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ARTICLE

Reading alphabetic and nonalphabetic writing systems: A case study of bilingual teachers' reading processes through eye movement miscue analysis

Yang Wang  | Ismahan Arslan-Ari  | Ling Hao  | Kyungjin Hwang 

Reading in a second language (L2) is a complex process that involves various reading skills and strategies (Cohen & Henry, 2020; Kung, 2019). To help teachers understand the reading processes of students from culturally and linguistically diverse backgrounds, educators and researchers need to learn more about reading in multiple languages. Understanding bilingual speakers' reading in their first language (L1) and the differences between those two languages is crucial for bilingual learning and teaching. Chinese and Korean are two widely spoken non-Roman-alphabetical languages in the world. Their grammar rules, word boundaries, and discourses are different from those in English, which affects those language speakers' reading. However, there are limited studies addressing nonalphabetic bilingual speakers' reading processes. To address this need, our study aimed to investigate bilingual reading processes. Specifically, we explored this research question: How do adult bilingual speakers read digital texts in their L1 and L2 through Eye Movement Miscue Analysis (EMMA)? This study is significant because it supports the understanding of nonalphabetic language speakers' reading process, adds to our understanding of the bilingual reading process, and provides implications for bilingualism.

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

Reading is a transactional sociopsycholinguistic process (Goodman, Fries, & Strauss, 2014; Goodman, Martens, & Flurkey, 2014). Readers use all the language-cueing systems to make meaning of the text no matter what languages they speak (Goodman et al., 2005). These language-cueing systems include linguistic systems and pragmatic systems (Watson

et al., 1988). Readers bring their background knowledge and construct their understanding of the text as they read (Rosenblatt, 1994). During transaction and active meaning construction, readers make variations from the text—miscues (Goodman, Fries, & Strauss, 2014; Goodman, Martens, & Flurkey, 2014). Readers may make high-quality miscues that are syntactically and semantically acceptable and do not change the text meaning and low-quality miscues that are syntactically and semantically unacceptable and change the text meaning. All readers make miscues, and analyzing those miscues informs readers' reading strategies and comprehension process (Goodman, Fries, & Strauss, 2014; Goodman, Martens, & Flurkey, 2014; Moore & Gilles, 2005).

Reading in an L2 is a crosslinguistic and complicated process (Koda, 2013). Many factors impact this process, such as reading in L1, readers' L2 proficiency, L2 decoding ability, readers' prior L1 and L2 literacy experience, and metalinguistic awareness (Koda, 2013; Koda & Zehler, 2008). Adult learners activate their L1 and L2 language systems and integrate their prior knowledge for meaning and high-level thinking (Song et al., 2020). L2 readers utilize several strategies including examining the text feature, studying the vocabulary, monitoring understanding, using the contexts, translating, etc. (Cohen & Henry, 2020). Readers transfer their reading skills across languages and use more strategies when reading in an L2 (Koda, 2013).

Chinese language

Chinese language uses a logographic writing system, and the character is the basic grapheme in Chinese orthography (Sung & Wu, 2011). The four tones, including high-level, high-rising, falling-rising,

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and high-falling, reduce the number of homophones and distinguish meaning (Taylor & Taylor, 2014). Chinese written and spoken forms are independent, while English written and spoken forms are related by sounds (Bawa & Watson, 2017). Compared to English, there are fewer grammar rules in Chinese syntactic structure, such as subject–verb agreement or marked plurality (Wang & Yang, 2008). Therefore, Chinese readers “focus on the individual word meanings and their semantic relations” (p. 129). Since there are no word boundaries between each character, readers need to check the syntactic and semantic relations to identify words and understand the text. Although both Chinese and English rely on word order to construct meaning, Chinese sentences have a more flexible and simpler word order.

Chinese readers need metalinguistic competencies, which include orthographic knowledge, grapho-phonological awareness, grapho-morphological awareness, and sentence processing skills (Wang & Yang, 2008). Studies have shown that morphological awareness and cultural schemata could affect readers' L1 comprehension (e.g., Li & Lai, 2012; Wang et al., 2006). Additionally, Hung (2014, 2019) examined elementary students' reading in Chinese using an eye-tracker and found they paid more attention to the print than the illustrations; participants who fixated more on illustrations understood the text better. Jian (2016) found that fourth graders reread the title and previous paragraphs of Chinese biology texts frequently to monitor their comprehension. When comprehending English texts, Chinese readers employ various reading strategies (e.g., Wang, 2019; Zhou & Zhao, 2014). Like their L1 reading, readers' morphological awareness (Zhang & Koda, 2014) and multicultural awareness (Zhang et al., 2021) affect their reading comprehension. Furthermore, factors including oral language proficiency, the amount of exposure to English, and phonological awareness could influence Chinese readers' comprehension of English (Jiang, 2016).

Korean language

The Korean language, Hangeul, is a non-Roman alphabetic orthography consisting of 24 basic symbols of 14 consonants and 10 vowels (Park, 2008). Sound–symbol correspondences are highly transparent and syllable formation rules are relatively simple (Taylor & Taylor, 2014). The basic word order of a sentence is subject–object–verb, but this word order is relatively free because Korean has postpositional case markers that indicate the grammatical roles of sentence components (Park, 2008). While English has a linear sequence of letters, Korean symbols are combined into syllable blocks (Park, 2008). Therefore, individual Korean symbols cannot be used independently but

must be packaged within syllable blocks to form words (Park, 2008). Additionally, the Korean inflectional and derivational systems of verb and adjective affixes are more extensive. Multiple suffixes can be attached sequentially after Korean predicates of verbs and adjectives, each providing different grammatical information such as tense, politeness, and sentence type (Cho & Whitman, 2019; Park, 2008). Last, while English is a stress-timed language, Korean is a syllable-timed language in which syllables take almost equal time to pronounce (Lee & Kim, 2005).

Many studies have investigated the Korean reading process and the structural and grammatical aspects of sentences, but only a few used eye-trackers. For example, Kwon et al. (2010) investigated factors affecting subject/object asymmetry in processing prenominal relative clauses in Korean and reported that object-relative clauses are more difficult to process than subject relatives. Another study conducted by Noh et al. (2013) demonstrated that there was no significant difference in the processing time by the type of negations in Korean. In their eye-tracking study, Lee et al. (2007) found that the association between the type of noun phrases and syntactic position influenced comprehension. Overall, these studies have provided critical information about linguistic and structural aspects of understanding Korean reading.

Previous EMMA studies

Scholars have conducted reading miscue analysis with English as second-language learners (ESLs) who use other languages, such as Arabic (Almazroui, 2015), Chinese (Blair et al., 2022; Wang, 2019; Wang & Gilles, 2017), Korean (Kim, 2010; Kim & Goodman, 2012), and Spanish (Moteallemi, 2010). There are limited studies to compare bilingual learners' reading processes using EMMA in which eye movement and miscue analysis were combined to indicate readers' eye fixations and verbal production of reading print texts (Liwanag et al., 2022). Fixation is the time when the eye is at rest for at least 150 milliseconds (Cook & Wei, 2017). Paulson (2000, 2002, 2008) first applied an eye-tracker in reading miscue analysis and invented EMMA to examine the monolingual reading process. In his study of college undergraduate students reading fictional narrative text, Paulson found that miscues were not caused by readers' careless reading or omitting words. Readers only fixated on approximately two-thirds of the text and typically fixated on an omission as well as a substitution. Results suggested that reading is a perceptual process as the eyes deliver information to the brain, and the brain interprets the information it receives.

Additionally, most previous EMMA studies worked with children reading picture books and found that

reading is a nonlinear process, reading is more than accurate word decoding, and readers used multimodal signs, such as print text and pictures, for comprehension (Kim & Meyer, 2017; Liwanag et al., 2016, 2017, 2020). Duckett (2002) found that young readers fixated on 65%–91% of the words in the text, and their fixation durations were not uniform. He reported that fixation durations on the same word varied in different contexts, and fixation locations within the exact words varied. He found that readers usually had longer fixation time on miscued words and content words. Additionally, Porter et al. (2020) reported adult readers fixated more on content words than function words to extract important ideas for understanding the text.

Dirix et al.'s (2019) eye-tracking study found that bilingual participants spent more time examining L2 texts compared with L1. Participants in Cop et al.'s (2015) study made more and longer fixations in L2 than in L1, displayed shorter lengths of saccade, which is the rapid eye movement between the fixations, and skipped fewer words in L2. Previous studies mainly focus on bilingual learners' reading in English (e.g., Wang, 2019; Wang et al., 2022; Wang & Arslan-Ari, 2021), whereas this current study will showcase adult bilingual teachers who use different L1s.

In addition, some previous EMMA researchers studied bilingual Spanish and English speakers (Ebe, 2008; Freeman, 2001; Nelson et al., 2008). They suggested that reading is a universal transactional socio-psycholinguistic process and readers used similar strategies in both languages. Moreover, bilingual readers fixated more and for a longer time than monolingual readers (Duckett, 2008). ESLs integrated all language-cueing systems more effectively in their L1 and reread more frequently in their L2 (Ebe, 2008). This current study will illuminate the reading processes of Chinese and Korean languages and add to our understanding of the expansion of languages and bilingual reading.

METHODS

This case study (Glesne, 2016; Stake, 1995) targets a bounded case of two bilingual readers who use different L1s. This study was approved by the University IRB

and conducted in the Human–Computer Interaction Lab at a large research university in the southeastern United States. Two participants were recruited following the criteria: they were proficient in English and one other language, and they were bilingual teachers in a graduate program. The two female participants Lulu and Dami's (pseudonyms) L1s are Chinese and Korean, and their informed consents were obtained prior to the beginning of the study. They both began learning English as an L2 in upper elementary school and completed their K-12 education and bachelor's degrees in their home countries. In the United States, they were pursuing their doctoral degree and taught at community heritage language schools (see Table 1).

This study is part of a larger project exploring bilingual teachers' reading perception and strategy use. This case study focused on the read-aloud and re-telling sections. Each teacher was trained and participated in two sessions and read the same text in English in the first session and different texts in their L1 in the second session. Yang selected English and Chinese texts and invited another multilingual teacher to recommend Korean texts. All texts are 500-to-1000-word long excerpts (see Table 2) from academic articles published in education journals; the content pertains to the participants' learning and research areas. The English text titled *The Social Construction of a Reading (Dis)ability* (Kabuto, 2016) is approximately college level (Lexile, 2021). The Chinese text about second language acquisition (Qin & Dai, 2013) and Korean text about bilingual writing (Lee & Jeon, 2014) are around the same difficulty level for college students from the researchers' evaluations. All texts share similar features: printed text, in-text citations, subheadings, and embedded graphs. Each text was retyped in a PowerPoint document with the same text size and similar layout on four pages for consistent screen display on the computer monitor. The graph was embedded within the text on one slide.

At the beginning of each session, participants' eye movements were calibrated with nine fixation points by asking them to follow nine calibration dots on the screen. Then, participants read aloud text on the screen while the Tobii Pro X3-120 screen-based eye-tracker attached to the 15-inch laptop screen recorded

TABLE 1 Participants' information.

Name	L1	Home country	Age	Years in the US	Background	Teaching experience	
						Home country	US
Lulu	Mandarin Chinese	Mainland China	28	5	BA in English Education, MEd in Reading	3 years of K-12 English	3 years of Chinese as a heritage language
Dami	Korean	South Korea	36	2	BA & MEd in English Education (TESOL certificate)	9 years of middle/secondary English	2 years of Korean as a heritage language

TABLE 2 Eye movement miscue analysis data.

Reader	Lulu		Dami	
	English	Chinese	English	Korean
Text total length	1025	1566	1025	1553
Miscue per hundred words	2.14	0.76	1.9	1.13
Retelling %	78	76	65	59
Meaning construction %				
No loss	68.42	80	47.1	85.7
Partial loss	15.79	10	23.5	7.15
Loss	15.79	10	29.4	7.15
Grammatical relation %				
Strength	36.84	60	41.2	64.3
Partial strength	15.79	10	5.9	7.15
Overcorrect	31.58	30	11.7	2.15
Weakness	15.79	0	41.2	7.15
Graphic similarity %				
High	86.67	25	60	44.44
Some	6.67	50	30	27.27
None	6.67	25	10	27.27
Sound similarity %				
High	80	0	60	36.36
Some	13.33	50	30	45.45
None	6.67	50	10	18.18
Integrative transition (frequency)	40	36	15	6
Total reading duration (second)	364.98	265.23	591.44	871.64
Text fixation duration (%)	92.44	87.39	92.73	96.02
Image fixation duration (%)	3.58	6.8	3.27	2.47
Total fixation count	2473	1739	2486	1404

their eye movements simultaneously. Eye movements were recorded with a sample rate of 120Hz which is optimal for reading studies (Leube et al., 2017) binocularly. Participants were allowed to navigate between the pages. After reading, they retold what they had just read.

All sessions were recorded and transcribed for analysis. We listened to the reading recordings, marked the miscues—any variations from the texts—analyzed each miscue for syntactical and semantical acceptability, meaning change, and graphophonetic similarity, and evaluated retellings following the Reading Miscue Inventory in-depth procedure (Goodman et al., 2005). See results in Table 2. Then, the Chinese-speaking lead researcher and one research assistant, who spoke Korean and had the miscue analysis training, checked the miscue markings, transcribed the retelling and conversations, and translated Chinese and Korean into English. They reached a consensus through discussion when they disagreed with the miscue markings and coding.

Eye movement data were analyzed through Tobii Pro Studio software. After the area of interests (AOIs) were determined for the text and figure, total fixation duration and fixation count for all AOIs and transitions were calculated. Also, gaze plots and heat maps were used to understand critical aspects of participants' eye movements.

All research team members shared similar English as an L2 learning experience. As member checking (Glesne, 2016), the participants were invited to provide their insights and interpret the data. The research assistant also contributed to the coding and analysis when checking the data. A thick description was provided for reporting (Glesne, 2016).

LULU'S READING IN ENGLISH

Lulu made 2.14 miscues per hundred words reading English text. About 84% of the miscues had *no loss* or *partial loss* in meaning construction, and 84% had

strong or partial grammatical relation or even *overcorrect* (see Table 2). The graphic similarity and sound similarity are both high. She used all the linguistic systems, and her eyes revisited the subheadings and the topic sentence of each paragraph as the eye-tracker recorded. When she retold the text, she stated the central purpose, listed the key points, mentioned some details, borrowed keywords from the text, and followed the text structure. Lulu used her pragmatic systems, including context of situation and background knowledge, to predict.

Lulu's eyes fixated longer on substituted texts. For example, Lulu made a nonword substitution “\$deriavative” (quotation marks indicate miscue and \$ indicates nonword) of the word *derivative* (italic indicates the text). This substitution looks and sounds like the text. The miscue and longer fixation indicate that Lulu spent more time using graphophonic information to read this word. Sometimes, Lulu's eyes only fixated on a portion of a word. For example, when she read the multisyllabic word *Transgenerational*, her eyes did not fixate on the *-al* suffix and she read “transgeneration” the first time she encountered this word. When she saw it again in the subheading on the next page, she made the same miscue and immediately corrected it. Her eyes fixated on the suffix *-al* this time and regressed when she corrected it.

Lulu's eyes did not fixate on every word, such as function words like *the*, *with*, and *and* even though she read them aloud. The article *the* appeared 70 times in the text. Miscue data show that Lulu omitted it twice and inserted it once, and they were all syntactically and semantically acceptable and did not change meaning. The gaze plots show that her eyes fixated on *the* 41 times (59%). Figure 1 shows that her eyes did not fixate

on *the* twice in the first two sentences. Skipping it did not affect her comprehension. Additionally, Lulu's eyes did not fixate on her omission miscues, and her eyes regressed to correct some.

Lulu made some dialect-related miscues (i.e., syntactical and phonological), and her eyes fixated on them. Although she struggled to read aloud some words in English, she understood their meanings. Her eyes fixated on all syntactical dialect miscues regarding tense (past, present) and form (singular, plural). There are two types of eye fixations in her phonological dialect miscues. Most of the time, her eyes fixated on every syllable as she pronounced it. For instance, she pronounced *focus* /fokurs/ and *components* /kumponents/. Occasionally, her eyes fixated on the first or last part of a word. Even for the same word that appeared multiple times, her eye fixations were different. In Table 3, when the word *Sociopsycholinguistic* appeared for the first time, Lulu's eyes fixated on “Sociopsycholing-” and she pronounced it as “\$Socialpsycholinguistic.” However, when it appeared for the second time, she read it the same and her eyes fixated on every syllable. Then, when Lulu encountered it for the third time, her eyes fixated on the first part “Sociopsycholinguis-.” She did not change her pronunciation and read it the same as the previous attempt.

Lulu used the image frequently while she read. She considered herself a visual learner and talked about the importance of using pictures to make sense of the print text in her retelling. Compared to Dami, Lulu made more integrative transitions between text and image (Table 2). Even before reading the text, she began to look at the image. Her reading speed was slower than when she read other pages without images. She

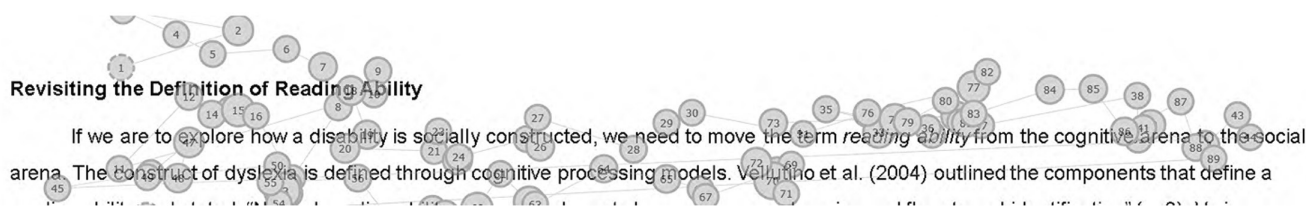
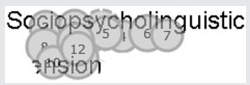




FIGURE 1 Lulu's gaze plot.

TABLE 3 Lulu's gaze plots on “Sociopsycholinguistic.”

Text: Sociopsycholinguistic	First time	
Dialect: \$Socialpsycholinguistic	Second time	
	Third time	

constantly interacted with the image whenever the text referred to it. After reading the paragraph describing the figure, Lulu's eyes moved to the figure and examined it. Then, her eyes returned to the text and reread that paragraph before moving on. Her rereading shows that she was using the image to understand the text.

LULU'S READING IN CHINESE

Lulu made fewer miscues reading in Chinese. She did not make any repeated miscues or nonword substitutions. Her meaning construction was high, and all miscues had *strong* grammatical relations (Table 2). About half miscues had *high* or *some* graphic and sound similarities. Even though Lulu retold in Chinese, she switched to English for some terms. The text embedded English words, and she reported that she was more familiar with the English definitions. Her retelling score was a little lower. She read Chinese text faster and her eyes moved faster when reading Chinese text. Her eye movements show that Lulu reread the passage multiple times silently, especially the subheadings and topic sentences of each paragraph.

In the Chinese reading, Lulu's eyes fixated on all the omitted words, which was different than her English reading. For example, Lulu omitted the character 和 (and) in a sentence. However, her gaze plot indicates that her eyes fixated on this character.

Lulu's eyes did not fixate on some content words but still read them aloud: 学习者 (*learner*), 社会文化 (*social culture*), and 语言 (*language*). Additionally, Lulu's eyes sometimes did not fixate on the function word, the particle character 的, which is a structural particle similar to "s" in English, for example, 学生的互动学习 (*learners' interactive learning*). This character is the most widely used in Chinese. Lulu's gaze plots indicate that her eyes did not fixate on this particle. In Lulu's oral reading, she did not omit it and inserted it once, and her gaze plots show that she fixated on 31 of 69 occurrences (45%). This shows that Lulu was using her linguistic knowledge to predict the text.

Lulu relied on image assistance in her Chinese reading. She looked at the figure many times and read the descriptive text. After she finished reading the text, she regressed to the figure and cross-checked it with the text. She looked at the text and tried to locate the corresponding section in the figure. For example, when the text read (见图1, 微观部分; see Figure 1, *Micro section*),

Lulu's eyes moved to the figure and looked at the *Micro section* in it. As indicated in her gaze plot, she looked at the figure and then went back to the sentence to reread the text. Lulu made more integrative transitions between text and image in her L1 reading (Table 2).

DAMI'S READING IN ENGLISH

When Dami read the English text, she made 1.9 miscues per hundred words (see Table 2). The meaning loss and weakness in grammatical relations in English were significantly higher than those in Korean. One reason could be that she often omitted or mispronounced the word suffixes. For example, she left out -ive of constructive in *a constructive process*, and -al of cultural in *cultural space*. Also, she read *historicity* as "historical." She sometimes mispronounced some words as nonwords, such as replacing *transgenerational* with "\$transgener."

Dami's eyes fixated on the text longer when she corrected and repeated the text. For example, when reading *the question of why*, Dami reversed two words in the first attempt ("the question why of") and then omitted "the" in the second attempt ("question why of"). And finally, she corrected it as it was printed in the text. As shown in Figure 2, her eyes fixated on the text longer than on other parts.

Although Dami's eyes fixated on some omissions and substitutions, she did not correct them. Specifically, her eyes fixated on some omitted words, which were mostly articles such as *a* and *the*. She fixated on her omissions of "the" in *the reading of texts* and in *the individuals* and "a" in *that reading is a constructive process*. Also, while fixating her gaze on the word *people* in *with other people*, she omitted it. Even when Dami substituted *the* with "a" in *through the sociocultural*, she fixated her eyes on *the*. Overall, function words such as articles (e.g., *a*, *the*) and collective nouns (e.g., *people*) did not affect her meaning construction, and she could infer from the context before and after. Therefore, omitting them in the read-aloud or skipping in the eye movement did not result in any meaning loss.

Dami displayed language-related phonological differences; however, she understood word meanings and these differences did not cause any meaning loss. Hence, she did not attempt any correction nor perceive them as miscues. In her phonological dialects,

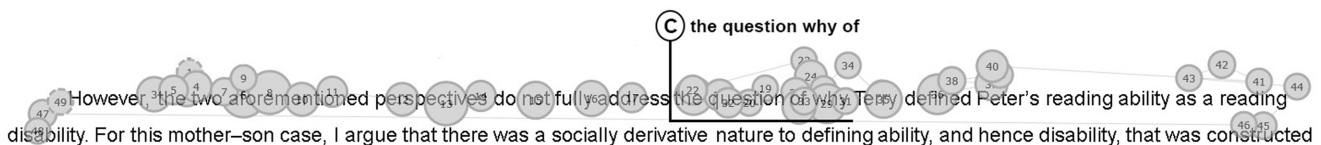


FIGURE 2 Eye fixation on correction and repetition.

there were three different types of eye fixations. Most of the time, she fixated on the entire word, but sometimes her eyes fixated on half of the word or none at all. Interestingly, some eye fixations varied on the same word in different contexts in the text. She fixated on every syllable of *sociocultural* and read as “\$socialcultural,” but did not fixate when she encountered it later in the text.

When reading text on pages containing images, Dami's eyes fixated more on the images with English text. They transitioned between the text and the image as she read and regressed to the former text for re-reading. Her gaze plots provide evidence that she used the image to understand the text and verify her understanding.

Dami's reading in Korean

Dami made fewer miscues in Korean, and most miscues did not significantly cause meaning change and had *strong* grammatical relations (Table 2). More than half miscues had *high or some* graphic and sound similarities. Dami's total fixation duration was longer when reading Korean compared to English, indicating that Dami spent more time understanding the Korean text. However, her Korean retelling score was lower. Yet, her eyes fixated mainly on the text and rarely on the image, and the integrative transition between text and image was rare.

In English, Dami's eyes fixated on the text longer in the case of correction or repetition, but this pattern was not observed in her L1 reading. Dami's Korean miscues were mostly substitutions, and her eyes fixated on most of them. Although some miscued texts were fixated longer than non-miscued ones, longer fixation was not limited to miscued texts; this occurred randomly in both miscued and non-miscued texts. Her overall fixation duration in Korean was longer than in L2 (Table 2).

Dami's eyes fixated mainly on content words and often did not fixate on function words for meaning making. For example, Dami read the text without fixating on several postpositional particles. In Korean, postpositional particles play a functional role in a sentence. In this text, “는” in *본 연구는* (*the current study*) indicates the subject position as a subject marker. “을” in *차이점을* (*differences*) is an object marker. “의” in *학습자의* (*of learners*) plays a similar role as *of* in English. Dami's eyes barely fixated on those postpositional particles. In addition, they did not often fixate on “다” as shown in *분석하였다* (*analyzed*) and *논의하였다* (*discussed*). “다” is a sentence-final ending used when describing a certain event, fact, or state. “다” appears 24 times in the entire text, but Dami only fixated on it five times.

Dami had a longer fixation duration and longer saccades in Korean text and made fewer integrative

transitions between the text and the image in her L1 reading (Table 2). Also, her image fixation duration was much shorter than the text fixation duration when she read in Korean. These results show that Dami relied less on the image in her L1 reading.

CROSS-CASE ANALYSIS AND DISCUSSION

Use of language systems

Both participants made fewer miscues in L1. Their L1 meaning constructions were higher and grammatical relations were stronger. Their L2 substitution miscues had higher graphic and sound similarities, which shows that they were over-relying on the graphophonetic cueing system. They had higher retelling scores in L2. The reason could be that they were more familiar with the content in English and more proficient in reading L2 academic texts. Like earlier studies with Spanish speakers (Ebe, 2008; Freeman, 2001; Nelson et al., 2008), these Chinese and Korean-speaking participants also used all linguistic and pragmatic language systems, which reveals that reading is a universal transactional socio-psycholinguistic process (Goodman, Fries, & Strauss, 2014; Goodman, Martens, & Flurkey, 2014). Bilingual speakers may use one or more dominant systems in one language and use different ones in the other language. Overall, they used similar cognitive reading strategies and all language-cueing systems in both languages.

Eye movements and miscues

Across different languages, the participants' eyes fixated on the substituted text, whether they corrected their miscues or not. Like Paulson's (2008) study with monolingual readers, both participants fixated on some words they omitted in their read-aloud. The participants' eyes may not fixate on articles in their L1 and L2; however, they may read these words aloud. This study extends previous studies (Duckett, 2002; Paulson, 2008) and shows similar results of readers not fixating on all the words and fixating less on function words in both languages. Additionally, the participants' eyes usually regressed when they corrected; however, they also corrected without regression. Therefore, they did not simply rely on what they saw to understand the text. Our bilingual participants did not read word by word in either language, and their eyes constantly regressed to gather information. This expands our understanding of previous studies with monolingual speakers and ESLs (Liwanağ et al., 2017; Paulson, 2008) and provides implications for teachers that reading is a nonlinear process.

Similar to Duckett's (2002) study, our participants had longer fixation times on miscued words, and their fixation locations on the same word varied in different contexts. They fixated on a portion of some multisyllabic words. Our participants had more fixations and shorter lengths of saccade in L2, which is aligned with Dirix et al.'s (2019) findings. The shorter length of saccade indicates more cognitive processing. When the text becomes difficult, the length of saccade gets shorter (Rayner et al., 2006). However, Dami's fixation durations were longer in L1, which contradicted Cop et al.'s (2015) results. Therefore, the relationships among fixation duration, time spent reading, language, and comprehension are inconclusive.

Language variations

The participants had two types of language-related differences caused by language differences between their L1s and L2: phonological dialects and syntactical dialects, which are high-quality miscues (Goodman et al., 2005). When the participants knew the words, their phonological dialects that varied from English speakers did not affect comprehension. Their eyes fixated on those words. For example, Dami sometimes struggled pronouncing long vowels because the Korean language often contains short vowels. However, the participants did not fixate on syntactical dialects. For example, Lulu missed a few past tenses in the English text. As shown in the earlier research (Wang et al., 2022), Chinese-speaking ESL learners left out -ed ending because the Chinese language used either another word marker or time marker for past tense, and there is no suffix change for Chinese words.

Additionally, both participants omitted some articles like *the* and *a* in English, and their eyes did not fixate on the articles for most of the time. They did this subconsciously as they read, and it shows that they focused on understanding the meaning of the text. Similarly, the eye movement data show that their eyes skipped many articles in their L1s, too. Those language variations show the L1 influence on L2 reading; however, they do not affect their L2 comprehension. That means that participants used their full linguistic repertoires in their reading processes, and each language did not work as an isolated system (García & Kleifgen, 2019).

Image use

Lulu and Dami made more integrative transitions between the text and graph in L2 than in L1. That

means they used more visual information in L2. As earlier studies show, young readers and monolingual speakers used multimodal signs for comprehension (Kim & Meyer, 2017; Liwanag et al., 2020); this study found that visual information helps bilingual adult learners in their reading. No matter what languages our participants spoke, using visual aids in the text facilitated their comprehension. Lulu used more visual aids and had more integrative transitions than Dami. Lulu's comprehension scores were higher, which corroborates Jaafar et al.'s (2018) findings related to a positive relationship between ESLs' comprehension and their integrative transitions. Lulu determined if the text description and image matched while she read. Additionally, she made multiple integrative transitions to pinpoint the exact place in the image. This shows that she actively chose and organized the relevant text and visual information and integrated those to create mental models for meaning construction (Mayer, 2020). Mason et al. (2013) also stressed that the creation of meaningful integrative links between the text and image is essential for optimal comprehension of a multimodal text. In previous EMMA research, Hung (2019) found that visual aids benefitted Chinese-speakers' reading comprehension. Our study makes an important contribution to the literature by extending our understanding of non-Roman alphabetical-speaking bilingual learners' use of images during reading. It suggests that using visual aids can help bilingual readers' meaning-making.

CONCLUSION

This case study shows the distinctive characteristics of the unique English as an additional language reading processes of two non-Roman-alphabetical language readers. Knowing those characteristics would help educators and teachers bridge the differences between multiple languages and help bilingual speakers achieve academic success. Teachers need to understand that readers may comprehend the text that they do not fixate on or omit in read-aloud. Conversely, they may read words aloud accurately but not comprehend them. The similarities and differences between the two bilingual readers in terms of the use of language systems, eye movements, language variations, and image use have implications for bilingual teachers. Therefore, teachers could guide students to use all language systems, integrate information from text and images, and embrace their linguistic repertoire.

This study has limitations and offers implications for researchers and educators. Two bilingual users of different L1s participated in this study. Each participant

only read one text in L1 and one in English. Therefore, data may provide limited information on the reading process for nonalphabetic L1 users, as each reader may have varied familiarity with the text format, the text feature, and the content. Other factors, such as learning styles, personalities, and aptitudes, may affect the L2 reading process. Future research could compare the reading processes of users of Roman alphabet-based and nonalphabetic writing systems and continue to investigate the unique language usage and knowledge of individual bilingual readers to understand better how they interact with texts with various visual and organizational features.

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CONFLICT OF INTEREST STATEMENT

No potential conflicts of interest were reported by the authors.

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