Perceptual span is independent of font size for older and young readers: Evidence from Chinese

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Abstract

Research suggests that visual acuity plays a more important role in parafoveal processing in Chinese reading than in spaced alphabetic languages, such that in Chinese, as font size increases, the size of the perceptual span decreases. The lack of spaces and the complexity of written Chinese may make characters in eccentric positions particularly hard to process. Older adults generally have poorer visual capabilities than young adults, particularly in parafoveal vision and so may find large characters in the parafovea particularly hard to process compared with smaller characters, due to their greater eccentricity. Therefore, the effect of font size on the perceptual span may be larger for older readers. Crucially, this possibility has not previously been investigated, however this may represent a unique source of age-related reading difficulty in logographic languages. Accordingly, to explore the relationship between font size and parafoveal processing for both older and young adult readers we manipulated font size and the amount of parafoveal information available with different masking stimuli in two silent reading experiments. The results show that decreasing font size disrupted reading behavior more for older readers, such that reading times were longer for smaller characters, but crucially, the influence of font size on the perceptual span was absent for both age groups. These findings provide new insight into age-related reading difficulty in Chinese by revealing that older adults can successfully process substantial parafoveal information across a range of font sizes. This indicates that older adults' parafoveal processing may be more robust than previously considered.

Key words: reading, perceptual span, visual acuity, font size

Main body word count, excluding abstract and references = 7820

Normal reading relies on a series of saccadic eye movements along each line of text, separated by brief fixational pauses, during which visual information is acquired. The region of text (e.g. the number of characters/letters or words) from which useful information can be extracted on a single fixation is termed the “perceptual span”. It has been studied using gaze-contingent moving-window techniques (McConkie & Rayner, 1975) in which text is presented normally within a specified region (window) around fixation and text beyond this window is obscured (e.g., by replacing letters in words with an ‘X’; McConkie & Rayner, 1975, 1976; for a review, see Rayner, 2014). This window moves in synchrony with the reader’s eye movements, so that when the eyes fixate a new location, text at this location is shown normally (within the defined window) and text outside of the window, both to the left and right of fixation, is masked. To examine the extent that readers use information in the periphery, the assumption is that when the window is smaller than the perceptual span, reading will be disrupted. The size of the window can be varied to determine the window size required for reading to proceed at its normal speed; this window represents the perceptual span.

The perceptual span plays an important role in fluent reading. Research shows that span size varies as a function of text difficulty and reading ability such that when the fixated word is more difficult to process, more resources are allocated to this word, resulting in a smaller perceptual span (Henderson & Ferreira, 1990; Kennison & Clifton, 1995). It is therefore noteworthy that substantial evidence indicates older adults (60+ years) typically experience greater reading difficulty than young adults (18-30 years) during alphabetic (e.g., English) or logographic (e.g., Chinese) reading and so have slower reading speeds and make more and longer fixations, despite typically achieving similar levels of comprehension in eye movement experiments (e.g., Kliegl, Grabner, Rolfs, & Engbert, 2004; McGowan, White, Jordan & Paterson, 2014; Paterson, McGowan, & Jordan, 2013a,b,c; Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Rayner, Yang, Schuett & Slattery, 2014; Warrington, McGowan, Paterson & White, 2018, 2019; Whitford & Titone, 2016, 2017; Li, Li, Wang, McGowan & Paterson, 2018; Wang, Li, Li, Xie, Chang, Paterson, White, & McGowan, 2018a; Wang, Li, Li, Xie, Liversedge, & Paterson, 2018b; Zang, Zhang, Bai, Yan, Paterson, & Liversedge, 2016; Xie, Li, Zhao, Wang, Paterson, White, & Warrington, 2019, though note that in depth off-line assessments of comprehension often do report age differences, see Wingfield & Stine-Morrow, 2000; Thornton & Light, 2006; DeDe & Flax, 2016; Stine-Morrow & Radvansky, 2017).

This has led researchers to speculate that visual and cognitive declines in later adulthood, including reduced sensitivity to parafoveal information (Crassini, Brown, & Bowman, 1988; Sekuler, Bennett, & Mamelak, 2000) results in a smaller perceptual span and produces slower reading. Indeed, Rayner et al. (2009) presented evidence that older adult readers have a smaller and less asymmetric perceptual span compared with young adult readers. Other studies also suggest less efficient parafoveal processing by older readers (Rayner, Castelhano, & Yang, 2010; Rayner et al., 2014). However, more recent research has failed to replicate this age difference (Whitford & Titone, 2015; see also Risse & Kliegl, 2011) or has suggested that age differences in parafoveal processing may depend on the cognitive demands of the task (Payne and Stine-Morrow, 2012). Further, generally the observed differences have been small and only marginally significant (Rayner et al., 2014). Therefore, whether there are adult age differences in the use of parafoveal processing to facilitate reading remains an open question.

Crucially, to date knowledge about the effects of visual and cognitive aging on the reading process is based almost exclusively on findings from alphabet languages and it is not known whether these effects generalize to other writing systems. As such, very little is known about the nature of parafoveal processing in older age in Chinese. However, there is reason to believe that parafoveal processing may be particularly challenging in logographic languages. The perceptual span of skilled young adult readers of Chinese extends approximately 1 character to the left of the fixated character and 3-4 characters to its right (Inhoff & Liu, 1998; see also Yan, Zhou, Shu, & Kleigl, 2015) compared with 3-4 letters to the left of fixation and 14-15 letters to the right (McConkie & Rayner, 1975, 1976; Rayner, Well, & Pollatsek, 1980) in English. This smaller perceptual span is likely a consequence of the increased visual complexity of written Chinese, relative to English. In particular, there are no spaces to mark word boundaries, and so readers must depend on lexical knowledge to segment characters into words (Li, Rayner, & Cave, 2009; Wei, Li, & Pollatsek, 2013). Individual characters can also contain many individual strokes (e.g., 鹳 [“guan”], meaning “stork”), making them visually dense. Further, characters typically carry more complex linguistic information (Inhoff & Liu, 1998; Liu, Angele, Luo, & Li, 2018) such that a single character can convey complex meaning which may require many letters in English. The increased complexity of written Chinese relative to languages such as English may pose unique difficulty to older readers. It therefore seems clear that exploring parafoveal processing in a visually dense language such as Chinese may be crucial to understanding cross-language variation (or similarity) in age-related reading difficulty. Particularly as evidence already suggests these characteristics of the Chinese script are a source of difficulty for older adults during normal reading (S. Li et al., 2018; L. Li et al., 2019; Zang et al., 2016).

In addition to the Chinese perceptual span being smaller in size, the factors determining the size of the span may also differ from alphabetic languages. Specifically, there is interesting evidence that, across a range of typical font sizes (O’Regan, 1983) the span for alphabetic languages is unrelated to letter size (and so, visual acuity) due to an almost perfect trade-off between the increase of letter visibility with large font size and the decrease of visual acuity with the large text becoming more eccentric (O'Regan, 1990). This has been demonstrated using parafoveal magnification to offset acuity limitations (Miellet, O'Donnell & Sereno, 2009), and more standard perceptual span paradigms (Yan, Zhou, Shu & Kliegl, 2015, Experiment 2). In contrast, research suggests that the perceptual span in Chinese is modulated by font size, such that the perceptual span is smaller when the text is larger (Yan et al., 2015, Experiment 3, see also Shu, Zhou, Yan & Kliegl, 2011.)

In Yan et al's (2015) study, text was presented either entirely normally (unmasked) or with one character to the left of fixation and three characters to the right presented normally and the remaining characters masked with visually similar characters. The aim was to directly examine the processing of parafoveal information for three font sizes: small, medium or large (corresponding to 0.7°, 1.0°, and 1.3° of visual angle per-character). They found that the disruption resulting from the parafoveal mask was greatest in the small font condition and smallest in the large font condition, such that in the large font condition, reading speeds were similar to in the unmasked condition. This reduction in disruption was taken to indicate more limited parafoveal processing for large characters. Yan et al (2015) concluded that the presence of spaces in alphabetic languages plays a key role in guiding the eyes across a range of font sizes, even when acuity is low (e.g., McConkie, Kerr, Reddix, & Zola, 1988; Reichle, Rayner, & Pollatsek, 1999; Shu, et al., 2011). The indication is that acuity plays a more important role in parafoveal processing in Chinese than in spaced alphabetic languages as the lack of spaces in written Chinese, coupled with the greater complexity of the characters, makes characters in eccentric positions particularly hard to process.

It is this finding that is of central interest in the current experiments as if the size of the perceptual span for Chinese is determined by visual acuity, we may expect these effects to be enhanced for older adults. It is well documented that older adults have poorer visual capabilities due to declines that occur naturally in later life and these declines are greater outside of central vision (for a review, see Owsley, 2011). In addition, older adults experience a loss of sensitivity to fine visual detail (Crassini et al., 1988; Elliott, Whitaker, & MacVeigh, 1990), a loss of contrast sensitivity (e.g., Wright and Drasdo, 1985), and an increase in sensitivity to visual crowding (Scialfa, Cordazzo, Bubric, & Lyon, 2013), all of which may limit their ability to resolve the identity of individual characters. Research in English suggests that older adults read more slowly when text is very small or very large (.15° and 12° per character, respectively, Akutsu, Legge, Ross, Schuebel, 1991). Moreover, such effects may be enhanced in Chinese due to visual complexity and the lack of spaces. Therefore, older Chinese adults' overall reading speed may benefit from having text presented in a larger font. However, as age-related declines in visual acuity are more pronounced in the parafovea, older adults may have particular difficulty in recognizing large font size characters parafoveally due to their eccentricity as fewer large characters can occupy foveal vision and the uncrowded window (Pelli, & Tillman, 2008). Older readers therefore may have a larger font size effect on the processing of parafoveal information compared with young adults, and so may have a smaller perceptual span for large characters, despite possibly having faster reading speeds due to the greater ease of identifying these characters foveally. No studies to date have investigated this issue for older adults. However, if older Chinese readers do show reduced parafoveal processing for large text, this may represent an important cross-linguistic difference in the manifestation of age-related reading difficulty. Therefore, in order to fully understand the relationship between acuity, attention and the perceptual span across different writing systems, it is crucial to examine font size effects on parafoveal processing for both older and young Chinese readers.

The key aim of the current experiments was to compare the effect of font size on parafoveal processing for the two age groups, and not to provide a comprehensive investigation of the size of the perceptual span. As such, the window size used in the masked condition was selected to match that employed by Yan et al (2015) and to roughly match the size of the perceptual span reported in previous experiments for young adults (one character available to the left of fixation and three to the right). However, the current study may also provide an important initial indication of whether the perceptual span changes in older age.

Accordingly, we manipulated font size (small, medium and large characters) in different viewing conditions (masked and unmasked) in two Experiments. We anticipated, in line with previous research, that older adults would read more slowly than their younger counterparts. In line with findings for alphabetic languages (e.g., Akutsu et al., 1991) we also anticipated that older adults may read particularly slowly when font size is small. With respect to the masking manipulation, for young adults, we expected to replicate the findings of Yan et al (2015), that is, the difference in reading times between unmasked and masked conditions would be largest for small font size characters and decrease with increasing font size, indicating a reduction in the perceptual span with increasing character size. Most importantly, we aimed to examine whether the effect of font size on the parafoveal processing differs in older age. A larger font size effect for older adults, such that the reduction in disruption between the masked and unmasked condition for large characters is greater for this age group, may indicate a greater decrease in the size of the perceptual span with increasing character size.

Method

This research was approved by the research ethics committee of the Faculty of Psychology at Tianjin Normal University and conducted in accordance with the principles of the Declaration of Helsinki.

Participants. Participants were 48 young adults from Tianjin Normal University and 48 older adults from a residential home in Tianjin. All participants completed both Experiment 1 and Experiment 2, and testing on Experiment 2 began around one month after the completion of Experiment 1. All were native Mandarin Chinese readers, assessed for educational background, interest in reading and visual and cognitive abilities, as described below. A summary of the participant characteristics is shown in Table 1. The age groups were closely matched on years of formal education and all participants reported reading for several hours per-week. Participants were screened for high-contrast acuity (corrected acuity of > 20/40 in Snellen values) using a Tumbling E eye-chart (Taylor, 1978), and as is typical (Elliott, Yang, & Whitaker 1995), acuity was higher for young than older adults. Participants were also screened for non-impaired cognition using the Beijing version of the Montreal Cognitive Assessment (Nasreddine et al., 2005), applying an exclusion criterion of < 26/30.

Vocabulary and working memory capabilities were assessed using the Vocabulary Knowledge Test from the WAIS-III Chinese version (Wechsler, Chen, & Chen, 2002) and the WAIS-III forward and backward Digit Span subtest (Wechsler, 1997). Raw vocabulary scores were slightly higher for older adults (though scaled scores did not differ). However, raw scores for both forward and backward digit span were lower for the older adults, as is typical for these age-groups (Ryan, Sattler, & Lopez, 2000).

Insert Table 1

Simulations of statistical power were conducted using the simR package in R (Green & MacLeod, 2016). We selected the participant number to match Yan et al.’s study (2015) and then conducted analyses to ensure that this design provided sufficient power. The power to detect effects of viewing condition, and font, and the interaction of viewing condition and font (L vs. M; M vs. S) were assessed based on means and standard deviations for fixation duration from Yan et al. (2015). (Note that Yan et al.’s (2015) study only included young adults). These analyses confirmed that this design was sufficiently powered (> 99%).

Materials and Design. One hundred and Ninety-two sentences were constructed as reading material. These were between 15 and 24 characters and 8 and 14 words long. Of these sentences, 96 were used in Experiment 1, another 96 were used in Experiment 2. In each Experiment, participants read 16 sentences in each condition, and across participants each sentence was shown in every experimental condition. The experimental sentences were preceded by 10 practice items in each experiment.

The sentences were presented using a gaze-contingent moving-window paradigm in which text outside the window region was masked. The study used a 2 (age-group: older adults and young adults) × 2 (viewing condition: unmasked and masked) × 3 (font size: 32, 42, and 56 pixels; corresponding to 0.7°, 1.0°, and 1.3° of visual angle per-character, respectively) mixed design. In order ensure comparability with previous research, viewing condition and font size were chosen to match those used in Yan et al.'s (2015) study. The masked viewing condition allowed readers to obtain correct character information from one character to the left of the fixated character and its three successive characters to the right of it.

In Experiment 1, characters outside the window of visible text were masked with pseudo-characters (characters formed from components found in Chinese characters but not a real character in Chinese). (See Figure 1). The average number of strokes contained in each character was slightly higher for pseudo-characters compared to the original characters (i.e. the characters presented in the normal condition, $M = 8.3$ for original, $M = 9.8$ for masking pseudo-characters, $p < .01$). The pseudo-characters were created with the character editor on a Window system laptop. A norming task with 10 young and 10 older adults (none of whom participated in the main experiment), where participants were asked to indicate whether the presented character was a real character or not, confirmed that participants were able to successfully identify these characters as pseudo-characters ($M = 95\%$).

In Experiment 2, characters outside the window of visible text were masked with visually-similar characters (See Figure 1). Visual similarity was achieved by matching shapes and structures between original characters and their corresponding masking characters. As shown in Figure 1, original characters were substituted by masking characters with the same layouts (i.e., horizontal, vertical, or surround). Characters were matched in number of strokes (*M* = 8.3 for original, *M* = 8.3 for masking similar characters) and character frequency (*M* = 665 per million for original, and *M* = 664 per million for masking). The frequency analysis is based on the Modern Chinese corpus: http://www.cncorpus.org/. Visual complexity (i.e. number of strokes) and frequency were controlled both within and outside the visible window of text. None of the masking characters provided a meaningful continuation of the text beyond the experimentally defined window.

Apparatus and Procedure. Sentences were displayed as black text on a white background in Song font on a 24-inch high-definition BenQ monitor (1920 x 1080 resolution, 144Hz refresh rate). The time taken for the display change to complete was ~9ms. The viewing distance used in the experiment was 75cm. Eye movements were recorded using an EyeLink 1000 plus eye-tracker (SR Research), using the tower mount, with a spatial resolution of .01° and the position of each participant's right eye sampled at 1000Hz. A chin and forehead rest were used to minimize head movements. Although viewing was binocular, only right eye movements were recorded.

At the start of the experiment, participants were instructed to read normally and for comprehension. The eye-tracker was calibrated for each participant using a 3-point horizontal calibration to ensure spatial accuracy < .40°. At the start of each trial, a fixation cross was presented to the left of the screen. To avoid having to vary the level of fixation accuracy required to trigger the sentence, the cross was the same size in all conditions (equal in size to one medium font character). Once the participant fixated this location, a sentence was presented, with the first character replacing the cross. Participants pressed a response key once they finished reading each sentence. On one-third of trials, the sentence was then replaced by a yes/no comprehension question, to which participants responded by pressing a response key. Calibration was checked between trials and the eye-tracker was recalibrated as necessary.

Data analysis. Comprehension accuracy was high for all participants (Experiment 1: young adults, *M* = 90.3%; older adults, *M* = 92.8%; Experiment 2: young adults, *M* = 95.2%; older adults, *M* = 96.5%, min: 81%) and did not differ across age groups (*ps* > .05), indicating that both groups could comprehend the sentences well. Mean comprehension accuracy was above 90% in all conditions and did not differ across font size or viewing condition (*ps* > .05). Following standard procedures, fixations shorter than 80ms or longer than 1200ms were removed (affecting 5.0% of fixations for Experiment 1 and 4.6% in Experiment 2), and trials were removed if they were terminated prematurely, if track loss occurred or if very few fixations were made (< 5 fixations, affecting < 1% trials in each experiment).

Data were analyzed with Linear Mixed-Effects Models (LMMs, Baayen, Davidson, & Bates, 2008) using R (R Development Core Team, 2016) and the lme4 package (Bates, Maechler, & Bolker, 2014). Following current practice, a maximal random effects model was used where possible (Barr, Levy, Scheepers, & Tily, 2013). If the maximal model did not converge, the model was trimmed by first trimming the random structure for items, starting with removal of the random effect correlations, then the random slopes. Participants and items were specified as crossed random effects. Contrasts to examine effects of age-group (young vs. older), viewing condition (unmasked vs. masked), and font size (large vs. medium, and medium vs. small) were defined using sliding contrasts in the MASS package (Venables & Ripley, 2002; sliding contrasts were employed both for main effects and to examine interactions).

Further contrasts comparing the large font size versus the small font size were also conducted; however, the pattern of results was very similar for the medium versus small contrast, and so, for brevity, these are reported in the Supplemental files. Following reviewer suggestion, additional models were also constructed with (centered) acuity and digit span scores included as continuous variables and model comparison was used to determine whether these variables should be included in the reported models. For both Experiments 1 and 2, including acuity did not improve model fit for any measure (in all cases p >.18). In both experiments, a larger digit span was associated with shorter fixation durations (Experiment 1: b = -3.28, SE = 1.28, t = -2.57, Experiment 2: b = -3.54, SE = 1.35, t = -2.62. However, digit span did not interact with age, font or viewing condition. Where adding digit span improved model fit, the pattern of effects was the same as for the base models in which digit span was not included. For simplicity, these variables are not discussed further and the remaining results report models without acuity or digit span.[i]

Sentences reading time is the main measure of interest[2]. In addition, to provide greater insight into the time course of these effects, several additional sentence-level measures were examined: average fixation duration (the mean duration of all fixations); progressive saccade length (the amplitude (in characters) of forward-moving saccades); number of regressions (number of backwards movements in the text); first-pass reading time (the sum of fixations that occurred the first time a word was encountered) and re-reading time (the sum of fixations on words after first-pass). As the pattern of results was consistent across measures, for simplicity, sentences reading time, average fixation and progressive saccade length are reported in the main text, while number of regressions, first-pass reading time and re-reading time are reported in Supplemental files. Analyses for both untransformed and log-transformed data produced the same patterns of results, and so only results for untransformed data are reported. Following convention, t > 1.96 were considered significant.

Experiment 1

In the current experiment, we first aimed to verify the effect of font size of the processing of parafoveal information found for young adults in Yan's study, and further explore whether there are age differences in this effect.

Results. Means and standard errors for eye movement measures are shown in Table 2. The results of LMM analyses are summarized in Table 3. Follow-up contrasts are summarized in the text and statistical values are included in the Supplemental files. Plots showing sentences reading time are shown in Figure 2. Compared with young adults, older adults read more slowly and made longer fixation durations. These findings suggest that the older adults experienced greater reading difficulty and resonate with previous findings on adult age differences in eye movements when reading Chinese or alphabetic languages (e.g., Li et al., 2018; Wang et al., 2018a, b; Warrington et al., 2018, 2019; Xie et al., 2019). Also consistent with previous findings for Chinese language reading, the older adults made shorter progressive saccades compared with the young adults (e.g., Li et al, 2018; Wang et al, 2018a, b; Xie et al, 2019), indicating that the older readers moved their eyes more cautiously.

Insert Table 2 and 3 and Figure 2

Further, the effect of viewing condition replicated previous findings (Yan et al., 2015). When rightward vision was limited to three characters, readers exhibited longer reading times, longer average fixation durations, and shorter progressive saccades. Thus, reading was disrupted when text to the right of the fixated word was limited to three characters and suggests that readers acquire parafoveal information at least four characters to the right of fixation.

These effects of viewing condition further interacted with age. Follow-up contrasts showed significant effects of viewing condition for both age groups, with longer reading times and longer fixation durations for the masked condition compared with unmasked condition, *ts* > 1.96. However, these effects of viewing condition were larger for the young adults (sentences reading time: young adults = 558-ms effect, older adults = 387-ms effect; average fixation duration: young adults = 17-ms effect, older adults = 11-ms effect) compared with the older adults. In addition, there was a significant difference in progressive saccade length between unmasked and masked viewing condition for younger, but not for older adults. These results provide evidence to suggest that both young and older adults can process parafoveal information at least four characters to the right of fixation when characters are masked by pseudo-characters. However, as these effects are larger for young adults, there may be age-group differences in the size of the perceptual span, or in the depth of parafoveal processing undertaken across the span. Further research is needed to establish this.

Moreover, main effects of font size were also significant. Increasing character size significantly decreased reading times, average fixation durations and the length of progressive saccades. Font size effects were qualified by interactions with age-group in all measures. Follow-up contrasts for average fixation duration showed significant effects of font size for both age groups, with longer fixation durations for smaller font size compared with larger, *ts* > 1.96. These effects were larger for older, compared to young adults (large vs. medium: young adults = 11-ms effect, older adults = 18-ms effect; medium vs. small: young adults = 10-ms effect, older adults = 23-ms effect). For the sentences reading time, further contrasts revealed that reading times for smaller font characters were significantly longer than for larger font characters for older, but not young adults (large vs. medium: young adults = 24-ms effect, older adults = 126-ms effect; medium vs. small: young adults = 21-ms effect, older adults = 199-ms effect). Similarly, for the progressive saccade length, there was significant difference in large and medium font size for older, but not young adults. Overall, young adults’ reading behaviour was quite consistent across different font sizes. However, for older adults, reading times decreased as font size increased. This indicates that older adults may experience difficulty processing small characters. This likely reflects age-related changes in vision and attentional mechanisms.

Surprisingly, there were no significant two-way interactions between font size and viewing condition in any of the measures examined, suggesting that the effect of font size is similar across different viewing conditions. Crucially, the absence of an interaction between viewing condition and font size is in direct contrast to the findings of Yan et al. (2015) and suggest that perhaps in Chinese, like in alphabetic languages, the perceptual span is independent of character size. Further, a three-way interaction was only found in average fixation duration. However, follow-up contrasts revealed a similar pattern of disruption for each age group. Overall, the results of the LMM analyses suggests that character size does not influence the acquirement of parafoveal information during the reading of Chinese for either older adults, or young adults.

In addition to the LMM analysis, Bayes factors (Kass & Raftery, 1995) were calculated for each measure to confirm the null two-way interaction between viewing condition and font size and the three-way interaction between age, viewing condition, and font size. These were computed using the lmBF function within the BayesFactor package (Morey & Rouder, 2015) in R (R Core Team, 2015), with the scaling factor for g-priors set to 0.5, and using 100,000 Monte Carlo iterations. Participants and items were specified as random factors. Following Vandekerckhove, Matzke, and Wagenmakers (2015), Bayes factors (BFs) > 3 were taken to provide weak to moderate support for a model, and BFs > 10 to provide strong support, while BFs < 1 were taken to provide evidence against a model and in favor of the base model. Based on the LMM analysis, we constructed a denominator model (base model to which other models were compared) for each measure. The Bayes factor analysis favored the denominator model over either a model containing a two-way interaction between viewing condition and font size (sentences reading time, BF = 0.004, average fixation duration, BF = 0.004, progressive saccade length, BF = 0.011) or a model containing a three-way interaction (sentences reading time, BF = 0.005; progressive saccade length, BF = 0.011), suggesting that the perceptual span is independent of the font size for both age groups. In addition, in line with the LMM analysis, Bayesian analysis for average fixation duration provided moderate support for a model including a three-way interaction (BF = 6.980). To sum, the Bayes Factor analysis confirmed the LMM analysis findings and provided evidence for the absence of a font size effect on the acquirement of parafoveal information.

Discussion. In the current study, we aimed to replicate the effect of font size on the acquirement of parafoveal information in Chinese reading reported by Yan et al. (2015). More importantly, we aimed to explore whether there are age differences in this effect. However, in Experiment 1, we failed to obtain evidence for a notion that the perceptual span depends on font size during Chinese reading for either age group, as most interactions between age, viewing condition and font size were far from significance. Overall, the findings in Experiment 1 give little evidence to show that character size has an effect on the acquirement of parafoveal information during Chinese reading. Therefore, this would suggest that older Chinese readers can successfully process parafoveal information across range of font sizes and that older adults' parafoveal processing may be more robust than previously assumed. If this is the case, age-related limitations in parafoveal acuity may not limit parafoveal processing in older age.

However, it is worthy to note that we adopted different mask stimuli from the ones used in Yan et al.'s (2015) study. In Experiment 1, each character outside the window of legible text was masked by a pseudo-character. These characters were generally more complex than the characters within the window, creating a difference in the average stroke-complexity within and outside of the defined window. This transition in complexity could have affected oculomotor activity even if it occurred to the right of the effective range of vision (Inhoff & Liu, 1998). Moreover, previous moving-window studies demonstrate that the size of the perceptual span of young adults is dynamically influenced by the type of masking stimuli (Yan, Zhang, Zhang, & Bai, 2013, note that this study is published in the Chinese language). This may be because visually-similar masks effectively provide useful parafoveal orthographic information, which is known to facilitate the subsequent foveal processing (Yan et al., 2015). The information provided by the pseudo-characters is not real information. Moreover, as the pseudo-character was unrelated to the masking character, it could not provide any useful orthographic information for pre-processing (e.g, see parafoveal-on-foveal effect, Drieghe, 2011) which may increase processing difficulty, and prove distracting. Considerable evidence suggests that older adults are typically more susceptible to external distraction than young adults (e.g., Kemper & McDowd, 2006; Mund, Bell, & Buchner, 2010; Meijer, de Groot, Van Boxtel, Van Gerven, & Jolles, 2006). Certain types of text replacement, such as pseudo-characters, may interfere with normal reading and the font size effects on the perceptual span, moreover, this interference may be more marked for older than young adult readers. Therefore, in order to provide a direct replication of Yan et al.'s (2015) study, and to further explore whether there is an effect of font size on the perceptual span for both older and young adults, Experiment 2 employs a visually-similar character-replacement.

Experiment 2

The results of Experiment 1 provided a suggestion that there is no effect of font size on parafoveal processing for either older adults, or young adults. As these results are in contrast to previous findings, we aimed to examine this issue further. Therefore, Experiment 2 examined whether the perceptual span depends on font size, and whether the nature and size of these effects differs across age groups, when characters are replaced by visually-similar characters. The design of this experiment is identical to that employed by Yan et al, with the addition of the older adult group.

Results. Means and standard errors are shown in Table 2. The results of LMM analyses are summarized in Table 4. Follow-up contrasts are summarized in the text and statistical values are included in the supplemental files. Plots showing sentences reading time are shown in Figure 3. In line with Experiment 1, main effects of age-group were obtained in all measures. This again suggests that older adults experienced greater reading difficulty than young adults. There were also significant main effects of viewing condition. In comparison to the unmasked condition, the masked viewing condition produced longer reading times, longer fixation durations and shorter progressive saccades.

Insert Table 4 and Figure 3

Main effects of viewing condition further interacted with age-group. Follow-up contrasts revealed significant effects of viewing condition for both age groups, *ts* > 1.96. However, these effects of viewing condition were larger for the young adults (sentence reading time: young adults = 972-ms effect, older adults = 447-ms effect; average fixation duration: young adults = 25-ms effect, older adults = 12-ms effect), compared with their older counterparts. As in Experiment 1, there was significant difference in progressive saccade length between unmasked and masked viewing condition for younger, but not for older adults. In line with Experiment 1, results indicate that both age groups utilize parafoveal information to the right of fixation, however there may be age differences in the processing of parafoveal information which require further investigation.

The effect of font size on eye movements nicely replicate Experiment 1. Increasing font size significantly decreased fixation durations and progressive saccade length. Moreover, smaller font size characters produced longer reading times. The main effects of font size were qualified by interactions with age-group. Follow- up contrasts revealed, in line with

Experiment 1, that older adults experienced exhibited longer reading times when the font was smaller, while young adults reading times were consistent across font sizes.

Crucially, in line with Experiment 1, but in contrast to the finding of Yan et al. (2015) there were no interactions between viewing condition and font size, and no three-way interactions, $t_s < 1.96$. As in Experiment 1, the Bayes Factors analysis were also calculated to confirm the null two-way interaction between viewing condition and font size and null three-way interaction. The denominator models were again constructed based on the LMM analysis for all the measures. These analyses favored a model with no three-way interaction (sentences reading time: BF = 0.015, average fixation duration: BF = 0.007, progressive saccade length, BF = 0.021), and no two-way interaction between viewing condition and font size (sentences reading time: BF = 0.009, average fixation duration: BF = 0.004, progressive saccade length: BF = 0.018). Again, the Bayes Factor analysis supports the LMM analysis and suggests an absence of a font size effect on the acquirement of parafoveal information for both age groups.

Discussion. Experiment 2 further investigated aging and the font size effect on parafoveal processing by masking characters outside the window of normal text with visually-similar characters. Crucially, in line with the findings of Experiment 1, there were no two-way interactions between viewing condition and font size and no three-way interaction between age, viewing condition and font size. Thus, the size of the perceptual span during the reading of Chinese appears to remain largely stable across font size. The current results are not consistent with Yan et al.'s (2015) study for young adults. Possible reasons for this are considered in the General Discussion. These results demonstrate that older Chinese readers can successfully process parafoveal information across range of font sizes. Furthermore, this work extends previous findings to suggest that the font size has no effect on the acquirement of parafoveal information for both young and older adult readers during Chinese reading.

General Discussion

The present study explored effects of font size on the perceptual span for older and young adults during Chinese reading to test whether older adults' parafoveal processing is more limited for larger font characters. We anticipated that older readers of Chinese may experience particular difficulty processing large characters and that this may represent an important source of age-related reading difficulty in logographic languages. To investigate this, we manipulated the font size and the amount of parafoveal information available with different masking stimuli in two experiments. These experiments yielded several key findings: (1) Compared with young adults, older adults experience reading difficulty during Chinese reading; (2) Both young and older adults read more slowly when parafoveal information is limited to one character to the left of fixation and three characters to the right of fixation; (3) Older adults experience greater reading difficulty when text is small, while reading times are quite consistent across font sizes for young adults; (4) Both experiments demonstrated that the effect of parafoveal masking is similar across font sizes for both older and young adults, providing evidence that perceptual span size in Chinese is independent of font size and that older adults can successfully process a similar amount of parafoveal information across a range of font sizes. Each of these findings is discussed in turn.

In these experiments older adults read more slowly, made longer fixations, and shorter progressive saccades compared with young adults. This replicates age-related differences in eye movement behavior reported in earlier studies and contributes to the growing body of evidence demonstrating that older readers of Chinese experience greater reading difficulty than their younger counterparts (e. g., Li et al., 2018; Wang et al., 2018a, b; Xie et al., 2019).

The results also suggest that when parafoveal information is masked by either pseudo-characters or visually-similar characters, both young and older adults make substantial use of parafoveal information to inform their reading. As we did not directly investigate perceptual span size, we cannot make strong claims about the exact size of the span. However, it appears to subtend at least four characters to the right for both older and young adults based on the present findings. However, the results also suggest there may be age-group differences in the extent of the perceptual span, or in the depth of processing undertaken across the span. Findings from alphabetic languages have produced inconsistent results with respect to age differences in parafoveal processing. It will be important for future research to establish whether there are cross-linguistic differences in such effects as this will inform our understanding of the generalizability of principles about how cognitive aging affects language processing. Further, research using a range of mask sizes and types is needed to establish whether there are truly differences in the perceptual span or whether this reflects some other age differences such as sensitivity to visual information outside the masked area which does not affect the perceptual span (see, e.g., Jordan, Kurtev, McGowan, & Paterson, 2016).

Both Experiments also show effects of font size on eye movement behavior. Notably for young adults, reading times were invariant across font size, while older adults had shorter reading times when reading larger font size characters compared with smaller characters. These results therefore provide an indication that effects of font size vary across the adult lifespan in Chinese reading, as in English (Akutsu et al., 1991). This is an important consideration for future research, as researchers should ensure that they use a font size sufficiently large for older adults to achieve their full reading performance. These results likely reflect the visual and attentional changes that occur in older age. Decreased sensitivity to fine visual detail (Crassini et al.,1988), may make the encoding of small characters less efficient, and changes in information processing and visual attention (Madden, 2007) may increase the time taken to process the large amount of information that is available in foveal vision.

Despite older adults’ shorter reading times when the font is larger, we anticipated that as a result of age-related declines in parafoveal visual vision and increased sensitivity to visual crowding (e.g. Crassini et al, 1988; Elliott et al.,1990), older adults would show reduced effects of parafoveal masking as font size increased, indicating a smaller perceptual span for large font characters. However, the absence of three-way interactions between age-group, viewing condition, and font size, indicates that, contrary to expectation, older adults do not have a larger font size effect on the perceptual span compared with young adults. This finding provides an important indication that in spite of age-related visual difficulty, older readers do not have greater difficulty processing parafoveal information when text is presented in large fonts, despite these large characters appearing at greater eccentricity than smaller characters. It has typically been assumed (e.g., Ball, Beard, Roenker, Miller, & Griggs, 1988; Sekuler, Bennett, & Mamelak, 2000) that older adults’ poorer acuity in the parafovea may limit their ability to process information parafoveally and that this may slow reading. These results dispute this assertion, as older adults are able to successfully parafoveally process eccentric large font characters. It has previously been argued that older adults of alphabetic languages may dynamically modulate the deployment of their attention to compensate for age-related limitations of visual acuity (Risse & Kliegl, 2011), in order to prioritize parafoveal processing (while making longer individual fixations). Such a strategy may allow older adults to maintain parafoveal processing across font sizes and this may represent a general strategy that is employed by older readers from a range of languages. However, to more fully understand the universality of the role of acuity on parafoveal processing in older age, these effects should also be investigated in alphabetic languages.

While we do not find evidence of an age difference in font size effects on parafoveal processing, one clear difficulty in the interpretation of these results for older adults is that while we did not find a three-way interaction, we also found no two-way interactions between viewing condition and font size. Taken together, these results suggest that the perceptual span in Chinese reading does not depend on font size, and therefore, visual acuity, for either young or older adults. These results could indicate that, like alphabetic language reading, a trade-off between the increase of character visibility with large font size and the decrease of visual acuity with the large text becoming more eccentric results in a similar span size across different font sizes (e.g. Miellet et al., 2009).

This suggests that in Chinese, as in English, the key factor limiting the perceptual span is attentional rather than visual constraints, with the physical size of the span adapting to the amount of information to be processed (as evidenced by the smaller span for Chinese compared with English). However, to fully establish this, further experiments may seek to modulate foveal processing demands (foveal load) during Chinese reading. Such experiments may be particularly illuminating as older readers of English show greater sensitivity to foveal load (e.g. Payne and Stine-Morrow, 2012). Therefore, it would be valuable to establish whether any age differences in parafoveal processing may be attention, rather than acuity based.

Yan et al reported that their results reflect the lack of spaces and greater complexity of written Chinese making characters in eccentric positions (such as large font characters) particularly hard to process. It has been suggested that Chinese readers may develop higher parafoveal processing efficiency compared with alphabetic language readers, because of the absence of spaces (Zhou, Kliegl, Yan, 2013). Thus, the lack of word boundaries in written Chinese is not a major obstacle to parafoveal processing as evidence suggests that the size of the perceptual span varies as a function of reading efficiency (Rayner et al., 2010), and so this increased efficiency may allow both young and older skilled readers to successfully move their eyes across a range of font sizes even in the absence of spaces.

However, it is unclear why Yan found this effect, yet we failed to. Further work is needed to establish this; however we consider a few possibilities. Notably, the average reading speed in Yan et al., (2015) was considerably slower than the speeds in the current experiments. A recent meta-analysis (Brysbaert, 2019) estimates average word-per-minute (wpm) reading rates for Chinese at 260wpm. Based on the information provided in Yan's paper, we estimate the wpm reading rate in the unmasked condition as around 170 (across font sizes). Whereas, when we convert our reading times to reading rates, we find rates more in line with the estimates given by Brysbaert (Exp1: 272wpm; Exp2: 251wpm). Readers allocate more processing resources to the foveally fixated word and engage less in parafoveal processing of upcoming text when they have greater difficulty processing words (e.g., Häikiö, Bertram, Hyönä, & Niemi, 2009; Rayner, 1986; Sperlich et al., 2016; Chace, Rayner, & Well, 2005; Rayner et al., 2010; Veldre & Andrews, 2014). Note, that while older adults are also slower readers, they are generally considered to be skilled readers who read with normal comprehension, but at a slower rate than their younger peers (Rayner et al., 2010) due to age-related decline, rather than lower skill. This may indicate that the readers in Yan et al's (2015) study were less efficient processers and so may have experienced greater difficulty guiding their eyes across a range of font sizes in the absence of word spacing. However, additional analyses considering fast and slow readers in the current experiments separately (based on sentence reading times) found no evidence of a font size effect on parafoveal processing for slower readers, despite our slow readers showing similar reading speeds to the participants in Yan et al. (2015). As these analyses involved splitting the dataset, we cannot rule out that this effect may be present with greater statistical power, but we did not observe any trends within our dataset. These analyses are reported in full in the Supplemental files.

An alternative interpretation is that because the perceptual span is larger than the masked viewing condition substantial disruption is found in all conditions. As readers could preview more than three characters even when reading largest font size text, a larger viewing condition may reveal more subtle font size effects obscured in this study. Overall, while we cannot exclude the possibility that more subtle font size effects may exist when using different masking stimuli or different mask sizes, at least when using masks that provide orthographic information, with a mask size that roughly matches the typical perceptual span size reported for Chinese, these effects do not appear to be present. Therefore, even if more subtle effects do exist, the clear finding is that an inability to process parafoveal information across a range of font sizes is unlikely to be a major contributory factor to adult age differences in Chinese reading. This finding has important implications for understanding the nature of adult age differences in reading across different writing systems.

In summary, while previous research has focused almost exclusively on alphabetic languages, the present study provides novel insight into parafoveal processing across adulthood during Chinese reading. The overall pattern of results suggests that during normal reading, as in English, the perceptual span is independent of font size for both young and older adults. Crucially, in spite of age-related visual decline, older adults’ parafoveal processing appears unaffected by font size. Therefore, the current experiments have furthered our knowledge of effects of normative aging on Chinese reading and indicate that older adults’ parafoveal processing may be more robust than previously considered.

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Footnotes

[1] Note, we do not make any claims about the role of acuity or digit span in the perceptual span, as it may be that the measures of acuity and digit span employed here lack the sensitivity to detect such effects in reading.

[2] Reading rate (average number of characters read per minute) is often the key measure of interest in gaze-contingent moving-window experiments and we originally intended to report this measure. However, there is evidence that calculating reading rates per-unit time can result in inflation of reading rates for short sentences and reading times (Trueswell, Tanenhaus, & Garnsey, 1994). As this inflation may differentially affect reading rates for young and older adults, raw sentence reading times were deemed to provide a more accurate reflection of the data. Reading rate analyses did, however, show the same pattern of effects reported here.

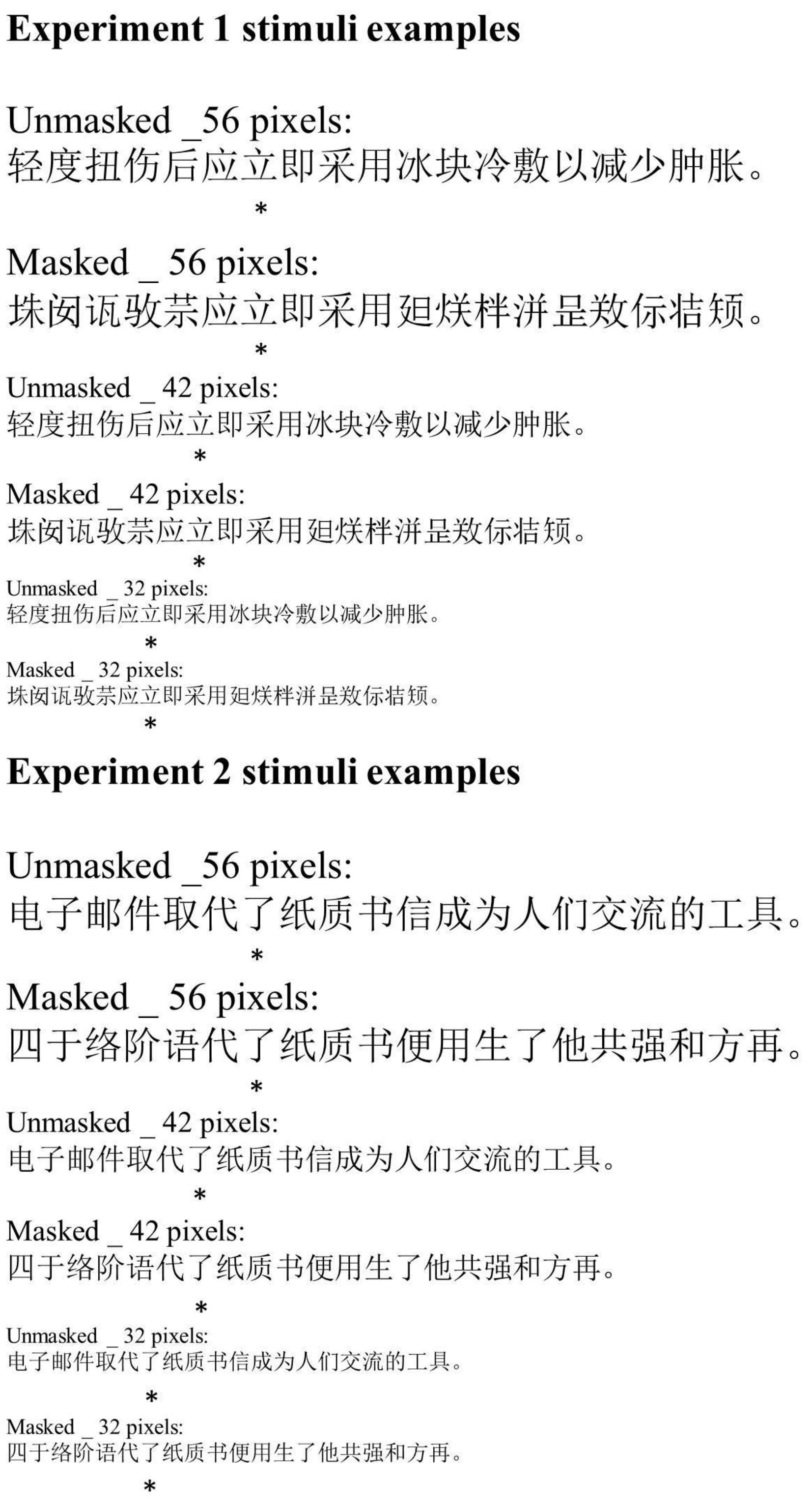
Figure legend

Figure 1. An example sentence in each condition for each experiment. The asterisk indicates the fixation location during reading.

Figure 2. Experiment 1. Sentences reading time in each condition both age groups. Error bars correspond to one standard error.

Figure 3. Experiment 2. Sentences reading time in each condition both age groups. Error bars correspond to one standard error.

Figure 1



Experiment 1 stimuli examples

Unmasked _56 pixels:
轻度扭伤后应立即采用冰块冷敷以减少肿胀。
*

Masked _ 56 pixels:
株闵讯驶荥应立即采用廻烪柈洴昰敥伝牿颏。
*

Unmasked _ 42 pixels:
轻度扭伤后应立即采用冰块冷敷以减少肿胀。
*

Masked _ 42 pixels:
株闵讯驶荥应立即采用廻烪柈洴昰敥伝牿颏。
*

Unmasked _ 32 pixels:
轻度扭伤后应立即采用冰块冷敷以减少肿胀。
*

Masked _ 32 pixels:
株闵讯驶荥应立即采用廻烪柈洴昰敥伝牿颏。
*

Experiment 2 stimuli examples

Unmasked _56 pixels:
电子邮件取代了纸质书信成为人们交流的工具。
*

Masked _ 56 pixels:
四于络阶语代了纸质书便用生了他共强和方再。
*

Unmasked _ 42 pixels:
电子邮件取代了纸质书信成为人们交流的工具。
*

Masked _ 42 pixels:
四于络阶语代了纸质书便用生了他共强和方再。
*

Unmasked _ 32 pixels:
电子邮件取代了纸质书信成为人们交流的工具。
*

Masked _ 32 pixels:
四于络阶语代了纸质书便用生了他共强和方再。
*

Figure 2

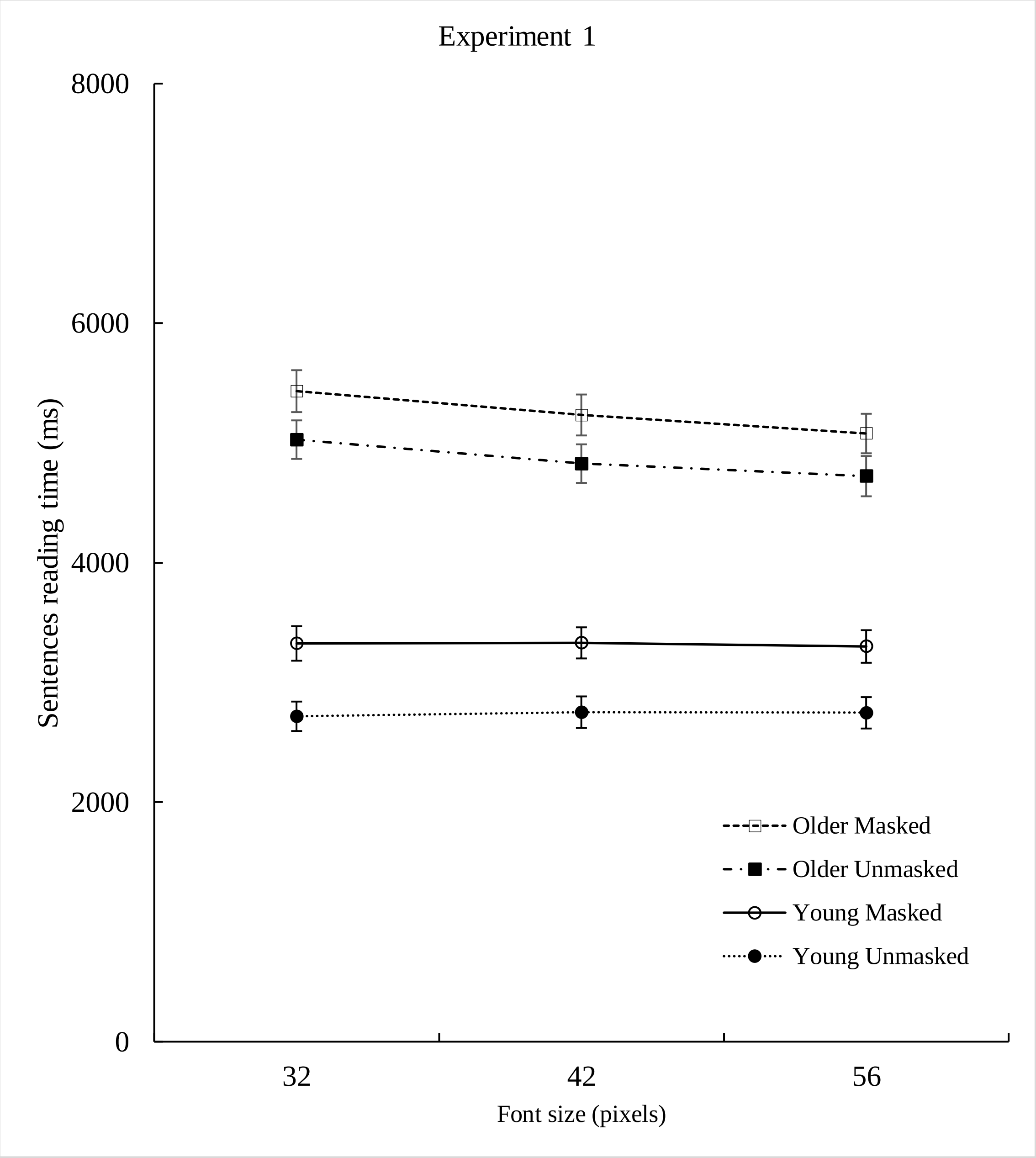

Experiment 1
8000
6000
4000
2000
0
Sentences reading time (ms)
32
42
56
Font size (pixels)
Older Masked
Older Unmasked
Young Masked
Young Unmasked

Figure 3

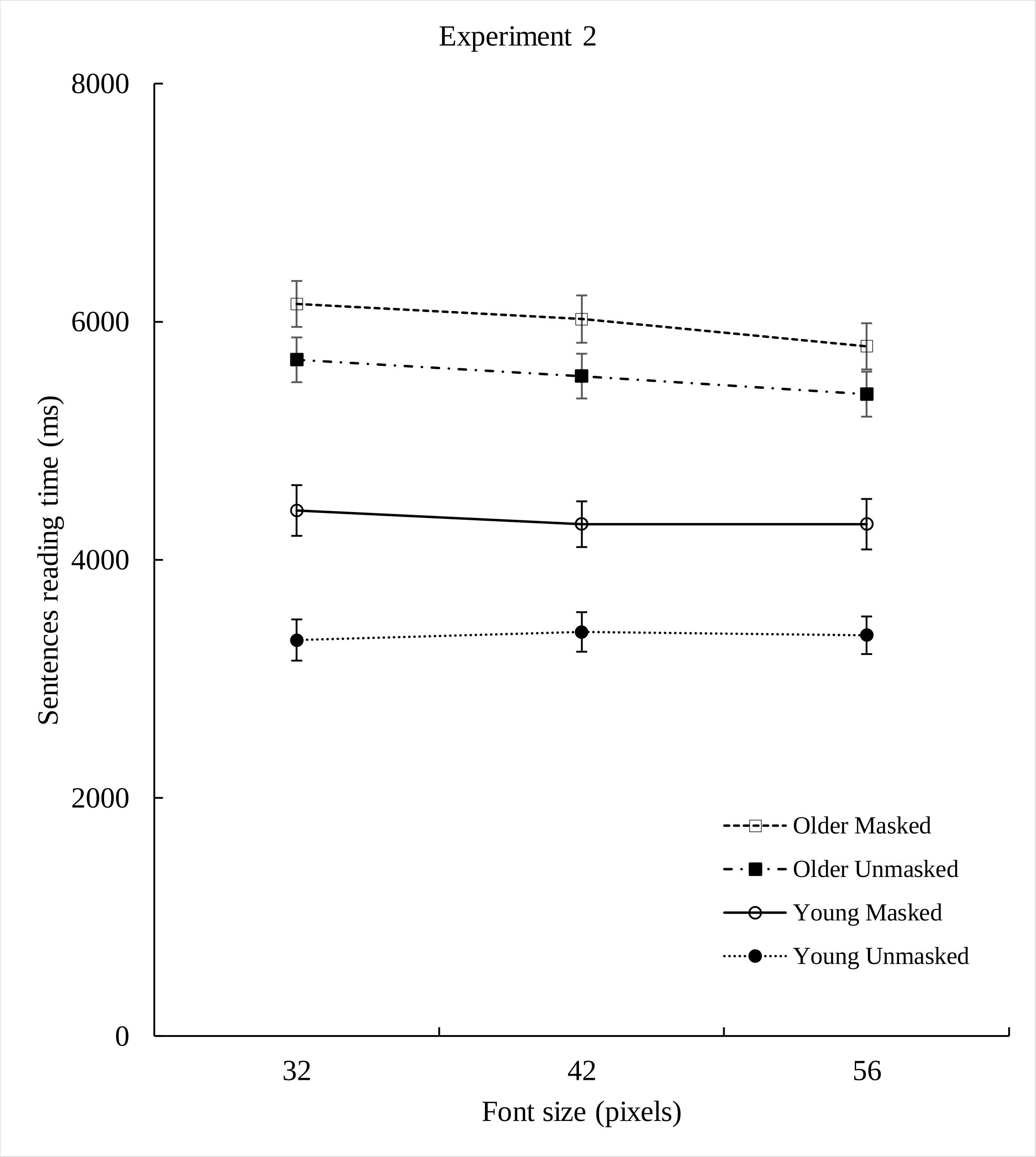

Experiment 2
Sentences reading time (ms)
8000
6000
4000
2000
0
32
42
56
Font size (pixels)
Older Masked
Older Unmasked
Young Masked
Young Unmasked

Table 1. Participant Characteristics.

Age Group	Age (Years)	Visual Acuity (Snellen Values)	Formal Education (Years)	Vocabulary		Digit Span (Raw scores)	
				Raw Scores	Scaled Scores	Forward	Backward
Young	19.4 (1.1)	20/24	13.7 (.97)	69.1 (5.9)	15.6 (1.8)	9.1 (.9)	6.0 (1.7)
	Range = 18-22	Range = 20/16-20/33	Range = 13-16	Range = 57-79	Range = 13-19	Range = 7-11	Range = 2-8
Older	66.9 (3.7)	20/32	12.9 (1.36)	72.0 (3.9)	15.6 (0.9)	7.7 (1.0)	4.7 (.9)
	Range = 61-76	Range = 20/19-20/40	Range = 9-16	Range = 64-78	Range = 14-17	Range = 5-10	Range = 3-7
				$t(94) = 2.83$,	$t(94) = .07$,	$t(94) = 6.90$,	$t(94) = 4.54$,
				$p = .006$	$p = .942$	$p < .001$	$p < .001$

Note. Only raw scores are presented for digit span because scaled scores can only be calculated from the combined measures. Scaled scores for the combined digit span produce the same pattern as the raw scores, Young, $M = 13.8$ $SD = 2.5$, Range = 7-19; Older, $M = 12.5$, $SD = 1.6$, Range = 8-16, $t(94)=3.16$, $p=.002$.

Table 2 Means and SDs and SEs for Eye Movements Measures in Experiment 1 and 2

	Young						Older						**AE**	**VE**	**FE**	
	Unmasked			Masked			Unmasked			Masked						
	56	42	32	56	42	32	56	42	32	56	42	32	Young **vs.** Older	Unmasked **vs.** Masked	42 **vs.** 56	32 **vs.** 42
Experiment 1																
Sentences reading time (ms)	2746 (131)	2751 (132)	2717 (123)	3300 (136)	3330 (130)	3325 (144)	4722 (168)	4827 (161)	5027 (161)	5078 (165)	5233 (171)	5432 (175)	-2011	-464	78	90
Average fixation duration (ms)	234 (4)	246 (4)	255 (5)	253 (4)	262 (4)	272 (4)	249 (3)	265 (3)	288 (4)	258 (3)	277 (4)	301 (4)	-19	-14	14	16
Progressive saccade length (characters)	2.1 (.06)	2.1 (.06)	2.5 (.08)	1.9 (.05)	1.9 (.04)	2.3 (.06)	1.6 (.04)	1.8 (.05)	2.1 (.06)	1.6 (.04)	1.8 (.04)	2.1 (.05)	0.3	0.2	0.1	0.3
Experiment 2																
Sentences reading time (ms)	3366 (158)	3394 (166)	3326 (173)	4299 (212)	4299 (192)	4414 (213)	5391 (189)	5543 (188)	5680 (188)	5793 (194)	6022 (199)	6149 (193)	-1911	-709	98	89

Average fixation duration (ms)	233 (3)	246 (4)	257 (4)	258 (4)	270 (4)	282 (4)	250 (3)	268 (3)	291 (4)	261 (3)	279 (3)	303 (4)	-17	-19	16	17
Progressive saccade length (characters)	2.0 (.05)	2.0 (.05)	2.4 (.07)	1.8 (.04)	1.8 (.04)	2.1 (.06)	1.6 (.04)	1.8 (.05)	2.1 (.06)	1.6 (.04)	1.7 (.05)	2.0 (.05)	0.2	0.2	0.1	0.4

Note. AE = age group effect; VE = viewing condition effect; FE = font size effect. Standard errors are shown in parentheses. SEs were calculated across participant variance.

Table 3 Linear Mixed Model Statistics for Eye Movements Measures in Experiment 1

		Sentences reading time (ms)	Average fixation duration (ms)	Progressive saccade length（characters）
Intercept	*b*	4039.67	263.26	1.99
	SE	114.15	2.81	0.04
	t	35.39	93.76	44.69
Age group	*b*	-2026.76	-19.35	0.31
Young vs. Older	*SE*	199.46	5.49	0.09
	t	-10.16*	-3.52*	3.63*
Viewing condition	*b*	487.02	14.28	-0.14
Masked vs. Unmasked	*SE*	41.89	1.27	0.02
	t	11.63*	11.25*	-7.37*
Font size	*b*	72.31	14.09	0.08
56 vs. 42	*SE*	25.68	0.71	0.01
	t	2.82*	19.93*	7.94*
42 vs. 32	*b*	88.40	16.42	0.36
	SE	25.68	0.71	0.01
	t	3.44*	23.22*	35.83*
Age group * Viewing condition	*b*	197.74	5.81	-0.23
	SE	83.79	2.45	0.04
	t	2.36*	2.38*	-6.36*
*Age group * Font size*	*b*	-116.32	-7.23	-0.12
Age group *56 vs. 42	*SE*	51.36	1.41	0.02
	t	-2.27*	-5.11*	-5.93*
Age group * 42 vs. 32	*b*	-219.17	-13.17	-0.00
	SE	51.37	1.41	0.02
	t	-4.27*	-9.31*	-0.17
*Viewing condition * Font size*	*b*	39.57	0.77	0.00
Viewing condition * 56 vs. 42	*SE*	51.36	1.41	0.02
	t	0.77	0.55	0.21
*Viewing condition * Font size*	*b*	13.20	0.65	-0.04

Viewing condition * 42 vs. 32	*SE*	51.37	1.41	0.02
	t	0.26	0.46	-1.76
*Age group * Viewing condition *Font size*	*b*	-12.80	-7.08	-0.01
Age * Viewing condition * 56 vs. 42	*SE*	102.73	2.83	0.04
	t	-0.13	-2.50*	-0.23
Age * Viewing condition * 42 vs. 32	*b*	18.52	1.66	0.05
	SE	102.74	2.83	0.04
	t	0.18	0.59	1.14

Note. Significant fixed factor effects are indicated with an asterisk.

Table 4 Linear Mixed Model Statistics for Eye Movements Measures in Experiment 2

		Sentences reading time (ms)	Average fixation duration (ms)	Progressive saccade length（characters）
Intercept	*b*	4805.97	266.54	1.91
	SE	138.03	2.94	0.04
	t	34.82	90.54	44.68
Age group	*b*	-1914.48	-17.52	0.20
Young vs. Older	*SE*	244.72	5.81	0.08
	t	-7.82*	-3.02*	2.35*
Viewing condition	*b*	713.58	18.36	-0.13
Masked vs. Unmasked	*SE*	62.40	1.41	0.02
	t	11.44*	13.01*	-6.29*
Font size	*b*	103.45	15.66	0.09
56 vs. 42	*SE*	34.23	0.69	0.01
	t	3.02*	22.56*	8.00*
42 vs. 32	*b*	76.88	17.16	0.34
	SE	34.25	0.69	0.01
	t	2.25*	24.72*	30.45*
Age group * Viewing condition	*b*	526.49	13.49	-0.16
	SE	120.21	2.80	0.04
	t	4.38*	4.82*	-3.98*
*Age group * Font size*	*b*	-180.20	-5.66	-0.14
Age group * 56 vs. 42	*SE*	68.46	1.39	0.02
	t	-2.63*	-4.08*	-6.18*
Age group * 42 vs. 32	*b*	-107.77	-12.27	0.02
	SE	68.50	1.39	0.02
	t	-1.57	-8.84*	0.73
*Viewing condition * Font size*	*b*	27.02	-0.54	-0.04
Viewing condition * 56 vs. 42	*SE*	68.46	1.39	0.02
	t	0.40	-0.39	-1.75
	b	81.57	1.40	-0.00

Viewing condition * 42 vs. 32	_SE_	68.50	1.39	0.02
	_t_	1.19	1.01	-0.18
Age * Viewing condition *Font size	_b_	-105.79	-2.24	0.04
Age * Viewing condition * 56 vs. 42	_SE_	136.93	2.78	0.05
	_t_	-0.77	-0.81	0.82
Age * Viewing condition * 42 vs. 32	_b_	207.17	1.06	0.04
	_SE_	137.00	2.78	0.05
	_t_	1.51	0.38	0.94

Note. Significant fixed factor effects are indicated with an asterisk.