2 reading behavior. For example, Hermena (2021) examined Persian L1 readers and found that disrupting conventional inter-word spacing and letter connectivity significantly increased fixation durations and total reading times, underscoring how strongly Persian readers rely on familiar visual cues for word segmentation. Alhazmi et al. (2019) examined Arabic L1 speakers reading English words and found that word processing difficulties were reflected in prolonged fixation times and increased regressions. Similarly, Conklin et al. (2020) compared reading-only and reading-while-listening conditions, using linear mixed-effects models to analyze eye-movement data. These studies highlight how real-time eye-tracking metrics can uncover cross-linguistic processing patterns that inform our understanding of L2 reading development. For instance, fixation duration can reflect cognitive effort, with longer fixations indicating difficulties in word recognition or syntactic parsing. Regression frequency, measured by re-reading behavior, can also address comprehension challenges. Persian readers, for instance, regress more often when encountering unfamiliar conventional spacing and word boundaries (Hermena, 2021). Saccadic patterns, including saccade length and direction, can offer insights into perceptual span adaptations. Analytical techniques in these studies include linear mixed-effects models to handle participant variability (Conklin et al., 2020), area of interest (AOI) analysis to isolate specific reading challenges (Zahedi & Khoshsaligheh, 2019), and time-course analysis to track learning over repeated exposures (Godfroid et al., 2018). These methodologies underscore the strength of eye-tracking in uncovering cross-linguistic transfer effects in L2 reading. They also demonstrate how L1 reading studies provide essential benchmarks for interpreting bilingual eye movement patterns.

Cognitive and Linguistic Influences on L2 Reading: The Role of L1 Transfer, Emotion, and Vocabulary Acquisition

Research from both L1 and L2 reading contexts demonstrates that characteristics of a reader's first language can have a profound influence on how second language (L2) texts are processed. These influences shape fixation patterns, cognitive load, and overall reading efficiency. One clear example of this is the phenomenon of vowel blindness observed in Arabic L1 readers. In Arabic, the writing system is consonantal, meaning short vowels are typically omitted from written texts. As a result, native Arabic speakers become accustomed to focusing almost exclusively on consonantal roots to decode meaning. When transitioning to reading English, this L1 strategy persists: Arabic L1 readers primarily fixate on consonants and tend to under-process vowels, which are critical for accurate word recognition in English. This transfer leads to measurable reading inefficiencies, including longer fixation durations on vowel-rich English words and a higher frequency of regressions, as readers often need to recheck or reinterpret words they initially misread (Alhazmi et al., 2019). The habit of prioritizing the tri-consonantal roots of words, while highly adaptive in Arabic, becomes a disadvantage in English where vowels play a central phonological and morphological role in distinguishing word forms. Beyond vowel processing difficulties, another critical L1 factor influencing L2 reading is reading directionality. In addition to phonological and directional challenges, the typographic nature of the L1 script also plays a significant role, particularly for Persian readers. Persian employs a cursive writing system in which letters within words are typically joined by ligatures, and the spacing between words follows highly consistent conventions. Hermena (2021) investigated these effects in an L1 Persian reading context and found that disrupting conventional inter-word spacing, by reducing spaces between words and extending ligatures, led to

slower reading speeds, increased fixation durations, and impaired word segmentation. These findings highlight how deeply Persian readers rely on familiar visual cues, such as clear inter-word spacing, to efficiently parse and recognize words. These results imply that when Persian readers shift to English, a script characterized by disconnected letters and rigid spacing conventions, they may encounter additional segmentation challenges. Even minor deviations from familiar visual patterns can disrupt cognitive processing, resulting in slower, less efficient reading despite preserved comprehension.

From a different perspective, word frequency, emotional and lexical factors may influence L2 reading efficiency, affecting how learners process words and acquire new vocabulary. Studies on Persian-English bilinguals highlight the role of emotional valence and word frequency in reading behavior. Amini et al. (2022) investigated the effects of emotional valence, word frequency, and gender on L2 word recognition using eye-tracking. The study found that there were no significant differences in processing time between positive, negative, and neutral words, as measured by eye fixation durations. In other words, the emotional valence of a word, whether it carried a positive, negative, or neutral emotional charge, did not substantially impact the speed with which L2 readers processed the words. Instead, the most influential factor affecting word recognition speed was lexical frequency. High-frequency words were processed significantly faster than low-frequency words, regardless of their emotional content. This suggests that familiarity and repeated exposure to a word play a more critical role in reading efficiency than the emotional associations a word might evoke. Beyond the influence of emotional and lexical factors, incidental vocabulary acquisition emerges as a crucial component in the development of L2 reading skills. Eye-tracking studies have provided valuable insights into this process by revealing how learners acquire new vocabulary indirectly, often through repeated exposure to unfamiliar words embedded in meaningful and context-rich texts. A longitudinal study conducted by Godfroid et al. (2018) demonstrated that fixation durations on previously unknown words gradually decreased over time as learners became more familiar with the lexical items. Initially, learners exhibited longer fixations, reflecting the cognitive effort required to process unfamiliar forms and meanings. However, with repeated encounters, these fixation durations shortened, indicating a transition toward more automatic and efficient word recognition. This finding underscores the importance of sustained, extensive reading practices in fostering natural vocabulary growth and enhancing overall reading fluency in a second language.

Recent eye-tracking research has further expanded our understanding of lexical processing among Arabic-speaking learners of English. Extending earlier findings by Amini et al. (2022) on the limited role of emotional valence, El-Dakhs et al. (2023) investigated the processing of emotion words and confirmed that emotional valence alone did not consistently influence reading behavior. Instead, lexical factors such as word frequency, arousal, and learner proficiency played a stronger role in determining processing efficiency. Extending this line of research, El-Dakhs et al. (2024) examined the processing of English collocations and reported faster reading times for collocational expressions than for non-collocational word combinations, suggesting that familiarity with multiword units facilitates lexical access during reading. More recently, El-Dakhs et al. (2025) explored the processing of English compound nouns and found limited evidence for direct L1 transfer effects. Rather, higher English proficiency was associated with more efficient processing patterns, indicating that language proficiency may outweigh cross-linguistic influence in some aspects of lexical processing. These studies suggest that while L1 background remains relevant, lexical familiarity, phraseological knowledge, and proficiency level are often stronger predictors of online reading behavior than emotional valence or direct transfer effects alone.

The pedagogical implications of these findings are significant, particularly for the design of instructional strategies aimed at optimizing L2 reading efficiency and vocabulary acquisition. One promising instructional approach involves the integration of multimodal learning tools, such as reading-while-listening (RWL) techniques. By combining auditory and visual inputs, RWL strategies

are thought to support word segmentation and provide multiple pathways for processing linguistic information. However, recent research by Conklin et al. (2020) complicates this assumption. Their study showed that while RWL can facilitate greater alignment between auditory and visual processing, it does not necessarily enhance reading comprehension or reduce cognitive strain in advanced learners. In fact, their results indicated that proficiency-matched pacing is critical, as mismatched audio speed can impose an additional burden on readers rather than alleviating it. So, while multimodal techniques can offer useful supplementary support, especially at lower proficiency levels, silent extensive reading remains essential for developing true automaticity and reading fluency at more advanced stages of L2 acquisition. Findings from both L1 and L2 eye-tracking studies underscore that reading efficiency is shaped by deeply embedded visual habits, lexical familiarity, and processing strategies, factors rooted in the first language and carried into L2 reading. These influences warrant careful consideration in both future research and instructional design.

Word Recognition & Processing Differences

Word recognition and processing in a second language (L2) are deeply shaped by the reader's first language (L1), especially when the two languages differ significantly in orthographic structure, morphological complexity, and script directionality. The L1 processing challenges discussed in this section provide valuable insights into how native reading habits may transfer to and shape reading behavior in L2 English contexts. For Persian and Arabic L1 speakers learning English, these structural differences introduce unique cognitive and perceptual challenges that affect several layers of reading, notably lexical access, morphological decoding, and word segmentation. Eye-tracking research provides evidence that these challenges are neither superficial nor easily overcome but reflect deep processing habits shaped by the native script.

One of the most critical challenges is lexical access, which refers to the speed and efficiency with which readers can retrieve the meaning of written words. Both Arabic and Persian use right-to-left (RTL) cursive scripts, where letter forms dynamically change depending on their position within a word, a vivid contrast to English's left-to-right (LTR) alphabetic system, where letter forms are largely stable and distinct. These differences lead to longer fixation durations and increased fixation counts when Arabic L1 speakers read English (e.g., Alhazmi et al., 2019). As noted earlier, Arabic readers often exhibit vowel blindness due to the consonant-heavy nature of their writing system, which can hinder decoding efficiency in English (Alhazmi et al., 2019). Similarly, readers from other RTL script backgrounds, such as Persian and Arabic, may also experience comparable perceptual strain when adapting to English L2 reading, due to differences in script directionality and visual processing demands. Beyond the challenges of lexical access, morphological and visual processing issues also emerge, particularly for Persian readers. Hermena (2021), in a study conducted in Persian (L1), demonstrated that manipulating spacing within texts in Persian words, specifically by reducing inter-word spacing while simultaneously increasing inter-letter spacing through extended ligatures, impaired reading efficiency. Readers exhibited longer fixation durations and more frequent regressions, suggesting that Persian readers depend heavily on conventional inter-word spacing to accurately segment and recognize words. Although Hermena's study focused on native Persian reading behaviors and did not directly examine second-language (L2) English reading, the findings imply that Persian readers transitioning to English face a double cognitive shift: not only must they adjust to a non-cursive script with distinct letter forms, but they must also recalibrate their expectations for word boundaries, which are visually clearer and more rigidly separated in English.

Word segmentation itself presents a further layer of complexity. Unlike English, which clearly demarcates word boundaries with consistent spacing, Persian and Arabic scripts connect letters in flowing ligatures, making word boundaries less visually distinct. This feature influences how readers allocate attention during reading. Zahedi and Khoshsaligheh (2019) found that Persian readers tend to fixate longer on content words compared to function words when reading subtitles, a pattern suggesting reliance on holistic, lexical-level processing rather than fine-grained, boundary-based

decoding. Although this study also focused on L1 reading, the tendency to prioritize lexical over structural cues may carry over to L2 reading, where fine segmentation is crucial. This holistic strategy, while efficient in the L1 context, may affect English reading, where precise parsing of distinct words is critical for maintaining comprehension and fluency. Such studies highlight how L1 reading behaviors, while not always directly observed in L2 contexts, nonetheless reveal stable processing preferences that influence L2 adaptation.

These layered challenges strongly argue for the need for targeted instructional strategies specifically designed for Persian and Arabic L1 learners of English. Research shows that explicit vowel training is very effective for Arabic-speaking learners because it helps them focus more carefully on vowelized structures, which are essential for recognizing English words (Alhazmi et al., 2019). Similarly, Persian readers can benefit from training that improves their sensitivity to English inter-word spacing, helping them overcome the segmentation difficulties caused by unfamiliar spacing patterns. As Hermena (2021) found, even small changes to familiar spacing can greatly reduce reading efficiency. These findings, though rooted in L1 research, offer valuable guidance for addressing L2 reading difficulties. Teaching strategies must directly target these deep-rooted reading habits. Focusing on such perceptual and cognitive strategies is important not only for speeding up word recognition but also for helping learners develop the automaticity and fluency they need for successful second-language (L2) reading.

Bilingual Reading Strategies & Cognitive Load

Bilingual readers use a variety of strategies to manage the challenges of reading in a second language (L2). These strategies often involve balancing the mental effort, or cognitive load, required to decode unfamiliar input, while also relying on mental translation, background knowledge, and cultural familiarity. Eye-tracking studies conducted in L1 and L2 contexts reveal how deeply entrenched reading strategies, formed through L1 experience, shape real-time processing in bilingual reading. One particularly common L2 strategy is mental translation, silently converting words or phrases into the native language to aid comprehension. Although Alhazmi et al. (2019) did not directly measure mental translation, their L2-based findings offer indirect evidence: native Arabic speakers reading English exhibited longer fixation durations and higher fixation counts, suggesting decoding strain. As discussed earlier, the Arabic script traditionally omits short vowels, encouraging readers to focus on consonantal roots. This L1 reading habit may persist in L2 contexts, leading learners to underprocess English vowels, where they are critical for word recognition, and rely instead on L1 decoding strategies such as mental translation to resolve ambiguity and fill in gaps in understanding.

Similarly, Godfroid et al. (2018) observed that non-native readers tended to fixate longer on unfamiliar words, suggesting deeper cognitive engagement. These longer fixations may reflect processes such as inferencing, contextual integration, or form-meaning mapping, although they may also be influenced by factors such as lexical unfamiliarity and overall L2 proficiency. While this increased processing effort may impose a short-term cognitive cost, it can contribute to vocabulary learning when readers encounter words repeatedly in meaningful contexts. Over time, repeated encounters with the same unfamiliar words were shown to lead to more efficient processing: fixation durations decrease, and words are recognized more quickly. These findings highlight that both repeated exposure and cumulative reading practice are key to building fluency in an L2. Beyond the word level, background knowledge and cultural familiarity also help bilingual readers read more efficiently. Just as repeated exposure to a word makes it easier to recognize, prior knowledge of a topic can reduce fixation durations and help readers move more smoothly through a text. Recent research has also looked at whether multimodal input, such as reading while listening (RWL), can make L2 reading easier. In an important study by Conklin et al. (2020), researchers compared the reading behaviors of both L1 and advanced L2 readers under two different conditions: traditional silent reading (reading-only, RO) and reading while listening (RWL).

Surprisingly, they found that RWL did not lead to significant improvements in comprehension scores for either group. This challenges the common assumption that combining listening with reading automatically makes learning more effective. Although aligning audio and text might seem like it would help readers, in reality, it did not appear to make a meaningful difference in understanding, at least for more advanced learners. These findings suggest that while RWL might offer some support, especially for lower-proficiency readers, its benefits should not be overstated.

Discussion

This review set out to examine how reading behaviors shaped by the structural features of Persian and Arabic, such as right-to-left directionality, cursive connectivity, and reduced vowel representation, inform the development of L2 English reading. By synthesizing findings from both L1 and L2 eye-tracking studies, the review highlights how deeply visual and cognitive reading strategies from the first language can carry over and impact second-language processing. These insights are especially important given the underrepresentation of Persian and Arabic scripts in cross-linguistic reading research, and highlight core perceptual and cognitive strategies, such as segmentation habits, script navigation, and morphological parsing, that directly impact second language reading acquisition. These effects are particularly noticeable for learners whose first languages, such as Persian and Arabic, differ substantially from English in terms of orthographic structure, morphological complexity, and reading direction. For instance, studies on L1 reading behaviors have shown that Persian readers are highly sensitive to interword spacing (Hermena, 2021), and Arabic readers often exhibit vowel blindness due to script characteristics (Alhazmi et al., 2019). When these deeply ingrained habits are carried over into English reading, they contribute to measurable cognitive strain, manifesting as longer fixations, increased regressions, and difficulty with rapid word recognition.

In terms of lexical processing, research also offers useful insights. Amini et al. (2022), in an L2 study, found that the emotional valence of a word, whether positive, neutral, or negative, does not significantly influence word recognition speed. Instead, lexical frequency was the dominant factor: frequently encountered words elicited faster fixation times, reinforcing the role of familiarity and exposure in efficient reading. This pattern aligns with the lexical quality hypothesis, which posits that fluency depends on well-established mental representations of word forms. Further support comes from Godfroid et al. (2018), who showed that repeated exposure to unknown words gradually decreases fixation durations, providing compelling evidence for the role of incidental vocabulary acquisition. Although this study focused on L2 reading, its implications reinforce the idea that fluency is built through repeated, meaningful encounters with lexical items, regardless of emotional content.

These findings highlight the clear need for direct, language-aware instruction that helps learners overcome L1-based challenges in second-language reading. Given the structural and perceptual habits rooted in Arabic and Persian orthographies, instructional strategies must go beyond general reading pedagogy to accommodate the specific challenges faced by these learner groups. Arabic-speaking learners, for instance, may benefit significantly from targeted training in vowel recognition and processing, as their L1 promotes consonant-focused decoding habits that do not readily transfer to English. Persian-speaking learners, on the other hand, may require targeted support in adapting to English-specific word segmentation norms, especially due to their reliance on cursive ligatures and consistent interword spacing in their native script. For both groups, structured and repeated exposure to high-frequency English words is critical, not only for accelerating lexical access but also for fostering automaticity in word recognition, a key component of fluent and efficient L2 reading. These implications reflect the broader goal of this review: to provide evidence-based insight into how foundational L1 reading behaviors shape L2 development and to help tailor pedagogical interventions that acknowledge and build upon the unique literacy profiles of Persian and Arabic L1 learners.

Gaps in the Literature

Despite valuable insights into L2 reading processes among Arabic and Persian-L1 speakers, significant gaps in the literature remain. First, while studies such as Hermena (2021) have examined Persian L1 reading behaviors, particularly the effects of spacing in Persian cursive scripts, research specifically addressing how Persian readers process English, especially challenges related to orthographic unfamiliarity, morphological decoding, and directional adjustments, remains scarce. Although L1-only studies provide valuable insight, more research is needed to explicitly trace how these reading habits transfer during L2 learning. Second, several key demographic groups are underrepresented. These include older adult learners, low-proficiency learners (notably absent from Conklin et al.'s (2020) RWL study, leaving instructional claims for this group unverified), and speakers of non-standard L1 varieties such as Dari or regional Arabic dialects. Finally, the majority of studies reviewed have been cross-sectional in design, restricting insights into how L2 reading skills develop over time. Longitudinal studies are needed to capture the dynamic nature of L2 reading acquisition, allowing researchers to observe how cognitive strategies and reading behaviors evolve as learners gain greater proficiency. Such research would offer deeper understanding of the developmental trajectory of L2 readers, providing valuable information for both theoretical models of reading and the design of more effective instructional interventions.

Practical Implications

The findings from eye-tracking research suggest several practical strategies to help Persian and Arabic-L1 learners develop stronger English reading skills. First, explicit training in vowel recognition should be prioritized for Arabic-speaking learners. Since the Arabic script omits short vowels, many learners develop a habit of overlooking vowels when reading English texts. Structured exercises that focus on recognizing and pronouncing vowels, such as using minimal pairs like "bit" and "bat", can help retrain reading habits and reduce confusion (Alhazmi et al., 2019). Instruction must also address the unique visual habits of Persian readers, who rely heavily on familiar interword spacing and connected letter forms in their native script. Clear instruction on word segmentation in English, which uses distinct spacing between words, is essential. Activities that emphasize identifying word boundaries and practicing reading with varied spacing can help learners transition smoothly to the non-cursive, space-dependent English script (Hermena, 2021).

Vocabulary instruction should prioritize high-frequency words, as these are recognized and processed more quickly, regardless of emotional tone (Amini et al., 2022). Designing extensive reading programs that expose learners repeatedly to common vocabulary will enhance reading fluency. Repetition across different contexts helps learners internalize word forms and meanings more naturally. Additionally, introducing culturally familiar texts, such as simplified stories from learners' home cultures, can ease cognitive load. When the content feels familiar, learners can focus more on decoding the new language instead of struggling with unfamiliar topics (Zahedi & Khoshsaligheh, 2019). This approach can make early reading experiences in English less overwhelming and more motivating.

For learners whose L1 is read right-to-left, such as Arabic-speaking learners, gradual and guided exposure to left-to-right reading conventions is essential. Simple practices like tracing English sentences from left to right or scaffolded reading tasks that reinforce leftward eye movement can ease the directional shift and help establish more natural reading patterns. By thoughtfully applying these strategies, educators can better support Persian and Arabic L1 learners in overcoming specific linguistic and cognitive challenges. Targeted interventions in vowel recognition, segmentation practice, vocabulary repetition, and cultural scaffolding can support more accurate decoding. In turn, this promotes stronger fluency, deeper comprehension, and greater confidence in L2 reading.

Conclusion & Future Research Directions

This review highlights how differences in L1 orthography, morphology, and script directionality impose notable cognitive demands on L2 readers, as evidenced in the reading behaviors of Persian and Arabic L1 speakers. Eye-tracking research offers critical insights into these real-time processing difficulties, with factors such as word frequency, vowel salience, and reading direction playing central roles in shaping reading efficiency.

In contrast to many reviews that focus primarily on L2 reading outcomes, the present review emphasizes the role of L1-specific orthographic and perceptual influences on L2 reading development. It makes three main contributions. First, it synthesizes eye-tracking evidence from both L1 and L2 reading contexts to demonstrate how deeply embedded L1 processing habits, such as vowel blindness in Arabic readers and reliance on spacing cues in Persian readers, may continue to influence L2 English reading. Second, it brings together research on Persian and Arabic, two orthographically complex and comparatively underrepresented scripts, providing a cross-linguistic perspective that has received limited attention in previous reviews. Third, it translates eye-tracking findings into empirically grounded pedagogical recommendations that address specific L1 transfer effects, including vowel processing and word segmentation challenges. These findings also highlight critical areas for pedagogical intervention and guide the next steps in research:

- Designing and evaluating targeted interventions that address L1 transfer effects, especially vowel training for Arabic speakers and segmentation practice for Persian learners.

- Conducting longitudinal studies to track how reading strategies and processing efficiency evolve with growing L2 proficiency.

- Assessing multimodal learning approaches, such as reading-while-listening (RWL), across different proficiency levels, with a particular focus on beginner learners.

- Exploring the effectiveness of culturally familiar materials and emotional engagement in enhancing L2 reading comprehension and learner motivation.

Addressing these gaps will advance our understanding of L2 reading development and support the creation of more effective, evidence-based instructional strategies for diverse learner populations.

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