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Music Reading Expertise Modulates Visual Spans in both Music Note and English Letter Reading

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Abstract

Here we investigated how music reading experience modulates visual spans in language reading. Participants were asked to identify music notes, English letters, Chinese characters, and novel symbols (Tibetan letters) presented at random locations on the screen while maintaining central fixation. We found that for music note reading, musicians outperformed non-musicians at some peripheral positions in both visual fields, and for English letter reading, musicians outperformed non-musicians at some peripheral positions in the RVF but not in the LVF. In contrast, in both Chinese character and novel symbol reading, musicians and non-musicians did not differ in their performance at peripheral positions. Since both music and English reading involve a left-to-right reading direction and a RVF/LH advantage, these results suggest that the modulation of music reading experience on visual spans in language reading depends on the similarities in the cognitive processes involved.

Keywords: Music reading expertise; visual span; English reading; Chinese reading; symbol reading

Introduction

Recent research has shown that experts have superior perceptual cognitive abilities than novices in meaningful tasks related to their expertise, such as in sports (Mann, Williams, Ward & Janelle, 2007) and in chess playing (Reingold, Charness, Pomplun & Stampe, 2001). From these studies, experts typically demonstrated superior response accuracy (ACC), faster response time (RT), fewer eye fixations of longer duration, or a larger visual span in the tasks. Visual span has been defined as the region around the fixation point within which visual stimuli can be recognized (O'Regan, Lévy-Schoen & Jacobs, 1983). The size of one's visual span can be enlarged through expertise training as in perceptual learning, and this can consequently improve reading/processing speed (Chung, Legge, & Cheung, 2004). For example, chess experts were found to have a larger visual span, fewer fixations, and faster RT in structured chess configuration detection than novices (Reingold et al., 2001), suggesting they are able to extract more information from one fixation in the field of expertise than novices. Similarly, musicians with extensive music reading experiences may have a larger reading span than poor readers of music notation. Indeed, one study found that well-trained musicians had a span of 6.5 notes, whereas the poorest reader only read 3.5 notes at a time (Sloboda, 1974).

Music reading involves mapping a set of spatially distributed notes and chords in a staff to a horizontal melodic line (Stewart, 2005). In the horizontal direction, musicians read further ahead from left to right and focus on areas between notes rather than a single note to ensure in-time playing (Goolsby, 1994). In the vertical direction, musicians read musical markings below staff without making an eye fixation, or attempt to read two staffs at the same time (such as in piano playing). These suggest that musicians may attempt to perceive as much information as possible through both horizontal and vertical peripheral vision (Goolsby, 1994), and consequently develop a larger visual span in both directions in music reading tasks.

Not only does music reading expertise influence visual span in music reading, but it may also modulate visual span in language reading due to similarities in the cognitive processes involved in both tasks. Both music and English are read from left-to-right, and thus music notes and letters are recognized in the right visual field (RVF) more often (Brysbaert & Nazir, 2005; Wong & Hsiao, 2012). This perceptual learning results in processing advantages in the RVF/left hemisphere (LH) (Brysbaert & Nazir, 2005). Indeed, previous studies have shown an RVF/LH advantage in both music note (Segalowitz, Bebout & Lederman, 1979) and English word processing (Brysbaert & d'Ydewalle, 1990). In addition, music notation reading involves note-to-sound mapping, and similarly English word reading involves grapheme–phoneme correspondence (Brown, Martinez & Parsons, 2006; Hsiao & Lam, 2013). Both types of mapping involve decomposing visual stimuli into components for mapping to sound components, and this kind of analytic encoding process is shown to be dominant in the LH (e.g., Bradshaw & Nettleton, 1981; Hébert & Cuddy, 2006; Hsiao & Lam, 2013; Segalowitz et al., 1979). Thus, music notation and English word reading may share similar underlying neural mechanisms. In support of this notion, patients with music reading deficiencies due to brain lesions in the LH also showed word reading difficulties in alphabetic languages such as English (Hébert & Cuddy, 2006). In short, music and English reading may share similar cognitive processes as evidenced by their similar processing advantages in the RVF/LH.

In contrast to left-to-right music and English reading, Chinese can be read in all directions (left to right, right to left, or vertically). Moreover, due to its unique logographic orthography, each Chinese character is regarded as a morpheme and corresponds to a syllable in the pronunciation. Since there is no grapheme-phoneme correspondence in Chinese, decomposition of a character into components is not required. This may account for a left visual field (LVF)/right hemisphere (RH) advantage typically observed in Chinese orthographic processing (e.g., Tzeng, Hung, Cotton & Wang, 1979; Tan et al., 2001; Hsiao & Lam, 2013). Consistent with this speculation, brain imaging studies typically showed more bilateral or right-lateralized activation in the visual area in Chinese character processing as compared with English word reading (e.g., Tan, Laird, Li & Fox, 2005). These findings suggest that music-reading expertise may have limited influence on Chinese reading due to the different hemispheric lateralization and cognitive processes involved.

In this study, we examine how music-reading expertise modulates visual span in music reading, as well as in English and Chinese reading according to their similar/different cognitive processes involved. We also investigate whether music-reading expertise modulates visual span in reading novel symbols (i.e., Tibetan letters) as a transfer effect. We hypothesize that musicians would have a larger visual span than non-musicians in music reading due to an expertise effect, and that for English reading, musicians may have a larger visual span than non-musicians in the RVF due to the similar cognitive processes inherent in both music and English reading. More specifically, musicians who are also expert English readers may have received more training in the RVF/LH through extensive music reading, which facilitates perceptual processing in the RVF/LH, and may thus further benefit English reading in the RVF. In contrast, for Chinese character reading, musicians and non-musicians may not display differences in visual span due to the different cognitive processes involved in music and Chinese reading. More specifically, musicians' RVF/LH processing advantage in music reading may not translate to an increased visual span in Chinese reading due to the reliance on LVF/RH processing in Chinese reading. Here we also examine if a larger visual span of musicians in music note reading can be found in novel symbol (i.e., Tibetan letter) reading due to a possible transfer effect. To test these hypotheses, here we conducted a visual word/symbol identity matching task, in which participants were asked to attend to a briefly presented screen filled with music notes, English letters, Chinese characters, or Tibetan letters, and match a target stimulus presented at a given location afterwards. We examined how musicians and non-musicians differ in their performance.

Methods

Participants

Participants consisted of 64 Cantonese (L1)-English (L2) bilinguals from Hong Kong, whose ages ranged from 18 to 29 (M = 22, SD = 2.9). They had similar linguistic and college education backgrounds. They were categorized as musicians (n = 32) and non-musicians (n = 32), with 16 males and 16 females in each group. Musicians were well-trained pianists, who started music training at age 3-10 (M = 4.9, SD = 1.8). All of them were either piano teachers, music undergraduate/postgraduate students, or frequent piano players. They had attained grade 8 or above in the graded piano examinations of the Associated Board of The Royal Schools of Music (ABRSM), with 8-25 years experience in piano playing (M = 16.3, SD = 4.2) and regular music reading hours per week (M = 9.3, SD = 11.5). In contrast, non-musicians did not receive any music training.

Aside from their music training background, musicians and non-musicians were closely matched in other aspects detailed as follows. All participants were right-handed, which was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971; musicians: M = 75.78, 5th right decile; non-musicians: M = 70.00, 4rd right decile, $t(62) = 1.295$, *n.s.*). Both musicians and non-musicians had normal or corrected to normal vision (20/20) as shown in the Freiburg Visual Acuity and Contrast Test (FrACT; Bach, 2006; musicians: M = 1.27; non-musicians: M = 1.33, $t(62) = -1.043$, *n.s.*). Both groups' verbal and spatial working memory performance were matched in an N-back task (Lau, Ip, Lee, Yeung & Eskes, 2013; Verbal ACC: musicians: M = 87.5%; non-musicians: M = 79.6%, $t(62) = 1.863$, *n.s.*; Spatial ACC: musicians: M = 81.7%; non-musicians: M = 74.0%, $t(62) = 1.746$, *n.s.).* All participants started learning English as a second language at age 3 (M = 3.4, SD = 1.57), and no participants had any experience with the Tibetan language.

Materials

Materials consisted of four types of stimuli: English letters, Chinese characters, music notes and Tibetan letters. English lower-case letters (a-z, n = 26) were included. Chinese characters stimuli (n = 4805) were selected from the *List of Graphemes of Commonly-used Chinese Characters* (Chinese Language Education Section, HKSAR, 2012), comprising Chinese characters ranging from low to high number of strokes and frequency according to Ho's (1998) database. As for the music notes (n = 11), crotchets (1 beat) ranging from D4 to G5[1] were selected. Tibetan letters (n = 46) were included as novel symbols.

Design

Participants completed a visual word/symbol identity matching task with English letters, Chinese characters, mu-

[1] D4 to G5 ranges across one octave from the D note below the first line to the G note above the fifth line.

sic notes, and Tibetan letters in four separate progressive blocks with 36 positions around a central fixation (Fig. 1).

In the visual word/symbol identity matching task, progressive testing started from level 1 to level 3 according to participants' ACC in the 36 testing positions of stimulus identification (Fig. 1). The progression threshold for each level was set at 50% ACC. For example, in level 1, participants proceeded to the next adjacent positions (position 8,9,14) in level 2 only if their performance in position 15 was above chance level (50%); otherwise they did not proceed to the adjacent positions at level 2 after finishing all trials at position 15. Similar progression rules applied to level 2 positions when advancing to level 3. The experiment was terminated if a participant was not able to proceed to any adjacent position.

We measured visual span in two different ways: the number of musicians and non-musicians who reached the testing positions under this progressive testing paradigm, and participants' ACC in the task. To ensure the readability of stimuli, we doubled the size of stimuli in the present study from their usual size for expert readers in daily life. For music notes, we doubled the size of a crotchet found in Grieg's (1888) Anitra's Dance from Peer Gynt Suite No.1, Op.46 in *Piano Pieces the Whole World Plays*, which is a piano piece for post-intermediate piano players. For English letters, Chinese characters and Tibetan letters, we doubled the size of an alphabet/a character/a letter found in the text of English/Chinese/Tibetan newspapers respectively.

Participants' viewing distance was fixed at 61 cm in our task. Under this viewing distance, a music note (crotchet) with its corresponding five-line staff subtended a horizontal and vertical visual angle of 1.19° x 2.25°. The 6 (horizontal) x 6 (vertical) testing positions of music notes subtended a visual angle of 7.10° x 13.41°. Here we included crotchets as a single unit comparable to the other stimuli in the visual word/symbol identity matching task (i.e., English letter, Chinese character, Tibetan letter). English letters were displayed in Courier – a serif font with fixed width – to ensure constant center-to-center spacing between letters. The lowercase letter 'x', as a reference letter without ascenders or descenders such as letter 'h' and 'g' respectively, subtended 0.47° of visual angle horizontally and 0.50° vertically on a rectangular background that subtended a visual angle of 0.47° x 0.76°, with 1 x standard letter spacing. The 6 (horizontal) x 6 (vertical) testing positions of English letters subtended a visual angle of 2.81° x 4.55°.

Chinese characters were presented in Microsoft DF-Hei font, a serif font with fixed width, to ensure constant center-to-center spacing between characters. Each character subtended a horizontal and vertical visual angle of 0.72° x 0.76° with 1x standard center-to-center character spacing. The 6 (horizontal) x 6 (vertical) testing positions of Chinese characters subtended a visual angle of 4.30° x 4.55°.

Tibetan letters were displayed in Himalaya font. The letter 'ཟ', as a reference letter without ascenders or descenders, subtended a horizontal and vertical visual angle of 0.69° x 0.73° on a rectangular background that subtended a visual angle of 0.72° x 1.25°, with 1x standard letter spacing. The 6 (horizontal) x 6 (vertical) testing positions of Tibetan letters subtended a visual angle of 4.30° x 7.52°.

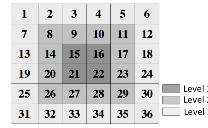


Figure 1. A sample of 36 testing positions of Chinese characters in a 6 x 6 layout around central fixation

The average luminance of stimuli was adjusted to 3.63 cd/m^2. With 73.8 cd/m^2 background luminance, the Weber contrast of the stimuli was -0.95. Experiments were conducted using SR Experiment Builder with an EyeLink 1000 eye tracker (SR Research Ltd., Canada) to ensure participants' central fixation. A chinrest was used to reduce head movement. Calibration and validation was performed before the start of each block. Block order was counterbalanced and trials were randomized across participants.

Procedure

Each trial started with a drift correction to ensure accurate central fixation. After detecting central fixation, a screen filled with stimuli was presented for 200 ms as the time constraint, to allow only one fixation without eye movement in letter recognition (Legge, Mansfield & Chung, 2001). After a 500ms blank screen, a target stimulus was then presented at one of the 36 testing positions around central fixation at the designated level (Fig. 1); the screen remained unchanged until participants responded (Fig. 2). Participants had to judge whether the target stimulus was identical to the stimulus presented earlier at the same position on the screen filled with stimuli, as quickly and accurately as possible, without shifting their gaze away from the central fixation (+). Each position consisted of 10 'yes' and 10 'no' trials that were randomly created without repetitions. Participants responded by pressing buttons on a response box with both hands. ACCs were recorded.

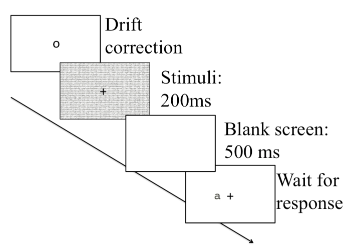


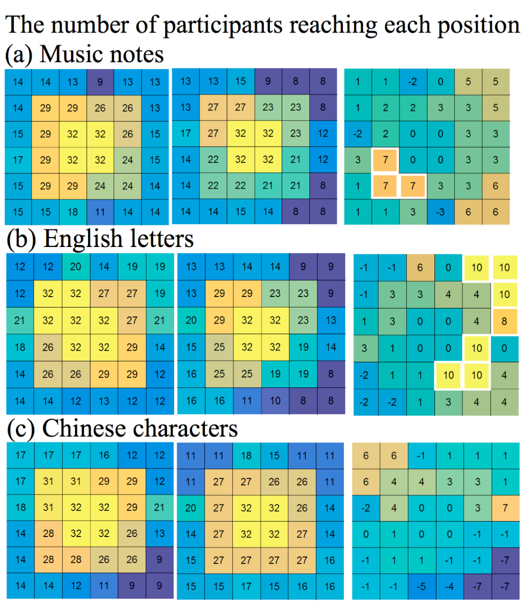
Figure 2. Procedure of the visual word/symbol identity matching task

Prior to the visual word/symbol identity matching task, a demographic and music background questionnaire, Freiburg Visual Acuity and Contrast Test (FrACT; Bach, 2006), Edinburgh Handedness Inventory (Oldfield, 1971) and an N-back task (Lau et al., 2013) were conducted to assess participants' language and music learning background, visual acuity, handedness and working memory capability.

Results

We first measured visual spans according to the number of musicians and non-musicians who reached the testing positions under our progressive testing paradigm. As shown in Figure 3, more musicians reached the 36 testing positions than non-musicians in music note and English letter reading, but not in Chinese character and Tibetan letter reading. For each testing position, we used Chi-square tests to examine whether there was a significant difference in the number of musicians and non-musicians reaching each position under progressive testing. For music notes, there were significantly more musicians reaching 3 level-2 positions in the lower LVF than non-musicians, including position 20 ($\chi^2(1)$ = 4.730, p = .030, φ = 0.27), 26 ($\chi^2(1)$ = 4.730, p = .030, φ = 0.27), and 27 ($\chi^2(1)$ = 4.730, p = .030, φ = 0.27; Fig. 3a). No significant differences in the number of musicians and non-musicians reaching other positions were observed.

For English letters, there was a significant difference in the number of musicians and non-musicians reaching 7 positions in the RVF, including position 5 ($\chi^2(1)$ = 6.349, p = .012, φ = 0.32), 6 ($\chi^2(1)$ = 8.349, p = .012, φ = 0.36), 12 ($\chi^2(1)$ = 8.349, p = .012, φ = 0.36), 18 ($\chi^2(1)$ = 4.016, p = .045, φ = 0.25), 23 ($\chi^2(1)$ = 8.333, p = .004, φ = 0.36), 28 ($\chi^2(1)$ = 8.333, p = .004, φ = 0.36), and 29 ($\chi^2(1)$ = 8.333, p = .004, φ = 0.36). More musicians reached positions at level 2 in the lower RVF and positions at level 3 in the upper RVF than non-musicians in English reading (Fig. 3b). No significant differences in the number of musicians and non-musicians reaching other testing positions were observed. For Chinese characters and Tibetan letters, no significant differences were found in the number of musicians and non-musicians reaching the 36 testing positions (Fig. 3c, 3d).



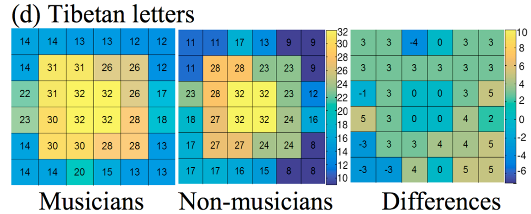
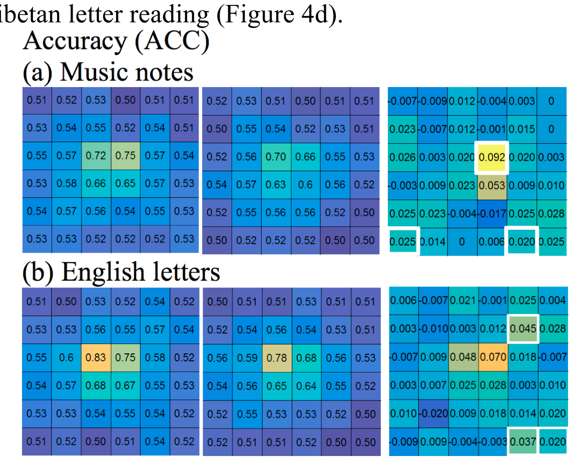


Figure 3. The number of musicians and non-musicians reaching each testing position, and the differences between the two groups (musicians - non-musicians) in reading (a) music notes, (b) English letters, (c) Chinese characters, and (d) Tibetan letters under progressive testing paradigm. (White borders: $p < .05$)

To examine participants' identification ACC, t-tests were used to compare musicians' and non-musicians' ACCs in the 6 (horizontal) x 6 (vertical) testing positions in the visual word/symbol identity matching task. In our analysis, we substituted the ACCs below the chance level (0.5) and missing data (i.e., for participants who did not reach a position due to their ACCs being below 0.5 in the corresponding position at the previous level) with the chance level performance (0.5). For music note ACC, a significant difference was found in position 16 ($t(62)$ = 2.469, p = .016, d = 0.63), 31 ($t(62)$ = 2.072, p = .042, d = 0.53), and 35 ($t(62)$ = 2.056, p = .044, d = 0.52; Figure 4a). Musicians performed better than non-musicians in music note reading at the central (level 1) position in the upper RVF and two positions at level 3 in the lower LVF and RVF. For English letter ACC, a significant difference was found in position 11 ($t(62)$ = 2.590, p = .012, d = 0.66), 35 ($t(62)$ = 2.729, p = .008, d = 0.69), and 36 ($t(62)$ = 2.425, p = .018, d = 0.62; Figure 4b). Musicians performed better than non-musicians when English letters were presented at one position at level 2 in the upper RVF and two positions at level 3 in the lower RVF. For Chinese character ACC, a significant difference was found in position 15 ($t(62)$ = 2.069, p = .043, d = 0.53; Figure 4c). Musicians performed better than non-musicians when Chinese characters were presented at the central position in the upper LVF. For Tibetan letter reading, no significant differences were found between musicians and non-musicians, suggesting that musicians did not hold a significant advantage over non-musicians in Tibetan letter reading (Figure 4d).



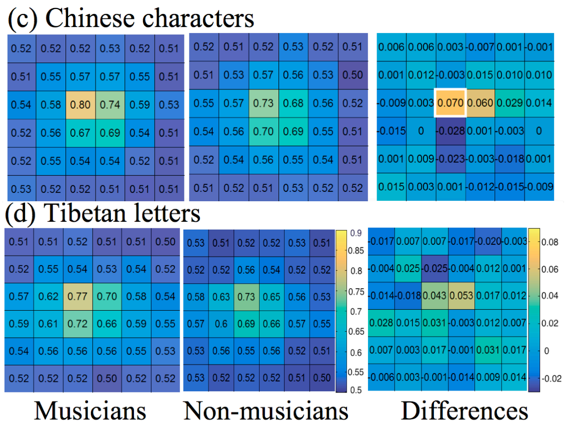


Figure 4. The ACCs of musicians, non-musicians, and the differences between the two groups (musicians - non-musicians) in reading (a) music notes, (b) English letters, (c) Chinese characters and (d) Tibetan letters. (White borders: $p < .05$)

Discussion

Here we examined how music reading expertise influences visual span in music note, English letter, Chinese character, and novel symbol (i.e., Tibetan) reading. For music note reading, musicians outperformed non-musicians at the central position in the upper RVF and some peripheral positions in both the lower LVF and RVF, suggesting that they have a larger visual span than non-musicians. This result is consistent with previous findings that experts may develop a larger visual span than novices in meaningful tasks related to their expertise, as shown in a chess configuration detection task (Reingold et al., 2001) and a music note playing task (Sloboda, 1974). The finding that musicians' advantage could be found in both visual fields was consistent with Proverbio, Manfredi, Zani and Adorni's (2012) finding that visual processing of music notes involves bilateral activations in the fusiform (BA37) and inferior occipital gyri (BA18). Note that this result is in contrast to Segalowitz et al.'s (1979) study, which showed a RVF advantage in a chord-playing task. This difference may be due to the involvement of left-lateralized motor planning in music playing tasks. Putting together, these results suggest that lateralization of music processing may depend on the task requirements.

For English letter reading, consistent with our hypothesis, musicians outperformed non-musicians at several peripheral positions in the RVF. This finding suggests that music-reading expertise may modulate visual span in English reading due to their similarities in the cognitive processes involved. Both music notations and English words are read from left-to-right, and thus music notes and English letters are recognized in the RVF more often (Brysbaert & Nazir, 2005; Wong & Hsiao, 2012). With extensive music reading experience, musicians hold a processing advantage in the RVF/ LH through perpetual learning, and this may translate to better English reading performance in the RVF. Moreover, both the note-to-sound mapping in music reading and the grapheme–phoneme correspondence in English reading (e.g., Brown, Martinez & Parsons, 2006) may involve more LH analytic processing than RH processing (Bradshaw & Nettleton, 1981; Hébert & Cuddy, 2006; Hsiao & Lam, 2013; Segalowitz et al., 1979). Due to these similarities in cognitive processing between music and English reading, music-reading expertise may facilitate perceptual processing in the RVF/LH, which further benefits English reading in the RVF.

For Chinese character reading, musicians performed better than non-musicians at the central position in the upper LVF, but not in any peripheral locations. This result is consistent with our hypothesis that music-reading expertise has less influence on the visual span for Chinese character reading than English letter reading. This effect may be due to the different cognitive processes involved in music and Chinese reading. Contrary to left-to-right music reading, Chinese can be read in all directions (left to right, right to left, or vertically), possibly resulting in different perceptual learning. Moreover, Chinese has no grapheme-phoneme correspondence, and thus decomposition of a character into components is not required. As such, Chinese reading tends to be right-lateralized (Tzeng et al., 1979) or bilateral (Tan et al., 2001) in its orthographic processing due to its unique logographic orthography. Taken together, the different processing advantages between music (RVF/LH) and Chinese (LVF/RH) reading may reduce the facilitation of music reading expertise on the visual span of Chinese reading. However, musicians' advantage in the central upper LVF suggests the possibility of modulation of music reading experience in Chinese character processing. Future work will examine this possibility.

For novel symbol (i.e., Tibetan letter) reading, no performance differences were found in any of the positions between musicians and non-musicians. This result suggests that the two groups have similar visual spans in novel symbol processing. The absence of a transfer effect to novel symbol processing suggests that the modulation of music reading experiences on visual spans in reading is limited to stimuli of expertise, and cannot be generalized to novel symbols.

Note that in the current study, we measured visual span as participants' identification performance when the target location within the stimulus was unknown beforehand. In other words, the visual span was measured in a distributed attention condition, in which participants had to pay attention to the whole stimulus without orienting their attention to a specific location beforehand. This is in contrast to some previous studies of visual span, in which a cue was provided prior to the presentation of the stimulus (e.g., Legge et al., 2001) to allow participants' orientation of attention to the targeted location beforehand. Future work will examine whether similar modulation effects can be observed when a different measure of visual span is used.

To conclude, this study examined how music reading expertise influences visual spans in reading music notes, English letters, Chinese characters, and novel symbols reading.

As an expertise effect, musicians outperformed non-musicians in music reading at some central and peripheral positions in both visual fields. Interestingly, for English letter reading, musicians also outperformed non-musicians in some peripheral positions in the RVF but not in the LVF. In contrast, in both Chinese character and novel symbol reading, musicians and non-musicians did not differ in their performance in any peripheral positions. These results can be explained by both music and English processing advantages in the RVF/LH, whereas Chinese character processing is more right-lateralized or bilateral. Thus, the modulation of music-reading expertise on visual spans in language reading depends on the similarities in the cognitive processes involved.

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