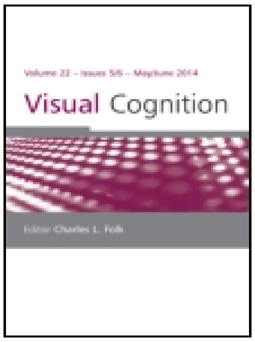

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There is no relationship between preferred viewing location and word segmentation in Chinese reading

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In Chinese, as there are no spaces between words to mark word boundaries, readers usually do not target their eyes to the centre of the word as readers of English do. Previous studies showed that the distribution of the initial landing positions on a word (the PVL curve) peaked at the beginning of a word when there was more than one fixation; but peaked at the centre of a word if there was only one fixation on the word. Based on this phenomenon, it was argued that Chinese readers move their eyes to the beginning of a word if they cannot correctly segment words in the parafovea, but move to the centre of a word if they can. In the present study, we implemented a natural sentence reading task in Experiment 1 and a shuffled-character reading task in Experiment 2 to test whether the above PVL phenomenon was in fact caused by word segmentation. In both experiments, we found that the different PVL patterns in multiple- and single-fixation cases occurred not only for a 3-character word region but also for a 3-character nonword region. These results suggest that the different PVL curves in multiple- and single-fixation cases are likely to be due to a statistical artefact instead of parafoveal word segmentation.

Keywords: Preferred viewing location; Landing position; Word segmentation; Chinese reading.

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In normal English reading of text for meaning, readers tend to make a forward saccade onto a word from prior text to a specific position within that word called the preferred viewing location (PVL) (Rayner, 1979). The PVL in English reading is at a position in that word slightly to the left of the centre of the word. Of course there is variability where the eyes land on a word and there is a distribution of landing positions, called the PVL curve. In normal English reading, this has an inverted U-shape and its peak is the PVL. The PVL is close to the optimal viewing location (OVP) on a word except for very long words. The OVP is a viewing position within a word where readers can recognize the word most efficiently when they are displayed in isolation. In English, the OVP is close to centre of a word (O'Regan & Jacobs, 1992; O'Regan, Lévy-Schoen, Pynte, & Brugaillère, 1984; Vitu, O'Regan, & Mittau, 1990). Thus, it is plausible that readers of English are intending to target the optimal location in the upcoming word for viewing. That readers of English can do so is probably because they can rely on interword spaces to segment words using parafoveal vision.

When interword spaces are removed, the peak of the PVL curve shifts to the beginning of the word (Paterson & Jordan, 2010; Perea & Acha, 2009; Rayner, Fischer, & Pollatsek, 1998; Sheridan, Rayner, & Reingold, 2013). One potential reason is that when there are no interword spaces, readers of English (and other naturally spaced languages) fail to segment words with parafoveal vision, so that they then cannot target their saccades to the centre of a word when they plan their saccades. As a result, reading speed decreases up to 30–70% (Morris, Rayner, & Pollatsek, 1990; Perea & Acha, 2009; Pollatsek & Rayner, 1982; Rayner et al., 1998; Rayner & Pollatsek, 1996; Rayner, Yang, Schuett, & Slattery, 2013; Winskel, Radach, & Luksaneeyanawin, 2009). Therefore, spaces as segmentation cues are quite important for guiding saccade-target selection and improving reading efficiency in naturally spaced languages.

In contrast, there are no spaces between Chinese words in natural Chinese reading, but Chinese readers appear to have little difficulty in reading unspaced Chinese texts (Bai, Yan, Liversedge, Zang, & Rayner, 2008). Therefore, one wants to know how Chinese readers select saccade targets without interword spaces. In Chinese, the OVP is also close to the centre of the word for 3- and 4-character Chinese words[1] (Liu & Li, 2013). Thus, during natural reading, readers should target their saccade to the OVP in order to recognize each word optimally. For this to be the case, however, it would depend upon whether the actual saccade-target selection mechanism can rely on readers being able to segment words in the parafovea. In natural English reading, the PVL is close to

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[1] For 2-character words, Liu and Li (2013) reported that the OVP was at the first character. Because only two positions were manipulated to present 2-character words, we cannot judge whether the OVP was at the centre of the word or not.

the OVP because readers can use interword spaces to segment words in the parafovea.

On the other hand, many previous studies have shown that Chinese readers could not do that and the PVL curves peaked at the beginning of a word rather than the centre of a word during natural Chinese reading (Li, Liu, & Rayner, 2011; Yan, Kliegl, Richter, Nuthmann, & Shu, 2010; Zang, Liang, Bai, Yan, & Liversedge, 2013). In addition, when spaces were inserted between all the words in Chinese, the peak of the PVL curves was still at the beginning of the word (Zang et al., 2013). However, Yan et al. (2010) argued that the PVL curve did not always peak at the beginning of a word in Chinese reading. When splitting their data into two parts based on whether the word was fixated once or more than once, they found that the PVL curve peaked at the beginning of the word when there were multiple fixations within a word; but peaked at the centre of the word when there was only one fixation within a word. This phenomenon of different PVL curves in multiple- and single-fixation cases was also reported in other studies on Chinese reading (Li et al., 2011; Zang et al., 2013), but the interpretations of this phenomenon are still hotly debated.

Yan et al. (2010) proposed a parafoveal word segmentation hypothesis based on the different PVL curves for the multiple- and single-fixation cases they had observed. They hypothesized that readers would move their eyes to the beginning of the upcoming word if they failed to segment the word in the parafovea, but would move to the centre of the upcoming word if they successfully segmented the word with parafoveal vision. That inference was challenged by Li et al. (2011). Li et al. (2011) simulated Chinese readers' eye movement behaviour using a constant distance hypothesis. They assumed that Chinese readers' eyes travelled with a constant distance (with variability) at each saccade. Although they did not make any assumption that Chinese readers target any specific position within a word, the simulation produced very similar PVL curves in multiple- and single-fixation cases to the curves that Yan et al. (2010) reported. These simulations indicated that Yan et al.'s (2010) hypothesis was not unambiguously supported by the PVL phenomenon in multiple- and single-fixation cases.

In the present study, instead of using a simulation, we designed two experiments to explore whether the different PVL curves in single- and multiple-fixation cases reported by Yan et al. (2010) was plausibly caused by readers being able to segment words in the parafovea. Experiment 1 used a natural sentence reading task and Experiment 2 used a "shuffled-character" reading task. In Experiment 1, a 3-character target word was embedded into each experimental sentence. We analyzed the initial landing position on the 3-character word region in order to replicate Yan et al.'s (2010) finding. In addition, we analyzed all the contiguous 3-character nonword regions (except for the first three characters and last three characters in each sentence) to see whether there was a similar PVL curve as that in the target word region analysis. If the different PVL patterns in multiple- and single-fixation cases were caused by parafoveal word segmentation, then we should expect different PVL curves for word regions and nonword regions.

In Experiment 2, we shuffled the characters in each sentence used in Experiment 1 to create shuffled-character sentences in which all the contiguous characters did not constitute words. The task was similar to the shuffled text reading performed by Schad, Nuthmann, and Engbert (2010) wherein the words in each normal sentence were shuffled to create meaningless sentences. In this experiment, Chinese readers cannot segment words because there are no words among contiguous characters. If the PVL curves are similar to those observed by Yan et al. (2010), it would suggest that the PVL curves observed by Yan et al. (2010) are not necessarily caused by parafoveal word segmentation.

EXPERIMENT 1

Method

Participants

Twenty-five undergraduate students from colleges around the Institute of Psychology, Chinese Academy of Sciences were paid to participate in the present study. All of them had either normal or corrected-to-normal vision.

Apparatus

The materials were presented on a 21-inch CRT monitor (resolution: 1024 × 768 pixels; refresh rate: 150 Hz) connected to a DELL PC. Each sentence was displayed on a single line in Song 20-point font and the characters were shown in black (RGB: 0, 0, 0) on a grey background (RGB: 128, 128, 128). Participants were seated at a viewing distance of 58 cm from the computer monitor. At this viewing distance, each character subtended a visual angle of approximately 0.7°. The head was stabilized by means of a chin rest and a forehead rest. Participants read sentences binocularly, but only the right eye was monitored. Eye movements were recorded by an SR Research EyeLink 1000 eye tracking system with a sampling rate of 1000 Hz.

Materials

Thirty sentences were created as experimental sentences. The length of each sentence was 24-characters. A critical 3-character word was embedded into each sentence, and none of the characters of the critical word were at any of the first five or the last five character positions of the sentence. The average frequency of the 3-character words was 2.4 occurrences per million (*SD* = 2). Neither the first two nor the last two characters of a 3-character word constituted a word. In the 30 sentences, 10% of the words were 1-character long, 68% were 2-characters long and 10% were 3-characters long. In a pretest, 10 participants (who did not participate in the eye movement experiments) were tested to see whether they agreed with the experimenters on where the word boundaries should be. The proportion of agreement was very high (96%).

Procedure

When participants entered the lab, they read instructions for the experiment and a brief description of the apparatus. The chair was then adjusted to make them feel comfortable and the eye tracker was calibrated. (The eye-tracker was re-calibrated again when needed.) A three-point calibration and validation procedure was used. The maximal error of the validation was below 0.5 degrees in visual angle and the mean error was 0.2 degrees (*SE* = .1). Next, each subject read six sentences for practice. This was followed by 30 experimental sentences and 30 filler sentences for the regular part of the experiment; the 60 sentences were presented in a random order. The participants were asked to read silently and to answer some comprehension questions after they had seen each of the three sets of 20 sentences. The filler sentences were not included in the data analysis. On a trial, each sentence appeared after participants successfully fixated on a character-sized box for 100 ms at the location of the first character of the sentence. After reading the sentence, the participants were asked to press a response button to start the next trial.

Results and discussion

The accuracy of the answers to the comprehension questions was high (93%), indicating that the participants understood the sentences well. Trials in which participants made three or more blinks were excluded from the analysis, resulting in a loss of 3% of the trials. Fixations with durations longer than 1000 ms or shorter than 80 ms (approximately 1% of all fixations) were also excluded from the analysis.

We report eye movement measures both globally (i.e., on the entire sentences) and locally (i.e., on three-character regions). In the global analyses, we report: (1) the distribution of fixation durations for all fixations; (2) the distribution of all forward saccade lengths (measured in number of characters); (3) character fixation probability (the probability that each character was fixated on first-pass reading). In the local analyses, the initial landing positions were recorded as 0, 1, and 2 on the first, second, and third character of a 3-character region, respectively. We reported the landing position distribution in both the multiple- and single-fixation cases for the 3-character word regions and for all the contiguous 3-character nonword regions. Both the probability of fixation and the average fixation duration measures are "first-pass" measures. That is, these measures on a region do not include fixations if the fixation was after a regression back to that region or to the left of that region. The nonword regions had no overlap in each sentence and did not contain the first and last three characters which meant that the following character groups were counted in the nonword region analysis: 4–6, 7–9, 10–12, 13–15, 16–18, and 19–21. In some cases, the 3-character strings include single-character words or 2-character words, but it does not invalidate the underlying logic of the nonword analyses. We conducted repeated measure ANOVAs with subjects as random variables to test whether there were differences on the distributions of initial landing positions across the contiguous 3-character regions and the trends of the distributions were evaluated by a polynomial analysis as Yan et al. (2010) did. All the proportion data were transformed using arcsine-square-root transform when we conducted ANOVA analyses.

Global analyses

There were 8177 analyzed fixations and the average fixation duration was 273 ms, with a standard deviation of 115 ms. The distribution of the fixation durations is shown in Figure 1A. The average saccade length (7461 saccades in total) was 2.07 characters, with a standard deviation of .94 characters. The distribution of forward saccade lengths is shown in Figure 1B. The average probability of fixating each character without including the first and last character in the sentence was .51, with a standard deviation of .02. The distribution of the probability that a character was fixated is shown in Figure 1C. The fixation probability on the first character in each sentence was 1, because only a fixation on the first character position for 100 ms can trigger the presentation of each sentence.

Three-character word regions

When calculating all initial landing positions in the critical 3-character word region, the probabilities of initially landing on the first, second, and third character positions were .59 (SD = .14), .29 (SD = .09), and .11 (SD = .09), respectively, which differed significantly, $F(2, 48) = 87.34$, $p < .001$, $\eta_p^2 = .79$. A polynomial analysis showed that only the linear trend was reliable, $F(1, 24) = 119.67$, $p < .001$, $\eta_p^2 = .83$. These results are consistent with previous findings (Li et al., 2011; Yan et al., 2010) that the peak of PVL curves is at the beginning of a 3-character word in Chinese reading.

When splitting all the initial landing positions into multiple- and single-fixation cases (see Figure 2A), we replicated Yan et al.'s (2010) finding. For multiple-fixation cases, the probabilities of initially landing on the first, second, and third character positions were .77 (SD = .14), .19 (SD = .09), and .04 (SD = .08), respectively, which differed significantly, $F(2, 48) = 175.32$, $p < .001$, $\eta_p^2 = .88$. A polynomial analysis showed that both the linear trend and the quadratic trend were reliable, $F(1, 24) = 244.91$, $p < .001$, $\eta_p^2 = .91$, $F(1, 24) = 16.38$, $p < .001$, $\eta_p^2 = .41$. Note that the quadratic trend indicates a concave curve rather than convex curve which is same pattern as that reported in Yan et al. (2010). For single-fixation cases, the probabilities of initially landing on the first, second, and third character positions were .37 (SD = .14), .44 (SD = .14), and .18

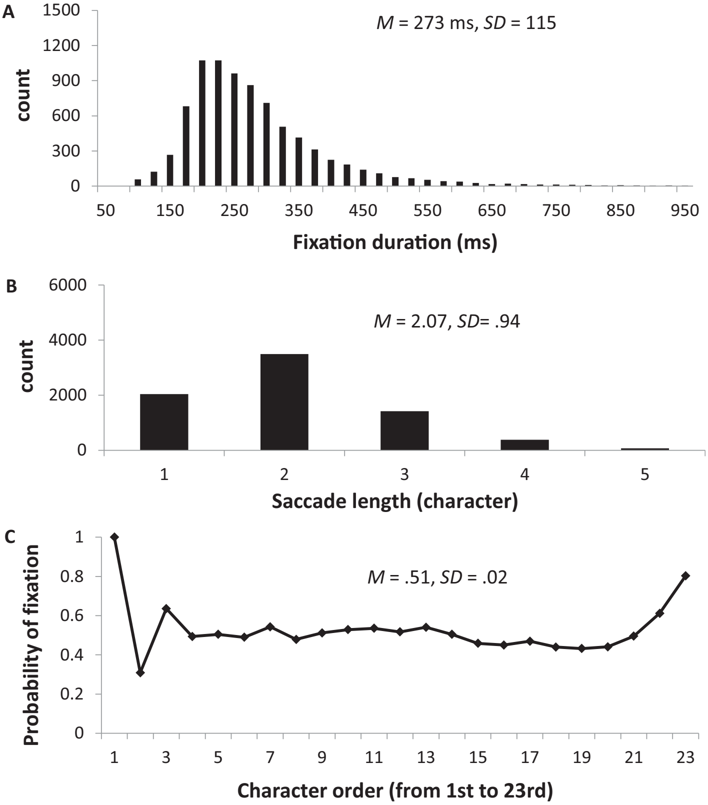

Figure 1. Global measures of Experiment 1. (A) Distribution of fixation duration; (B) Distribution of forward saccade length; (C) Fixation probability on each character.
Note: The value in Panel C for the first Character is an artefact as participants were always fixating the box, and hence the first character, when the characters appeared.

(*SD* = .11), respectively, which differed significantly, $F(1, 48) = 17.39$, $p < .001$, $\eta_p^2 = .42$. A polynomial analysis showed that both the linear trend and the quadratic trend were reliable, $F(1, 24) = 18.82$, $p < .001$, $\eta_p^2 = .44$, $F(1, 24) = 15.87$, $p = .001$, $\eta_p^2 = .39$. The average of the initial landing positions in the single-fixation cases (*M* = .81, *SD* = .21) was significantly closer to the centre of a word than in the multiple-fixation cases (*M* = .27, *SD* = .21), $F(1, 24) = 114.92$, $p < .001$, $\eta_p^2 = .83$.

Three-character nonword regions

When calculating all initial landing positions in the 3-character nonword regions, we found that the PVL was at the beginning of the 3-character nonword region, which was similar to the word region analysis above. The probabilities of initially landing on the first, second, and third character positions, respectively,

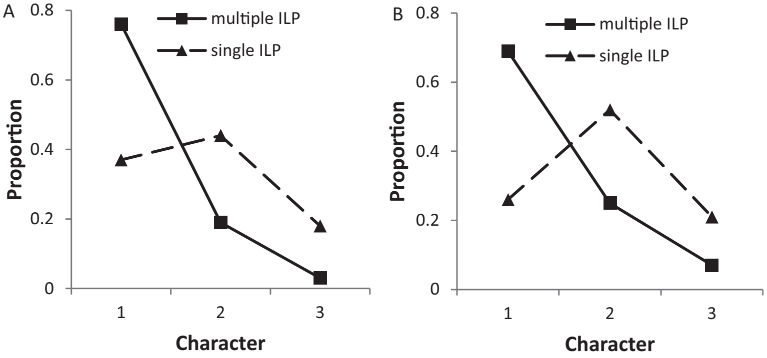

Figure 2. Initial landing positions (ILP) in multiple- and single-fixation cases in Experiment 1. (A) 3-character word regions; (B) 3-character nonword regions.

were .47 (*SD* = .08), .39 (*SD* = .04), and .13 (*SD* = .08), which differed significantly, $F(2, 48) = 97.39$, $p < .001$, $\eta_p^2 = .80$. A polynomial analysis showed that both the linear trend and the quadratic trend were reliable, $F(1, 24) = 97.45$, $p < .001$, $\eta_p^2 = .80$, $F(1, 24) = 96.82$, $p < .001$, $\eta_p^2 = .80$.

Most importantly, when splitting all initial landing positions into multiple- and single-fixation cases (see Figure 2B), we found the PVL patterns were similar to those in the word region analysis. For multiple-fixation cases, the probability of initially landing on the first, second, and third character position, respectively, were .68 (*SD* = .12), .24 (*SD* = .05), and .07 (*SD* = .11), which differed significantly, $F(2, 48) = 147.35$, $p < .001$, $\eta_p^2 = .86$. The polynomial analysis showed that both the linear trend and the quadratic trend were reliable, $F(1, 24) = 164.21$, $p < .001$, $\eta_p^2 = .87$, $F(1, 24) = 12.21$, $p = .002$, $\eta_p^2 = .34$. For single-fixation cases, the probabilities of initially landing on the first, second, and third character position, respectively, were .26 (*SD* = .09), .52 (*SD* = .09), and .21 (*SD* = .07), which differed significantly, $F(2, 48) = 56.23$, $p < .001$, $\eta_p^2 = .70$. A polynomial analysis showed that both the linear trend and the quadratic trend were reliable, $F(1, 24) = 3.53$, $p = .072$, $\eta_p^2 = .12$, $F(1, 24) = 103.32$, $p < .001$, $\eta_p^2 = .81$. Similar to the word region analysis, the average of the initial landing positions in the single-fixation cases (*M* = .95, *SD* = .13) was significantly closer to the centre of a nonword than that in multiple-fixation cases (*M* = .41, *SD* = .24), $F(1, 24) = 102.76$, $p < .001$, $\eta_p^2 = .81$. In these nonword region analyses, we still found that PVL curve peaked at the beginning of the region in multiple-fixation cases, but peaked at the centre of the region in single-fixation cases. Thus the "wordness" of the region is irrelevant to the pattern of the data, and therefore these results indicate that parafoveal word segmentation is irrelevant to the different PVL curves in multiple- and single-fixation cases reported by Yan et al. (2010).

Contrast between word and nonword regions

To further investigate whether the "wordness" of the region can affect saccade-target selection in multiple- and single-fixation cases, we examined whether there was a word-nonword by single-multiple interaction. We performed a 2 (word and nonword region) × 2 (multiple- and single-fixation cases) repeated ANOVA analyses on the probabilities of initially landing on each character position of the three-character region respectively. As was expected, the probability of initially landing on the first character position was larger in the multiple-fixation cases ($M = .73$, $SD = .12$) than that in the single-fixation cases ($M = .32$, $SD = .10$), $F(1, 24) = 137.38$, $p < .001$, $\eta_p^2 = .85$. These results imply that readers fixate closer to the centre of a region in single-fixation cases than that in multiple-fixation cases. Even though the probability of initially landing on the first character position was larger in the word regions ($M = .57$, $SD = .11$) than that in the nonword regions ($M = .47$, $SD = .06$), $F(1, 24) = 31.65$, $p < .001$, $\eta_p^2 = .57$, all the interactions between word-nonword and single-multiple conditions on each character position were not statistically significant, Fs < 1, ps $> .503$. We used Bayes Factor Calculator (Rouder, Morey, Speckman, & Province, 2012) to reveal that the null hypothesis of no interaction was at least 4.5 times more likely to be true than the alternative hypothesis. These results suggest that the "wordness" of the region does not affect saccade-target selection in multiple- and single-fixation cases. That is, the significant effect of "wordness" just reported above was a main effect (i.e., averaged over both single-fixation and multiple-fixation conditions) and could merely be due to some uncontrolled aspect of the materials other than their wordness.

EXPERIMENT 2

In Experiment 2, Chinese readers read character strings (shuffled-character sentences) that did not make any sense. In shuffled-character sentences, the characters were the same 24 characters as each sentence used in Experiment 1, but the order of characters were randomly shuffled so that none of the sequences of characters constituted a word. We investigated whether a PVL pattern similar to that in Experiment 1 and in Yan et al. (2010) can exist even in this shuffled-character reading task. If so, it would suggest that the pattern has little to do with word processing and word segmentation in reading.

Method

Participants

Twenty-five undergraduate students from the same participant pools as in Experiment 1 were paid to participate in the present study. All of them had either normal or corrected-to-normal vision. None of them participated in Experiment 1.

Apparatus

The same as in Experiment 1.

Materials

The characters from each sentence in Experiment 1 were shuffled to create a shuffled-character sentence. Thus, there were 30 shuffled-character sentences.

Procedure

The same procedure was used as in Experiment 1. Readers were asked to read the shuffled-character sentences as carefully as they would in natural sentence reading. They were allowed to freely choose strategies to read the sentences in order to recognize all the characters. The participants were asked in retrospect what they were trying to do with the character strings. Almost all readers confirmed that they just tried to recognize all the characters from left to right, but they did not realize whether they were processing all the characters one by one or by other strategies (e.g., trying to group contiguous characters together).

Results and discussion

We used the same methods of data analysis as in Experiment 1. Trials in which participants made three or more blinks were excluded from analysis, resulting in a loss of 2% of the trials. Fixations with durations longer than 1000 ms or shorter than 80 ms (approximately 2% of all fixations) were also excluded from the analysis. We reported the same eye movement measures as in Experiment 1. Both global sentences and local contiguous 3-character regions were analyzed. In addition, we compared fixation durations, saccade lengths and fixation probabilities between Experiment 1 and Experiment 2.

Global analysis

There were 10,967 analyzed fixations in Experiment 2 and the average fixation duration was 312 ms, with a standard deviation of 134 ms. The distribution of fixation durations is shown in Figure 3A. The average forward saccade length (10,239 saccades in total) was 1.53 characters, with a standard deviation of .73 characters. The distribution of forward saccade lengths is shown in Figure 3B. The probability that a character without including the first and last character was fixated from a forward saccade was .66, with a standard deviation of .02. The distribution of the probability that a character was fixated is shown in Figure 3C. As in Experiment 1, the data analysis was based on “first-pass” measures.

Compared with natural sentence reading in Experiment 1, there were more fixations in the shuffled-character reading task in Experiment 2. The average

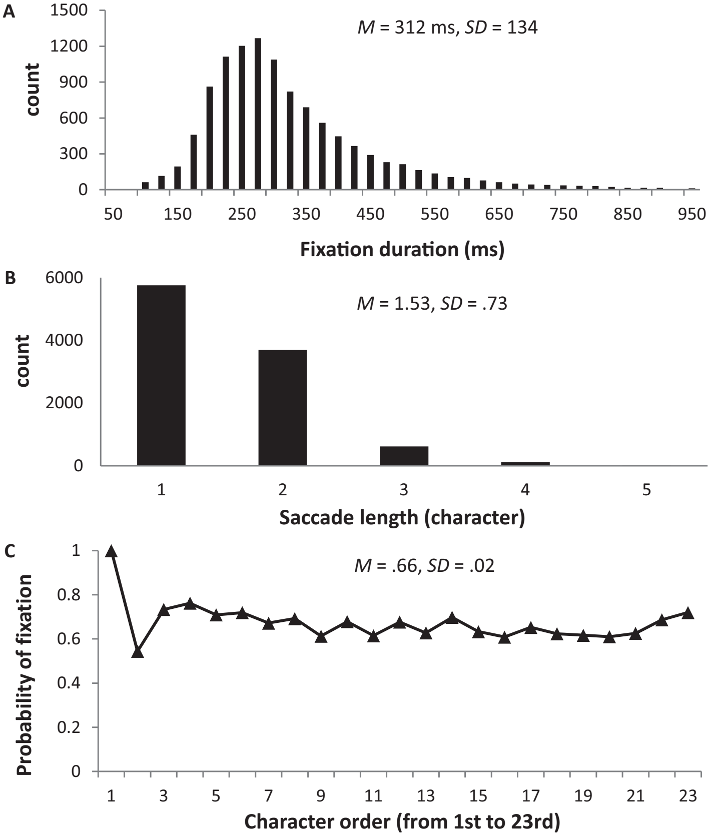

Figure 3. Global measures of Experiment 2. (A) Distribution of fixation duration; (B) Distribution of forward saccade length; (C) Fixation probability on each character.
Note: The value in Panel C for the first Character is an artefact as participants were always fixating the box, and hence the first character, when the characters appeared.

fixation duration in shuffled condition was longer than that in the natural reading condition, $F(1, 24) = 12.53$, $p = .002$, $\eta_p^2 = .34$. The average saccade length in reading shuffled-character sentences was shorter than that in natural reading, $F(1, 24) = 45.65$, $p < .001$, $\eta_p^2 = .65$. The probability of fixating a character in the shuffled-character sentence condition was greater than that in the natural reading condition, $F(1, 24) = 49.14$, $p < .001$, $\eta_p^2 = .67$. These data suggest that readers confront more difficulties in reading shuffled-character sentences than reading natural sentences. Because contiguous characters cannot constitute words longer than one character in shuffled-character sentences, recognizing each character cannot get feedback from the word level (e.g., 2- or 3-character words) which might delay recognition of each character (Li, Rayner, & Cave, 2009).

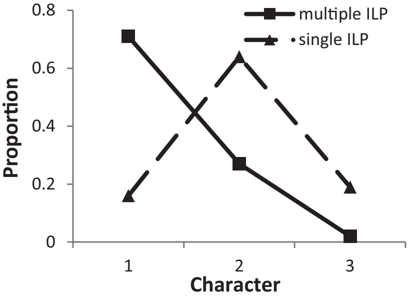

Figure 4. Initial landing positions (ILP) in multiple- and single-fixation cases for 3-character nonword regions in Experiment 2.

However, this is speculation, as it is not clear what exactly subjects construed their task to be in Experiment 2.

Three-character nonword regions

When calculating all initial landing positions in the 3-character nonword regions (except those including the first and last three characters in each sentence), the probabilities of initially landing on the first, second, and third character position, respectively, were .62 (*SD* = .09), .32 (*SD* = .07), and .05 (*SD* = .04), which significantly differed, $F(2, 48) = 266.77$, $p < .001$, $\eta_p^2 = .92$. A polynomial analysis showed that both the linear and quadratic trends were reliable, $F(1, 24) = 385.88$, $p < .001$, $\eta_p^2 = .94$, $F(1, 24) = 3.89$, $p = .060$, $\eta_p^2 = .14$.

Most importantly, when splitting all initial landing positions into multiple- and single-fixation cases (see Figure 4), we found the same PVL phenomenon even in shuffled-character reading task. For multiple-fixation cases, the probabilities of landing on the first, second, and third character position, respectively, were .71 (*SD* = .07), .26 (*SD* = .06), and .03 (*SD* = .03), which differed significantly, $F(2, 48) = 521.08$, $p < .001$, $\eta_p^2 = .96$. Furthermore, a polynomial analysis showed that only the linear trend was reliable, $F(1, 24) = 899.83$, $p < .001$, $\eta_p^2 = .97$. For single-fixation cases, the probabilities of initially landing on the first, second, and third character position, respectively, were .16 (*SD* = .11), .64 (*SD* = .15), and .19 (*SD* = .13), which differed significantly, $F(2, 48) = 42.95$, $p < .001$, $\eta_p^2 = .64$. A polynomial analysis showed that the linear trend was not reliable, $F < 1$, but the quadratic trend was reliable, $F(1, 24) = 73.95$, $p < .001$, $\eta_p^2 = .75$. Readers initially fixated closer to the centre of the critical region in single-fixation cases ($M = 1.03$, $SD = .19$) than in the multiple-fixation cases ($M = .32$, $SD = .08$), $F(1, 24) = 359.31$, $p < .001$, $\eta_p^2 = .94$.

Thus, it was the same pattern in the shuffled-character reading condition in Experiment 2 as in Experiment 1. That is, when subjects made a single fixation on a three-character (nonsense) region, they fixated closer to the centre of the region, but when they made more than one fixation on the region, they fixated nearer to the beginning of the region. Because there are no words in shuffled-character sentences, the data here further suggest that the cause of the different PVL patterns in multiple- and single-fixation cases has nothing to do with word segmentation planning the location of the initial fixation location on the region.

DISCUSSION

In the present study, we tested whether the different PVL patterns in multiple- and single-fixation cases reported by Yan et al. (2010) are caused by parafoveal word segmentation. That is, they observed that the PVL curve peaked at the beginning of the word in multiple-fixation cases, but peaked at the centre of the word in single-fixation cases. They attributed this difference most notably to the hypothesis that readers, in the single-fixation cases, had located the target word in the parafovea and were targeting its centre. Presumably, in the multiple fixation cases, they had not located the target word in time (i.e., in time to target a saccade) and had chosen some default target instead.

In the natural sentence reading task in Experiment 1, we replicated Yan et al.'s (2010) finding that the PVL curve peaked at the beginning of the word in multiple-fixation cases, but peaked at the centre of the word in single-fixation cases. However, the key finding in Experiment 1 was that the same phenomenon occurred not only in the 3-character word regions but also in the 3-character nonword regions. That is, when we grouped the contiguous 3-character nonword regions as regions of interest, the peak of the PVL curves was still at the centre of the region when there was a single fixation in one of those regions whereas it peaked near the beginning of the region when there were multiple fixations on the region. Since the characters in a region did not constitute a word, this kind of PVL curve was not likely caused by the fact that readers had successfully segmented a 3-character "word" using parafoveal vision.

Moreover, in Experiment 2, we used a shuffled-character reading task, where none of the sequences of characters constituted words. Thus, Chinese readers should rarely if ever be able to segment the characters into meaningful units (if not words) with parafoveal vision when doing this task. However, we still found that the PVL curves peaked at the beginning of a 3-character nonword region when there were multiple fixations in that nonword region, but peaked at the centre of that region when there was a single fixation. Although these different PVL curves in multiple- and single-fixation cases were similar to those reported by Yan et al. (2010) when readers read natural sentences, it again seems quite unlikely that these different PVL curves in multiple- and single-fixation cases are due to readers targeting the centre of a word (or meaningful unit) in the single-fixation case.

What is the best way to interpret the PVL curves observed in the current study and previous studies (Li et al., 2011; Yan et al., 2010; Zang et al., 2013)? First, the

PVL at the beginning of a word in Chinese reading is likely to be at least partly, if not wholly, a statistical artefact. When calculating the PVL curve of a region, only the saccades launched from the characters to the left of the region are counted. However, the saccades launched from the target word (i.e., refixations) are not counted. Taking a 3-character word as an example, all forward saccades that land on the first character are counted. In contrast, for the second character, the saccades launched from the first character are not included and for the third character, the saccades launched from both the first and second characters are not included. As a result, the proportion of counted fixations decreases from the first character to the third character which in turn leads to fixation probability decreasing from the first to the third character region.

Second, why do readers fixate the beginning of a region for multiple-fixation cases, but fixate the centre for single fixations? Li et al. (2011) also explained this phenomenon as a statistical artefact. When readers land on the beginning of the region, they are more likely to refixate on the region, whereas if they land on the centre of the region, they are less likely to refixate.[2] This is likely to have nothing to do with planning the initial saccade. As you can see in the distribution of saccade length, the average of saccade length was close to two characters. Taking a 3-character region as an example, if readers saccade to the centre of the 3-character region (no matter whether it constitutes a word or not), they are much less likely to refixate the 3-character region once more. On the other hand, if they fixate at the beginning of the 3-character region, there would be a greater probability of refixating the 3-character region once more. This seems like perfectly satisfactory "sufficient" explanation for why different PVL curves were observed in multiple- and single-fixation cases.

In summary, this study revealed different PVL patterns in multiple- and single-fixation cases in both word and nonword regions analysis which implied that the "wordness" of a region did not affect saccade-target selection in multiple- and single-fixation cases. Therefore, the different PVL patterns reported in previous studies are likely a statistical artefact as we discussed instead of what is caused by parafoveal word segmentation.

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[2] In Experiment 1, refixation probabilities were larger when readers initially fixated on the beginning of a region (word region: $M = .67$, $SE = .04$; nonword region: $M = .67$, $SE = .04$) than when they fixated on the center of the region (word region: $M = .34$, $SE = .03$; nonword region: M = .30, SE = .03), Fs > 88.25, ps <.001. In Experiment 2, refixations probabilities were also larger when readers initially fixated on the beginning of a region ($M = .95$, $SE = .01$) than when they fixated on the center of the region ($M = .70$, $SE = .03$), $F(1, 24) = 197.23$, $p < .001$.

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