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Investigating the effects of background knowledge on Chinese word processing during text reading: evidence from eye movements

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This study investigates the effects of background knowledge on Chinese word processing during silent reading by monitoring adult readers' eye movements. Both higher knowledge (physics major) and lower knowledge (nonphysics major) graduate students were given physics texts to read. Higher knowledge readers spent less time rereading and had lower regression rates on unfamiliar physics words and common words in physics texts than did lower knowledge readers; they also had shorter gaze durations and fewer first-pass fixations on familiar physics words than on unfamiliar physics words. For unfamiliar physics words and common words, both groups predominantly fixated first on the beginnings of words when they made multiple fixations on a word and on a left-of-centre location when they fixated only once on a word. These findings suggest that both groups comprise mature readers with strong language concepts. However, differences in background knowledge led to different reading processes at different stages of reading.

Research has demonstrated the effects of background knowledge on text comprehension. Readers with higher background knowledge (HiK) comprehend texts better than those with lower background knowledge (LoK) (Caillies, Denhière & Kintsch, 2002; Kendeou & van den Broek, 2007; McNamara, 2001; O'Reilly & McNamara, 2007; Salmerón, Kintsch & Cañas, 2006; Surber & Schroeder, 2007). However, research on the effects of background knowledge on the processing of words is scant, with most studies only involving the alphabet rather than Chinese words (Kaakinen, Hyona & Keenan, 2003). Construction-integration (CI) theory, proposed by Kintsch (1988), suggests that reading is a highly interactive process that comprises a two-phase cycle of construction and integration. Construction is regarded as a 'bottom-up' process, and integration is regarded as a 'top-down' process (Kintsch, 1988, 2005). Background knowledge is an important element of both phases.

This article was published online on 9 July 2012. An error was subsequently identified. This notice is included in the online and print versions to indicate that both have been corrected.

Reading words and sentences involves processing some text elements according to reader background knowledge. Connecting new and old information provides the reader with a clear mental representation of the text. Kaakinen et al. (2003) used CI theory to manipulate prior knowledge, working memory and information relevance to investigate how these factors influence eye movements while reading expository texts. Alphabetic language readers had longer fixation durations and spent more time rereading text information about which they had little background knowledge compared to information about which they had more background knowledge.

In terms of word processing, word familiarity and subjective familiarity are relevant to background knowledge. Readers have more background knowledge on high-familiarity words than on low-familiarity words. Eye-movement studies show that readers have longer first fixation durations (FFD), gaze durations (GD) and rereading times when processing unfamiliar words than when processing familiar words (Chaffin, Morris & Seely, 2001; Juhasz & Rayner, 2003; Just & Carpenter, 1980; Williams & Morris, 2004). Readers with less background knowledge or familiarity with target words needed more time to construct meaning from relevant information (Bell & Perfetti, 1994; Just & Carpenter, 1980). The findings of the aforementioned studies suggest that relevant background knowledge and word familiarity have facilitatory effects on word processing in alphabetic reading.

Chinese text comprises strings of equally spaced symbols called characters. One or more characters form a word, and most characters carry independent meanings; thus, word meanings consisting of characters become complicated. Consider a Chinese physics word, '電感' (inductance), as an example. The Chinese character '電' means 'electricity', and '感' means 'to feel, to sense, [or] to realise'. Although the meanings of both characters are familiar to adult readers, it is not easy for readers with little knowledge of physics to comprehend '電 感' (inductance) simply by combining the meanings of its constituent characters. If readers have relevant background knowledge of certain physics words, they may access the words' meanings from their mental lexicons and easily recognise them. In contrast, if readers have no related background knowledge of a word despite familiarity with both constituent characters, they may only understand aspects of the word without inferring its entire meaning. Further complicating matters, there are no spaces between words in Chinese texts; therefore, there are no visual cues for word segmentation. The concept of 'word' in Chinese is not defined as clearly as that in English (Rayner, Li & Pollatsek, 2007; Yang & McConkie, 1999). Chinese readers do not always agree where words are divided when they are asked to segment sentences into words (Peng & Chen, 2004). Thus, preferred viewing location (PVL) is an important indicator of eye movement in Chinese reading. PVL describes the position in a word where the reader's gaze first lands (Rayner, 1979) and is often used as an index of whether readers view a word as a reading unit (Yan, Kliegl, Richter, Nuthmann & Shu, 2010; Yang & Vitu, 2007). Readers generally have a very stable PVL that falls halfway between the beginning and middle of an alphabetic word (McConkie, Kerr, Reddix & Zola, 1988; Rayner, Sereno & Raney, 1996). Because of the lack of visual cues for word boundaries in Chinese, the PVLs of Chinese readers might reflect linguistic factors that play roles in controlling gaze location. Readers may use implicit linguistic knowledge to segment words while reading sentences (Yan et al., 2010; Yang & Vitu, 2007).

Studies have investigated whether readers have PVLs in Chinese reading, but the issue remains controversial. Some researchers have not found PVL in words and claimed that Chinese readers do not see words as reading units (Tsai & McConkie, 2003; Yang & McConkie, 1999). However, more recent research has shown PVLs in Chinese reading and claimed that the word is the primary reading unit of Chinese texts (Bai, Yan, Liversedge, Zang & Rayner, 2008; Chen & Ko, 2011). Chinese readers have different PVLs under different fixation conditions. Yan et al. (2010) found that undergraduate participants tended to direct their first fixation to the centre of the Chinese word when single fixations occurred and to the beginning of the word when multiple fixations occurred. They suggested that Chinese readers switch between these two alternative strategies depending on the success or failure of parafoveal word segmentation. When successfully segmenting words, readers use the word as a reading unit and require only a single fixation on the word. However, when failing to segment words, readers fixate multiple times on the word and use the character as a reading unit. Li, Liu and Rayner (2011) asked Chinese university students to read Chinese sentences containing two- and four-character target words.

The results replicated the patterns found by Yan et al. (2010). However, Li et al. (2011) interpreted these results differently, arguing that readers employ a combination of character-based and word-based targeting when planning eye movements, contingent on word segmentation processes.

The present study examines how readers with more and less physics background knowledge read physics-related words. HiK and LoK physics readers were recruited; they read the same common words and unfamiliar physics words in physics texts (details are elaborated in the Materials section). This work compared the eye movements of the two groups while reading unfamiliar physics words and common words to determine whether HiK and LoK adult readers use different reading strategies when reading physics texts. This study also compares the eye movements of HiK readers while reading familiar and unfamiliar physics words, and predicts that HiK and LoK readers will have eye-movement patterns that reflect differences in early word recognition (Just & Carpenter, 1980; Williams & Morris, 2004) due to the groups' different levels of background knowledge of physics words.

This study also tests whether readers use a character-by-character strategy to process unfamiliar physics words. If so, the results may show different PVL patterns between unfamiliar physics words and common words for both HiK and LoK readers.

Method

Participants

Thirty graduate students at National Central University in Taiwan who were native Chinese speakers volunteered to participate in the experiment and received a monetary reward for participation. Fifteen of these students were from the Department of Physics (HiK readers), and 15 were from the College of Liberal Arts or College of Management (LoK readers). All participants had normal or corrected-to-normal visual acuity.

Apparatus

Eye movements were recorded by an EyeLink II eye tracker. Although viewing was binocular, eye movements were recorded from the right eye only. The sampling rate was 250 Hz. Text was displayed on a 19-inch LCD monitor. The size of the characters presented was 24 × 24 pixels. Participants sat approximately 65 cm from the monitor during the reading tasks; each Chinese character subtended 1° of visual angle.

Materials

Subjective ratings of word familiarity. Thirty physics texts were selected from Scientific American (Chinese edition), and a physics professor circled technical physics words from these texts. The researcher then constructed a physics-word familiarity questionnaire using the marked words. A subjective familiarity rating questionnaire was used rather than word frequency to define the familiarity of physics words for two reasons: (1) no word frequencies of technical physics words are included in the Word List with Accumulated Word Frequency (Chinese edition) (Academia Sinica Taiwan, 1998), and (2) although word frequency has been widely used as a measure of word familiarity in reading research (Juhasz & Rayner, 2006; Rayner & Juhasz, 2004), some researchers have considered subjective ratings of word familiarity to be more sensitive for detecting familiarity (Juhasz & Rayner, 2003; Williams & Morris, 2004). For example, Williams and Morris (2004) suggested that although the words 'pizza' and 'assay' had equivalent frequencies in the Francis and Kucera (1982) corpus, undergraduate participants felt more familiar with 'pizza' than with 'assay'.

Sixty-four university graduate students were asked to complete the physics-word familiarity questionnaire to select the targets used in this study. Of these, 32 students from the Department of Physics were assumed to have more background knowledge of physics, while the other 32 raters from the College of Liberal Arts and the College of Management had less background knowledge of physics. All participants were required to evaluate whether or not they knew the meaning of each physics word in the questionnaire. These participants did not participate in the subsequent text reading experiment. Analysis of the questionnaire showed that 25 physics words were unfamiliar to both the HiK and LoK readers (defined as fewer than 40% of HiK and LoK readers knowing them); these were deemed 'unfamiliar physics words' in this study. Thirty-three words were familiar to HiK readers (defined as at least 60% of HiK readers knowing them) but not to LoK readers; these were deemed 'physics words familiar to HiK readers' in this study.

Physics words in these two categories were selected as targets for the text reading experiment. All target physics words were unfamiliar to LoK readers; some of the target words were familiar and some unfamiliar to HiK readers. To create a balanced design, only 25 unfamiliar physics words were analysed for both HiK and LoK readers; each group therefore had an equal number of targets for statistical testing.

Reading texts. The reading texts comprised 16 samples selected from 30 physics texts taken from Scientific American (Chinese edition). The text selection criteria were the inclusion of at least one familiar physics word and one unfamiliar physics word. Each text ranged from 190–220 characters in length. In the analysis stage, all texts were parsed by a Chinese word segmentation system designed by Chinese Knowledge and Information Processing (Academia Sinica Taiwan, 1999). The 16 physics texts contained 25 unfamiliar physics words (unfamiliar to both HiK and LoK readers), 33 physics words familiar only to HiK readers and 1,510 common words.

In addition to the 16 physics texts, participants also read four general expository texts (Ko et al., 2005) to check whether HiK and LoK readers read general expository texts similarly.

Procedure

Participants read each text silently at their own pace. The 20 texts were presented randomly, one at a time on the screen. Prior to reading each text, a drift-correct screen appeared, and participants were instructed to look at the calibration dot located on the first character in each text. When participants completed the drift correction procedure, the complete test text appeared on the screen.

Reading was self-paced, and participants were instructed to press a button on a game pad when they finished reading. After the participants pressed the button, the screen's contents were replaced by a 'yes/no' comprehension question for participants to answer. After participants indicated that they understood the experimental procedure, nine-point calibration and validation procedures were used. A chin rest was used to minimize head movement. The experiment took approximately 40 minutes for each participant to complete.

Results

As in previous studies (Andrews, Miller & Rayner, 2004; Chen & Ko, 2011), individual fixations shorter than 100 ms (comprising approximately 2% of data) were excluded from analysis. This study reports its results in three sections: the initial processing stage, the late processing stage and PVL distributions. Three indicators are measured during the initial processing stage: (1) FFD (the duration of the reader's first fixation on a word), (2) GD (the sum of all first-pass fixations on a word prior to a saccade to another word) and (3) the number of first-pass fixations (the number of first-pass fixations on a word prior to leaving the word). Two indicators are measured during the late processing stage: (1) rereading time (time spent on the word after the first fixation) and (2) regression rate (i.e., regression probability). This work uses the same analysis method of PVL distribution as previous research (Li et al., 2011; Yan et al., 2010), including two outcomes: only one or more than one fixation on a word. Both outcomes require calculation of the number of first-pass fixation(s), but not the number of second-pass fixation(s) on the target word. [Correction made here after initial online publication]

Eye movements of HiK versus LoK readers while reading general expository texts

Prior to formal experimental analysis, this work compared the eye-movement patterns of the HiK and LoK groups while reading general expository texts to ensure that any differences in eye movements between the two groups while reading physics texts were due to differences in relevant background knowledge rather than reading abilities. As expected, the differences between groups in terms of global eye-movement data were not significant (t's < 1), including characters read per minute (HiK: $M = 428.91$, $SEM = 128.07$; LoK: $M = 450.86$, $SEM = 143.94$), average forward fixation duration (HiK: $M = 218.25$ ms, $SEM = 22.90$ ms; LoK: $M = 217.49$ ms, $SEM = 22.62$ ms), average backward fixation duration (HiK: $M = 218.95$ ms, $SEM = 21.65$ ms; LoK: $M = 214.51$ ms, $SEM = 22.64$ ms), forward saccade length (HiK: $M = 2.98$ characters, $SEM = 0.47$ characters; LoK: $M = 3.31$ characters, $SEM = 0.78$ characters) and backward saccade length (HiK: $M = 2.44$ characters, $SEM = 0.82$ characters; LoK: $M = 2.65$ characters, $SEM = 0.74$ characters).

This study also used the Chinese word as a unit to conduct detailed analysis of eye-movement data. The four general expository texts used comprised 502 Chinese words. There were no significant differences (t's < 1) between the two groups with regard to either the initial or late processing stages when reading general expository texts; measurements that lacked significant findings included FFD (HiK: $M = 219.68$ ms, $SEM = 22.12$ ms; LoK: $M = 218.14$ ms, $SEM = 23.25$ ms), GD (HiK: $M = 240.48$ ms, $SEM = 29.64$ ms;

Table 1. The means (in milliseconds) and standard errors of unfamiliar physics words and common words for HiK/LoK readers ($N = 15$).

	Unfamiliar physics words		Common words	
	M	*SD*	*M*	*SD*
Initial processing time				
First fixation duration				
HiK	243.96	39.28	225.09	24.96
LoK	248.11	42.84	226.91	24.27
Gaze durations				
HiK	434.23	112.26	249.09	33.38
LoK	512.98	165.95	250.48	34.88
The number of first-pass fixations				
HiK	1.87	0.30	1.11	0.05
LoK	2.03	0.40	1.11	0.05
Late processing time				
Rereading time				
HiK	731.23	310.14	393.72	88.54
LoK	1259.86	404.73	481.31	73.42
Regression rates				
HiK	24.50%	0.09	11.10%	0.05
LoK	39.59%	0.11	22.49%	0.07

LoK: $M = 236.39$ ms, $SEM = 33.97$ ms), the number of first-pass fixations (HiK: $M = 1.10$, $SEM = 0.02$; LoK: $M = 1.09$, $SEM = 0.01$), rereading time (HiK: $M = 334.62$ ms, $SEM = 59.08$ ms; LoK: $M = 341.42$ ms, $SEM = 58.33$ ms) and regression rate (HiK: $M = 9.13\%$, $SEM = 4.01\%$; LoK: $M = 9.80\%$, $SEM = 5.12\%$). These data indicate that overall, the members of the two groups had similar reading abilities.

Eye movements while reading Chinese unfamiliar physics words and common words for HiK versus LoK readers

For each of the eye-movement measures, a 2 (background knowledge: HiK vs LoK) × 2 (word type: unfamiliar physics words vs common words) analysis of variance was conducted on participant data (F_1) and on item data (F_2). Table 1 shows the five eye-movement measures for HiK and LoK readers.

This study determines whether readers' relevant background knowledge has an effect on how Chinese words are read and whether there is an interaction between the two experimental variables, but it was not designed to compare participants' eye movements when they read unfamiliar physics words versus common words.

Therefore, the main effect of word type was not the focus of this study. This research also did not control for word properties of the two word types, such as word frequency, word length or word predictability. Therefore, after conducting two-way mixed design ANOVAs, the main effects of the background knowledge and word type were reported, but the effects of word type are not explained herein.

Initial processing stage. The FFD measure showed no main effects of background knowledge, F's < 1, but there was a reliable main effect of word type, F_1 (1, 28) = 14.99, $p < .01$; F_2 (1, 3065) = 20.30, $p < .001$. There was no interaction between background knowledge and word type, F's < 1. In GD, the effect of background knowledge was not reliable, F_1 (1, 28) = 1.67, $p > .2$, F_2 (1, 3065) = 12.08, $p < .01$, but there was a reliable main effect of word type, F_1 (1, 28) = 109.69, $p < .001$; F_2 (1, 3065) = 799.13, $p < .001$. No significant interaction was shown between background knowledge and word type, F's < 1. The effect of background knowledge on the number of first-pass fixations was not significant, F's < 1, but there was a significant main effect of word type on the number of first-pass fixations, F_1 (1, 28) = 205.27, $p < .001$; F_2 (1, 3065) = 1077.23, $p < .001$. No significant interaction existed between background knowledge and word type, F's < 1.

HiK and LoK readers did not differ significantly in terms of FFD, GD or the number of first-pass fixations while reading unfamiliar physics words and common words.

Late processing stage. The rereading time results revealed reliable main effects of background knowledge, F_1 (1, 28) = 15.39, $p < .01$; F_2 (1, 2092) = 81.98, $p < .001$, and word type, F_1 (1, 28) = 105.95, $p < .001$; F_2 (1, 2092) = 325.24, $p < .001$.

The interaction between relevant background knowledge and word type was also statistically significant, F_1 (1, 28) = 16.54, $p < .001$; F_2 (1, 2092) = 55.23, $p < .001$. HiK readers had significantly shorter rereading times than did LoK readers for both unfamiliar physics words, F_1 (1, 14) = 31.139, $p < .001$; F_2 (1, 48) = 12.66, $p < .01$, and common words, F_1 (1, 14) = 74.87, $p < .001$; F_2 (1, 2854) = 41.31, $p < .001$.

Regression rate data also showed a significant main effect of relevant background knowledge, F_1 (1, 28) = 22.49, $p < .001$; F_2 (1, 3065) = 67.36, $p < .001$, and word type, F_1 (1, 28) = 122.62, $p < .001$; F_2 (1, 3065) = 25.44, $p < .001$, with no reliable interaction between background knowledge and word type (F's < 1).

PVL of both groups for unfamiliar physics words and common words

The proportions of single fixations and multiple fixations on Chinese unfamiliar physics words and common words for HiK and LoK readers are shown separately in Figures 1 and 2, respectively. These results show that among the HiK and LoK groups, whether reading unfamiliar physics words or common words, the proportions of single and multiple fixations do not differ significantly for two-, three- or four-character unfamiliar physics words (F's < 1).

The landing-position distributions (PVL distributions) of single and multiple fixations for unfamiliar physics words and common words are shown separately in Figures 3 and 4. Seven two-character unfamiliar physics words were used as target words in the experimental text, and these words received multiple fixations in only 18.6% of the trials. Because there were insufficient data to conduct valid calculations, this study only reports the PVL distributions for three- and four-character unfamiliar physics words.

Whether reading three- or four-character unfamiliar physics words or common words, HiK and LoK readers tended to direct their first fixations to the beginnings of target words when multiple fixations were made and shift their fixations slightly left of centre when only single fixations were made.

Eye movements of HiK readers when reading familiar/unfamiliar physics words

Table 2 shows the eye movement measures associated with familiar and unfamiliar physics words for HiK readers.

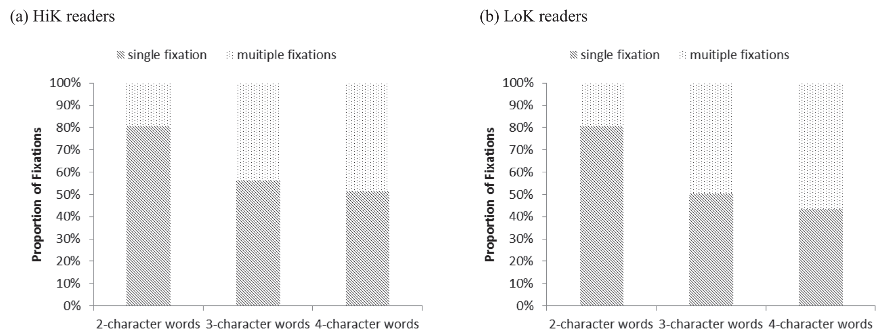

Figure 1. Proportions of single fixations and multiple fixations on Chinese unfamiliar physics words ranging from two to four characters in length.

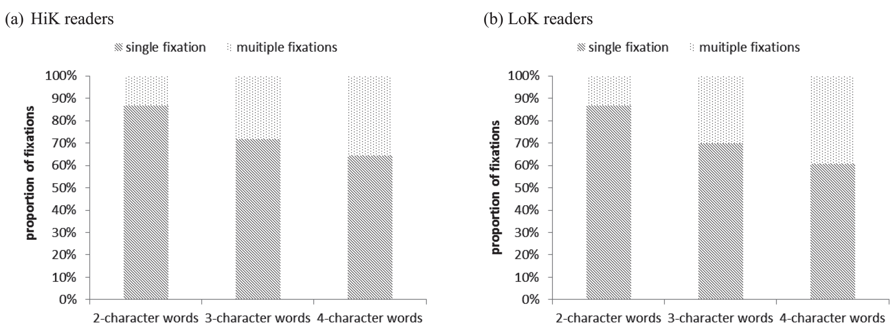

Figure 2. Proportions of single fixations and multiple fixations on Chinese common words ranging from two to four characters in length.

Initial processing stage. The results show that HiK readers had higher GD for unfamiliar than for familiar physics words, $t_1(14) = 2.37$, $p < .05$; $t_2(56) = 1.95$, $p = .05$. In terms of the number of first-pass fixations, HiK readers tended to have higher GD for unfamiliar than for familiar physics words; this familiarity effect was statistically significant for readers but was only marginal for items, t_1 $(14) = 3.24$, $p < .01$; t_2 $(56) = 1.61$, $p > .1$. These two physics word types did not differ significantly in terms of FFD (t's < 1).

Late processing stage. The rereading time for HiK readers did not differ when reading familiar versus unfamiliar physics words (t's < 1), nor did the regression rate (t's < 1).

PVL of HiK readers for familiar and unfamiliar physics words

Figure 5 shows the proportions of single and multiple fixations on familiar and unfamiliar two- to four-character physics words for HiK readers. For three-character words, the proportions of single and multiple fixations among HiK readers differed significantly on familiar versus unfamiliar physics words, $t(14) = 2.83$, $p < .05$. HiK readers had higher proportions of multiple fixations on three-character unfamiliar physics words than on familiar physics words. However, for two- and four-character physics words, the proportions of single and multiple fixations did not differ significantly between the two groups (F's < 1).

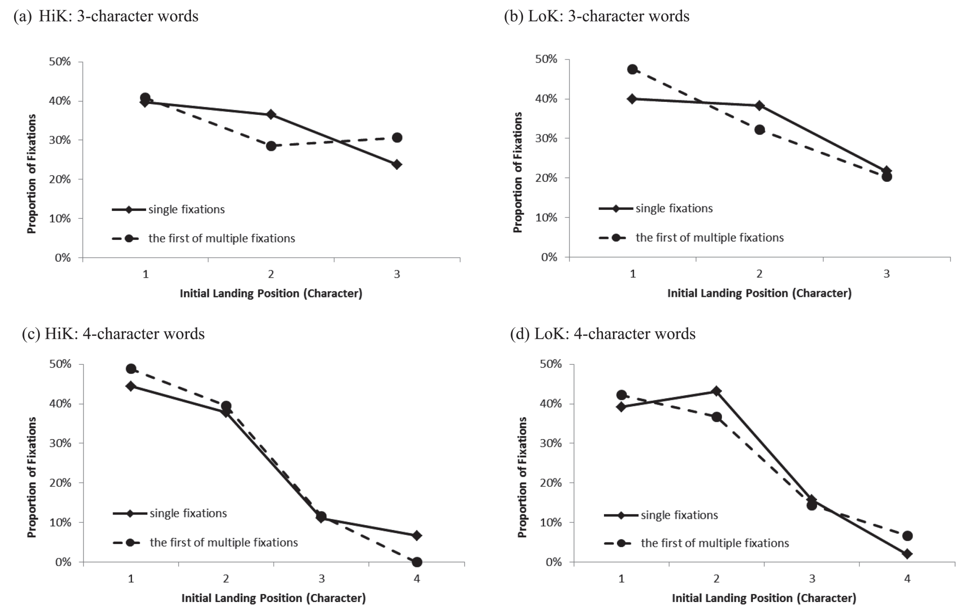

Figure 3. PVL curves for Chinese unfamiliar physics words.

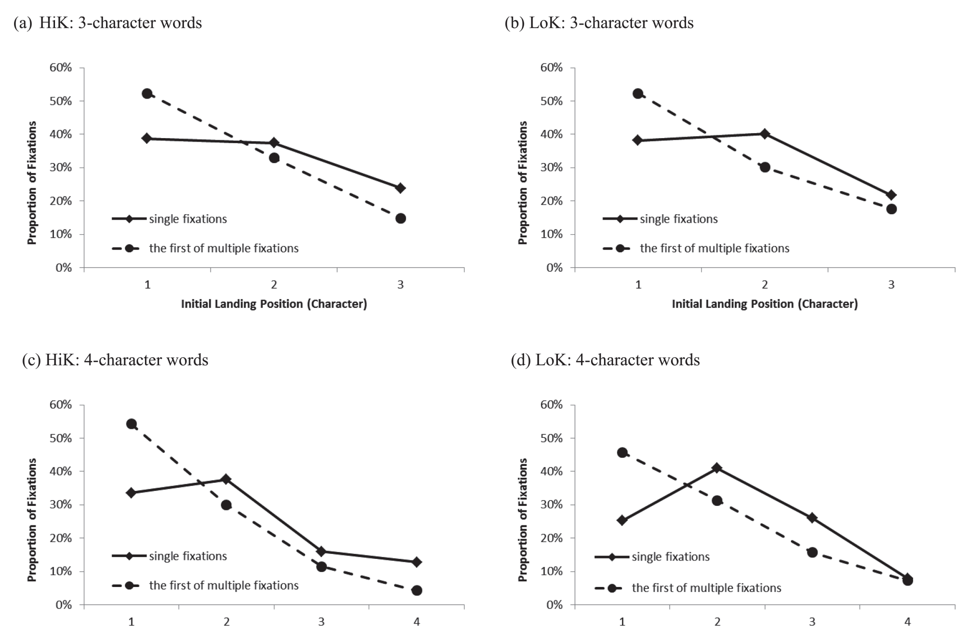

Figure 4. PVL curves for Chinese common words.

Table 2. The means (in milliseconds) and standard errors of familiar and unfamiliar physics words for HiK readers ($N = 15$).

	M	*SD*	*t*
Initial processing stage			
First fixation duration			
Familiar physics words	236.13	32.29	–1.23
Unfamiliar physics words	243.96	39.28	
Gaze durations			
Familiar physics words	375.32	93.66	–2.37*
Unfamiliar physics words	434.23	112.26	
The number of first-pass fixations			
Familiar physics words	1.61	0.29	–3.47**
Unfamiliar physics words	1.87	0.30	
Late processing stage			
Rereading time			
Familiar physics words	747.94	352.54	0.23
Unfamiliar physics words	731.23	310.14	
Regression rates			
Familiar physics words	24.96%	0.11	1.02
Unfamiliar physics words	24.50%	0.09	

*$p < .05$; **$p < .01$.

As the number of characters increased, the proportion of single fixations decreased and that of multiple fixations increased for both types of physics words.

The PVL distributions of single and multiple fixations on familiar and unfamiliar physics words for HiK readers are shown in Figure 6. PVL distributions for two-character words were not analysed for the same reason that the PVL distributions comparing HiK and LoK readers were not used. Again, there were no significant differences between groups in terms of PVL results. Whether reading three- or four-character familiar or unfamiliar physics words, HiK readers tended to direct their first fixations to the beginnings of target words when multiple fixations were made and fixate on slightly left-of-centre locations when single fixations were made. The overall patterns were similar to those found in previous research (Li et al., 2011; Yan et al., 2010). When multiple fixations were made, even though the experimental materials were physics words, they were common; therefore, subjects directed their first fixations to the beginnings of the target words. In slight contrast with the results of Li et al. and Yan et al., HiK and LoK readers both directed single fixations to slightly left-of-centre locations.

Discussion

This study examined the effects of background knowledge on the processing of unfamiliar Chinese words during silent reading by analysing the eye movements of HiK and LoK graduate students. These participants exhibited similar reading patterns when reading general expository texts, indicating that the two groups had similar overall reading abilities. However, when they read physics texts, their eye-movement patterns differed significantly.

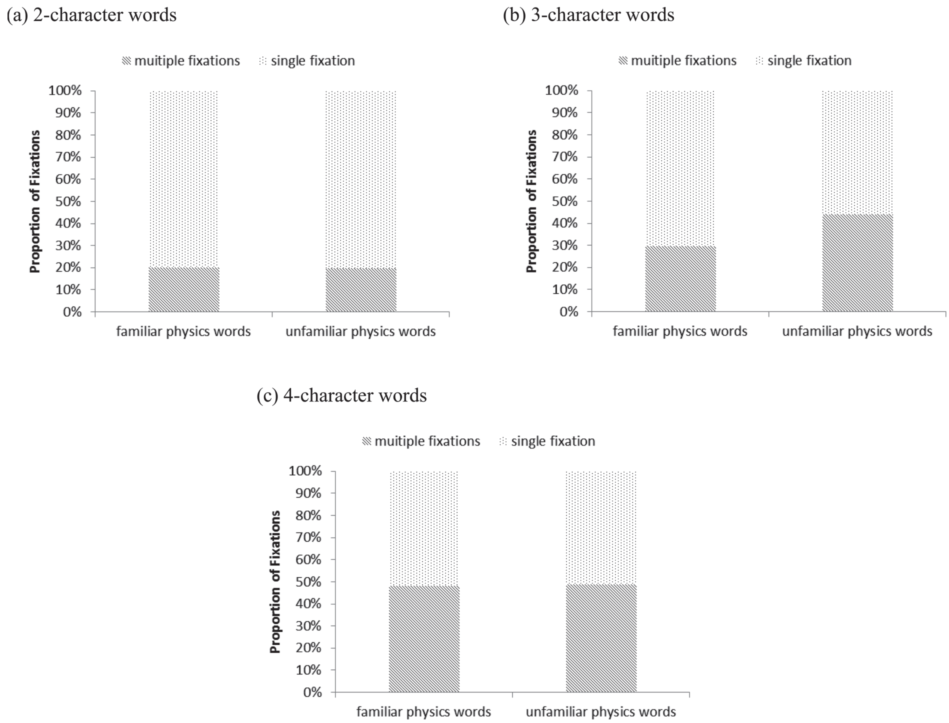

Figure 5. Proportions of single fixations and multiple fixations on familiar and unfamiliar physics words for HiK readers.

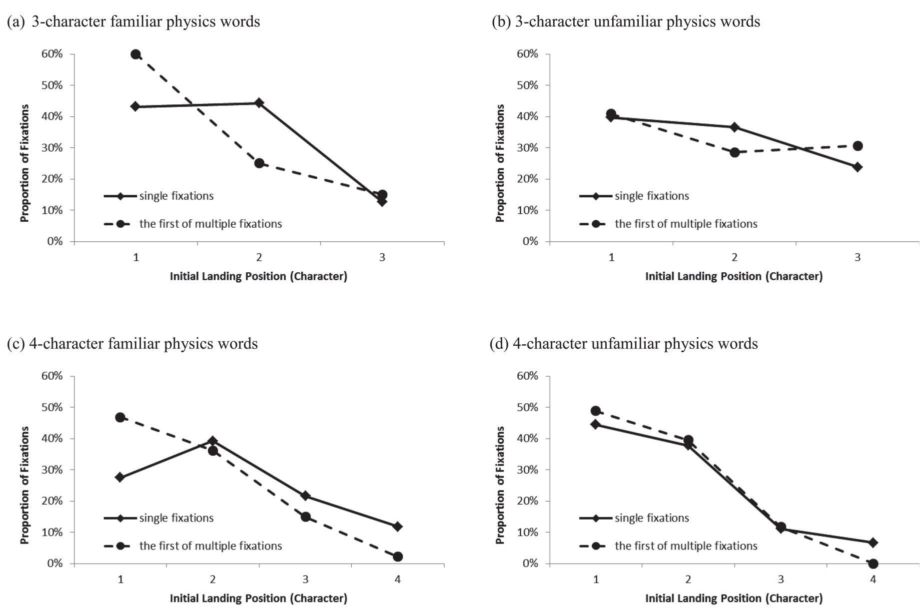

Figure 6. PVL curves for familiar and unfamiliar physics words for HiK readers.

This work considered two processing stages that occur during reading, the initial and late processing stages, which include decoding words and integrating word meanings, respectively (Just & Carpenter, 1980; Williams & Morris, 2004). We also compared participants' PVL distributions to further explain the possible strategies of HiK and LoK readers while reading unfamiliar physics words.

The study had three main findings: (1) in the initial stage, the processing times of HiK and LoK readers did not differ significantly either for unfamiliar physics words or common words. However, HiK readers had longer GD and a greater number of first-pass fixations on unfamiliar than on familiar physics words. (2) In the late processing stage, HiK readers had significantly shorter rereading times and lower regression rates than LoK readers for both physics words and common words. However, there were no significant differences in late processing depending on whether the HiK group was confronted with familiar or unfamiliar physics words. (3) The overall results of PVL analyses were identical between the knowledge groups whether they were reading three- or four-character unfamiliar physics words or common words; HiK and LoK readers tended to direct their first fixations to the beginnings of target words when making multiple fixations; single fixations were directed to slightly left-of-centre positions on words. HiK readers had similar PVL patterns regardless of the familiarity of the physics words read.

In this study, HiK and LoK readers showed similar PVL patterns on unfamiliar physics words and common words, and the PVL pattern on common words was also similar to previous research, which used common words as experimental materials (Li et al., 2011; Yan et al., 2010). This indicates that Chinese readers prefer targeting their eyes at the beginning of a word when making more than one fixation on a word. The patterns between our data and those of Yan et al. (2010) for single fixations differ somewhat; our data showed that subjects prefer targeting their eyes to the left-of-centre location within a word, whereas the research of Yan et al. showed that Chinese readers' eyes landed at the centre of words. However, after adopting the same criterion as Yan et al., and recalculating by adding the percentages of fixations landing on the first and second characters of the three-character words, our results were comparable to those of Yan et al. In our study, HiK and LoK readers made 76% and 78% of their fixations on the first and second characters of three-character words when targeting unfamiliar physics words or common words; the results of Yan et al., calculated by adding the rates of fixations on the first and second characters of three-character words, were 76%. The PVL distributions did not differ significantly between our two word types and the common words used by Yan et al., suggesting that adult readers use strategy rather than chance to read Chinese words. Both groups grasped concepts of Chinese language and knew where Chinese words were divided, even unfamiliar physics words; this is reasonable, given that our subjects were mature and educated adults who were Chinese speakers. However, neither HiK nor LoK readers understood the meanings of unfamiliar physics words at the initial stage, and there were no spaces between words to guide readers about word locations; therefore, when fixating on an unfamiliar physics word, readers' knowledge of Chinese linguistics helped them to parse the locations of Chinese words.

This study also found that most adult readers are able to recognise common Chinese words. This was confirmed by results showing that when both HiK and LoK readers read either common words or physics words, their average FFD was approximately 225–250 ms, similar to values found in previous Chinese reading research (Ko et al., 2005; Rayner, 1998). Unfamiliarity with words did not interfere with reading at the initial stage. However, after reading words at the initial stage, relevant background knowledge became helpful to HiK readers and helped them to construct the meaning of the unfamiliar word at this stage. This finding was supported by two pieces of evidence within the HiK group: (1) their GD was longer and their number of first-pass fixations was higher for unfamiliar than for familiar physics words. (2) Their rate of multiple fixations was higher for unfamiliar than for familiar physics words. While HiK readers constructed the meaning of an unfamiliar physics word, their reading continued. They showed shorter rereading times and lower regression rates at the late processing stage than did LoK readers.

These findings imply that HiK readers activated their background knowledge in the initial stage, which helped them construct the meanings of unfamiliar physics words.

The efforts of HiK readers to comprehend unfamiliar physics words appeared successful, because during the late processing stage, these readers read the unfamiliar physics words as fluently as if they were reading familiar physics words. This is corroborated by the non-significant differences in rereading times and regression rates among the HiK readers between reading unfamiliar and familiar physics words. In contrast, LoK readers – who had little background knowledge of physics – failed to access the meanings of these unfamiliar physics words in their mental lexicons during the initial processing stage. The LoK readers seemed to rely heavily on contextual information when searching for the meanings of physics words (Caillies et al., 2002; Kendeou & van den Broek, 2007). They repeatedly read the unfamiliar physics words and contextual information in the physics texts; this is supported by the finding that LoK readers had longer rereading times and higher regression rates than HiK readers at the late processing stage for both unfamiliar physics words and common words in the physics texts. Perfetti (1985) was the first to observe that word identification is affected by context more in less-skilled readers. Our LoK readers of physics were not less skilled at reading general texts, but they were hampered by their relative lack of knowledge in physics; thus, their patterns of reading were similar to those of a less-skilled reader reading a general text.

In summary, the evidence from measures of fixation duration and PVLs converged to show that when reading unfamiliar physics words, HiK and LoK readers did not differ in terms of the initial processing stage (PVLs, FFD, GD and number of first-pass fixations), but did differ in terms of the late processing stage (rereading time and regression rate). This suggests that both groups are goal-directed to learn new word meanings from the physics texts; however, HiK and LoK readers are qualitatively different in terms of strategic processing related to their differences in background knowledge. HiK readers combined information from the text (bottom-up) and their background knowledge (top-down) to construct and integrate all information at the word level, forming a semantic representation of a physics word that was originally unfamiliar. LoK readers repeatedly read the unfamiliar physics words to try to learn their meanings. Repeatedly reading a novel word is a good reading strategy, reflecting readers' cognitive processes of self-monitoring and self-correcting (Paris, Wasik & Turner, 1991; Schmitt, 2001). They also tried hard to understand words by examining their context, but this did not improve comprehension of unfamiliar physics words.

Finally, even though HiK and LoK readers exhibited similar patterns in the ways they treated Chinese words, this study demonstrated that when reading technical texts in a specific field such as physics, background knowledge does play a role in guiding mature readers to solutions to comprehension problems encountered in different ways. HiK readers solve the comprehension problem during the initial processing stage, whereas LoK readers recruit support from context during the late processing stage.

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