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## The Effect of Foveal Processing in Fast and Slow Readers on Parafoveal Preview

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### Abstract

In Chinese reading, whether individual differences exist in preview benefit and whether it is modulated by foveal processing remains unclear. This study employed eye-tracking technology and the boundary paradigm to investigate how foveal processing in fast and slow readers influences parafoveal preview, by manipulating the processing load of the pretarget word (high vs. low) and the preview of the target word (identical vs. pseudocharacter). The results demonstrated a significant main effect of foveal load: the fast reader group exhibited shorter first-fixation and single-fixation durations on low-load words compared to high-load words, whereas the slow reader group showed no difference in these measures between the two load conditions, indicating that the fast group could more rapidly process foveal words by utilizing lexical properties. A significant main effect of preview was also observed; specifically, compared with pseudocharacter preview, identical preview resulted in shorter fixations on the target word, longer forward saccades, and higher skipping rates for both reader groups. Moreover, this effect did not interact with foveal load. These findings suggest that the fast and slow groups extracted equivalent preview benefit, which was not modulated by their foveal processing. The E-Z Reader model and the SWIFT model cannot fully explain the present results.

### Full Text

#### The Influence of Foveal Processing Load on Parafoveal Preview in Fast and Slow Readers during Chinese Reading

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## Abstract

In Chinese reading, it remains unclear whether individual differences exist in the amount of preview benefit and whether such differences are modulated by foveal processing. The present study employed eye-tracking technology and the boundary paradigm to investigate how foveal processing influences parafoveal preview in fast and slow readers by manipulating the processing load of pre-target words (high vs. low) and the preview of target words (identical vs. pseudo-character). The results revealed a significant main effect of foveal load: fast readers showed shorter first-fixation and single-fixation durations on low-load words than on high-load words, whereas slow readers exhibited no difference in these measures between the two load conditions, indicating that fast readers could more rapidly utilize lexical properties to process foveal words. The preview effect was also significant, with identical previews leading to shorter fixation times, longer forward saccades, and higher skipping rates for target words compared to pseudo-character previews for both groups. Critically, this effect did not interact with foveal load, suggesting that fast and slow readers extracted equivalent amounts of preview that were not modulated by their foveal processing. Neither the E-Z Reader model nor the SWIFT model can fully account for these findings.

**Keywords:** fast readers; slow readers; parafoveal preview; foveal processing load; Chinese reading

## 1.1 Individual Differences in Parafoveal Preview

During natural reading, the effective visual region from which readers extract information in a single fixation includes both foveal and parafoveal areas. The foveal area, which is currently being fixated, has the highest visual acuity and yields the most detailed visual information. Due to the sharp decline in visual acuity, information extracted from parafoveal words (i.e., preview) is relatively limited, including phonological, orthographic, and sublexical information (and possibly semantic information). This information reduces processing time for these words and produces preview benefit (Bai et al., 2011; Rayner, 2009), while also facilitating saccade target selection (Li et al., 2017; Liu, Reichle, & Li, 2015; Wang et al., 2018). Overall, preview enhances reading efficiency (Rayner, 2009; Schotter, Angele, & Rayner, 2012). In research on individual differences in skilled reading, a key question concerns whether and how preview varies with individual reading ability.

Previous studies have measured individual reading ability using either reading test scores (e.g., Ashby, Rayner, & Clifton, 2005; Chace, Rayner, & Well, 2005; Veldre & Andrews, 2015a, 2015b) or reading speed under effective comprehen-

sion conditions as a proxy for test scores (e.g., Frömer et al., 2015; Rayner, Slattery, & Bélanger, 2010; Risse, 2014). Under effective reading conditions, faster reading speed indicates higher reading efficiency (Ashby et al., 2005; Rayner et al., 2010). Consequently, reading speed is considered a comprehensive index of reading ability (Ashby et al., 2005; Rayner, Schotter, Masson, Potter, & Treiman, 2016).

From a spatial perspective, individual differences in preview first manifest in preview span. Rayner et al. (2010) compared the perceptual spans of fast and slow readers, finding that slow readers had a preview span of one word, whereas fast readers' span exceeded two words. Ashby, Yang, Evans, and Rayner (2012) further demonstrated that when effective preview span increased, fast readers gained substantially greater preview benefit than slow readers. Similar results emerged when using reading ability to distinguish individuals: compared to low-ability readers, high-ability readers extracted more preview information and obtained greater preview benefit when preview span increased, leading to larger improvements in reading speed (Veldre & Andrews, 2014). These findings indicate that high reading ability or fast reading speed is associated with a wider preview span.

From a temporal perspective, individual differences in preview also appear in the degree of preview benefit. Chace et al. (2005) compared preview types between generally skilled readers and low-ability readers, finding that skilled readers obtained larger phonological preview benefit, whereas low-ability readers could not extract phonological information from the parafovea and thus failed to benefit from effective preview. Veldre and Andrews (2015a, 2015b) examined orthographic preview processing in readers with different abilities, revealing that high-ability readers extracted parafoveal orthographic information earlier, faster, and more accurately. Accurate orthographic preview yielded greater preview benefit for high-ability readers, while invalid preview severely disrupted their lexical processing. This suggests that high-ability readers read faster because they extract preview information more rapidly and utilize it more extensively.

## 1.2 The Influence of Foveal Lexical Processing on Parafoveal Preview and Its Individual Differences

Regarding foveal lexical processing, word frequency has typically been used to examine lexical processing (Clifton et al., 2016; Rayner, 2009) because frequency is the primary attribute affecting lexical processing difficulty. High-frequency words are easier to process and impose low processing load, whereas low-frequency words are more difficult and impose high processing load. Research on alphabetic reading has shown that low-ability readers spend longer processing low-frequency words, exhibiting larger word frequency effects (Ashby et al., 2005), whereas high-ability readers show shorter processing times for low-frequency words and smaller frequency effects (Kuperman & Van Dyke, 2011; Taylor & Perfetti, 2016), indicating more efficient foveal lexical processing in high-ability readers.

Researchers have speculated that low-ability readers read slowly because foveal lexical processing consumes more attentional resources and is less efficient, leaving minimal resources for extracting parafoveal information. In contrast, high-ability readers read faster because their efficient foveal lexical processing allows them to allocate more attentional resources to extract more extensive preview (Ashby et al., 2012; Chace et al., 2005; Rayner, 1986; Veldre & Andrews, 2015b). In other words, individual differences in parafoveal preview may merely be a byproduct of individual differences in foveal lexical processing (Rayner, 1986; Veldre & Andrews, 2015b). This interpretation is based on the “Foveal Load Hypothesis” (Henderson & Ferreira, 1990). Veldre and Andrews (2015b) tested this possibility by examining how foveal processing load (high frequency: low load; low frequency: high load) affected the type of preview extracted (word length and preview accuracy) in high- and low-ability readers. Their results showed that for first-fixation and single-fixation durations, when foveal load was low, high- and low-ability readers obtained equivalent preview benefit, but when foveal load was high, high-ability readers extracted more preview. Conversely, Risse (2014) found that slow readers obtained greater preview benefit than fast readers. Based on the view of parallel lexical processing (see Section 1.3), Risse explained that fast readers’ lexical processing had reached an automatic level, with fixation durations on foveal words at a minimal threshold, leaving no extra time for preview. This extremely high level of lexical processing efficiency could compensate for their reduced preview. Slow readers required longer fixations on foveal words, providing more opportunities to extract preview. Although Risse did not directly manipulate foveal load, her explanation predicts that slow readers, who need more time to process foveal words under high load, should extract more preview.

Thus, research on individual differences in preview has yet to reach consistent conclusions.

### 1.3 Theoretical Explanations for Individual Differences in Parafoveal Preview

The two dominant models of reading eye movement control—the E-Z Reader model and the SWIFT model—offer different explanations for individual differences in the degree of preview benefit. The E-Z Reader model posits that lexical processing proceeds serially, with attention allocated to only one word at a time. After familiarity verification (L1) of the currently fixated word (word  $n$ ), the oculomotor system begins programming the next saccade; after lexical access (L2) and before the next saccade is executed, attention shifts to the next word  $n+1$ , and parafoveal preview begins (Reichle, 2011; Reichle, Pollatsek, Fisher, & Rayner, 1998). The simpler the foveal word or the lower the processing load, the faster L1 and L2 are completed, the earlier attention shifts to word  $n+1$ , and the more preview is extracted from and the more likely word  $n+1$  is to be skipped. This model predicts that high-ability or fast readers obtain more preview because their foveal processing is faster and attention shifts to word

$n+1$  earlier.

The SWIFT model assumes that attention is distributed in a gradient across words within the perceptual span, with words processed in parallel. While fixating the current word  $n$ , readers also begin processing parafoveal words, though processing efficiency for parafoveal words decreases due to reduced visual acuity. This suggests that longer foveal processing times yield greater preview benefit (Engbert & Kliegl, 2011; Engbert, Nuthmann, Richter, & Kliegl, 2005). Low-ability or slow readers, who have longer foveal fixations, should extract more preview, which contradicts the E-Z Reader model's prediction.

Regarding individual differences in preview span, the E-Z Reader model predicts that when sufficient preview is obtained from word  $n+1$  quickly enough to achieve lexical access, attention shifts to word  $n+2$  and preview of word  $n+2$  begins (Reichle, 2011; Schotter et al., 2012). Compared to low-ability or slow readers, high-ability or fast readers' faster foveal processing leads to earlier attention shifts to word  $n+1$ , making lexical access of word  $n+1$  more likely and thus increasing the probability of previewing word  $n+2$ . The SWIFT model posits that foveal processing difficulty or load modulates preview span: easier foveal processing or lower load yields a wider preview span. This predicts that higher reading ability or speed, which is associated with easier foveal processing or lower load, should produce a wider preview span. Thus, both models make predictions about individual differences in preview span.

#### 1.4 Parafoveal Preview in Chinese Reading

The aforementioned studies and theories focus on alphabetic reading. Although Henderson and Ferreira (1990) demonstrated that preview benefit decreases as foveal processing load increases, subsequent studies have failed to replicate this result (Veldre & Andrews, 2018; White, Rayner, & Liversedge, 2005). One possible reason is that word length varies substantially in alphabetic scripts, and different studies have used target words of varying lengths, making it difficult to control preview span when examining how foveal processing affects the degree of preview benefit. As previously noted, parafoveal information processing involves both the degree and span of preview. When examining preview degree, the ideal approach is to maximize manipulation of preview degree within a limited spatial unit. In contrast, Chinese word length shows less variation, with approximately 90% of common words being 1-3 characters long (Li, Zang, Liversedge, & Pollatsek, 2015). More importantly, each Chinese character occupies identical space, yet varies in visual and lexical complexity, meaning more parafoveal information can be presented within a single word unit and may be more sensitive to foveal processing effects (Zhang, Liversedge, Bai, Yan, & Zang, 2019).

Zhang et al. (2019) investigated Chinese reading while controlling preview span to a single character and found that foveal lexical processing load did not modulate preview benefit in fixation duration measures. Liu et al. (2015), however,

found that foveal load effects on preview appeared in saccade length, such that under normal preview conditions, lower foveal processing load produced longer forward saccades, consistent with the E-Z Reader model. Nevertheless, Liu et al. used a special symbol (※) as an invalid preview, which may have disrupted normal sentence reading. Under normal reading conditions, Zhang et al. and Wang et al. (2018) demonstrated that foveal processing load and preview independently affect forward saccade length. Additionally, Yan (2015) examined the effect of foveal visual processing load (few strokes: low load; many strokes: high load) on preview (valid or nonword preview) and found a reverse modulation: as foveal visual processing load increased, more preview was extracted, supporting the SWIFT model's prediction and suggesting that foveal visual and lexical processing may differentially affect preview. In summary, Chinese reading research has yet to reach consistent conclusions regarding whether and how foveal processing load modulates preview benefit.

Studies of child readers and international students learning Chinese have found that as individual reading ability improves, their preview span becomes wider and they extract more types and greater amounts of preview (Wang, Zhou, Shu, & Yan, 2014; Yan, Li, Wang, Liu, & Wang, 2018; Yan, Wang, Wu, & Bai, 2011). Chinese reading researchers have speculated that this occurs because low-ability readers experience greater difficulty processing foveal words, occupying more attentional resources and shifting attention to parafoveal words later or with fewer resources available for extraction (Wang et al., 2014; Yan, Xiong, & Bai, 2008). However, this speculation lacks direct empirical support.

To investigate whether individual differences in preview benefit among Chinese adult readers are modulated by foveal processing, or whether inconsistent findings regarding foveal load effects on preview benefit stem from individual differences, the present study examined adult readers. Following previous research, we used reading speed as an index of reading ability to select fast and slow readers (Ashby et al., 2005; Rayner et al., 2016). We selected two-character words as pre-target words (foveal words) and single-character words as target words (parafoveal words). Two-character words have high probabilities of being fixated (Zang, Fu, Bai, Yan, & Liversedge, 2018), while using single-character words minimized preview space to the smallest lexical unit, substantially increasing the probability that the parafoveal word would be previewed. Target word previews consisted of identical previews (the target word itself) and pseudo-character previews. Pseudo-character previews served as a baseline condition providing “zero” preview, whereas identical previews provided “full” preview. Comparing fixation times on target words between pseudo-character and identical preview conditions yielded the total amount of preview benefit obtained (Rayner, 1975, 2009). Our hypotheses were: (1) If foveal load modulates preview benefit differently for readers of varying speeds, then according to the E-Z Reader model, which predicts a positive modulation of foveal load on preview benefit, fast and slow readers should show equivalent preview benefit under low foveal load, but fast readers should extract more preview than slow readers under high foveal load. According to the SWIFT model, which predicts a negative

modulation, fast and slow readers should show equivalent preview benefit under low foveal load, but slow readers should extract significantly more preview than fast readers under high foveal load. (2) If foveal load does not affect preview benefit for fast and slow readers, then both groups should extract equivalent amounts of preview regardless of foveal processing load.

### 2.1.1 Screening Procedure for Fast and Slow Readers

Previous studies have primarily used two methods to screen fast and slow readers. One approach divides participants into fast and slow groups based on the median reading speed (e.g., Rayner et al., 2010). The alternative method selects fast and slow readers from the extremes of a distribution after ranking all participants by reading speed (e.g., Hawelka, Schuster, Gagl, & Hutzler, 2015), which provides greater differentiation between groups. The present study adopted the second approach, following Hawelka et al.'s method of screening participants based on three-minute reading speed.

Specifically, we randomly selected 300 Chinese native-speaking university students and graduate students from Tianjin Normal University, all with normal or corrected-to-normal vision. Participants' task was to silently read a series of simple, comprehensible sentences and respond "yes" or "no" as quickly and accurately as possible to statements about each sentence's meaning. The number of sentences correctly judged within three minutes constituted each participant's reading speed.

Following Hawelka et al. (2015), we developed 150 common-knowledge sentences for the screening test (see Appendix). Each sentence expressed a fact that either conformed to common knowledge (e.g., "The moon orbits the earth") or violated it (e.g., "An elephant's trunk is very short"). Conforming and violating sentences each comprised half of the materials. Sentence length was  $10 \pm 3$  Chinese characters. Prior to formal testing, 20 participants completed a pilot test. Results indicated that within the 3-minute limit, participants judged between 66 and 132 sentences, with an average response time of 1911 ms ( $SD = 1010$  ms) and an average accuracy of 95%.

The test program was developed in E-prime 2.0, with stimuli presented in 32-point Song font on a 15.6-inch Dell laptop. Only one sentence appeared at a time, with each participant tested individually at a viewing distance of approximately 60 cm. Participants received instructions stating: "A series of sentences related to common knowledge will be presented on the screen, one at a time. Before each sentence appears, please fixate on the fixation point '+'. Your task is to judge whether each sentence's meaning is correct or incorrect as quickly and accurately as possible. Press the 'D' key if the sentence conforms to common knowledge, and the 'J' key if it violates common knowledge. The practice session will begin now." The fixation point "+" appeared for 1000 ms before each sentence. Four practice sentences preceded the formal test to familiarize participants with the procedure. During practice, feedback was provided, and

participants had to correctly judge more than three sentences to proceed to the formal test; otherwise, they repeated practice. No feedback was provided during formal testing.

### 2.1.2 Screening Results for Fast and Slow Readers

Based on the reading speed test results, fast and slow readers were selected through a two-step procedure. First, we excluded 70 participants who scored below 90% accuracy on sentence judgments or were unwilling to continue with the subsequent eye-tracking experiment. Second, among the remaining 234 participants, we ranked them by the number of correctly judged sentences and selected the top 28 as fast readers and the bottom 28 as slow readers. The fast readers had a mean age of  $22 \pm 2$  years, including 20 females. The slow readers had a mean age of  $22 \pm 2$  years, including 22 females.

The performance of fast and slow groups on the sentence judgment task is shown in Table 1. Results indicated that fast readers correctly judged significantly more sentences within 3 minutes than slow readers,  $F(1, 27) = 656.15$ ,  $p < 0.001$ ,  $p^2 = 0.96$ . Fast readers' average time per judgment was significantly shorter than that of slow readers,  $F(1, 27) = 535.95$ ,  $p < 0.001$ ,  $p^2 = 0.95$ . However, the two groups did not differ in accuracy,  $F(1, 27) = 1.55$ ,  $p = 0.22$ ,  $p^2 = 0.05$ . These results demonstrate that the fast group had significantly higher effective reading speed than the slow group.

**Table 1** Basic information for fast and slow groups on the sentence judgment task (standard deviations in parentheses)

Group	Total Sentences Judged	Correctly Judged Sentences	Accuracy (%)	Average Response Time (ms)
Fast	130 (9)	125 (10)	96 (2.6)	1380 (94)
Slow	73 (6)	70 (6)	96 (2.3)	2500 (244)

## 2.2 Experimental Materials

The present study used the same experimental materials as Zhang et al. (2019). We selected two-character words as pre-target words (foveal words) and manipulated their lexical frequency (high vs. low). Previous research has primarily used word frequency to manipulate foveal lexical processing load (e.g., Wang et al., 2018; Henderson & Ferreira, 1990; Liu et al., 2015; Veldre & Andrews, 2018; White et al., 2005; Zhang et al., 2019), and we employed the same approach. High-frequency words are easily processed, representing low foveal processing load, whereas low-frequency words are difficult to process, representing high foveal processing load.

Thirty-two pairs of high- and low-frequency words were selected. High-frequency words had significantly higher frequency than low-frequency words,  $F(1, 31) =$

21.49,  $p < 0.001$ . The two sets did not differ significantly in stroke count,  $F(1, 31) = 0.15$ ,  $p = 0.70$ . Each high-low frequency word pair was combined with a single-character word within the same sentence frame, yielding 32 single-character target words (parafoveal words). All sentences were highly plausible, with both pre-target and target words having low predictability, as shown in Table 2.

**Table 2** Basic information for pre-target words and sentences under different foveal processing loads (standard deviations in parentheses)

Foveal Load	Word Frequency (per million)	Stroke Count	Sentence Plausibility	Pre-target Predictability (%)	Target Predictability (%)
Low	242.9 (295.7)	16.8 (1.8)	4.0 (0.3)	1.3 (3.7)	0.4 (0.3)
High	16.6 (1.9)	3.9 (0.3)	0.6 (2.5)	2.3 (4.9)	4.5 (7.7)

The boundary paradigm (Rayner, 1975) was used to manipulate target word preview. Specifically, an invisible boundary was set immediately before the target word. Before the eyes crossed this boundary, the preview of the target word was either identical or a pseudo-character (see Figure 1 [Figure 1: see original paper]). When the eyes crossed the boundary, the preview changed to the target word. Pseudo-characters were matched to target words in stroke count. There were 32 sets of sentences, each with four experimental conditions: low foveal load-identical preview, low foveal load-pseudo-character preview, high foveal load-identical preview, and high foveal load-pseudo-character preview. Using a Latin square design, sentences from each condition were distributed across four blocks. In addition to experimental sentences, each block included 6 practice sentences and 24 filler sentences. Each participant read only one block of sentences. Furthermore, 46% of sentences were followed by reading comprehension questions.

**Figure 1** Example sentences in the four experimental conditions before and after the eyes cross the boundary (Note: “挑战/诱捕” are pre-target words, “熊” is the target word, the dashed line indicates the invisible boundary location, and \* represents two consecutive fixation points before and after the boundary)

The experiment employed a 2 (reading group: fast vs. slow)  $\times$  2 (foveal processing load: high vs. low)  $\times$  2 (parafoveal preview: identical vs. pseudo-character) mixed design, with reading group as a between-subjects factor and both foveal processing load and parafoveal preview as within-subjects factors.

We used an EyeLink 1000 eye tracker manufactured by SR Research (Canada) with a sampling rate of 1000 Hz and a display refresh rate of 150 Hz. Experimental materials were presented in Song font on a white background. Each Chinese character subtended approximately 1.1° of visual angle.

## 2.4 Experimental Procedure

During the eye-tracking experiment, each participant was tested individually. Before the experiment, the experimenter seated the participant at the testing station, instructed them to place their chin on a chinrest, and minimize head movements during the experiment. Instructions on the screen read: “A series of Chinese sentences will be presented one at a time. Please read and understand each sentence carefully. Some sentences will be followed by comprehension questions. Please answer ‘yes’ or ‘no’ based on the original sentence meaning. The left button on the controller is ‘yes,’ the right button is ‘no.’ ” After ensuring comprehension of the task, the experimenter performed a three-point calibration of the participant’s eyes. Upon successful calibration, participants completed practice trials before proceeding to the formal experiment.

Sentences were presented randomly during the formal experiment. Participants’ button responses and eye movements were recorded automatically. The experimenter monitored participants’ fixation patterns and recalibrated when necessary to ensure data accuracy. The entire experiment lasted approximately 20 minutes.

Both fast and slow groups achieved 92% accuracy on reading comprehension questions, indicating good sentence understanding with no significant difference between groups,  $F(1, 54) = 0.27$ ,  $p = 0.61$ ,  $\eta^2 = 0.005$ . For raw eye movement data screening, we first removed fixations shorter than 80 ms or longer than 1200 ms. We then screened trials by: (1) removing sentences with tracking loss due to button press errors or head movements (approximately 0.06% of total data); (2) for whole-sentence analyses, removing sentences more than three standard deviations from the mean on any measure (1.20%); (3) for pre-target word analyses, removing sentences more than three standard deviations from the mean (1.23%); and (4) for target word analyses, removing sentences where blinks occurred during first-pass boundary crossing or target word fixation, where text changes occurred too early or too late (14.79%), and then removing sentences more than three standard deviations from the mean (0.38%).

We first conducted global analyses at the sentence level to examine overall differences between fast and slow readers. Analyzed measures included temporal dimensions (total sentence reading time, average fixation duration, and reading speed) and spatial dimensions (total number of fixations, number of forward saccades, forward saccade length, and number of regressions) (Yan et al., 2013). Total reading time reflects overall sentence processing and increases with sentence difficulty. Total fixation count is closely related to total reading time, with more fixations generally corresponding to longer reading times. Average fixation duration reflects overall processing per fixation and increases with sentence difficulty. Reading speed, which integrates total reading time and sentence length, is a relatively stable and effective indicator of overall reading performance. Forward saccade length primarily reflects processing of upcoming text before saccade initiation; when upcoming text is easier to process or more information is

extracted, forward saccades become longer. Forward saccade count is inversely related to forward saccade length, with more forward saccades corresponding to shorter saccade lengths. Regression count reflects later semantic integration processes, with more regressions indicating greater integration difficulty.

We then conducted local analyses with pre-target and target words as regions of interest (see Figure 2 [Figure 2: see original paper]). Local analysis measures were selected from commonly used first-pass reading indicators (Yan et al., 2013): (1) first-fixation duration—the duration of the first fixation on the target word during first-pass reading, reflecting earliest lexical processing; (2) single-fixation duration—the fixation duration when the target word receives exactly one fixation during first-pass reading, reflecting lexical identification processes in a single fixation; (3) gaze duration—the sum of all fixation durations on the target word during first-pass reading, reflecting lexical identification across one or multiple fixations; (4) skipping probability—the probability that the target word is skipped during first-pass reading, reflecting advance processing, with easier words being skipped more frequently; and (5) forward saccade length—the distance from the launch site on the pre-target word to the landing position after the boundary, reflecting processing difficulty, with easier processing producing longer saccades. The first three measures reveal early lexical identification processes from a temporal perspective, with identical values when a word receives only one fixation. Skipping probability and forward saccade length are spatial measures that reveal saccade target selection processes.

**Figure 2** Region of interest 划分 for pre-target and target words in local analyses

Data analysis was conducted using linear mixed models (LMM) with the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) in the R environment (R Development Core Team, 2018). Significance estimates were obtained using Markov-Chain Monte Carlo algorithms to derive posterior distributions of model parameters ( $b$ ), which simultaneously capture variation across participants and items (Baayen, Davidson, & Bates, 2008). Before running LMMs, fixation durations, fixation counts, saccade lengths, and reading speed measures were log-transformed. Skipping probability was analyzed using generalized linear mixed models (GLMM). In the models, foveal processing load and preview were treated as fixed factors. Participants and items were specified as crossed random effects, with both random intercepts and random slopes considered (Barr, Levy, Scheepers, & Tily, 2013).

### 3.1 Global Analysis

Descriptive results from global analyses are presented in Table 3, with statistical test results in Table 4. Reading group effects were highly significant across all measures ( $|t|s > 3.20$ ,  $ps < 0.01$ ): compared to fast readers, slow readers showed longer total sentence reading times, more fixations, longer average fixation durations, more and shorter forward saccades, and more regressions. These results indicate that slow readers' reading speed was significantly lower than that

of fast readers, confirming the effectiveness of our participant selection.

**Table 3** Global fixation patterns for fast and slow groups on sentences (standard deviations in parentheses)

Measure	Fast Group	Slow Group
Total Sentence Reading Time (ms)	3013 (881)	4911 (1977)
Average Fixation Duration (ms)	221 (23)	239 (20)
Total Fixation Count	13.5 (3.6)	20.6 (8.3)
Forward Saccade Count	9.3 (2.4)	13.6 (5.1)
Regression Count	3.4 (1.1)	5.5 (3.1)
Forward Saccade Length (characters)	2.5 (0.6)	2.0 (0.6)
Reading Speed (characters/minute)	458 (139)	299 (114)

**Table 4** Fixed effect estimates for fast and slow groups on sentence measures

Measure	Reading Group Effect (Slow vs. Fast)	<i>b</i>	<i>t</i>	<i>p</i>	95% CI
Total Sentence Reading Time	0.46	6.23	<0.001		[0.27, 0.63]
Average Fixation Duration	0.08	3.48	<0.001		[0.03, 0.13]
Total Fixation Count	0.37	4.98	<0.001		[0.20, 0.54]
Forward Saccade Count	0.35	4.78	<0.001		[0.17, 0.52]
Forward Saccade Length	-0.23	-	<0.001		[-0.36, -0.10]
Regression Count	0.39	4.23	<0.001		[0.16, 0.62]

*Note: CI = Confidence Interval*

### 3.2.1 Pre-Target Word Analysis

Fixation patterns for fast and slow groups on pre-target words are shown in Table 5. Participants fixated pre-target words with 84% probability, confirming that our selection of two-character words as foveal words effectively ensured that preview of target words occurred while fixating pre-target words.

Reading group main effects were significant for first-fixation duration ( $b = 0.11$ ,  $SE = 0.04$ ,  $t = 2.67$ ,  $p = 0.01$ , 95% CI = [0.03, 0.20]), single-fixation duration ( $b = 0.13$ ,  $SE = 0.04$ ,  $t = 2.85$ ,  $p = 0.006$ , 95% CI = [0.04, 0.21]), gaze duration ( $b = 0.30$ ,  $SE = 0.05$ ,  $t = 5.73$ ,  $p < 0.001$ , 95% CI = [0.20, 0.40]), and forward saccade length ( $b = -0.26$ ,  $SE = 0.07$ ,  $t = -3.58$ ,  $p < 0.001$ , 95% CI = [-0.40, -0.12]): slow readers showed longer first-fixation, single-fixation, and gaze durations on pre-target words and made shorter forward saccades than fast readers.

Word frequency main effects were also significant (first-fixation duration:  $b = 0.05$ ,  $SE = 0.01$ ,  $t = 3.68$ ,  $p < 0.001$ , 95% CI = [0.03, 0.08]; single-fixation duration:  $b = 0.05$ ,  $SE = 0.02$ ,  $t = 2.93$ ,  $p = 0.004$ , 95% CI = [0.02, 0.08]; gaze duration:  $b = 0.12$ ,  $SE = 0.02$ ,  $t = 4.90$ ,  $p < 0.001$ , 95% CI = [0.07, 0.16]; forward saccade length:  $b = -0.10$ ,  $SE = 0.02$ ,  $t = -4.16$ ,  $p < 0.001$ , 95% CI = [-0.15, -0.05]): both groups showed longer first-fixation, single-fixation, and gaze durations on low-frequency words than high-frequency words, and made shorter forward saccades from low-frequency words. These frequency effects are consistent with previous research (Clifton et al., 2016; Rayner, 2009), confirming effective manipulation of foveal processing load.

Parafoveal preview main effects were not significant for any first-pass reading time measures ( $|t|s < 1.15$ ,  $ps > 0.05$ ), indicating no preview type effects on pre-target word processing and no parafoveal-on-foveal effects. Preview type significantly affected forward saccade length ( $b = -0.14$ ,  $SE = 0.02$ ,  $t = -5.95$ ,  $p < 0.001$ , 95% CI = [-0.18, -0.09]), with pseudo-character previews producing significantly shorter forward saccades than identical previews. This preview effect on forward saccade length reflects saccade target selection processes.

The interaction between reading group and word frequency was significant for first-fixation duration ( $b = -0.06$ ,  $SE = 0.03$ ,  $t = -2.14$ ,  $p = 0.03$ , 95% CI = [-0.12, -0.01]) and single-fixation duration ( $b = -0.12$ ,  $SE = 0.03$ ,  $t = -3.46$ ,  $p < 0.001$ , 95% CI = [-0.18, -0.05]), but not for gaze duration or forward saccade length ( $|t|s < 1.81$ ,  $ps > 0.05$ ). Simple effects analysis revealed significant word frequency effects for fast readers (first-fixation duration:  $b = -0.09$ ,  $SE = 0.02$ ,  $t = -4.16$ ,  $p < 0.001$ ; single-fixation duration:  $b = -0.11$ ,  $SE = 0.02$ ,  $t = -4.77$ ,  $p < 0.001$ ), with fast readers fixating high-frequency words 24 ms and 29 ms shorter than low-frequency words for first-fixation and single-fixation durations, respectively. In contrast, slow readers showed no significant differences between high- and low-frequency words for first-fixation duration (frequency effect = -9 ms,  $b = -0.02$ ,  $SE = 0.02$ ,  $t = -1.18$ ,  $p = 0.24$ ) or single-fixation duration (frequency effect = -4 ms,  $b = 0.01$ ,  $SE = 0.02$ ,  $t = 0.31$ ,  $p = 0.76$ ), requiring similarly long processing times for both word types. Figure 3 [Figure 3: see

original paper] presents single-fixation durations for high- and low-frequency pre-target words for both groups.

**Figure 3** Single-fixation durations for high- and low-frequency pre-target words for fast and slow groups (Note: \*\*\* indicates  $p < 0.001$ )

Reading group  $\times$  preview and word frequency  $\times$  preview interactions were not significant for first-pass reading times or forward saccade length ( $|b|s < 0.04$ ,  $|t|s < 0.80$ ,  $ps > 0.05$ ). The three-way interaction among reading group, word frequency, and preview was significant for first-fixation duration ( $b = -0.15$ ,  $SE = 0.07$ ,  $t = -2.29$ ,  $p = 0.02$ , 95% CI = [-0.28, -0.02]) and single-fixation duration ( $b = -0.22$ ,  $SE = 0.07$ ,  $t = -3.02$ ,  $p = 0.003$ , 95% CI = [-0.37, -0.08]), and marginally significant for gaze duration ( $b = -0.15$ ,  $SE = 0.09$ ,  $t = -1.74$ ,  $p = 0.08$ , 95% CI = [-0.32, 0.02]). Simple effects analysis for first-fixation and single-fixation durations revealed similar word frequency effects for fast and slow readers under identical preview conditions ( $|t|s < 0.37$ ,  $ps > 0.05$ ). However, under pseudo-character preview conditions, word frequency effects differed between groups ( $|t|s > 3.52$ ,  $ps < 0.001$ ). Simple-simple effects analysis showed significant word frequency effects for fast readers ( $|t|s > 4.53$ ,  $ps < 0.001$ ) but not for slow readers ( $|t|s < 1.52$ ,  $ps > 0.05$ ). This indicates that, compared to fast readers, slow readers' processing of high-frequency foveal words was more susceptible to interference from pseudo-character previews. Since pseudo-characters differ from target words primarily in orthographic form, this result actually reflects an orthographic parafoveal-on-foveal effect, which has been observed in previous studies (Drieghe, 2011).

**Table 5** Fixation times and forward saccade lengths for fast and slow groups on pre-target words under different conditions (standard deviations in parentheses)

	First-fixation Duration (ms)	Single-fixation Duration (ms)	Gaze Duration (ms)	Forward Saccade Length (characters)
<b>Fast Group</b>				
Low load-identical	219 (47)	216 (47)	237 (52)	2.62 (0.97)
Low load-pseudo	207 (33)	202 (36)	243 (62)	2.29 (0.72)
High load-identical	229 (42)	231 (46)	258 (68)	2.40 (0.82)
High load-pseudo	245 (68)	248 (70)	283 (90)	2.14 (0.75)

	First-fixation Duration (ms)	Single-fixation Duration (ms)	Gaze Duration (ms)	Forward Saccade Length (characters)
<b>Slow Group</b>				
Low load- identical	245 (36)	248 (43)	317 (78)	1.99 (0.54)
Low load- pseudo	250 (39)	257 (44)	329 (66)	1.73 (0.56)
High load- identical	258 (44)	263 (55)	387 (108)	1.82 (0.82)
High load- pseudo	253 (41)	246 (54)	379 (102)	1.57 (0.60)

### 3.2.2 Target Word Analysis

Means and standard deviations for all eye movement measures on target words are presented in Table 6. Reading group main effects were significant for target word first-fixation duration ( $b = 0.09$ ,  $SE = 0.04$ ,  $t = 2.11$ ,  $p = 0.04$ , 95% CI = [0.01, 0.17]), single-fixation duration ( $b = 0.10$ ,  $SE = 0.04$ ,  $t = 2.35$ ,  $p = 0.02$ , 95% CI = [0.02, 0.18]), gaze duration ( $b = 0.11$ ,  $SE = 0.04$ ,  $t = 2.67$ ,  $p = 0.01$ , 95% CI = [0.03, 0.20]), and skipping probability ( $b = -0.78$ ,  $SE = 0.24$ ,  $z = -3.24$ ,  $p = 0.001$ ): slow readers showed longer first-fixation, single-fixation, and gaze durations on target words and skipped target words less frequently than fast readers.

Parafoveal preview main effects were highly significant (first-fixation duration:  $b = 0.12$ ,  $SE = 0.03$ ,  $t = 4.47$ ,  $p < 0.001$ , 95% CI = [0.07, 0.17]; single-fixation duration:  $b = 0.16$ ,  $SE = 0.03$ ,  $t = 5.60$ ,  $p < 0.001$ , 95% CI = [0.10, 0.21]; gaze duration:  $b = 0.18$ ,  $SE = 0.03$ ,  $t = 6.81$ ,  $p < 0.001$ , 95% CI = [0.13, 0.23]; skipping probability:  $b = -0.61$ ,  $SE = 0.12$ ,  $z = -5.29$ ,  $p < 0.001$ , 95% CI = [-0.84, -0.39]): compared to pseudo-character previews, when target word previews were valid, both groups showed shorter first-fixation, single-fixation, and gaze durations and higher skipping rates.

Foveal load effects on target words (i.e., word frequency spillover effects) appeared significantly in single-fixation duration as a reverse spillover effect ( $b = -0.05$ ,  $SE = 0.03$ ,  $t = -2.03$ ,  $p = 0.046$ , 95% CI = [-0.10, -0.00]): under high-frequency conditions, both groups showed 10 ms longer single-fixation durations on target words than under low-frequency conditions. No spillover effects were found for first-fixation duration or gaze duration ( $|b|s < 0.04$ ,  $|t|s < 1.45$ ,  $ps$

> 0.05). Foveal load also significantly affected target word skipping probability ( $b = -0.34$ ,  $SE = 0.13$ ,  $z = -2.59$ ,  $p = 0.01$ , 95% CI = [-0.59, -0.08]), with higher skipping rates under low-load than high-load conditions, consistent with forward saccade length results on pre-target words.

Critically, no three-way interactions among reading group, foveal load, and preview emerged for fixation times or skipping probability (fixation times:  $|b|s < 0.10$ ,  $|t|s < 0.99$ ,  $ps > 0.05$ ; skipping probability:  $b = -0.69$ ,  $SE = 0.46$ ,  $z = -1.51$ ,  $p = 0.13$ , 95% CI = [-1.60, 0.21]). No two-way interactions were significant either (fixation times:  $|b|s < 0.08$ ,  $|t|s < 1.32$ ,  $ps > 0.05$ ; skipping probability:  $|b|s < 0.33$ ,  $|z|s < 1.26$ ,  $ps > 0.05$ ).

**Table 6** Fixation times and skipping rates for fast and slow groups on target words under different conditions (standard deviations in parentheses)

	Skipping ConditionRate	First-fixation Duration (ms)	Single-fixation Duration (ms)	Gaze Duration (ms)
<b>Fast Group</b>				
Low load-identical	0.60 (0.27)	245 (72)	249 (73)	286 (74)
Low load-pseudo	0.44 (0.22)	272 (53)	262 (51)	315 (75)
High load-identical	0.52 (0.23)	234 (57)	252 (73)	296 (70)
High load-pseudo	0.45 (0.25)	269 (78)	267 (53)	326 (70)
<b>Slow Group</b>				
Low load-identical	0.44 (0.24)	250 (51)	317 (78)	336 (84)
Low load-pseudo	0.32 (0.25)	312 (65)	329 (66)	379 (102)
High load-identical	0.38 (0.22)	260 (53)	387 (108)	296 (70)
High load-pseudo	0.23 (0.28)	292 (78)	379 (102)	273 (80)

### 3.2.3 Bayesian Analysis

To further examine the absence of interaction effects among reading group, foveal load, and preview on target words, we conducted Bayesian analyses on forward saccade length, first-fixation duration, single-fixation duration, gaze duration, and skipping probability using the BayesFactor package (Morey et al., 2018). We computed Bayes factors for the full model (including main effects of reading group, foveal load, parafoveal preview, and their three-way interaction) and for the main-effects-only model. Comparing these models ( $BF = BF\_Full/BF\_Main$ ) evaluated whether an interaction existed. BF values less than 1 support the null hypothesis (no three-way interaction), while values greater than 1 support the alternative hypothesis (significant three-way interaction). Using default prior probability of 0.5 and 100,000 Monte Carlo iterations, Bayesian analyses yielded BF values less than 1 for all measures (forward saccade length:  $BF = 0.12$ ; first-fixation duration:  $BF = 0.36$ ; single-fixation duration:  $BF = 0.18$ ; gaze duration:  $BF = 0.17$ ; skipping probability:  $BF = 0.28$ ), supporting the null hypothesis. Sensitivity analyses using different prior probabilities (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, and 0.8) also supported the null hypothesis ( $BFs < 0.75$ ).

### 4.1 Foveal Lexical Processing in Fast and Slow Readers

The present study investigated differences in parafoveal preview between fast and slow readers and how these differences are modulated by foveal processing load. Results showed that when reading comprehension accuracy was equivalent, fast and slow readers differed globally: fast readers exhibited shorter total sentence reading times, shorter average fixations, fewer fixations, longer forward saccades, and faster reading speeds than slow readers, consistent with previous research (Rayner et al., 2010; Risse, 2014). These findings demonstrate both that fast readers are more efficient than slow readers and that our participant selection method was highly effective. We now discuss foveal processing and parafoveal preview separately for fast and slow readers.

First-pass reading time analyses on pre-target words revealed significant reading group main effects, with fast readers spending less time processing foveal words than slow readers, consistent with previous findings (Ashby et al., 2005; Kuperman & Van Dyke, 2011; Taylor & Perfetti, 2016) and indicating faster overall lexical processing in fast readers. More importantly, fast readers showed significant word frequency effects in first-fixation and single-fixation durations, fixating high-frequency words significantly shorter than low-frequency words, whereas slow readers showed no frequency effects, requiring similarly long fixation times for both word types. This suggests that fast readers process high-frequency foveal words more efficiently than slow readers. Both groups showed significant frequency effects in gaze duration. These results indicate that, similar to alphabetic reading research, individual differences in lexical processing between fast and slow readers in Chinese reading manifest in both “degree” and “quality” (Ashby et al., 2005), though the pattern differs from alphabetic scripts.

In Chinese reading, fast readers activate word frequency information and begin using it immediately upon fixation, whereas slow readers utilize word frequency information relatively later. In alphabetic reading, high-ability readers show greater efficiency in processing low-frequency words compared to low-ability readers (Ashby et al., 2005; Taylor & Perfetti, 2016).

One reason for this different pattern of frequency effects may be variations in participant selection criteria across studies. Ashby et al. (2005) divided 44 participants into generally skilled and highly skilled groups, while Taylor and Perfetti treated reading scores as a continuous variable across 35 participants. In contrast, the present study selected fast and slow groups from a larger sample (234 valid participants), yielding greater group differentiation and potentially including slower readers with lower reading proficiency than previous studies, resulting in early processing difficulties even for high-frequency words. Another reason may be that slow readers rely more heavily on context during lexical processing than fast readers (Ashby et al., 2005). Our pre-target words had low predictability in sentence context, meaning both groups could not utilize contextual information for lexical processing. This may have caused extreme difficulty for slow readers in early lexical processing regardless of word frequency, whereas fast readers only experienced difficulty with low-frequency words. Additionally, Chinese' s unique writing system (e.g., closely spaced characters, lack of clear word boundaries, dense information distribution) may lead fast and slow Chinese readers to adopt different lexical processing patterns or strategies than alphabetic readers (Liversedge et al., 2016; Zang et al., 2016). Future research is needed to verify these possibilities.

## 4.2 Parafoveal Preview in Fast and Slow Readers

During first-pass reading, pre-target words were fixated with 84% probability, confirming effective selection that ensured preview of parafoveal words occurred during foveal fixation. Target word analyses revealed that both fast and slow readers extracted information from valid parafoveal previews, with no significant difference in the amount extracted. Despite slower foveal processing, particularly for high-frequency words in early stages, this did not affect slow readers' ability to extract equivalent preview benefit to fast readers. Indeed, we found no modulating effect of foveal load on preview benefit, consistent with some alphabetic reading studies (Drieghe, Rayner, & Pollatsek, 2005; Marx, Hawelka, Schuster, & Hutzler, 2017; Vasilev, Slattery, Kirkby, & Angele, 2018; Veldre & Andrews, 2018; Zhang et al., 2019).

Like most previous research, we used word frequency to index foveal lexical processing load. Chinese reading studies have employed different ranges for high and low frequency: Liu et al. (2015) used high frequency = 120.5 per million and low frequency = 2.17 per million; Wang et al. (2018) used high frequency = 405.08 per million and low frequency = 7.64 per million; the present study used high frequency = 242.9 per million and low frequency = 0.4 per million. Despite these differences, our study, like Liu et al. and Wang et al., found no interaction

between foveal load and preview in fixation duration measures, suggesting that different ranges of foveal processing load are unlikely to modulate this effect.

As noted, word length may influence how foveal load affects preview. Veldre and Andrews (2015b) demonstrated that high-ability readers can better utilize parafoveal word length information to extract more preview, suggesting an advantage in processing visual-spatial information from the parafovea. Perceptual span research also shows that high-ability readers extract preview from a wider span and in greater amounts (Rayner et al., 2010; Veldre & Andrews, 2014). Combining these findings suggests that differences between fast and slow readers may occur only in the spatial dimension of preview and may be modulated by foveal processing. Under this interpretation, our results can be explained as follows: when preview information is limited to a single character and the preview word is adjacent to the foveal word, substantial preview can be obtained regardless of reading speed or foveal processing load.

Furthermore, because the present study focused on individual differences in preview benefit within a single preview unit, we included only identical and pseudo-character preview types. Chace et al. (2005) found that high-ability readers extract greater phonological preview, suggesting that differences between readers of varying speeds or modulating effects of foveal load may appear for specific preview types (e.g., orthographic, phonological, or semantic). Future research should explore this possibility.

### **4.3 Implications of Individual Differences in Parafoveal Preview for Reading Eye Movement Control Theories**

According to the E-Z Reader model, as foveal processing load decreases, more preview is extracted from the parafovea and parafoveal words are more likely to be skipped (Reichle, 2011; Reichle & Drieghe, 2013). This predicts that fast readers, with faster foveal processing, should extract more preview and skip more target words. Although we found that fast readers processed foveal words faster than slow readers, neither group showed modulated or different amounts of preview benefit. Moreover, foveal processing load and reading speed did not affect forward saccade length or skipping probability by modulating preview amount (similar results appear in Wang et al., 2018; Liu et al., 2015). These findings suggest that the mechanisms by which foveal load affects preview and saccade target selection may not operate entirely as predicted by the E-Z Reader model (Drieghe et al., 2005), with similar evidence from alphabetic reading studies (Drieghe et al., 2005; Vasilev et al., 2018; Veldre & Andrews, 2018). This indicates that the E-Z Reader model's assumptions about the stages at which preview and saccade planning occur may require improvement or refinement to explain foveal load effects on preview and individual differences therein.

The SWIFT model differs most fundamentally from the E-Z Reader model in assuming parallel lexical processing within the perceptual span. Therefore, longer

foveal processing times should yield greater simultaneous preview extraction from parafoveal words and increase parafoveal word skipping. This predicts that slow readers, with longer foveal fixations, should obtain more preview. Our findings that slow readers' longer foveal fixations did not produce greater preview benefit, and that high-load words receiving longer fixations did not yield more preview, clearly contradict the SWIFT model's predictions about individual differences in preview benefit.

A major point of contention between the SWIFT and E-Z Reader models concerns parafoveal-on-foveal effects. The SWIFT model posits simultaneous foveal and parafoveal lexical processing, so parafoveal information (particularly at the lexical level) should affect foveal word processing, producing parafoveal-on-foveal effects (Engbert & Kliegl, 2011). The E-Z Reader model assumes attention shifts to parafoveal words only after foveal lexical processing is complete, so parafoveal lexical processing should not affect foveal processing (Reichle, 2011). Notably, both models' debate about serial versus parallel processing concerns the lexical level. At the visual information processing level, the E-Z Reader model also assumes that during early pre-attentive processes, visual information from multiple words (e.g., word length, orthographic form) can be extracted simultaneously (Angele, Slattery, & Rayner, 2016; Drieghe, 2011). Our finding of a three-way interaction among reading group, foveal load, and preview type on pre-target words—where fast and slow readers showed similar processing under identical preview, but slow readers' foveal processing was disrupted under pseudo-character preview, producing an orthographic parafoveal-on-foveal effect—can be accommodated by both models. During very early visual information extraction, fast and slow readers process visual information from foveal and parafoveal regions in parallel. Moreover, when invalid previews appear in the parafovea, slow readers are more susceptible to such visual interference, which affects their foveal lexical processing. This supports the view that lower-ability readers depend more on visual text information (Rayner, Yang, Schuett, & Slattery, 2013; Zang et al., 2016).

Under the conditions of the present study, we conclude: (1) During early lexical processing, fast readers can more quickly utilize lexical properties to process foveal words and complete lexical identification than slow readers; (2) Within a single-character preview span, fast and slow readers extract equivalent amounts of preview that are not modulated by foveal processing. These findings provide preliminary insights into the relationship between reading speed and foveal/parafoveal processing in Chinese adult readers, offer individual-difference evidence for testing the Foveal Load Hypothesis, and provide Chinese reading evidence for current reading eye movement control models regarding how foveal load affects preview and its individual differences, offering implications for future model revision and extension.

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## Appendix

Three-Minute Fast and Slow Reader Screening Test Materials (Sentences marked with \* indicate incorrect statements)

1. Every week has seven days
2. A common year has 365 days
3. Our country' s capital is located in Beijing
4. The author of *Journey to the West* is Wu Cheng' en
5. Airplanes can fly in the sky
6. Eagles soar in the sky
7. Lions run on the grassland
8. October 1st is National Day every year
9. China implements nine-year compulsory education
10. Little monkeys have flexible tails
11. People can write with brushes
12. The earth revolves around the sun
13. China is located in the northern hemisphere of the earth
14. China is a socialist country
15. There are twenty-four solar terms in a year
16. Summer temperatures are high so it' s very hot
17. People carry umbrellas when it rains
18. Monkeys' bottoms are red
19. The earth we live on is a sphere
20. Bees like to gather nectar among flowers
21. People can communicate by telephone
22. Airplanes can fly in the sky
23. People' s lives cannot do without water
24. The moon orbits the earth
25. The earth itself rotates
26. Cells can be seen using a microscope
27. Normal people walk with two legs
28. People can ride camels across deserts
29. White clouds float high in the sky
30. Seawater in the ocean tastes salty
31. Some maple leaves are red in autumn
32. Pine needles remain green year-round
33. Ice cubes turn into water when melted
34. The earth is surrounded by air
35. The Yellow River is China' s mother river
36. Mount Everest is the world' s highest peak

37. People use combs to brush hair
38. Submarines can travel underwater
39. Rainbows have seven colors
40. Yangtze River water flows to the sea
41. Cameras can take photographs
42. People see things with their eyes
43. Trash cans hold discarded items
44. Lights turn on after connecting power
45. China' s national flag is red
46. Rice becomes rice after processing
47. Fire extinguishers can put out fires
48. The sun can emit light and heat
49. China has fifty-six ethnic groups
50. Ordinary glass is fragile
51. Alcohol is flammable
52. Spring is the season when everything grows
53. Humans are advanced mammals
54. Fresh water can freeze into ice cubes
55. The first day of lunar January is Spring Festival
56. There are twenty-six English letters
57. Trees can be used to make timber
58. Driving cars on highways requires a license
59. One hour has sixty minutes
60. The piano is a playable musical instrument
61. Airplanes can carry people flying in the sky
62. Little tigers have four legs
63. Carrots grow under the ground
64. Goats are grass-eating animals
65. Cups are containers that can hold liquids
66. Bananas and grapes are both fruits
67. China' s national flag is called the Five-starred Red Flag
68. Lei Feng is a role model for us to learn from
69. Running red lights violates traffic rules
70. Sun Wukong is also called the Monkey King
71. Tadpoles grow up to become frogs
72. Flies are pests that spread diseases
73. June 1st is Children' s Day
74. Sun Wukong is a character in *Journey to the West*
75. Monkeys like to eat bananas
76. \*Scales can measure people' s height
77. \*Cars drive quickly on water surfaces
78. \*Sharks can live on land
79. \*People wear cotton-padded jackets in summer
80. \*Newborn babies can run
81. \*The moon at night emits its own light
82. \*A frog can swallow an eagle in one bite

83. \*An average person' s height is about 5 meters
84. \*Cars can fly in the sky
85. \*Turtles run faster than leopards
86. \*People can run 100 meters in one second
87. \*Human lifespan can reach a thousand years
88. \*The red scarf is blue in color
89. \*Horses run in the sky
90. \*People can see bacteria with naked eyes
91. \*Puppies have a pair of wings
92. \*Car wheels are square-shaped
93. \*Snowflakes float in the summer sky
94. \*Giraffes have shorter necks than hippos
95. \*Ordinary stones can float on water
96. \*Whales can fly in the sky
97. \*Eggs are harder than stones
98. \*The moon is square-shaped
99. \*Normal people have three eyes
100. \*Gasoline is drinkable
101. \*Solar energy is a type of plant
102. \*Butterflies are heavier than elephants
103. \*Power banks measure body temperature
104. \*Toilet paper is made of steel and cement
105. \*Carrots are a type of meat
106. \*Computer mice are made from real mice
107. \*Watches are tools for measuring weight
108. \*Cosmetic boxes can hold large houses
109. \*White chalk can write black characters
110. \*Trains travel quickly on the sea surface
111. \*Computers are very delicious food
112. \*Table salt tastes sweet
113. \*Roosters on farms lay eggs
114. \*Normal human blood is

*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv –Machine translation. Verify with original.*