Language and Cognition (2025), 17, e69, 1–28
doi:10.1017/langcog.2025.10028

ARTICLE

The effects of interword spacing and morphological complexity in reading Thai: an eye-tracking study

Suphasiree Chantavarin[1] and Tommi Tsz-Cheung Leung[2]

[1]Faculty of Psychology, and COgnition Audition and LAnguage (CoALa) Research Group, Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand and [2]Department of Cognitive Sciences, United Arab Emirates University, Al-Ain, UAE
Corresponding author: Tommi Tsz-Cheung Leung; Email: leung@uaeu.ac.ae

(Received 30 November 2024; Revised 22 June 2025; Accepted 17 July 2025)

Abstract
This study examined how word identification is influenced by interword spacing and morphological complexity in Thai, a script without interword spacing. While previous research supported the facilitative effect of interword spacing on Thai word identification , they did not account for the potential effects of the words' morphological structure. The challenge of word identification becomes more pronounced when readers have to identify compound words (e.g., *bathroom*) when reading sentences without interword spacing. In an eye-tracking experiment that manipulated interword spacing (unspaced, spaced) and noun type (bimorphemic compound, monomorphemic) in Thai sentences, we confirmed previous findings that interword spacing has a facilitative effect on word identification, as evidenced by shorter first fixation duration, gaze duration and total fixation time. Furthermore, we observed an interaction effect indicating that interword spacing had a larger facilitative effect on the identification of compounds compared to monomorphemic words. Our results also revealed that the morphological structure of Thai words can influence saccadic movements, e.g., the first fixation landing position was closer to the beginning of compounds than to simple words. We suggest that the orthography-language interface, a language-specific feature, should be considered a major component in eye movement models of reading.

Keywords: compounds; eye tracking; interword spacing; morphology; reading; Thai

1. Introduction

Reading is a complex cognitive task. In the normal reading setting, readers must first decode the language-specific orthographic symbols to segment the lexical (i.e., word) units and, potentially, morphological units of complex words. Some models of eye movement control in reading, originated from some experimental work on English, assume that interword spaces facilitate lexical processing in reading (e.g., E-Z Reader model; Reichle et al., 1998, 2003). While the significant impact of interword spacing on lexical and sentence processing has been well established (e.g., Rayner et al., 1998, among others), these Anglocentric models make no specific claims regarding the mechanisms of word segmentation and saccadic programming in writing systems without interword spaces. Such writing systems, while relatively less common, do exist and do not seem to pose any reading problems for native readers. Thai, for instance, is an alphabetic language like English but is typically written without spaces between words. This raises important questions about how readers of unspaced scripts segment lexical units and coordinate eye movements during reading.

Characterizing the process of lexical processing in reading is further complicated by the fact that what constitutes a written word may be somewhat ambiguous across scripts, especially in writing systems that have no spaces between words (Evertz-Rittich, 2020; McBride-Chang et al., 2012). For example, polymorphemic words such as compound words (e.g., *bathroom*) create ambiguity in eye guidance and word identification when reading scripts that do not contain interword spaces. Defining the concept of a ‘word’ as the unit of analysis in reading across scripts is an essential first step toward developing comprehensive models of lexical processing in reading across different writing systems (McBride-Chang et al., 2012). To this end, the Chinese reading model (CRM; Li & Pollatsek, 2020) and the Chinese E-Z reader model (CEZR; Liu et al., 2024) have recently been developed to characterize eye movement control in reading Chinese, another ‘unspaced’ language. These two models serve as a starting point for understanding eye movement control in reading Thai, although the fact that Chinese is a logographic writing system may limit the extent to which they can account for reading an unspaced alphabetic writing system like Thai. The present study contributes to this line of research by using Thai compound words to investigate how interword spacing and morphological complexity affect eye guidance and word identification in reading Thai. The study tests the role of interword spaces in facilitating eye guidance and lexical processing and examines how this physical cue interacts with the morphological processes involved in word segmentation and lexical retrieval in reading Thai.

1.1. Spacing effects in reading

Prominent models of oculomotor control assume that interword spaces provide low-level word boundary information which serves as an important cue in guiding the decision of where to move the eyes next (Li & Li, 2013; Rayner et al., 1998; Rayner & Pollatsek, 1996; Slattery & Rayner, 2013; Xia et al., 2023; Zang et al., 2013). This view is supported by findings from Latin-script languages which compared eye movement patterns when reading normally spaced texts compared to texts with the spacing information removed or manipulated. Removing or replacing the spacing with other characters led to disruptions in eye movement patterns that indicate reading difficulty, such as making more and longer fixations, more regressions and shorter progressive saccades (McGowan et al., 2013; Perea & Acha, 2009; Rayner et al., 1998, 2013; Stenberg & Cross, 2019; Veldre et al., 2017). The disruptive effect of interword spacing removal on readability extends to non-Latin-script languages. For instance, Baek et al. (2022) reported that removing interword spacing or replacing interword spaces with symbols in Korean text (a spaced language) hindered

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

readability as evidenced by more fixations, longer sentence reading times, as well as mean fixation durations, though not to the same extent as in English. It should be pointed out, however, that the deleterious effects of interword space removal can interact with the language's orthographic system. For instance, Leung et al.'s (2021) study on Arabic (a spaced language) showed that removing interword spacing did not significantly impact measures of readability such as total sentence reading time and average reading rate. They further argued that the lack of an interword spacing removal effect may stem from Arabic orthography, namely, the cursive and ligature system of Arabic letters which naturally defines a written word without needing to rely on the redundant cue of interword spacing.

Although facilitative effects of interword spacing on reading have been found across numerous alphabetic scripts, including German (Inhoff et al., 2000), Spanish (Perea & Acha, 2009) and French (Mirault et al., 2019), these assumptions may not be directly applicable to writing systems that do not normally contain interword spaces. Studies examining the role of word boundary information in these unspaced scripts have revealed nuanced findings. A robust finding across numerous eye-tracking studies on reading Chinese text (Bai et al., 2008; Liu & Lu, 2018; Ma, 2017; Zang et al., 2013) and Japanese Hiragana text (Sainio et al., 2007) is that adding interword spacing leads to shorter fixation durations on words, supporting the hypothesis that interword spacing facilitates lexical processing even in unspaced languages. In terms of eye movement control, adding interword spacing shifts the mean initial landing position to be further into Chinese words and therefore closer to the optimal viewing position (OVP), suggesting easier word segmentation (Liu & Lu, 2018; Ma, 2017; Zang et al., 2013). These facilitative effects of interword spacing on word segmentation and recognition in unspaced languages come with the tradeoff in terms of a greater number of fixations and longer overall reading time on the sentence (Bai et al., 2008; Winskel et al., 2009; Zang et al., 2013), which may reflect the cost of the unusual visual appearance of spaced text. It is worth noting that in these unspaced writing systems, the unique characteristics of each writing system may already contain sufficient cues to word segmentation, such as the presence of postpositional particles in Korean sentences (Baek et al., 2022), the visual salience of Kanji characters in mixed Kanji-Hiragana Japanese text (Sainio et al., 2007) and the position-specific character frequencies of word-initial and word-final characters in Thai text (Kasisopa et al., 2013).

The Thai writing system is called *abugida* in the sense that the consonant letters are the primary writing units, and vowel symbols may be used to indicate the word's vowel quality (Bright, 2000; Jenny, 2021). The Thai alphabet consists of 44 consonant letters, 16 vowel symbols and four tone marks as the diacritics. In most situations, Thai words are not separated by a space in a sentence, and letters do not possess upper and lower case, which potentially poses a challenge for word identification. Using a read-aloud task, Kohsom and Gobet (1997) found that participants were faster in reading and made fewer errors when interword spaces were added to Thai sentences, providing preliminary evidence that interword spacing may facilitate eye guidance and/or lexical access. Winskel et al. (2009) was the first work that looked into the effect of interword spacing on Thai word identification by measuring readers' eye movements. Unsurprisingly, mean sentence reading times were longer for spaced than unspaced sentences as the sentence was spatially lengthened by interword spacing (12.8%), an indication that interword spacing did not necessarily facilitate sentence readability (see Kasisopa et al., 2013 for the same conclusion). At the target

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

word level, while the first fixation duration did not show any significant difference between the two spacing conditions, gaze durations and total fixation durations were significantly shorter on the target words for the spaced than unspaced sentences, indicating that interword spacing facilitated later measures of word processing. There was no significant difference between the two spacing conditions on the first fixation landing position, suggesting that interword spacing did not impact oculomotor control in Thai. Their results concluded that interword spacing facilitated word recognition, consistent with the findings on reading Chinese (Bai et al., 2008; Liu & Lu, 2018; Ma, 2017; Zang et al., 2013), but spacing did not affect eye guidance and lexical segmentation in Thai.

1.2. Identifying compound words

The current study focuses on the interaction between interword spacing and lexical compounds in Thai. Compound words have a dual nature as whole words (e.g., *watercolor*) and as lexical combinations of two or more independent lexemes (i.e., *water* + *color*), a feature that can reveal fundamental aspects of orthographic, lexical and morphological processing of polymorphemic words across languages (Libben et al., 2020). A primary purpose for our current inquiry concerns the psychological reality of lexical compounds as a unit of processing in reading Thai, an 'unspaced' script. Native speakers, regardless of language, can easily identify the individual constituents of compound words (Libben, 2006), making compounds a useful testing ground for the processing of complex words across languages.

Psycholinguistic research on lexical compounds, primarily in Latin-script languages, has explored three key processing models: (1) holistic retrieval (whole-word approach), (2) constituent-based decomposition and (3) hybrid dual-route mechanisms integrating both strategies. Holistic approaches propose that complex words are initially accessed via their whole-word representations, with morphological processing of constituents playing a minimal role (Taft & Forster, 1976; van Jaarsveld & Rattink, 1988). Proponents of the decompositional approach proposed that the individual components in compounds, for instance, the first and second constituents, impact compound processing, with constituent frequency identified as a key factor (Juhasz et al., 2005; Kuperman et al., 2009; Reznick & Friedmann, 2015; Zhang et al., 2011). Several studies confirmed the role of compound constituents in lexical decision and naming tasks (Andrews, 1986; Coolen et al., 1991; van Jaarsveld & Rattink, 1988; Zwitserlood, 1994). Their results showed that reaction times were shorter for semantically transparent compounds (e.g., *birdhouse, cheesecake*) than for opaque ones (e.g., *hotdog, jailbird*) (Libben et al., 2003). Some eye-tracking studies also supported the decompositional approach, indicating that constituent frequency affected gaze duration and fixation when reading compounds embedded in sentences (Andrews et al., 2004; Bertram & Hyona, 2003; Pollatsek et al., 2011). Hybrid and multiple-route approaches propose that both whole-word access and morphological decomposition routes are available, with factors such as word frequency, transparency, length and constituent frequency determining which route is activated (Baayen et al., 1997; Hyönä et al., 2020; Inhoff et al., 2000; Libben et al., 2020; Pollatsek et al., 2000; Zhou & Marslen-Wilson, 1995).

Research on 'unspaced' languages also investigated the issue of whether compound recognition was a primarily holistic, decompositional, or multiple-route

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

process. In a visual lexical decision study by Cui et al. (2017), adding spacing between constituents sped up recognition of semantically transparent bisyllabic compounds but slowed down recognition of matched monomorphemic words, which suggested that the holistic route was primarily used in recognizing Chinese monomorphemic words, whereas the morphological decomposition route is primarily used in processing Chinese compound words. A cross-linguistic eye-tracking study on reading Finnish and Chinese compounds by Hyönä et al. (2024) found that first constituent frequency did not influence fixation times on two-character Chinese compounds, suggesting that whole-word representations may overrule the activation of constituents during the recognition of Chinese compound words.

The majority of the literature on compound word recognition manipulated the frequency of the constituents as the litmus test for the activation of constituent representations during compound processing, but an alternative method is to directly compare the processing of complex words against monomorphemic words that have been matched on word frequency and length. For 'spaced' languages, studies using visual lexical decision and word naming task have generally found faster response times to compound words (e.g., *flagship*) than to matched monomorphemic words (e.g., *crescent*), suggesting that access to the lexical entries of the constituents, which are generally higher frequency than the compound, might facilitate the processing of compounds (Bronk et al., 2013; Fiorentino & Poeppel, 2007; Inhoff et al., 1996; Ji et al., 2011). However, using the eye-tracking method, Inhoff et al. (1996) found longer first fixation durations on compounds (e.g., *blueberry*) compared to monomorphemic controls (e.g., *arthritis*), suggesting that morphological complexity incurs a processing cost in sentence reading. Morphological complexity effects have also been investigated in unspaced languages, for instance Chinese, which have found faster visual lexical decision response times to two-character Chinese compounds compared to matched monomorphemic words (Hsu et al., 2019; Wei et al., 2023). This result mirrored the facilitative effect of compound processing that has been observed in lexical decision experiments in other spaced languages.

In sum, there is substantial evidence from both spaced and unspaced languages that compound constituents are activated during compound recognition, but that the whole-word representation of compounds also plays a role. These effects may be qualified by the degree of semantic transparency and the length of the compounds. Studies comparing the processing of compounds and matched monomorphemic words have revealed a processing advantage for compounds in isolated word recognition tasks such as lexical decision and word naming, whereas eye-tracking experiments have revealed a processing cost for compounds in terms of longer fixation durations than for matched monomorphemic words.

1.3. Current study

For writing systems in which words are not normally spaced out, e.g., Thai, the sentence processing mechanism would naturally require two tasks, i.e., word segmentation in the absence of spaces and compound identification in the absence of spaces or hyphens between the constituents. Given the absence of interword spaces in Thai, it becomes impossible to visually distinguish between compounds (as a single lexical entry) and phrases (consisting of two or more lexical entries). In some extreme cases, sentence ambiguity will arise, e.g., the word '**ข้าวเย็น**' in (1) is semantically

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

ambiguous between a compound meaning ‘dinner’ and a phrase meaning ‘cold rice’ (Hongthong et al., 2019, p. 57):

(1) **เขาไม่กินข้าวเย็น** ‘He does not eat dinner/cold rice’.

Due to the lack of word spacing cues to demarcate word boundaries, there is potential ambiguity during word segmentation and recognition in determining whether the currently fixated word is a word on its own or whether it should be combined with the following words to form a polymorphemic word or a phrase. Therefore, in addition to the effects of interword spacing, morphological structure (in this case, the compound structure) may also play a role in word segmentation and recognition, a factor that was not considered in previous eye-tracking research on reading Thai (e.g., Kasisopa et al., 2013, 2016; Winskel et al., 2009).

To this aim, we conducted an eye-tracking study of sentence reading and focused on Thai compound words. The experiment directly compared compound words, which are hypothesized to have a word-internal morphological structure, with matched monomorphemic words. In addition, we reexamined the interword spacing effect on Thai sentence reading and verified whether interword spacing facilitated reading in Thai. We also investigated whether interword spacing interacts with morphological structure – specifically, whether spacing facilitates word recognition and word targeting more for compound words than for simple words by providing a visual cue that helps disambiguate the parsing of polymorphemic words in Thai reading.

2. Method

This experiment investigated the effects of interword spaces and morphological complexity on Thai sentence reading. Participants’ eye movements were examined while silently reading sentences written with or without spaces between words, and the target word was either a compound noun or a simple monomorphemic noun. The study employed a within-subjects factorial design comprising 2 spacing conditions (unspaced or spaced) × 2 noun types (compound noun or simple noun).

2.1. Participants

A total of 55 participants from the Chulalongkorn University community participated either for course credit or a chance to win one out of five stainless steel tumblers (~$30 per tumbler). All participants had normal or corrected-to-normal vision and were native speakers of Thai. The experiment obtained ethics approval from the Research Ethics Committee at Chulalongkorn University and United Arab Emirates University. All participants signed a written consent form before the experiment.

2.2. Materials

A total of 76 Thai bimorphemic compound nouns were selected. This type of compound was chosen because it is the most common type of compound word in Thai (Phaholphinyo et al., 2009), and its simplicity provided a suitable testing ground for our preliminary investigation on morphological processing in the Thai language.

All compounds were bisyllabic, contained two monosyllabic constituent nouns and were semantically transparent. All compounds were head-modifiers, for example, '**ห้องน้ำ**' ('bathroom' = **ห้อง** 'room' + **น้ำ** 'water') is a type of room. These compound nouns were matched to 76 Thai simple nouns. Word length was measured as the number of individual consonants and vowel characters along the horizontal plane, excluding the vowel markers, tone marks and diacritics written above or below those characters. The length of the selected compounds ranged from 3 to 8 characters (M = 5.14, SD = 0.98), whereas the simple nouns ranged from 3 to 7 characters (M = 4.76, SD = 1.02). Word frequency estimates were obtained from the Thai web corpus (Thai Web 2018 [thTenTen18]) accessed via *Sketch Engine* (Kilgarriff et al., 2014). The simple nouns had an average frequency of 47 per million, while the compounds had an average frequency of 12 per million. The compounds' first constituents ranged from 1 to 5 characters (M = 2.63, SD = 0.65), with an average frequency of 310 per million. Second constituents ranged from 1 to 4 characters (M = 2.51, SD = 0.64), with an average frequency of 209 per million. Stimuli properties are summarized in Table 1. Since word frequency and word length may not be perfectly matched between the compounds and simple nouns, we included these variables as covariates in the analyses of reading times.

Sentence frames were created for each pair of compound nouns and simple nouns, and these target words were followed by at least one to two words to avoid sentence wrap-up effects in the eye movement measures. The word count in each sentence ranged from 8–13 words (M = 9.68, SD = 1.21).

Target word predictability, word familiarity and sentence naturalness were assessed through norming studies with Chulalongkorn University participants who were native speakers of Thai. These participants did not take part in the eye-tracking study. The predictability of the target words was assessed through a cloze norm. A total of 21 participants were presented with the sentence fragments up to but not including the target word and were asked to fill in the word that first came to mind. The cloze probabilities indicated that both the compound nouns (M = 0.02, SD = 0.05) and the simple nouns (M = 0.02, SD = 0.07) were unpredictable from the sentence context, and there was no significant difference in cloze probability between

Table 1. Lexical properties of the word stimuli, showing the averages per condition (standard deviations in parentheses)

	Whole-word representation		Morphological structure	
Noun type	Compound	Simple	Constituent 1	Constituent 2
Example	รถไฟ /rót.faj/ 'train'	ทะเล /tʰaː.leː/ 'sea'	รถ /rót/ 'car'	ไฟ /faj/ 'fire'
Number of syllables	2	2	1	1
Word frequency[a]	0.64 (0.62)	1.10 (0.72)	2.05 (0.62)	2.02 (0.59)
Word length[b]	5.14 (0.98)	4.76 (1.02)	2.63 (0.65)	2.51 (0.64)
Word predictability[c]	0.02 (0.05)	0.02 (0.07)	–	–
Word familiarity[d]	4.89 (0.22)	4.92 (0.12)	–	–

[a]Scaled to 1 million and log-transformed.
[b]Number of consonant and vowel characters excluding the vowels, tone marks and diacritics located above or below those characters.
[c]Assessed through a cloze study.
[d]Rating scale from 1 to 5.

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

the two conditions ($t = -0.11$, $p = 0.914$). Word familiarity was assessed by asking 22 participants to rate the target words on a 5-point scale (5 = very familiar, 1 = very unfamiliar), with familiar words operationalized as words that they have seen or heard often and that they confidently know the definition of those words. Both the compounds ($M = 4.89$, $SD = 0.22$) and the simple nouns ($M = 4.92$, $SD = 0.12$) were rated as highly familiar, with no significant difference between the conditions ($t = -1.16$, $p = 0.249$). Sentence naturalness was assessed by asking 20 participants to rate on a 5-point scale how natural each sentence sounds to them (5 = very natural, 1 = very unnatural), with naturalness defined as sentences that contain words that are expected and the overall meaning of the sentence flows well. Sentences in both the compound noun condition ($M = 4.29$, $SD = 0.67$) and the simple noun condition ($M = 4.31$, $SD = 0.50$) were rated as very natural, with no significant difference between the conditions ($t = -0.14$, $p = 0.890$).

The spaced condition was created by inserting two consecutive spaces between the words in the test sentences (see Figure 1). Word segmentation was systematically determined by the researcher who was a native speaker of Thai, following a conservative definition of Thai word units as lexemes with internal cohesion. For ambiguous cases (e.g., **ห้างสรรพสินค้า, ร้านอาหาร**), internal cohesion was checked by looking up whether the word was listed in the dictionary-based Thai National Corpus (https://www.arts.chula.ac.th/ling/tnc3/)(Aroonmanakun, 2007); if the entire word chunk was not listed, it was segmented into its component morphemes (e.g., **ร้านอาหาร** 'restaurant' was not listed in the corpus and was therefore segmented into two words: 'food-store'). A total of 304 sentences (76 sentence frames × 2 noun conditions × 2 spacing conditions) were counterbalanced across four lists using a Latin square design. Each list contained 76 sentences, with 19 sentences in each of the four experimental conditions. Thus, participants saw a particular sentence frame with either the compound noun or the simple noun, but not both. Participants were randomly assigned to one of the four lists (See Appendix for examples).

2.3. Apparatus

Participants' eye movements during reading were recorded using the Eyelink Portable Duo (SR Research, Ltd.) at a sampling rate of 1,000 Hz. A chinrest was used to minimize head movement. Participants read binocularly, although eye movements were recorded only from the right eye. The stimuli were presented in a 20-point black

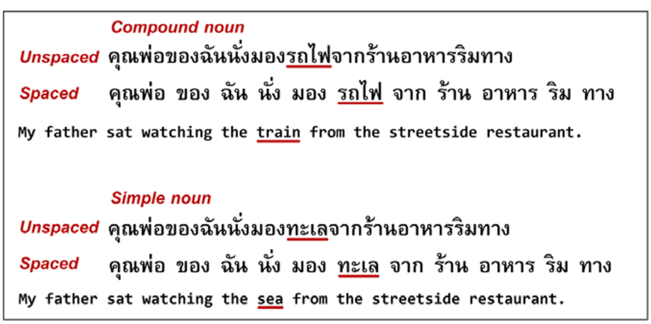

Figure 1. Example experimental sentences by conditions, with target words underlined for illustration.

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

Browallia New font on a white background on a Lenovo Legion 5S Pro display monitor (2560 × 1600 × 60 Hz). We decided against using a fixed-width font because it caused the vowels and tone marks to appear unnaturally stretched to match the width of the consonants. Participants were seated 45 cm from the eye tracker and 65 cm from the computer screen that displayed the sentences. At this distance, one character occupied approximately one degree of visual angle. Each sentence fitted on a single line.

2.4. Procedure

Participants read and signed a consent form that explained the overview of the experimental procedure. After the eye tracker was adjusted for each participant, an initial calibration and validation procedure was performed on a 3×3 grid on the screen. The accuracy of the calibration on each trial was checked by the experimenter, and another calibration was performed whenever necessary. The experimenter also monitored each trial and kept a log of the eye-tracking quality to ensure that a track loss did not occur. Participants were instructed to read silently for comprehension at their normal pace. Each participant read three practice sentences, followed by 76 experimental sentences presented in random order. At the beginning of each trial, a fixation dot was displayed near the left edge at the vertical center of the screen. After reading each sentence, participants pressed the spacebar, which replaced the sentence with the fixation dot for the next trial. In 19 of the trials (25%), the sentence was replaced with a true-or-false comprehension question. Participants responded to the question by pressing the 'Z' or 'M' key. Each session lasted approximately 30 minutes.

2.5. Analysis

Two items were removed from the analyses due to typographical errors in stimulus presentation, resulting in 74 remaining items. Fixations shorter than 80 ms and on adjacent characters were combined using the standard 'merge nearby fixations' filter in the data analysis software EyeLink Data Viewer (SR Research Ltd.), and therefore, the minimum fixation duration in the data was 80 ms. Fixation duration values were deleted on trials where the target word was skipped, because those values misrepresented the data. None of the trials in the raw data indicated a track loss. Only one first fixation duration (out of 4,070 data points) was longer than 1,200 ms (=1,643 ms). Aside from the data screening described, we did not perform further data trimming because we wanted to maintain as much of the raw data as possible, in order to maximize statistical power.

Three sentence-level eye movement measures were generated from the data in order to examine the processing costs of the overall sentence. *Sentence reading time* refers to the time it takes to read each sentence. *Average fixation duration* indicates the average duration of all fixations on each sentence. *Fixation count* is the total number of fixations made while reading each sentence. Longer sentence reading time, average fixation duration and fixation count indicate greater difficulty in sentence processing (Payne et al., 2020; Raney et al., 2014; Rayner & Morris, 1992; Veldre & Andrews, 2014).

For the target word region, five measures were selected in order to examine the time course of word recognition. *First fixation duration* is the duration of the first

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

fixation within the region, regardless of other additional fixations on the target word. *Gaze duration* is the sum of fixation durations before moving to another word. *Total fixation time* is the sum of all fixation durations within the region, including time spent rereading the target word. *Skipping rate* is the likelihood of skipping over the word without fixating on it during first-pass reading. We also examined the *first fixation landing position* on the target word, which is the location on which the eyes initially land within the region at the first fixation, a measure of oculomotor control. This was calculated into a percentage by dividing the landing position of the first fixation (i.e., number of pixels from the left edge of the interest area to the horizontal position of the first fixation) by the horizontal width of the word (i.e., number of pixel units from the left edge to the right edge of the interest area) to obtain a landing position measure relative to the word length (e.g., a landing position of 0.5 would indicate that the fixation is located squarely at the horizontal center of the word). To gain further insight into morphological processing, we also calculated the proportion of trials on which the compound nouns received only 1 fixation, and the proportion of trials on which the first constituent and the second constituent were fixated, respectively.

Differences in these eye movement measures across the spacing and noun conditions were analyzed using linear mixed-effects regression models using the *lmer()* function from the *lme4* package (Bates et al., 2015) in R, version 4.3.1 (R Core Team, 2020). Each dependent measure was analyzed in separate models, with spacing condition, noun condition and their interaction as fixed effects. The two levels of each condition were treatment-coded, with the unspaced condition and the simple noun condition as reference levels. Models fitted for eye movement measures on the target word also included log-transformed word frequency and word length as covariates, since these variables are known to influence the eye movement measures of word recognition (Dürrwächter et al., 2010; Hermena et al., 2019; Joseph et al., 2009; Kliegl et al., 2006; Schad et al., 2014; Tiffin-Richards & Schroeder, 2015; Wotschack & Kliegl, 2013). The random effect structure contained by-participant and by-item intercepts, as well as by-participant and by-item random slopes for the spacing condition and the noun condition. In cases when the full model failed to converge, we removed the random effect(s) that captured the smallest variance until the model reached convergence (Barr et al., 2013). Statistical significance was computed using the *lmerTest* package (Kuznetsova et al., 2017). All data files and data analysis scripts can be found on https://osf.io/43mde/.

3. Results

Mean accuracy of participants' responses to the comprehension questions was high (M = 0.92, SD = 0.06, range = 0.79–1), indicating that participants were paying attention and understanding the sentences while reading. Therefore, all of the 55 participants' data were included in the analyses.

3.1. Sentence-level measures

Table 2 summarizes the descriptive statistics of the sentence-level measures and the target word measures by spacing condition and noun condition.

Figure 2 shows the sentence-level fixation measures (sentence reading time, average fixation duration and fixation count) by spacing condition and noun

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

Table 2. Means and standard deviations of the sentence-level measures and target word measures by spacing condition and noun condition

	Compound		Simple	
Dependent measures	Unspaced	Spaced	Unspaced	Spaced
Sentence-level measures				
Sentence reading time (ms)	3676 (1432)	3804 (1495)	3546 (1385)	3675 (1487)
Average fixation duration (ms)	239 (42)	228 (40)	237 (41)	227 (43)
Fixation count	13.19 (4.69)	14.04 (4.93)	12.84 (4.78)	13.61 (5.01)
Target word measures				
First fixation duration (ms)	330 (157)	297 (135)	219 (78)	210 (74)
Gaze duration (ms)	352 (180)	315 (149)	272 (137)	260 (129)
Total fixation time (ms)	463 (282)	406 (237)	401 (253)	364 (222)
Skipping rate (%)	0.10 (0.30)	0.11 (0.31)	0.14 (0.34)	0.13 (0.34)
First fixation landing position (% of word width)	0.37 (0.25)	0.4 (0.24)	0.42 (0.28)	0.42 (0.26)

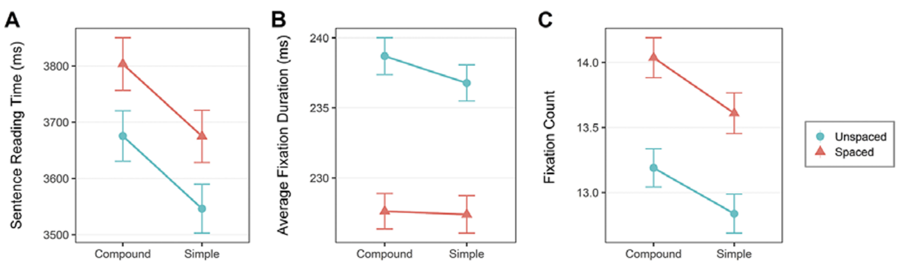

Figure 2. Sentence-level fixation measures by spacing (unspaced versus spaced) and noun type (compound versus simple), showing mean sentence reading time (ms), average fixation duration (ms) and number of fixations on the sentences. Error bars indicate the standard error. Noun type is plotted on the x-axis. Blue lines/circles represent the unspaced condition; red lines/triangles represent the spaced condition.

condition. Table 3 summarizes the results of the mixed-effects regression models for these global measures. Total sentence reading time in the spaced condition was significantly longer than in the unspaced condition, and it was also longer in the compound noun condition than in the simple noun condition. The fixation count in the spaced condition was greater than in the unspaced condition, and it was also greater in the compound noun condition than in the simple noun condition. On the contrary, the average fixation duration in the spaced condition was shorter than in the unspaced condition. Overall, these results indicated that, when spaces were added to Thai sentences, there were processing costs in terms of longer sentence reading time and a higher number of fixations, yet it also resulted in a processing advantage in terms of faster word recognition. Participants also took longer to read sentences with compound nouns than those with simple nouns, and they also made more fixations on those sentences.

3.2. Target word measures

Figure 3 shows the fixation measures on the target word (first fixation duration, gaze duration, total fixation time and skipping rate) by spacing condition and noun

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

Table 3. Estimated effects of spacing condition and noun condition on sentence reading time (ms), average fixation duration (ms) and mean fixation count

	Sentence reading time				Average fixation duration				Fixation count			
Predictors	*Estimate*	*SE*	*t*	*p*	*Estimate*	*SE*	*t*	*p*	*Estimate*	*SE*	*t*	*p*
(Intercept)	3675.05	140.83	26.10	**<0.001**	232.62	3.97	58.63	**<0.001**	13.42	0.46	29.10	**<0.001**
Spacing: spaced	132.46	34.61	3.83	**<0.001**	−10.36	1.08	−9.63	**<0.001**	0.83	0.12	7.05	**<0.001**
Noun: compound	127.42	38.18	3.34	**0.001**	1.08	1.12	0.96	0.336	0.38	0.13	3.05	**0.002**
Spacing × Noun	0.66	63.04	0.01	0.992	−1.53	1.86	−0.82	0.413	0.08	0.22	0.37	0.712

Note: Bold values indicate statistical significance at $p < 0.05$.

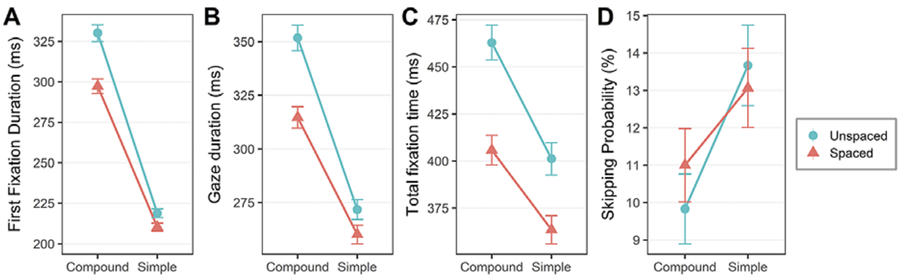

Figure 3. Target word fixation measures by spacing and noun type: first fixation duration (ms), gaze duration (ms), total fixation time (ms) and skipping rate (%). Error bars indicate the standard error. Noun type is plotted on the x-axis. Blue lines/circles = unspaced condition; red lines/triangles = spaced condition.

Table 4. Estimated effects of spacing condition and noun condition on first fixation duration (ms), gaze duration (ms) and total fixation time (ms) on the target word, with log word frequency and word length included as covariates

		Estimate	*SE*	*t*	*p*
First fixation duration	(Intercept)	261.43	15.41	16.97	**<0.001**
	Spacing: spaced	−21.09	4.62	−4.57	**<0.001**
	Noun: compound	93.74	7.30	12.83	**<0.001**
	Word frequency	−7.38	3.99	−1.85	0.064
	Word length	1.74	2.69	0.65	0.518
	Spacing × Noun	−24.15	7.27	−3.32	**0.001**
Gaze duration	(Intercept)	239.84	20.54	11.68	**<0.001**
	Spacing: spaced	−24.95	5.62	−4.44	**<0.001**
	Noun: compound	55.20	7.60	7.26	**<0.001**
	Word frequency	−13.31	5.26	−2.53	**0.011**
	Word length	14.14	3.54	3.99	**<0.001**
	Spacing × Noun	−25.22	9.18	−2.75	**0.006**
Total fixation time	(Intercept)	286.89	32.80	8.75	**<0.001**
	Spacing: spaced	−47.74	9.64	−4.95	**<0.001**
	Noun: compound	35.03	12.74	2.75	**0.006**
	Word frequency	−13.74	8.34	−1.65	0.100
	Word length	25.95	5.62	4.62	**<0.001**
	Spacing × Noun	−19.83	15.20	−1.30	0.192
Skipping rate	(Intercept)	−1.18	0.34	−3.48	**<0.001**
	Spacing: spaced	0.02	0.13	0.14	0.885
	Noun: compound	−0.23	0.11	−1.98	**0.048**
	Word frequency	0.02	0.08	0.20	0.841
	Word length	−0.26	0.06	−4.54	**<0.001**
	Spacing × Noun	0.22	0.21	1.07	0.285

Note: Bold values indicate statistical significance at $p < 0.05$.

condition. Table 4 summarizes the results of the mixed-effects regression models for these target word measures. Participants had shorter first fixation duration, gaze duration and total fixation time on the target word when reading spaced sentences than unspaced sentences.[1] This indicates that the addition of spaces resulted in faster

[1]To assess whether our design and sample size were sufficiently powered to detect the observed effects, we conducted a post-hoc simulation power analysis using Monte Carlo simulations with the *simr* package in R. Based on 1000 simulations with 55 participants and 76 items, the study had 93.20% power (95% CI [91.46, 94.68]) to detect the interaction effect between spacing and noun type on first fixation duration ($B = -24$ *ms*).

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

word recognition. Participants had longer first fixation duration, gaze duration, and total fixation time on compound nouns than on simple nouns, and they were less likely to skip over compound nouns compared to simple nouns during first-pass reading. These results may reflect the processing cost due to the greater morphological complexity. In addition, there was a significant interaction effect between spacing condition and noun condition for first fixation duration and gaze duration, indicating that the spacing effect was larger in the compound noun condition than in the simple noun condition. This result indicates that adding spaces to Thai sentences led to faster word recognition, especially for compound nouns. The covariates also influenced reading times on the target word. Participants had shorter gaze duration on higher-frequency target words than on those that were lower frequency. They also had shorter first fixation duration and gaze duration on shorter target words than longer target words, and they were more likely to skip over shorter target words than longer target words. These results mirror the robust effects of word frequency and word length on eye movement measures of word recognition (Chamberland et al., 2013; Hermena et al., 2019; Joseph et al., 2009; Kliegl et al., 2006; Pollatsek et al., 2008; Raney & Rayner, 1995; Schad et al., 2014; Tiffin-Richards & Schroeder, 2015; Wotschack & Kliegl, 2013).

3.3. Compound words only

Additional analyses were conducted on the compound words only to investigate the role of full-form representations and constituent representations in compound processing. Models were fitted to each dependent variable with the spacing condition, compound frequency, frequency of the first constituent, and frequency of the second constituent as fixed effects. Table 5 summarizes the results of the mixed-effects regression models for these analyses. There was a significant effect of compound frequency for all three measures: first fixation duration, gaze duration and total fixation time. The fact that the compound frequency predicted both the early and late measures of lexical processing suggests that the full-form representation of the compound remained activated throughout the word recognition process. In contrast, the frequency of the first constituent and the second constituent did not significantly predict any of the reading time measures. This suggests that morphological constituent representations did not play a role in compound recognition during sentence reading.

Out of the 2,035 data points for the compound word region, there were 212 trials (10.4%) on which the compound noun was skipped during first-pass reading. Among the 1,823 trials on which the compound word was fixated during first-pass reading, there were 586 trials (32.1%) on which the compound was identified by fixating on the first constituent only, 587 trials (32.2%) on which the compound was identified by fixating on the second constituent only and 650 trials (35.7%) on which the

---

A post-hoc sensitivity analysis was also conducted using the *simr* package to estimate the smallest effect size of interest (SESOI) that our study could reliably detect with 80% power. Based on 1000 simulations of the observed first fixation duration model, the study was powered to detect spacing × noun type interactions of $B = -20$ *ms* or larger, with 82% power (95% CI [79.48, 84.33]). We would like to thank one reviewer for their comment on the effect size.

Table 5. Fixed effects of regression models fitted to fixation duration measures on the compounds only

	First fixation duration				Gaze duration				Total fixation time			
Predictors	*Estimate*	*SE*	*t*	*p*	*Estimate*	*SE*	*t*	*p*	*Estimate*	*SE*	*t*	*p*
(Intercept)	329.56	25.65	12.85	**<0.001**	347.26	32.00	10.85	**<0.001**	416.72	51.06	8.16	**<0.001**
Spacing: spaced	−33.19	6.90	−4.81	**<0.001**	−37.65	7.79	−4.84	**<0.001**	−58.33	13.49	−4.32	**<0.001**
Word frequency	−22.62	10.00	−2.26	**0.024**	−31.84	12.54	−2.54	**0.011**	−44.72	19.72	−2.27	**0.023**
Constituent 1 frequency	1.41	8.97	0.16	0.875	3.52	10.94	0.32	0.748	10.64	17.93	0.59	0.553
Constituent 2 frequency	−2.94	8.27	−0.36	0.723	−1.31	10.33	−0.13	0.899	9.69	16.62	0.58	0.560

Note: Bold values indicate statistical significance at $p < 0.05$.

compound was identified by fixating on both constituents. These data suggest that in most instances (64.3%), the compounds were identified in a single fixation.

3.4. First fixation landing position

Figure 4 shows the distribution of the first fixation landing position on the target word by spacing condition and noun condition. Table 6 summarizes the results of the mixed-effects regression models for this measure of oculomotor control. Across the spacing conditions, the mean first fixation landing position was just left of the center of the target word. The mean initial landing position did not differ between the spacing conditions. On the contrary, the mean landing position differed across the noun conditions. Mean first fixation landing position was more toward the left of the

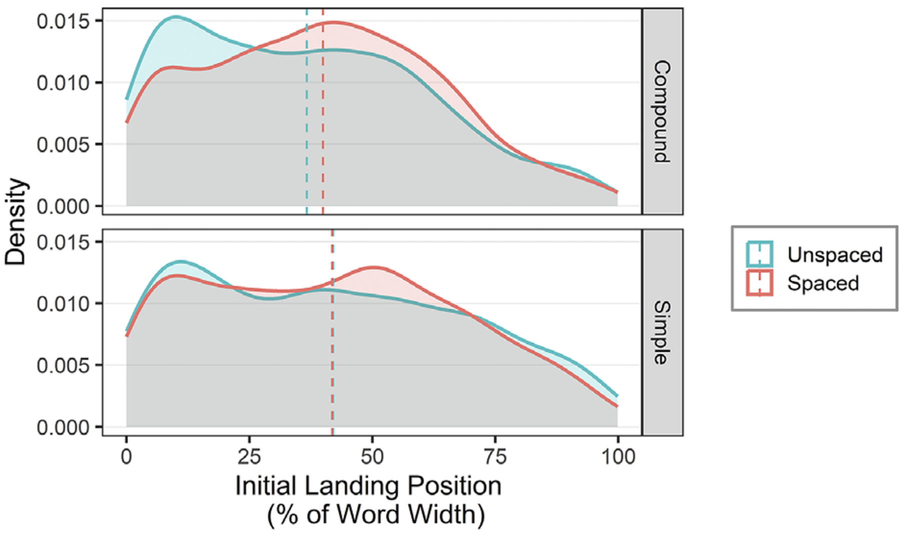

Figure 4. First fixation landing position on target words by spacing and noun type. Top panel: compounds; bottom panel: simple nouns. Error bars indicate the standard error. Blue lines = unspaced condition; red lines = spaced condition. Vertical dashed lines indicate the mean initial landing position for each spacing condition.

Table 6. Estimated effects of spacing condition and noun condition on the first fixation landing position on the target word (percentage of the word width), with word frequency and word length included as covariates

	First fixation landing position (% of Word width)			
Predictors	*Estimate*	*SE*	*t*	*p*
(Intercept)	0.50	0.03	18.31	**<0.001**
Spacing: spaced	0.02	0.01	1.81	0.070
Noun: compound	−0.02	0.01	−2.09	**0.037**
Word frequency	0.01	0.01	1.82	0.070
Word length	−0.02	0.00	−4.50	**<0.001**
Spacing × Noun	0.03	0.02	2.07	**0.039**

Note: Bold values indicate statistical significance at $p < 0.05$.

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

center of the target word (i.e., closer to the word beginning) when reading compound nouns, compared to simple nouns. There was also an interaction effect between spacing condition and noun condition, indicating that although spacing did not impact landing position on simple nouns, it did impact landing position on compound nouns. Mean first fixation landing position on the compound nouns was closer to the word center in the spaced condition than in the unspaced condition.

4. Discussion

In this eye-tracking study, we tested the effects of interword spacing and morphological complexity (i.e., compound words, in this experiment) on word identification and oculomotor control in Thai sentence reading. While Thai sentences do not normally contain interword spaces, we hypothesized that the addition of interword spaces would still facilitate word identification (Winskel et al., 2009). We further hypothesized that this facilitative effect of interword spacing should be more pronounced for compounds compared to monomorphemic words, since in normal unspaced Thai sentences, there are no reliable orthographic cues that demarcate spatially adjacent words.

The results showed clear-cut effects of interword spacing on word identification. The global analyses indicated that participants had longer sentence reading time and made more fixations when interword spaces were added to the sentences, but that participants also had shorter average fixation duration on individual words when the sentences contained interword spaces. These findings illustrate a tradeoff when spaces are added between Thai words, such that it incurs a cost on overall sentence processing but facilitates individual word recognition, consistent with past research on reading Thai (Winskel et al., 2009) and Chinese (Bai et al., 2008; Winskel et al., 2009; Zang et al., 2013). Results from the target word region also clearly showed a facilitative effect of spacing on word identification across all measures, as evidenced by shorter first fixation duration, gaze duration and total reading time on the target word in the spaced condition compared to the unspaced condition. These results overall concur with the previous work by Winskel et al. (2009), confirming the interword spacing effect in Thai. Since Thai script's orthography is 'unspaced', the observed facilitative effect of space information is not due to familiarity with spaced text. Instead, spacing information may serve as nonlinguistic visual cues that help readers determine where a word ends and begins. Spacing demarcation may reduce the effects of visual crowding and reduce uncertainty about which group of characters constitutes a word, thereby speeding up word identification (Chiu & Drieghe, 2023; McGowan et al., 2015; Risse, 2014). The facilitative effect of interword spacing also confirms that words are the relevant unit that drives eye movements in reading Thai, just as they are in English (see Bai et al., 2008, for a similar argument for Chinese reading).

The findings also clearly supported the second hypothesis regarding the interaction between spacing information and morphological complexity on word identification. There was a larger facilitative effect of interword spacing in the compound noun condition compared to the simple noun condition, corresponding to a 24 ms difference between conditions for first fixation duration and a 25 ms difference for gaze duration. This effect was restricted to initial word recognition and not on later processing of the target word, since an interaction effect was not found for total reading time. The interaction effect was statistically significant despite including word frequency and word length as covariates, suggesting that the effect is unlikely to be caused by word frequency and word length differences of the compound nouns compared to the monomorphemic nouns. This interaction effect, therefore, suggests that inserting spaces facilitated early morphological processing, particularly for Thai compounds, relative to monomorphemic nouns. Interword spaces, as compared with unspaced text in normal Thai sentences, may serve as segmentation cues that reduce the obscurity in word identification, and this effect was especially salient for polymorphemic words. Past research has shown that in the absence of spaces, Thai readers can use position-specific frequencies of word boundary characters to direct eye movements to optimal landing sites on words (Kasisopa et al., 2013, 2016). However, reliance on low-level linguistic information, such as letter and letter sequence frequencies, may not be as beneficial for identifying polymorphemic words because their identification would require integrating across adjoining words (constituents) during lexical processing. Adding spacing information, therefore, provides an overt perceptual cue for word segmentation that can speed up lexical processing, especially for compound words.

The facilitative effect of spacing on lexical processing is broadly consistent with previous research on reading spaced alphabetic scripts (Drieghe et al., 2005; Inhoff et al., 2000; McGowan et al., 2015; Rayner et al., 1998; Rayner & Pollatsek, 1996) and also on reading unspaced scripts including Thai (Winskel et al., 2009; Winskel et al., 2012) and Chinese (Cui et al., 2014). However, some aspects of our results differ from these studies. Previous eye-tracking research on Thai reading found facilitative interword spacing effects on later measures of word identification (gaze duration and total duration) but not on first fixation duration. Winskel et al. (2009) also did not find an interaction between spacing and word frequency (a variable that reflects the relative ease or difficulty of word identification and lexical access), whereas we found an interaction between spacing and morphological complexity. Thus, contrary to previous research, our findings suggest that inserting spaces between Thai words does affect the late as well as the early stages of lexical processing. One possible explanation for these differences is the determination of word boundaries for the spaced condition, which necessarily involves some degree of subjectivity since Thai script is normally written without interword spaces. Our study used a relatively conservative criterion for what constitutes a word unit, such that we treated ambiguous cases of compound words (e.g., ร้านอาหาร = 'restaurant' = 'store' + 'food') as separate constituent words (ร้าน 'store' and อาหาร 'food'). The example stimuli provided in previous eye-tracking research on Thai reading suggested that a less conservative criterion was possibly used in those studies (Winskel et al., 2009; Winskel et al., 2012), resulting in some longer word units, which might explain the lack of a spacing effect on early word identification in these previous studies. Although the full list of stimuli in those studies was not accessible, the example stimuli indicated that words such as อาหาร 'food' (simple/monomorphemic) and น้ำพริก 'chili sauce' (compound/polymorphemic) were used as target words (Winskel et al., 2009, p. 343). In fact, the lack of a consistent criterion for demarcating words might explain why some previous studies on Thai reading failed to find any effect of interword spacing on word identification (e.g., Kasisopa et al., 2013). It should be pointed out that the studies by Winskel et al. (2009) and Winskel et al. (2012) were not specifically designed to delve into the issue of morphological complexity. Nevertheless, we have an impression that the result of the interaction effect might be

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

different if morphological information were taken into consideration. Future research could use an automated word segmentation tool to eliminate the subjectivity in demarcating words in unspaced languages, though it is worth noting that the accuracy of these tools would still vary depending on the type of algorithm chosen (Haruechaiyasak et al., 2008).

Another key finding that emerged was the processing cost of compounds relative to monomorphemic nouns. In most psycholinguistic studies on compounds that have focused on the quantitative distinction between transparent (e.g., *toothbrush, bookstore*) and opaque (e.g., *pickpocket, redneck*) compounds (Fiorentino & Fund-Reznicek, 2009; Hyönä et al., 2018; Kim et al., 2018; Shoolman & Andrews, 2003), the widely agreed assumption is that compounds consist of morphological structures and constituents, each of which can incur a processing load (Kuperman et al., 2008). By comparison, simple words are indecomposable, express a definitive meaning and are expected to be accessed more directly – even when matched in length to compound words such as *notebook* (a compound) and *dinosaur* (a simple word; Wheeldon & Lahiri, 2002). The global measures in our experiment indicated an overall sentence processing cost in terms of longer reading time and a greater number of fixations while reading sentences with compounds compared to those with simple nouns. This additional processing cost also corresponded to the processing of the target word itself, as indicated by longer fixation durations on compounds compared to simple nouns, as well as a lower likelihood of skipping over compounds compared to simple nouns. Specifically, we found that the first fixation duration was 21 ms longer when reading compounds compared to monomorphemic words, similar to previous research in English which found that the first fixation duration was 26 ms longer when reading bimorphemic English compounds (e.g., *blueberry*) compared to monomorphemic words matched in word length and word frequency (e.g., *arthritis*) (Inhoff et al., 1996).

Morphological complexity also impacted eye movement control such that readers' eyes tended to land closer to the word beginning (further from the word center) when reading compounds compared to simple nouns. The distinct first fixation landing position on compounds can be interpreted as a slight variation from the OVP in Thai script, which is located at or near the word center (Kasisopa et al., 2013, 2016; Winskel et al., 2009). We also found an interaction effect showing that although interword spacing did not impact the landing position on the simple nouns, it did impact the landing position on the compound nouns such that the first fixation landing position on compounds was closer to the word center in the spaced condition compared to the unspaced condition. This finding is consistent with past research which has shown that adding interword spaces to unspaced scripts like Japanese (Sainio et al., 2007) and Chinese (Liu & Lu, 2018; Ma, 2017; Zang et al., 2013) shifts the initial landing position toward the word center, suggesting that spacing helps readers determine the optimal location for targeting their saccades by providing visually distinct target words in nonfoveal vision. It is worth noting that our findings depart from Winkel et al. (2009) which found that in reading Thai, the first fixation landing position on the target words was not significantly influenced by the addition of interword spacing. We suspect that the lack of impact of interword spacing on the first fixation landing position in previous research was partly due to the selection of target word stimuli, which did not account for the morphological structure. One possible explanation for our findings is that readers parafoveally processed the first compound constituent and programmed the forthcoming saccade on the first constituent before planning the subsequent saccade on the compound, under the view that compound constituents are identified sequentially in reading (Drieghe et al., 2010; Pollatsek et al., 2003). By comparison, simple nouns were spatially longer than the first constituents in compounds (see Table 1 for stimulus properties), which may explain why the first fixation landing position on the simple nouns was closer to the word center compared to those on the compounds (Ma et al., 2018; O'Regan et al., 1984; Smilek et al., 2009; Zang et al., 2018). This result concurs with (though does not necessarily support) the original insight of the decompositional approach to compounds which proposes that readers process compound words by sequentially accessing their morphological constituents, a process that may be reflected in the observed differences in fixation landing positions (Fiorentino & Poeppel, 2007; Libben et al., 1999; Taft, 1988, 2004; Taft & Forster, 1975).

Finally, the effect of whole-word frequency on fixation durations on the compounds (Table 4) suggests that full-form representations of compounds are involved in both the early as well as late stages of compound word processing. The effect of whole-word frequency early in the time course of compound processing suggests that readers can recognize the compound's identity as soon as their eyes land on the word. The compounds in this study were relatively short words (on average, five characters long), so the entire word can likely be identified within the perceptual span during compound viewing. This early whole-word frequency effect we found appears to be incompatible with models of compound processing that assume obligatory decomposition for compounds in sentence reading, and in particular, models of morphological processing which assume that the compound representation is accessed only after accessing the compound's constituents (Andrews, 1986; Sandra, 1990; Taft, 1994; Taft & Forster, 1975, 1976). Although our study did not specifically focus on the role of compound constituents in reading, our findings dovetail with past research which has found that both whole-word representations as well as constituent representations are activated during compound processing, for example, the hybrid/dual-route approaches to morphological processing (Baayen & Schreuder, 1999; Bertram & Hyona, 2003; Diependaele et al., 2009; Kuperman et al., 2009). For instance, Kuperman et al.'s (2008) eye-tracking study on Finnish compounds in sentence reading found early effects of both whole-word frequency and first-constituent frequency on first fixation duration and effects of second-constituent frequency on subsequent fixations on the compound. Similarly, Andrews et al. (2004) found effects of whole-word frequency as well as first- and second-constituent frequency on gaze duration and total fixation time on English compounds during sentence reading, and Pollatsek et al. (2000) found these same effects in reading Finnish compounds.

In summary, our results demonstrate (1) that the addition of interword spaces provides salient word boundary information that facilitates both early and later stages of lexical processing in Thai sentence reading, (2) that this facilitative effect of interword spacing was especially salient for bimorphemic compound words relative to monomorphemic words and (3) that compounds incurred a processing cost on word identification and eye movement control relative to simple words. The interaction between interword spacing and morphological complexity supports the view that interword spacing can influence the early stages of morphological processing in addition to visual processing in the course of reading and highlights the importance of morphological processing in eye-tracking research on unspaced languages.

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

Taken together, our findings highlight the possibility of extending Anglocentric eye movement models of reading (e.g., E-Z Reader Model; Pollatsek et al., 2003; Reichle et al., 1998, 2003) to non-Latin-script languages, specifically to characterize the mechanism and time course of word segmentation and recognition of polymorphemic words in unspaced languages. Eye movement models of Chinese reading (e.g., CRM and CEZR) may offer preliminary insights into word segmentation and identification mechanisms in unspaced writing systems like Thai. For instance, these models could help distinguish between familiarity-guided segmentation followed by lexical access (Liu et al., 2024) and simultaneous segmentation and identification (Li & Pollatsek, 2020). Nonetheless, adaptations would be necessary to account for Thai's morphological complexity and the phonological cues inherent to its alphabetic script. The present study contributes to our understanding of the role of interword spacing and of the processing of complex words across writing systems and can inform a potentially parameterized model of reading in which the orthography-language interface is a central component.

Acknowledgments. We would like to express our gratitude to the United Arab Emirates University for sponsoring this research and publication. Additionally, this project has been granted funds from the research affairs of the Faculty of Psychology, Chulalongkorn University, grant # PSY-CU-01-2566, and is supported by Ratchadaphiseksomphot Fund, Chulalongkorn University (COgnition, Audition and LAnguage (CoALa) Research Group). We would like to thank our research assistants, Fatima Boush, Chaiwat Takkanat, Chada Bhiraset and Sutasinee Chaidej, for assisting with preparing the stimuli, programming the eye-tracking experiment, data collection and data cleaning. Part of this paper was presented at the 5th International Conference on Theoretical East Asian Psycholinguistics (ICTEAP-5) in Tokyo and the 47th Annual Meeting of the Cognitive Science Society (CogSci 2025) in San Francisco. We would like to thank the audience for their valuable suggestions and comments.The preliminary version of a portion of this work was published in Chantavarin and Leung (2025).

Competing interest. The authors declare none.

References

Andrews, S. (1986). Morphological influences on lexical access: Lexical or nonlexical effects? *Journal of Memory and Language*, 25(6), 726–740. https://doi.org/10.1016/0749-596X(86)90046-X.

Andrews, S., Miller, B., & Rayner, K. (2004). Eye movements and morphological segmentation of compound words: There is a mouse in mousetrap. *European Journal of Cognitive Psychology*, 16(1–2), 285–311. https://doi.org/10.1080/09541440340000123.

Aroonmanakun, W. (2007). Creating the Thai National Corpus. *Manusya: Journal of Humanities*, 10(3), 4–17. https://doi.org/10.1163/26659077-01003001.

Baayen, H., & Schreuder, R. (1999). War and peace: Morphemes and full forms in a noninteractive activation parallel dual-route model. *Brain and Language*, 68(1–2), 27–32. https://doi.org/10.1006/brln.1999.2069.

Baayen, R. H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language*, 37(1), 94–117. https://doi.org/10.1006/jmla.1997.2509.

Baek, H., Choi, W., & Gordon, P. (2022). Reading spaced and unspaced Korean text: Evidence from eye-tracking during reading. *Quarterly Journal of Experimental Psychology*, 76(5), 1072–1085. https://doi.org/10.1177/17470218221104736.

Bai, X., Yan, G., Liversedge, S. P., Zang, C., & Rayner, K. (2008). Reading spaced and unspaced Chinese text: Evidence from eye movements. *Journal of Experimental Psychology: Human Perception and Performance*, 34(5), 1277–1287. https://doi.org/10.1037/0096-1523.34.5.1277.

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001.

Bates, D., Maechler, M., Bolker, B. M., & Walker, S. C. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Bertram, R., & Hyona, J. (2003). The length of a complex word modifies the role of morphological structure: Evidence from eye movements when reading short and long Finnish compounds. *Journal of Memory and Language*, 48(3), 615–634. https://doi.org/10.1016/S0749-596X(02)00539-9.

Bright, W. A. (2000). Matter of typology: Alphasyllabaries and Abugidas. *Studies in the Linguistic Sciences*, 30, 63–71.

Bronk, M., Zwitserlood, P., & Boelte, J. (2013). Manipulations of word frequency reveal differences in the processing of morphologically complex and simple words in German. *Frontiers in Psychology*, 4. https://doi.org/10.3389/fpsyg.2013.00546.

Chamberland, C., Saint-Aubin, J., & Légère, M.-A. (2013). The impact of text repetition on content and function words during reading: Further evidence from eye movements. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, 67(2), 94–99. https://doi.org/10.1037/a0028288.

Chiu, T.-Y., & Drieghe, D. (2023). The role of visual crowding in eye movements during reading: Effects of text spacing. *Attention, Perception, & Psychophysics*, 85(8), 2834–2858. https://doi.org/10.3758/s13414-023-02787-1.

Chantavarin, S., & Leung, T. (2025). Comparing eye movement and lexical decision experiments on Thai compound recognition. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 47. Retrieved from https://escholarship.org/uc/item/0kw6j6v7.

Coolen, R., Van Jaarsveld, H. J., & Schreuder, R. (1991). The interpretation of isolated novel nominal compounds. *Memory & Cognition*, 19(4), 341–352. https://doi.org/10.3758/BF03197138.

Cui, L., Drieghe, D., Bai, X., Yan, G., & Liversedge, S. P. (2014). Parafoveal preview benefit in unspaced and spaced Chinese reading. *Quarterly Journal of Experimental Psychology*, 67(11), 2172–2188. https://doi.org/10.1080/17470218.2014.909858.

Cui, L., Häikiö, T., Zhang, W., Zheng, Y., & Hyönä, J. (2017). Reading monomorphemic and compound words in Chinese. *The Mental Lexicon*, 12(1), 1–20. https://doi.org/10.1075/ml.12.1.01cui.

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: The case of prefixed words. *Memory & Cognition*, 37(6), 895–908. https://doi.org/10.3758/MC.37.6.895.

Drieghe, D., Brysbaert, M., & Desmet, T. (2005). Parafoveal-on-foveal effects on eye movements in text reading: Does an extra space make a difference? *Vision Research*, 45(13), 1693–1706. https://doi.org/10.1016/j.visres.2005.01.010.

Drieghe, D., Pollatsek, A., Juhasz, B. J., & Rayner, K. (2010). Parafoveal processing during reading is reduced across a morphological boundary. *Cognition*, 116(1), 136–142. https://doi.org/10.1016/j.cognition.2010.03.016.

Dürrwächter, U., Sokolov, A. N., Reinhard, J., Klosinski, G., & Trauzettel-Klosinski, S. (2010). Word length and word frequency affect eye movements in dyslexic children reading in a regular (German) orthography. *Annals of Dyslexia*, 60(1), 86–101. https://doi.org/10.1007/s11881-010-0034-9.

Evertz-Rittich, M. (2020). What is a written word? And if so, how many? In Y. Haralambous (Ed.), *Grapholinguistics in the 21st Century: Proceedings of the 2020 Conference, Part II* (Vol. 4, pp. 25–45). Flux Editions. https://doi.org/10.36824/2020-graf-ever.

Fiorentino, R., & Fund-Reznicek, E. (2009). Masked morphological priming of compound constituents. *The Mental Lexicon*, 4(2), 159–193. https://doi.org/10.1075/ml.4.2.01fio.

Fiorentino, R., & Poeppel, D. (2007). Compound words and structure in the lexicon. *Language and Cognitive Processes*, 22(7), 953–1000. https://doi.org/10.1080/01690960701190215.

Haruechaiyasak, C., Kongyoung, S., & Dailey, M. (2008). A comparative study on Thai word segmentation approaches. In *2008 5th International conference on electrical engineering/electronics, computer, telecommunications and information technology* (pp. 125–128). https://doi.org/10.1109/ECTICON.2008.4600388

Hermena, E. W., Liversedge, S. P., Bouamama, S., & Drieghe, D. (2019). Orthographic and root frequency effects in Arabic: Evidence from eye movements and lexical decision. *Journal of Experimental Psychology-Learning Memory and Cognition*, 45(5), 934–954. https://doi.org/10.1037/xlm0000626.

Hongthong, K., Thepkanjana, K., & Aroonmanakun, W. (2019). Is there a dichotomy between synthetic compounds and phrases in Thai? *Taiwan Journal of Linguistics*, 17(1). https://doi.org/10.6519/TJL.201901_17(1).0002.

Hsu, C.-H., Pylkkänen, L., & Lee, C.-Y. (2019). Effects of morphological complexity in left temporal cortex: An MEG study of reading Chinese disyllabic words. *Journal of Neurolinguistics*, 49, 168–177. https://doi.org/10.1016/j.jneuroling.2018.06.004.

Hyönä, J., Cui, L., Heikkilä, T. T., Paranko, B., Gao, Y., & Su, X. (2024). Reading compound words in Finnish and Chinese: An eye-tracking study. *Journal of Memory and Language*, 134, 104474. https://doi.org/10.1016/j.jml.2023.104474.

Hyönä, J., Pollatsek, A., Koski, M., & Olkoniemi, H. (2020). An eye-tracking study of reading long and short novel and lexicalized compound words. *Journal of Eye Movement Research*, 13(4). https://doi.org/10.16910/jemr.13.4.3.

Hyönä, J., Yan, M., & Vainio, S. (2018). Morphological structure influences the initial landing position in words during reading Finnish. *Quarterly Journal of Experimental Psychology*, 71(1), 122–130. https://doi.org/10.1080/17470218.2016.1267233.

Inhoff, A. W., Briihl, D., & Schwartz, J. (1996). Compound word effects differ in reading, on-line naming, and delayed naming tasks. *Memory & Cognition*, 24(4), 466–476. https://doi.org/10.3758/BF03200935.

Inhoff, A. W., Radach, R., & Heller, D. (2000). Complex compounds in German: Interword spaces facilitate segmentation but hinder assignment of meaning. *Journal of Memory and Language*, 42(1), 23–50. https://doi.org/10.1006/jmla.1999.2666.

Jenny, M. (2021). Writing systems of MSEA. In P. Sidwell & M. Jenny (Eds.), *The languages and linguistics of mainland Southeast Asia* (pp. 879–906). De Gruyter. https://doi.org/10.1515/9783110558142-036.

Ji, H., Gagné, C. L., & Spalding, T. L. (2011). Benefits and costs of lexical decomposition and semantic integration during the processing of transparent and opaque English compounds. *Journal of Memory and Language*, 65(4), 406–430. https://doi.org/10.1016/j.jml.2011.07.003.

Joseph, H. S. S. L., Liversedge, S. P., Blythe, H. I., White, S. J., & Rayner, K. (2009). Word length and landing position effects during reading in children and adults. *Vision Research*, 49(16), 2078–2086. https://doi.org/10.1016/j.visres.2009.05.015.

Juhasz, B. J., Inhoff, A. W., & Rayner, K. (2005). The role of interword spaces in the processing of English compound words. *Language and Cognitive Processes*, 20(1–2), 291–316. https://doi.org/10.1080/01690960444000133.

Kasisopa, B., R., G. R., Luksaneeyanawin, S., & Burnham, D. (2013). Eye movements while reading an unspaced writing system: The case of Thai. *Vision Research*, 86, 71–80. https://doi.org/10.1016/j.visres.2013.04.007.

Kasisopa, B., Reilly, R. G., Luksaneeyanawin, S., & Burnham, D. (2016). Child readers' eye movements in reading Thai. *Vision Research*, 123, 8–19. https://doi.org/10.1016/j.visres.2015.07.009.

Kilgarriff, A., Baisa, V., Bušta, J., Jakubíček, M., Kovář, V., Michelfeit, J., Rychlý, P., & Suchomel, V. (2014). The sketch engine: Ten years on. *Lexicography*, 1(1), 7–36. https://doi.org/10.1007/s40607-014-0009-9.

Kim, S. Y., Yap, M. J., & Goh, W. D. (2018). The role of semantic transparency in visual word recognition of compound words: A megastudy approach. *Behavior Research Methods*, 51(6), 2722–2732. https://doi.org/10.3758/s13428-018-1143-3.

Kliegl, R., Nuthmann, A., & Engbert, R. (2006). Tracking the mind during reading: The influence of past, present, and future words on fixation durations. *Journal of Experimental Psychology: General*, 135(1), 12–35. https://doi.org/10.1037/0096-3445.135.1.12.

Kohsom, C., & Gobet, F. (1997). Adding spaces to Thai and English: Effects on reading. *Proceedings of the Cognitive Science Society*, 19, 388–393.

Kuperman, V., Bertram, R., & Baayen, R. H. (2008). Morphological dynamics in compound processing. *Language and Cognitive Processes*, 23(7–8), 1089–1132. https://doi.org/10.1080/01690960802193688.

Kuperman, V., Schreuder, R., Bertram, R., & Baayen, R. H. (2009). Reading polymorphemic Dutch compounds: Toward a multiple route model of lexical processing. *Journal of Experimental Psychology: Human Perception and Performance*, 35(3), 876–895. https://doi.org/10.1037/a0013484.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software*, 82(13). https://doi.org/10.18637/jss.v082.i13.

Leung, T., Boush, F., Chen, Q., & Al Kaabi, M. (2021). Eye movements when reading spaced and unspaced texts in Arabic. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 43. https://escholarship.org/uc/item/56b348fk

Li, P., & Li, X. (2013). Inserting spaces before and after words affects word processing differently in Chinese: Evidence from eye movements. *British Journal of Psychology*, 105(1), 57–68. https://doi.org/10.1111/bjop.12013.

Li, X., & Pollatsek, A. (2020). An integrated model of word processing and eye-movement control during Chinese reading. *Psychological Review*, 127(6), 1139–1162. https://doi.org/10.1037/rev0000248.

Libben, G. (2006). Why study compound processing? An overview of the issues. In G. Libben & G. Jarema (Eds.), *The representation and processing of compound words* (pp. 1–22). Oxford University Press.

Libben, G., Derwing, B. L., & De Almeida, R. G. (1999). Ambiguous novel compounds and models of morphological parsing. *Brain and Language*, 68(1–2), 378–386. https://doi.org/10.1006/brln.1999.2093.

Libben, G., Gagné, C. L., & Dressler, W. U. (2020). The representation and processing of compounds words. In V. Pirrelli, I. Plag, & W. U. Dressler (Eds.), *Word knowledge and word usage* (pp. 336–352). De Gruyter. https://doi.org/10.1515/9783110440577-009.

Libben, G., Gibson, M., Yoon, Y. B., & Sandra, D. (2003). Compound fracture: The role of semantic transparency and morphological headedness. *Brain and Language*, 84(1), 50–64. https://doi.org/10.1016/S0093-934X(02)00520-5.

Liu, P., & Lu, Q. (2018). The effects of spaces on word segmentation in Chinese reading: Evidence from eye movements. *Journal of Research in Reading*, 41(2), 329–349. https://doi.org/10.1111/1467-9817.12106.

Liu, Y., Yu, L., & Reichle, E. D. (Eds.) (2024). Towards a model of eye-movement control in Chinese reading. *Psychonomic Bulletin & Review*. https://doi.org/10.3758/s13423-024-02570-9.

Ma, G. (2017). Does interword spacing influence lexical processing in Chinese reading? *Visual Cognition*, 25(7–8), 815–824. https://doi.org/10.1080/13506285.2017.1338322.

Ma, G., Li, Z., Xu, F., & Li, X. (2018). The modulation of eye movement control by word length in reading Chinese. *Quarterly Journal of Experimental Psychology*, 72(7), 1620–1631. https://doi.org/10.1177/1747021818799994.

McBride-Chang, C., Chen, H.-C., Kasisopa, B., Burnham, D., Reilly, R., & Leppänen, P. (2012). What and where is the word? *Behavioral and Brain Sciences*, 35(5), 295–296. https://doi.org/10.1017/S0140525X1200009X.

McGowan, V. A., White, S. J., Jordan, T. R., & Paterson, K. B. (2013). Aging and the use of interword spaces during reading: Evidence from eye movements. *Psychonomic Bulletin & Review*, 21(3), 740–747. https://doi.org/10.3758/s13423-013-0527-8.

McGowan, V. A., White, S. J., & Paterson, K. B. (2015). The effects of interword spacing on the eye movements of young and older readers. *Journal of Cognitive Psychology*, 27(5), 609–621. https://doi.org/10.1080/20445911.2014.988157.

Mirault, J., Snell, J., & Grainger, J. (2019). Reading without spaces revisited: The role of word identification and sentence-level constraints. *Acta Psychologica*, 195, 22–29. https://doi.org/10.1016/j.actpsy.2019.03.001.

O'Regan, J. K., Lévy-Schoen, A., Pynte, J., & Brugaillère, B. (1984). Convenient fixation location within isolated words of different length and structure. *Journal of Experimental Psychology: Human Perception and Performance*, 10(2), 250–257. https://doi.org/10.1037/0096-1523.10.2.250.

Payne, B. R., Federmeier, K. D., & Stine-Morrow, E. A. L. (2020). Literacy skill and intra-individual variability in eye-fixation durations during reading: Evidence from a diverse community-based adult sample. *Quarterly Journal of Experimental Psychology*, 73(11), 1841–1861. https://doi.org/10.1177/1747021820935457.

Perea, M., & Acha, J. (2009). Space information is important for reading. *Vision Research*, 49(15), 1994–2000. https://doi.org/10.1016/j.visres.2009.05.009.

Phaholphinyo, S., Purodakananda, S., Kriengket, K., & Kosawat, K. (2009). Some observations about Thai synonymous compounds from the BEST 2009 corpus. *Eighth International Symposium on Natural Language Processing*, 2009, 194–199. https://doi.org/10.1109/SNLP.2009.5340920.

Pollatsek, A., Bertram, R., & Hyönä, J. (2011). Processing novel and lexicalised Finnish compound words. *Journal of Cognitive Psychology*, 23(7), 795–810. https://doi.org/10.1080/20445911.2011.570257.

Pollatsek, A., Hyönä, J., & Bertram, R. (2000). The role of morphological constituents in Reading Finnish compound words. *Journal of Experimental Psychology: Human Perception and Performance*, 26(2), 820–833. https://doi.org/10.1037/0096-1523.26.2.820.

Pollatsek, A., Juhasz, B. J., Reichle, E. D., Machacek, D., & Rayner, K. (2008). Immediate and delayed effects of word frequency and word length on eye movements in reading: A reversed delayed effect of word length.

Journal of Experimental Psychology: Human Perception and Performance, 34(3), 726–750. https://doi.org/10.1037/0096-1523.34.3.726.

Pollatsek, A., Reichle, E. D., & Rayner, K. (2003). Modeling eye movements in Reading: Extensions of the E-Z reader model. In J. Hyönä, R. Radach, & H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp. 361–390). North-Holland.

R Core Team. (2020). *R: A language and environment for statistical computing* [Computer software]. http://www.R-project.org/

Raney, G. E., Campbell, S. J., & Bovee, J. C. (2014). Using eye movements to evaluate the cognitive processes involved in text comprehension. *Journal of Visualized Experiments*, 83, 50780. https://doi.org/10.3791/50780-v.

Raney, G. E., & Rayner, K. (1995). Word frequency effects and eye movements during two readings of a text. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, 49(2), 151–173. https://doi.org/10.1037/1196-1961.49.2.151.

Rayner, K., Fischer, M., & Pollatsek, A. (1998). Unspaced text interferes with both word identification and eye movement control. *Vision Research*, 38(8), 1129–1144. https://doi.org/10.1016/S0042-6989(97)00274-5.

Rayner, K., & Morris, R. K. (1992). Eye movement control in reading: Evidence against semantic preprocessing. *Journal of Experimental Psychology: Human Perception and Performance*, 18(1), 163–172. https://doi.org/10.1037/0096-1523.18.1.163.

Rayner, K., & Pollatsek, A. (1996). Reading unspaced text is not easy: Comments. *Vision Research*, 36(3), 461–465. https://doi.org/10.1016/0042-6989(95)00132-8.

Rayner, K., Yang, J., Schuett, S., & Slattery, T. J. (2013). Eye movements of older and younger readers when reading unspaced text. *Experimental Psychology*, 60(5), 354–361. https://doi.org/10.1027/1618-3169/a000207.

Reichle, E., Pollatsek, A., Fisher, D., & Rayner, K. (1998). Toward a model of eye movement control in reading. *Psychological Review*, 105(1), 125–157. https://doi.org/10.1037/0033-295X.105.1.125.

Reichle, E., Rayner, K., & Pollatsek, A. (2003). The E-Z reader model of eye-movement control in reading: Comparisons to other models. *Behavioral and Brain Sciences*, 26(4), 445–476. https://doi.org/10.1017/S0140525X03000104.

Reznick, J. S., & Friedmann, N. (2015). Evidence from neglect dyslexia for morphological decomposition at the early stages of orthographic-visual analysis. *Frontiers in Human Neuroscience*, 9. https://doi.org/10.3389/fnhum.2015.00497.

Risse, S. (2014). Effects of visual span on reading speed and parafoveal processing in eye movements during sentence reading. *Journal of Vision*, 14(8), 11–11. https://doi.org/10.1167/14.8.11.

Sainio, M., Hyönä, J., Bingushi, K., & Bertram, R. (2007). The role of interword spacing in reading Japanese: An eye movement study. *Vision Research*, 47(20), 2575–2584. https://doi.org/10.1016/j.visres.2007.05.017.

Sandra, D. (1990). On the representation and processing of compound words: Automatic access to constituent morphemes does not occur. *Quarterly Journal of Experimental Psychology*, 42, 529–567. https://doi.org/10.1080/14640749008401236.

Schad, D. J., Risse, S., Slattery, T. J., & Rayner, K. (2014). Word frequency in fast priming: Evidence for immediate cognitive control of eye movements during reading. *Visual Cognition*, 22(3–4), 390–414. https://doi.org/10.1080/13506285.2014.892041.

Shoolman, N., & Andrews, S. (2003). Racehorses, reindeer, and sparrows: Using masked priming to investigate morphological influences on compound word identification. In S. Kinoshita & S. J. Lupker (Eds.), *Masked Priming: The State of the Art* (pp. 241–278). Psychology Press. https://doi.org/10.4324/9780203502846.

Slattery, T. J., & Rayner, K. (2013). Effects of intraword and interword spacing on eye movements during reading: Exploring the optimal use of space in a line of text. *Attention Perception & Psychophysics*, 75(6), 1275–1292. https://doi.org/10.3758/s13414-013-0463-8.

Smilek, D., Solman, G. J. F., Murawski, P., & Carriere, J. S. A. (2009). The eyes fixate the optimal viewing position of task-irrelevant words. *Psychonomic Bulletin & Review*, 16(1), 57–61. https://doi.org/10.3758/pbr.16.1.57.

Stenberg, A., & Cross, I. (2019). White spaces, music notation and the facilitation of sight-reading. *Scientific Reports*, 9(1). https://doi.org/10.1038/s41598-019-41445-1.

Taft, M. (1988). A morphological-decomposition model of lexical representation. *Linguistics*, 26(4), 657–667. https://doi.org/10.1515/ling.1988.26.4.657.

Taft, M. (1994). Interactive-activation as a framework for understanding morphological processing. *Language and Cognitive Processes*, 9(3), 271–294. https://doi.org/10.1080/01690969408402120.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *Quarterly Journal of Experimental Psychology Section A-Human Experimental Psychology*, 57(4), 745–765. https://doi.org/10.1080/02724980343000477.

Taft, M., & Forster, K. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, 14, 638–647. https://doi.org/10.1016/S0022-5371(75)80051-X.

Taft, M., & Forster, K. (1976). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior*, 15, 607–620. https://doi.org/10.1016/0022-5371(76)90054-2.

Tiffin-Richards, S. P., & Schroeder, S. (2015). Word length and frequency effects on children's eye movements during silent reading. *Vision Research*, 113, 33–43. https://doi.org/10.1016/j.visres.2015.05.008.

van Jaarsveld, H. J., & Rattink, G. E. (1988). Frequency effects in the processing of lexicalized and novel nominal compounds. *Journal of Psycholinguistic Research*, 17(6), 447–473. https://doi.org/10.1007/BF01067911.

Veldre, A., & Andrews, S. (2014). Lexical quality and eye movements: Individual differences in the perceptual span of skilled adult readers. *Quarterly Journal of Experimental Psychology*, 67(4), 703–727. https://doi.org/10.1080/17470218.2013.826258.

Veldre, A., Drieghe, D., & Andrews, S. (2017). Spelling ability selectively predicts the magnitude of disruption in unspaced text reading. *Journal of Experimental Psychology Human Perception & Performance*, 43(9), 1612–1628. https://doi.org/10.1037/xhp0000425.

Wei, Y., Niu, Y., Taft, M., & Carreiras, M. (2023). Morphological decomposition in Chinese compound word recognition: Electrophysiological evidence. *Brain and Language*, 241, 105267. https://doi.org/10.1016/j.bandl.2023.105267.

Wheeldon, L., & Lahiri, A. (2002). The minimal unit of phonological encoding: Prosodic or lexical word. *Cognition*, 85(2), B31–B41. https://doi.org/10.1016/s0010-0277(02)00103-8.

Winskel, H., Radach, R., & Luksaneeyanawin, S. (2009). Eye movements when reading spaced and unspaced Thai and English: A comparison of Thai–English bilinguals and English monolinguals. *Journal of Memory and Language*, 61(3), 339–351. https://doi.org/10.1016/j.jml.2009.07.002.

Winskel, H., Perea, M., & Ratitamkul, T. (2012). On the flexibility of letter position coding during lexical processing: Evidence from eye movements when reading Thai. *Quarterly Journal of Experimental Psychology*, 65(8), 1522–1536. https://doi.org/10.1080/17470218.2012.658409.

Wotschack, C., & Kliegl, R. (2013). Reading strategy modulates parafoveal-on-foveal effects in sentence reading. *Quarterly Journal of Experimental Psychology*, 66(3), 548–562. https://doi.org/10.1080/17470218.2011.625094.

Xia, X., Liu, Y., Yu, L., & Reichle, E. D. (2023). Are there preferred viewing locations in Chinese reading? Evidence from eye-tracking and computer simulations. *Journal of Experimental Psychology Learning Memory and Cognition*, 49(4), 607–625. https://doi.org/10.1037/xlm0001142.

Zang, C., Fu, Y., Bai, X., Yan, G., & Liversedge, S. P. (2018). Investigating word length effects in Chinese reading. *Journal of Experimental Psychology: Human Perception and Performance*, 44(12), 1831–1841. https://doi.org/10.1037/xhp0000589.

Zang, C., Liang, F., Bai, X., Yan, G., & Liversedge, S. P. (2013). Interword spacing and landing position effects during Chinese reading in children and adults. *Journal of Experimental Psychology: Human Perception and Performance*, 39(3), 720–734. https://doi.org/10.1037/a0030097.

Zhang, J., Anderson, R. C., Wang, Q., Packard, J. L., Wu, X., Tang, S., & Ke, X. (2011). Insight into the structure of compound words among speakers of Chinese and English. *Applied PsychoLinguistics*, 33(4), 753–779. https://doi.org/10.1017/s0142716411000555.

Zhou, X., & Marslen-Wilson, W. (1995). Morphological structure in the Chinese mental lexicon. *Language and Cognitive Processes*, 10(6), 545–600. https://doi.org/10.1080/01690969508407114.

Zwitserlood, P. (1994). The role of semantic transparency in the processing and representation of Dutch compounds. *Language and Cognitive Processes*, 9(3), 341–368. https://doi.org/10.1080/01690969408402123.

Appendix

Below is the list of sentences that were used in this study. Target words are underlined for illustrative purposes. The first word is the compound noun, whereas the second word is the simple noun. Participants saw only one of these conditions.

1. คุณแม่ขอให้คุณพ่อช่วยล้างกรงนก/กระทะให้สะอาด.
2. คุณแม่ใช้กล้วยไข่/ทุเรียนทำขนมหวานไปแจกเพื่อนๆ.
3. น้องชายกลืนก้างปลา/กุญแจลงคอจึงต้องรีบไปพบแพทย์.
4. คุณอาทำแก้วน้ำ/แจกันใบโปรดของฉันหล่นแตก.
5. ฉันพาคุณปู่คุณย่าไปตรวจข้อเท้า/มะเร็งที่โรงพยาบาล.
6. เพื่อนของฉันซื้อเข็มทิศ/กระจกมาจากร้านขายของเก่า.
7. หัวหน้าขอยืมเข็มหมุด/กรรไกรจากเพื่อนร่วมงานของฉัน.
8. คุณป้าไปซื้อไข่ไก่/กะทิที่ตลาดสำหรับทำอาหาร.
9. เด็กๆชอบกินไข่ดาว/โดนัทสำหรับอาหารมื้อเช้า.
10. ทุกๆเช้าฉันเห็นคนงาน/สุนัขเดินผ่านหน้าบ้าน.
11. คุณหมอถามหาคนไข้/ภารโรงที่หายไปจากโรงพยาบาล.
12. คุณยายชอบไปเดินดูเครื่องครัว/กระเป๋าที่ห้างใกล้บ้าน.
13. ฉันใช้เงินเดือน/คูปองทั้งหมดซื้อของขวัญให้คุณพ่อ.
14. เมื่อเช้าคุณพ่อใช้ช้อนชา/ตะเกียบชงกาแฟก่อนดื่ม.
15. คุณครูสั่งให้ใช้คำว่าดวงตา/รางวัลในการแต่งกลอน.
16. คุณพ่อซ่อนของมีค่าไว้ในถุงเท้า/ลิ้นชักเพื่อกันขโมย.
17. คุณแม่วานฉันไปซื้อถุงมือ/องุ่นที่ห้างสรรพสินค้า.
18. โจรสลัดในตำนานซ่อนสมบัติไว้ที่ท่าเรือ/อุโมงค์แห่งนี้.
19. คุณปู่พาฉันไปเดินเที่ยวทุ่งนา/ปราสาทที่ต่างจังหวัด.
20. ฉันฝันว่าฉันวิ่งเล่นบนทุ่งหญ้า/สวรรค์กับม้าตัวหนึ่ง.
21. เขาเปรียบอารมณ์เหมือนดั่งน้ำตา/ถนนที่ไม่มีจุดจบ.
22. คุณลุงใส่น้ำปลา/มะนาวในมาม่าชามนี้มากเกินไป.
23. เมื่อวานฉันเจอขวดน้ำผึ้ง/กาแฟวางอยู่ในตู้เสื้อผ้า.
24. สมัยก่อนคุณย่าชอบดื่มน้ำฝน/โอเลี้ยงเป็นประจำทุกวัน.
25. เพื่อนของฉันแนะนำน้ำพริก/ก๋วยเตี๋ยวร้านดังที่อร่อยมาก.
26. นักวิจัยทำขวดแก้วที่มีน้ำยา/แมลงอยู่ข้างในตกแตก.
27. คุณแม่ชอบดื่มน้ำส้ม/โซดาผสมมะนาวทุกวัน.
28. คุณปู่จับฉลากได้น้ำตาล/ปากกาเป็นของขวัญปีใหม่.
29. ต้นไม้นั้นมีรูปร่างเหมือนนิ้วเท้า/มนุษย์อย่างน่าแปลก.
30. ฉันได้รับฉายาว่านิ้วมือ/ตะเกียงจากเพื่อนสมัยประถม.
31. หัวหน้าเผ่าหยิบใบชา/เมล็ดประหลาดมาชงให้ฉันดื่ม.
32. ครูอนุบาลเคยสอนการใช้ใบไม้/กระดาษมาทำงานศิลปะ.
33. ฉันเห็นปลาดาว/พะยูนและปะการังระหว่างดำน้ำทะเล.
34. ตั้งแต่เกิดมาฉันพึ่งเคยจับปลาทอง/คางคกด้วยมือเปล่า.
35. ฉันชอบไปกินปลาหมึก/บะหมี่ที่ร้านอาหารญี่ปุ่น.
36. หมู่บ้านของฉันมีป้อมยาม/ฟิตเนสที่ไม่มีใครใช้มานาน.
37. ผู้กำกับสั่งให้ผู้ช่วยแขวนป้ายชื่อ/ชิงช้าไว้บนต้นไม้.
38. คุณยายชอบใส่ผ้าถุง/กระโปรงเวลาพักผ่อนอยู่ที่บ้าน.
39. พี่สาวชวนเพื่อนบ้าน/สะใภ้มาทานอาหารมื้อเย็นที่บ้าน.
40. ฉันจ้างแม่บ้านมาเช็ดล้างมุ้งลวด/เพดานทั้งหมดในบ้าน.
41. นักพยากรณ์อากาศบอกว่าจะมีเมฆฝน/พายุวันนี้.
42. คุณหมอตรวจพบเม็ดเลือด/ไวรัสแปลกๆในผลเลือด.
43. คุณพ่อเอารถตู้/สมบัติไปขายเพื่อนำเงินมาใช้หนี้.
44. นายกประกาศซื้อรถถัง/อาหารนำเข้าจากต่างประเทศ.
45. คุณพ่อของฉันนั่งมองรถไฟ/ทะเลจากร้านอาหารริมทาง.
46. ฉันมีความฝันอยากขับรถม้า/จรวดมาตั้งแต่สมัยเด็ก.
47. คนขับโทรเรียกให้ช่างมารับรถราง/แท็กซี่ไปซ่อมบำรุง.
48. เมื่อวานฉันเห็นเรือใบ/ขยะลอยผ่านไปในทะเล.
49. การก่อสร้างโรงงาน/สะพานนี้ทำให้ถนนเส้นนี้รถติดมาก.

https://doi.org/10.1017/langcog.2025.10028 Published online by Cambridge University Press

50. หลานสาวชอบวิ่งเล่นในโรงรถ/ศาลาทีบ้านของคุณปู่.
51. หัวหน้าโทรติดต่อจองโรงหนัง/รีสอร์ทเพือจัดกิจกรรม.
52. ฉันเคยซือแว่นตา/กำไลราคาหลักแสนเพือเอาใจแฟน.
53. วัยรุ่นไทยนิยมใส่สร้อยคอ/แจ็คแก็ตตามเทรนด์แฟชัน.
54. สมัยนีคนนิยมปลูกสวนครัว/กระเพราบริเวณหลังบ้าน.
55. ฉันจะไปเทียวสวนสัตว์/ระยองกับเพือนในวันหยุด.
56. ฉันสนใจโครงการอนุรักษ์สัตว์ป่า/โลมาทีใกล้สูญพันธุ์.
57. น้องชายของฉันชอบดูสารคดีสัตว์ปีก/แพนด้าก่อนนอน.
58. นักกีฬาใช้สายตา/อาวุธข่มขวัญคู่ต่อสู้ก่อนการแข่งขัน.
59. ฉันเผลอถอดสายไฟ/ลำโพงทีต่ออยู่กับคอมพิวเตอร์.
60. เมือกีฉันเดินสะดุดสายยาง/กระป๋องอย่างไม่ทันตั้งตัว.
61. นักวาดรูปชือดังใช้สีน้ำ/พู่กันเป็นหลักในการวาดภาพ.
62. โรงงานข้างบ้านรับผลิตเสาธง/เก้าอีในราคาถูก.
63. ช่างก่อสร้างบอกว่าเสาเข็ม/คอนกรีตมีราคาสูงขึนมาก.
64. สวนสัตว์นีพึงรับเสือดาว/ฮิปโปตัวหนึงเข้ามาดูแล.
65. ร้านเสือผ้าจะลดราคาเสือกล้าม/กางเกงทุกๆสินเดือน.
66. เพือนฉันแต่งงานกับหมอฟัน/ตำรวจคนหนึงเมือปีก่อน.
67. เมือคืนฉันฝันเห็นหมาป่า/ยีราฟนอนอยู่ทีริมถนน.
68. เชฟคนหนึงใช้เนือหมูป่า/สิงโตมารังสรรค์เมนูพิสดาร.
69. เศรษฐีคนหนึงซือแมวน้ำ/เพนกวินมาเลียงในราคาล้านบาท.
70. คุณแม่วางแผนจะต่อเติมห้องครัว/ระเบียงให้กว้างขึน.
71. ศิลปินชือดังวาดภาพห้องโถง/กษัตริย์โดยใช้ปากคาบพู่กัน.
72. สถาปนิกชือดังออกแบบห้องน้ำ/อาคารสไตล์วินเทจให้ฉัน.
73. คุณป้ามีห้องแถว/คอนโดให้คนงานเช่าอยู่ทีชลบุรี.
74. คุณตาอยากได้หีบเพลง/หนังสือโบราณในตลาดของเก่า.
75. นักวิจัยตรวจพบแผ่นดิน/อากาศในดาวเคราะห์เพือนบ้าน.
76. คุณปู่เคยทำธุรกิจนำเข้าแผ่นเสียง/กระเบืองจากต่างประเทศ.

Cite this article: Chantavarin, S., & Leung, T. T.-C. (2025). The effects of interword spacing and morphological complexity in reading Thai: an eye-tracking study, *Language and Cognition*, 17, e69, 1–28. https://doi.org/10.1017/langcog.2025.10028