Exploring the eye movement patterns as Chinese children reading texts:
A developmental perspective

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Abstract

This study was to investigate Chinese children’s eye patterns while reading different text genres from a developmental perspective. Eye movements were recorded while children in the second through sixth grades read two expository texts and two narrative texts. Across passages, overall word frequency was not significantly different between the two genres. Results showed that all children had longer fixation durations for low frequency words. They also had longer fixation durations on content words. These results indicate that children adopted a word-based processing strategy like skilled readers do. However, only older children’s rereading times were affected by genre. Overall, eye movement patterns of older children reported in this study are in accordance with those of skilled Chinese readers, but younger children are more likely to be responsive to word characteristics than text level when reading a Chinese text.
Reading is a complicated process during which readers must control their eye movements to accommodate incoming printed information. Researchers have established that an interaction occurs between the text and the reader (Kintsch, 1998) and that such linguistic factors as word frequency, text difficulty, and the reader’s background knowledge influence eye-movement patterns during reading (see Rayner, 1998, for a review).

Research on eye-movement control, for example, has indicated that readers of alphabetic writing systems tend to fixate longer when a word appears less frequently (Inhoff & Rayner, 1986; Rayner & Duffy, 1986); readers’ eye movements are also affected by word type (Carpenter & Just, 1983) and word predictability (Ehrlich & Rayner, 1981; Frisson, Rayner, & Pickering, 2005; Rayner & Well, 1996). These findings suggest that words play an important role for readers of alphabetic writing systems. Such readers are well aware of the word as a distinct unit because of the spaces between words. Pollatsek and Rayner (1982) found that reading speed decreased by up to 50% when space information was eliminated.

This set of findings raises questions concerning the role of words for scripts such as Chinese, which have no spaces between successive characters and words. Still, converging evidence has indicated that words play an important role for Chinese reading (Bai, Yan,
Liversedge, Zang, & Rayner, 2008; Rayner, Li, Juhasz, & G. Yan, 2005; Rayner, Li, & Pollatsek, 2007; G. Yan, Tian, Bai, & Rayner, 2006; M. Yan, Kliegle, Richter, Nuthmann, & Shu, in press). Much of what we know about word-based processing in different languages comes from studies of skilled readers. Given that the mechanism of reading-based eye movements undergoes developmental changes, it is important to examine how children read Chinese text in terms of characters or words. The present study seeks to fill this gap.

Before introducing the study design, we first discuss existing eye-movement data on reading in Chinese. Then we review existing data on developmental changes in reading-based eye movements relative to both English and Chinese readers.

**Eye movements in reading Chinese**

In Chinese, the character is generally considered to be the basic unit of writing. Each character corresponds to one syllable and usually has its own meaning. Chinese words are made up of either an individual character or multiple characters. According to the Chinese corpus of Academia Sinica Taiwan (1998), the proportions of one-, two-, three-, and four-character words are 9.5%, 65.6%, 12.4%, and 11.6%, respectively. Most words are thus multiple-character words.

The first line of evidence supporting the existence of word-based processes in Chinese
reading is how the properties of words, such as predictability and frequency, affect Chinese skilled readers’ eye-movement patterns. For word predictability, Rayner et al. (2005) found that subjects spent less time fixating on and were more likely to skip over high- and medium-predictable Chinese target words than low-predictable target words. G. Yan et al. (2006) found that Chinese readers looked longer at low-frequency words than at high-frequency ones, and that character frequency only mattered when words were low frequency.

The second line of evidence in support of word-based processes in Chinese reading is the Preferred Viewing Location (PVL), a term that Rayner (1979) originated to describe the position in a word where the eyes first land during reading. If words have a primary role for Chinese readers, then it is reasonable to expect that there is a PVL for Chinese reading. Yet, Yang and McConkie (1999) and Tsai and McConkie (2003) did not find evidence to support this prediction. Instead, they found that readers fixed their viewing equally or nearly equally on all characters in the studied words. However, a recent study conducted by M. Yan et al. (in press) supports the view that Chinese readers engage in word-based targeting, although the PVL peak differed between single-fixation cases and in two-fixation cases. M. Yan et al. argued for a two-stage process during Chinese reading. If parafoveal word segmentation is successful within a single fixation, then landing positions
are distributed with a preference for proximity to the word center. If not, then the PVL peak shifts to the beginning of the word, with a focus on word segmentation and an increased forward refixation (which they called “two-fixation cases”). M. Yan et al.’s results hint that Chinese reading entails word-based processing, but that Chinese readers adopt different strategies depending on demands related to parafoveal word segmentation.

Manipulating information relative to word boundaries is the third line of evidence supporting the assertion that the word is the primary reading unit of Chinese texts. Bai et al. (2008) asked native Chinese readers to read texts that did or did not have word boundaries marked and investigated whether adding spaces between words would facilitate reading time. In their study, sentences had four types of spacing: normal unspaced text, text with spaces between words, text with spaces between characters that yielded non-words, and text with a space between every character. Both global and local eye-movement measures indicated that sentences with word spacing yielded a shorter reading time than non-word spacing or spacing between every character. This finding suggests that word-based processing might be adopted in Chinese reading. In sum, a growing body of research on Chinese readers’ eye movements has demonstrated that there is a word-based effect, even when characters are distinct writing units well known to Chinese readers.
**Children’s eye-movement patterns**

As children become proficient readers, their eye-movement behaviors undergo substantial changes. McConkie, Zola, Grimes, Kerr, Bryant, and Wolff (1991), for example, found that the average fixation duration decreased from 304 ms in the first grade to 243 ms in the fifth grade. The mean saccade length increased from 3.6 letters for first graders to 6.3 letters for fifth graders. Research also found that the number of fixations per word decreased continuously from first through sixth grade (Rayner, 1978, 1986; Taylor, 1965). In addition, a reduction of regression rates and an increase of word skipping was found among first through sixth graders (McConkie et al., 1991). Rayner (1986) proposed that as children become more proficient readers (by approximately the fourth grade), their reading becomes similar to that of skilled readers.

In fact, few studies have examined developmental characteristics of eye movements as they relate to Chinese children’s reading. To our knowledge, Chen, Song, Lau, Wong, and Tang (2003) were the first to investigate eye movement development in reading Chinese. Their study reported data involving second-, fourth-, and sixth-grade students from Hong Kong, reading sixth-grade-level prose passages. More recently, Feng, Miller, Shu, and Zhang’s (2009) examined third- and fifth-graders from Beijing as they read one expository text and one fable story. Although the two studies differed in regards to the
grades of the sampled Chinese-speaking children, they reported similar findings regarding overall developmental eye-movement patterns. Both studies found that students in the lower grades exhibited longer fixations than those in the higher grades. Average forward saccade length increased from the second graders to those in higher graders.

In addition to general quantitative development in reading proficiency, Chen et al.’s (2003) noted some qualitative changes. They found, for example, that character frequency produced stronger effects for sixth graders than word frequency did. In contrast, word frequency had a greater impact than character frequency for second-graders. If fourth graders read like adult readers (Rayner, 1986), then it is not clear why older children did not utilize the word as the primary reading unit, as skilled Chinese readers apparently do.

In addition to lexical processing, integration across different portions of a text is an important factor during reading. Vauras, Hyönen, and Niemi (1992) found that incoherent text prompted readers of an alphabetic language to exhibit more regressive fixations than did coherent text. Kaakinen, Hyönen, and Keenan (2003) found a similar pattern: As increases in text difficulty prompted greater fixation durations, saccade length decreased and regression frequency increased. Recently, Wang, Chen, Yang, and Mo (2008) asked Chinese skilled readers to read narratives containing coherent or conflicting information prior to the target sentence. The results revealed that the first-pass reading time increased.
when conflicts were embedded in the target sentence and suggested that higher mental processes in reading Chinese exhibit patterns similar to those found in reading alphabetic scripts. Following these “text-effect” studies, we explored the text-genre effect on children’s reading of Chinese.

**Purpose of the study**

Researchers have made considerable progress over the past few years in understanding Chinese skilled readers’ eye-movement patterns. Most of the pertinent studies reviewed above revealed that both characters and words play a role during reading. In addition, researchers have identified a text effect in the integration process of reading Chinese. To identify the roles of characters, words, and text for children’s reading of Chinese, we asked children to read short narratives and expository passages for comprehension. Via this design, we aimed to answer three questions: (1) Does character frequency, word frequency, and word type affect lexical processing in reading Chinese text? (2) Does text genre affect children’s eye-movement behaviors? (3) What is the developmental trajectory of reading Chinese as reflected in eye-movement patterns?
Method

Participants
Seventy-two children participated in the experiment, including 18 second graders, 14 third graders, 14 fourth graders, 10 fifth graders, and 16 sixth graders. All were native speakers of Mandarin and had either normal or corrected vision. The children were tested just before the beginning of the school year and were all judged by their teachers as being high-level readers among their peers.

Apparatus
Participants sat 65 cm from a Samsung 19-inch LCD monitor that presented the participants with 7-line texts to be read. From this distance, one character space equaled 1° of visual angle. Eye movements were recorded by an SR Eyelink II head-mounted eye-tracker and recorded from the right eye only, although viewing was binocular. A chin rest was used to minimize head movements. The sampling rate was 250 HZ.

Materials
Two narrative and two expository texts were used in this study (see Appendix I). On average, the passages were 180 characters. Each text was about seven lines long, with a maximum of 27 Chinese characters per line. Chinese words, like English words, differ not only in frequency, but also in word type (content words and function words). High-frequency (HF) words in this study were those that occurred more than 2557 per
million in the Academia Sinica Balanced Corpus (ASBC, Academia Sinica Taiwan, 1998), and low-frequency (LF) words were those that occurred less than 42 times per million in the ASBC. Three kinds of words were examined in the current study: HF content words, LF content words, and HF function words. No LF function words were included in the study. Words in both narratives and expository texts were at the elementary-school level, and texts at this level include no LF function words.

According to the ASBC, the average character frequencies of low and high frequency characters were 101.5 and 2713 per million Mean character frequencies of expository texts and narratives were 343 and 328, respectively. Character frequency did not differ between expository and narrative texts, $t < 1$. Word frequency (ASBC) also did not differ between expository ($M = 2,813$) and narrative texts ($M = 3,076$), $t < 1$. The two text genres yielded different levels of semantic coherence, however. We calculated each text’s coherence in a Chinese semantic space (Chen, Wang, & Ko, 2009; Wang, Pomplun, Chen, Ko, & Rayner, in press), via Latent Semantic Analysis (Landauer, 2006). A plausible assumption is that a coherent text is easier to read than a text that is less coherent. In this study, the cosine value of narratives ($M = .31$) was significantly higher than that of expository texts ($M = .20$), $t(59) = 2.81$, $p < .01$. This finding means that expository texts should be more difficult to read than narratives in the present study. Each text had four multiple-choice questions,
each with four possible responses. The purpose of the comprehension questions was to urge students to read texts carefully.

*Procedure*

The experiment was conducted in an elementary school. When participants arrived, the experimenter first explained the experimental procedure. Then, the eye-tracker was adjusted for optimal tracking. Participants were calibrated with a standard 9-point grid and validated with another 9-point grid. After calibration, participants were asked to read each passage carefully for comprehension and they were told that they would have to answer comprehension questions after they finished all readings. At the start of each trial, a drift-calibration screen appeared, and participants were instructed to look at the calibration dot on the location identical to the location of the text’s first character. When participants passed the drift correction, a whole text appeared on the screen. Participants read the text at their own pace and pressed a button on a control pad to indicate they had finished reading. After the participant pressed this button, the text disappeared and the drift-correction screen appeared again. Each participant read four texts presented in a counterbalanced order. Immediately after reading the four texts, participants were taken to another room where they completed the comprehension test.
Results

Four measurement indicators were examined in this study: first fixation duration (FFD), gaze duration (GD), rereading time, and total fixation duration (TFD). From the order of words that readers fixate on, researchers have inferred that there are two word-processing phases: “initial processing time” and “rereading time” (Chaffin, Morris, & Seely, 2001; Juhasz & Rayner, 2003; William & Morris, 2004). FFD is the duration of the reader’s first fixation on a character or a word independent of the total number of fixations. GD is the sum of all first-pass fixations on a character or a word prior to moving the eyes to another word. Both FFD and GD reflect initial processing time. Considering the skipping rate and longer words were fixated more once, gaze duration is a better indicator of initial processing time than first fixation duration (for review, see Rayner, 1998; 2009) Rereading time is the sum of the durations of second-pass fixations on a character or a word. TFD is the sum of first- and second-pass fixations on a character or a word. Both Rereading time and TFD reflect rereading processing time.

Following the aforementioned indicators, we conducted analyses on the basis of (a) individual Chinese characters to examine character frequency effects and (b) Chinese words to examine word-frequency and word-type effects; we also examined (c) the text-genre effect on children’s various eye-movement measures.
Effects of character/word frequency on children’s various measures

If either character frequency or word frequency affects children’s fixation time, a reasonable prediction would be that children’s fixation times would be shorter with HF characters or words. One way to assess the effect of frequency is to test whether the characters/words with lower frequency showed evidence of longer durations in the eye-movement measures. We conducted the ANOVA using subjects (F<sub>s</sub>) and items (F<sub>i</sub>) analyses. The mean fixation durations for the four eye-movement measures for low and high character/word frequency appear in Table 1.

Insert Table 1 in here.

Initial processing time. The pattern of results across FFD and GD was consistent with effects of character frequency, word frequency, and grade. Character frequency had a significant effect: FFD, F<sub>s</sub> (1, 68) = 35.05, p < .001, η² = .34; F<sub>i</sub> (1,660) = 12.66, p < .001, η² = .02; GD, F<sub>s</sub> (1.68) = 57.91, p < .001, η² = .46; F<sub>i</sub> (1, 660) = 15.38, p < .001, η² = .02. A main effect of grade was also found. FFD, F<sub>s</sub> (4, 68) = 4.45, p < .01, η² = .21; F<sub>i</sub> (4, 2640) = 72.95, p < .001, η² = .10; GD, F<sub>s</sub> (4, 68) = 4.67, p < .01, η² = .22; F<sub>i</sub> (4, 2640) = 82.72, p < .001, η² = .11. Character frequency and grade did not interact in the two measures of initial processing time (all F's < 1; P's > .05)

Word frequency also yielded a significant effect: FFD, F<sub>s</sub> (1, 68) = 30.64, p < .001,
\( \eta^2 = .31; F_1 (2, 426) = 20.75, p < .001, \ \eta^2 = .05; GD, F_1 (1.68) = 97.43, p < .001, \ \eta^2 = .59; F_1 (1, 426) = 83.20, p < .001, \ \eta^2 = .16 \). A main effect of grade was also found.

FFD, \( F_2 (4, 68) = 3.99, p < .01, \ \eta^2 = .19; F_1 (4, 1704) = 67.72, p < .001, \ \eta^2 = .14; GD, F_1 (4, 68) = 2.73, p < .05, \ \eta^2 = .14; F_i (4, 1704) = 80.44, p < .001, \ \eta^2 = .16 \). Again, word frequency and grade did not interact in the two measures of initial processing time (all \( F_s < 1; P_s > .05 \)).

**Rereading processing time.** Character frequency had a main effect on both rereading time and TFD: rereading time, \( F_2 (1.68) = 23.15, p < .001, \ \eta^2 = .25; F_1 (1, 660) = 8.95, p < .01, \ \eta^2 = .013; TFD, F_2 (1.68) = 69.67, p < .001, \ \eta^2 = .51; F_1 (1, 660) = 13.88, p < .001, \ \eta^2 = .02 \). The main effect of grade was not significant for either rereading time or TFD by the subjects analysis: rereading time, \( F_2 (4, 68) = 2.07, p > .05, \ \eta^2 = .11; TFD, F_2 (4, 68) = 2.31, p > .05, \ \eta^2 = .12 \). However, the main effect of grade was significant in the items analysis: rereading time, \( F_i (4, 2640) = 109.06, p < .001, \ \eta^2 = .14; TFD, F_i (4, 2640) = 151.44, p < .001, \ \eta^2 = .19 \). There were no interactions between character frequency and grade (all \( F_s < 1; P_s > .05 \)).

Word frequency also yielded a main effect on both rereading time and TFD: rereading time, \( F_1 (1.68) = 97.13, p < .001, \ \eta^2 = .58; F_i (1, 301) = 39.71, p < .001, \ \eta^2 = .12; TFD, F_1 (1.68) = 166.11, p < .001, \ \eta^2 = .71; F_i (1, 427) = 90.57, p < .001, \ \eta^2 = .18 \). The main
effect of grade was not significant for either *rereading time* or *TFD* by the subjects analysis:

*rereading time*, $F_s(4, 68) = 1.01, p > .05, \eta^2 = .05; TFD, F_s(4, 68) = 2.06, p > .05, \eta^2 = .11$. However, the main effect of grade was significant by the items analysis: *rereading time*, $F_i(4, 1204) = 20.88, p < .001, \eta^2 = .07; TFD, F_i(4, 1704) = 92.64, p < .001, \eta^2 = .18$. Again, there were no interactions between character frequency and grade (all $Fs< 1; Ps > .05$).

Overall, across the various measures for both initial processing time and rereading time, children’s average fixation times for LF characters and words were longer than for HF characters and words. Also, there was a consistent grade effect across the measures wherein fixation times decreased as the children got older.

**Effect of word type on children’s various measures**

In addition to the effect of word frequency, we conducted a series of ANOVAs to examine whether word type affected children’s various eye-movement measures. These analyses provided an additional opportunity for us to test whether word-based processing plays a primary role for Chinese children.

Words were divided into content words and function words. As noted above, there were no LF-function words in the present study. Therefore, we conducted a series of ANOVAs with three word types (HF content, LF content, HF function) and five grades
(grades two through six) as an independent samples factor by subjects ($F_s$) and by items ($F_i$). Table 2 shows the means for all four measures in the three types of words.

Insert Table 2 in here.

*Initial processing time.* The pattern of results across *FFD* and *GD* was consistent. Word type had a significant effect: *FFD*, $F_s (2, 136) = 26.91$, $p < .0015$, $\eta^2 = .28$; $F_i (2, 425) = 11.79$, $p < .001$, $\eta^2 = .05$; *GD*, $F_s (2, 136) = 89.40$, $p < .001$, $\eta^2 = .57$; $F_i (1, 426) = 51.29$, $p < .001$, $\eta^2 = .19$. To establish which conditions differed from each other, we conducted paired $t$ tests. Both *FFD* and *GD* were longer on LF-content words than on HF-content words ($p < .001$), and both of the initial processing measures were longer on HF-content words than HF-function words ($p < .05$). Results showed that readers fixated longest on LF-content words. This both confirms that word type affected readers’ initial processing time and implies that children adopted word-based processing while reading Chinese.

Grade also yielded a main effect: *FFD*, $F_s (4, 68) = 4.41$, $p < .01$, $\eta^2 = .21$; $F_i (4, 1704) = 102.74$, $p < .001$, $\eta^2 = .20$; *GD*, $F_s (4, 68) = 3.31$, $p < .05$, $\eta^2 = .16$; $F_i (4, 1704) = 102.31$, $p < .001$, $\eta^2 = .19$. Consistent with prior research, as children got older their fixations become shorter. The main effects of *FFD* were qualified by the significant interaction between word type and grade, however. Only fifth and sixth graders had
statistically significant longer FFD on HF content words than on HF function words (the differences were 14ms and 9ms for the fifth and sixth graders, respectively). Children in the third grade and higher had longer FFD for LF-content words than for HF-content and function words (the differences were 18, 26, 12, and 10ms for the third through sixth grades, respectively). However, the interaction between grade and word type for GD was not significant ($F < 1; p > .05$). This result suggests that the properties of words affect all children’s GD.

**Rereading processing time.** Word type had a main effect on both rereading time and TFD: rereading time, $F_s (2, 136) = 68.46, p < .001, \eta^2 = .51; F_i (2,300) = 23.96, p < .001, \eta^2 = .14; TFD, F_s (2, 136) = 147.76, p < .001, \eta^2 = .69; F_i (2,426) = 57.97, p < .001, \eta^2 = .21$. A sampled $t$ test showed that all children returning to fixate on LF-content words had a longer fixation time than they did on HF-content words ($p < .001$). They also had longer fixation time on HF-content words than on HF-function words ($p < .001$). The main effect of grade was not significant for either rereading time or TFD by the subjects analysis: rereading time, $F_s (4, 68) = 1.09, p > .05, \eta^2 = .09; TFD, F_s (4, 68) = 2.18, p > .05, \eta^2 = .114$. The main effect of grade, however, was significant by the items analysis: rereading time, $F_i (4, 1935) = 19.95, p < .001, \eta^2 = .04; TFD, F_i (4, 1704) = 104.85, p < .001, \eta^2 = .20.$
Preferred first-fixation location relative to two-character words

As we pointed out earlier, the two-character word is the most frequent among compound words in Chinese. The question concerned which character would attract more fixations as children first set their eyes on the two-character word. Does word frequency affect children’s preferred fixation location in a two-character word?

Insert Table 3 in here.

Table 3 shows the mean percentages of first-fixation locations relative to the first character and second character for both HF words and LF words, with second graders through sixth graders as the sample population. A series of sampled t tests showed that, for HF words, the percentages of first fixation on the first character for all grades were significantly higher than the percentages of first fixation on the second character ($p < .05$). This finding indicates that all children preferred sending their first fixation to the first character when they encountered a HF two-character word. For LF words, the fixation percentage of first fixation on the first character was not significantly different from that of the second character for fourth, fifth, and sixth graders ($p > .05$). But the second and the third graders did not differ for LF and HF words — graders sent more of their first fixations to the first character ($p < .05$). Thus, the overall pattern indicates that children look more often at the first character when they encounter HF words. When encountering a
LF word, however, only younger children look more often at the first character. Older children are likely to fixate on either character of a LF word.

**Effects of text genre on various eye-fixation measures**

We next tested whether text genre affects children’s eye movements. Children read both narratives and expository texts in this study. Means for all measures in different genres are shown in Table 4. Below, we report the initial per-word processing and rereading processes, followed by the reading-speed analyses for a whole text.

Insert Table 4 in here.

First, we conducted a series of ANOVAs with two genres (expository texts and narratives) as a related samples factor and five grades (grades two through six) as an independent samples factor. Following this, we conducted analyses on the basis of individual Chinese words. Herein, we did not categorize HF and LF words as a repeated measure because the items in each cell were too few to justify such an analysis. We conducted only a two-way ANOVA by subjects ($F_s$) and by items ($F_i$).

*Initial processing time.* There was a main effect of genre. Both the FFD and the GD for expository texts were longer than for narratives regardless of the students’ grade: FFD, $F_s (1, 68) = 7.03, p < .05, \eta^2 = .09; F_i (1, 507) = 16.88, p < .001, \eta^2 = .03; GD, F_s (1, 68) = 34.03, p < .01, \eta^2 = .33; F_i (1, 507) = 34.79, p < .001, \eta^2 = .06$. It was not surprising
that the older the children were, the shorter their $FFD$ and $GD$: $FFD, F_s (4, 68) = 4.16, p < .01, \eta^2 = .20; F_i (4, 2028) = 132.91, p < .001, \eta^2 = .21; GD, F_s (4, 68) = 3.77, p < .001, \eta^2 = .18; F_i (4, 2028) = 144.18, p < .001, \eta^2 = .22$. The interaction was not significant (all $Fs < 1$). As we already mentioned, the word frequency between two genre texts was not different, but the semantic coherence for expository texts was lower than that for narratives. This result indicates that as semantic coherence declined, children’s initial processing time on a word increased.

**Rereading time.** Rereading time and $TFD$ for expository texts were longer than for narratives: $Rereading time, F_s (1, 68) = 13.46, p < .001, \eta^2 = .16; F_i (1, 332) = 6.63, p < .05, \eta^2 = .02; TFD, F_s (1, 68) = 27.40, p < .001, \eta^2 = .28; F_i (1, 507) = 24.07, p < .001, \eta^2 = .05$. The older that children were, the shorter their Rereading time and $TFD$: $Rereading time, F_s (4, 68) = 2.53, p < .05, \eta^2 = .13; F_i (4, 1328) = 31.52, p < .001, \eta^2 = .087; TFD, F_s (4, 68) = 3.07, p < .05, \eta^2 = .15; F_i (4, 2028) = 140.69, p < .001, \eta^2 = .22$.

The interaction between grade and genre was significant by the items analysis: $Rereading time, F_i (4, 1328) = 3.05, p < .05, \eta^2 = .009; TFD, F_i (4, 2028) = 8.51, p < .05, \eta^2 = .017$. A paired samples $t$ test revealed that only fifth and sixth graders’ Rereading time and $TFD$ on expository texts were significantly longer than those on narratives: $Rereading time, t(10) = 5.38, p < .01$ and $t(15) = 4.69, p < .001; TFD, t(10) = 3.87, p < .01$.
and $t(15) = 2.16, p < .05$. These findings suggest that older children adjusted their rereading processing as they read different texts, but younger children used a similar strategy as they reread both genres.

Reading speed. Characters per minute (CPM) is an index to reflect readers’ reading speed. We conducted, only by subjects, an ANOVA with genre (expository texts vs. narratives) as a related samples factor and grade as an independent samples factor. Grade had a significant main effect, $F_s (4, 108) = 2.58, p < .05, \eta^2 = .08$. However, the main effect of genre was not significant, $F_s (1, 108) = .98, p > .05, \eta^2 = .009$. The interaction between grade and genre was significant, $F_s (4, 108) = 6.92, p < .001, \eta^2 = .21$. A paired samples $t$ test showed that only fifth- and sixth-grade CPMs of narrative texts were higher than those of expository texts, $t(10) = 3.12, p < .05$, and $t(14) = 2.18, p < .001$, respectively. Third- and fourth-grade CPMs exhibited no significant difference between expository texts and narrative texts, $t(12) = .06, p > .05$, and $t(14) = -.37, p > .05$, respectively. This pattern was unexpected but understandable: Both third and fourth graders had longer initial times for expository texts, but their rereading times did not differ between the two text genres.

According to this finding, both third and fourth graders seemed to know that words appearing in expository texts carried more information than words appearing in narratives, but third and fourth graders were less capable of rereading for comprehension than were
fifth and sixth graders.

It was surprising to find that second graders’ CPM of expository texts was higher than that of narrative texts, \( t(17) = 2.49, \ p < .05 \). A LSA analysis indicated that the expository texts in the current study were more difficult to read than the narratives, because the expository texts’ semantic coherence was lower than that of the narratives. A reasonable reading pattern is that readers’ reading speed is lower for expository texts than narratives. We suspected that second graders would not comprehend expository texts as well as narratives. This was supported by two indices: First, the number of fixations for expository texts \( (M = 141.2, \ SD = 58.22) \) was less than those of narratives \( (M = 157.5, \ SD = 48.37) \), \( t(17) = -1.99, \ p = .06 \). Second, their scores on the accuracy-of-comprehension questions differed; second graders’ accuracy for expository texts \( (M = 1.78, \ SD = .86) \) was significantly lower than the corresponding narrative texts \( (M = 3.15, \ SD = .65) \), \( t(17) = -11.00, \ p < .001 \).

**General Discussion**

As was mentioned at the beginning, the concept of “word” in Chinese is less clear than in alphabetic language. However, a number of studies have suggested that word-based processes are adopted in Chinese reading. In the current study, we attempted to explore whether Chinese children, like Chinese skilled readers, adopted word-based processes
during reading a text. We first investigated whether character - or word -level variables affected initial processing and rereading time during Chinese children’s reading of short passages. Overall, we found that the character-frequency effect was evident in both the initial processing time and the rereading time for all children: Chinese children fixated longer on low-frequency characters than on high-frequency characters. With regard to word frequency effect, we found that it was evident during both the initial processing time and the rereading time for all children: Chinese children fixated longer on LF words than on HF words. Obviously, this finding is in line with Chinese skilled readers’ patterns, and the more likely explanation rests in the possibility of word-based processes also adopted by Chinese children.

Finding a PVL is another way to support word-based eye movement in reading (Yang & Vitu, 2007). In the present study, we examined which character of a word attracted more fixations as children first set their eyes on a two-character word. We proposed that a “preferred fixation location” analysis may reflect “quasi-PVL” phenomena to some degree. The principle findings suggested that (1) for HF words, children in all grades tended to land more often on the first character than the second character; (2) for LF words, the younger children tended to land more on the first character than the second character, but older children were as likely to land on the second character as the first. The finding with
HF words may suggest that a word-based processes strategy is adopted by children in all grades. Further work is obviously required to figure out what factors contribute to the different pattern between younger and older children for they read LF words.

During the reading of a text, skilled readers are not only decoding words. They usually keep adjusting their reading strategy to comply with the familiarity of text content, the difficulty of words in the text, and the complexity of syntax. In the current study, expository texts were more difficult to read than narratives. In cases such as this, higher order comprehension processes affect the normal eye movement pattern in which lexical processing is driving the eyes and results in longer fixations or regressions back to earlier parts of the text (Rayner, 2009). It is not surprising to find that older children exhibited a slower reading rate, and longer initial and rereading time as they read expository texts compared to narrative texts. However, the text genre effect only showed up in younger children’s initial processing time. This implies that younger children might be aware of text-level characteristics but lack sufficient understanding of rereading as a strategy for a better comprehension of expository texts. Clearly, more research is needed to understand moment-to-moment discourse processing of children.

Now, let us turn to the last question: What is the development of eye-movement patterns in reading Chinese? Basically, the main findings of this study are consistent with
those of Feng et al. (2009). The fixation duration data indicate that children’s word decoding skill is getting more mature as they get older and have more experience with reading. However, although younger children’s word decoding is not as proficient as older children, younger children also treat words as major processing units like older children do. It is worth noting that, in the present study, older children had no preferred viewing location when they read LF two-character words. We acknowledge that our analysis is not without limitations, and more work is needed to test why younger and older children show different landing pattern for LF words.

Developing the ability to read is a complex process involving a variety of skills, including both basic language skills and comprehension skills. In this study, we provided children with narrative and expository texts in order to examine whether children of different ages exhibit different comprehension skills. Our results suggest that older children are different from the younger children. Older children not only increased their gaze duration, they also increased their rereading time as they read expository texts. This adjustment is accordance to those findings in the study of Kaakinen et al. (2003). However, when younger children read expository texts, they increased their gaze duration but did not increase their rereading time. This result implies that younger children might have been aware of the characteristics of genre, but did not exhibit a corresponding strategy that
would enable them to comprehend better.

In closing, we have demonstrated the existence of a developmental eye-movement pattern for Chinese readers between second grade and sixth grade. We have found that younger readers read by word-based processing without differentiating genre. In contrast, older graders who read like skilled Chinese readers reread more frequently while encountering different text genres.

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References


Appendix I: Reading Material

Text 1: Monarch Butterfly (Expository)

Monarch Butterfly (Expository)

Text 2: Dolphin (Expository)

Dolphin (Expository)
Text 3: Story of Deer Banbi (Narrative)

小鹿班比住在快樂森林裡，有一天森林失火了，班比很著急，他要想辦法把火滅掉。他去找住在附近的小豬來幫忙，小豬說他腳痛不能來幫忙。班比更著急了，他要找其它的人來幫忙。他想起夏令營跟他同一組的大象，他想找大象來幫忙。大象曾經說過他家住河的對岸，班比過橋後四處打聽。他找到了大象的家，班比和大象一起回到了快樂森林，大象用鼻子噴出強力的水柱，很快的就撲滅了這場大火。

Text 4: Story of boy (Narrative)

阿宏的母親長年臥病在床，城裡來了一位醫術高明的大夫，阿宏很想請那位大夫來幫媽媽治病。阿宏到處跟左右鄰舍籌措金錢，他籌到的錢還不夠請那位好大夫，阿宏好難過。阿宏有一隻小母牛，阿宏想賣掉自己養的小母牛。他天天給小母牛吃草喝水，小母牛長得又壯又健康，小母牛在市場上賣得了好價錢。阿宏看著這些錢心中無比地興奮，他急忙地駕著馬車到城裡，阿宏請到了那位好醫生。