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BRIEF COMMUNICATION

The impact of reading and writing skills on a visuo-motor integration task: A comparison between illiterate and literate subjects

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Abstract

Previous studies have shown a significant association between reading skills and the performance on visuo-motor tasks. In order to clarify whether reading and writing skills modulate non-linguistic domains, we investigated the performance of two literacy groups on a visuo-motor integration task with non-linguistic stimuli. Twenty-one illiterate participants and twenty matched literate controls were included in the experiment. Subjects were instructed to use the right or the left index finger to point to and touch a randomly presented target on the right or left side of a touch screen. The results showed that the literate subjects were significantly faster in detecting and touching targets on the left compared to the right side of the screen. In contrast, the presentation side did not affect the performance of the illiterate group. These results lend support to the idea that having acquired reading and writing skills, and thus a preferred left-to-right reading direction, influences visual scanning. (*JINS*, 2007, *13*, 359–364.)

Keywords: Illiteracy, Schooling, Reading and writing, Non-verbal skills, Visuoperceptual skills, Visual scanning

INTRODUCTION

The study of illiterate subjects and their matched literate controls provides an opportunity to investigate the interaction between neurobiological and cultural factors on the outcome of cognitive development and learning. In our work, the acquisition of reading and writing skills, as well as other cognitive skills, during formal education serves as a model for structured cultural transmission (Petersson & Reis, 2006; Petersson et al., 2001) and it is known that this acquisition influences several aspects of the cognitive processing. There are consistent behavioral as well as structural and functional neuroimaging results suggesting a significant impact of literacy and formal education on human cognition and its structural and functional correlates (for reviews see Petersson & Reis, 2006; Petersson et al., 2001). Most of these studies have documented the influence of reading and writing skills on language related cognitive functions (Morais et al., 1979; Petersson et al., 2000; Rosselli et al., 1990). One reason for this bias is a claim that non-verbal cognitive functions and consequently non-verbal cognitive tests are relatively independent of cultural and educational factors. However, Rosselli and Ardila (2003) recently argued that a significant effect of educational level on non-verbal neuropsychological tests can be found in individuals within the same cultural group. In this context, it is important to note that learning to read and to write—the acquisition of literacy—is not just learning how to match a phoneme with a grapheme. Among other things, subjects also become overtrained on how to write with pen and pencil and how to visually scan information using a preferred spatial (e.g., left-to-right) direction. From a neurobiological perspective, it is possible that the acquisition of reading and writing promotes an increased asymmetry in information transfer

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between the right and left hemispheres. This is supported by results suggesting that the corpus callosum, in particular the posterior mid-body region that interconnects the left and right parieto-temporal cortices, is thinner in illiterate compare to literate subjects (Castro-Caldas et al., 1999). Additional evidence comes from studies with illiterate populations using non-verbal stimuli. For example, Reis and colleagues documented that illiterate subjects had trouble in decoding two-dimensional representations (Reis et al., 2001), whereas color information significantly improved the two-dimensional object naming performance in illiterate subjects (Reis et al., 2006).

The impact of literacy and formal education on non-verbal cognitive domains has remained under-explored. In an earlier study, Ostrosky-Solis et al. (1991) made an interesting observation about the visual scanning behavior of non-literate subjects. In that study, a group of illiterate and literate participants were required to detect a target pattern presented simultaneously with a number of similar non-target foil patterns. Although the overall accuracy of target detection was identical in both groups, there were significant differences between the detection pattern of the literate and illiterate subjects. The nature of these differences suggests that the acquisition of reading skills can cause literate subjects to adopt more consistent scanning paths (Ostrosky-Solis et al., 1991). In more recent work, Matute and colleagues (2000) demonstrated that literacy also plays a significant role on visuo-constructional tasks. The authors tested illiterate, semi-literate, and literate adults on a stick figure copying task and reported that global fidelity and disarticulation errors allow a better discrimination between the literacy groups than errors of spatial rotation or distortion, suggesting a specific perceptual difference between groups. Finally, Byrd and colleagues (2005) used a delayed recognition and matching version of the Benton Visual Retention Test (BVRT) to identify specific sources of performance variance in a sample of elderly individuals with different reading levels. The results suggested that reading levels were related to the search strategy on the BVRT: elders with lower reading levels were less accurate when the correct target appeared on the bottom half of the matrix display. This result lends support to the idea that reading level is an important reflection of mechanisms responsible for variation in performance on visuo-perceptual tests (Byrd et al., 2005). This finding is also consistent with a previous study (Le Carret et al., 2003) which showed that individuals with a lower educational level have less effective search strategies and produce fewer successful responses to target items appearing in the lower half of 2×2 response matrices. Although the results of these studies suggest poor strategic search skills in illiterate, and low-literate subjects as well as poor readers, it is possible that the low performance could be related to poor shape recognition skills (Byrd et al., 2005; Matute et al., 2000).

Another line of evidence concerning the effect of reading on visual scanning mechanisms comes from studies performed in literate populations that have acquired orthographies with different reading directions (left-to-right and right-to-left) suggesting that reading systems can bias the visual scanning behavior. One of the first studies that reported an influence of reading habits on visual recognition presented English words (read from left to right) and Yiddish words (read from right to left) in the left and right visual fields of subjects who could read both languages (Mishking & Forgays, 1952). When words were presented in English, the accuracy was 40% greater in the right than in the left visual field, whereas the recognition of the Yiddish was 25% higher in the left than in the right visual field. They concluded that the reversal of field advantage was caused by the direction in which words are normally read in text. More recently, Chokron and Imbert (1993) used a line-bisection task to investigate the impact of reading and writing habits on visuo-motor integration skills. The authors analyzed the performance of normal dextral French subjects and normal dextral Israelis subjects. Bisection performance was found to depend on the reading habits of the subjects: Israeli tended to bisect the lines to the right of the objective middle, whereas French subjects placed their subjective middle to the left of the objective center. Finally, Zivotofsky (2004) compared the performance on several line partition tasks in two groups with different reading directions (English and Hebrew subjects) and found similar results to the ones of Chokron and Imbert (1993). Taken together, these results suggest that reading skills modulate the way that space is scanned under some circumstances.

In this study, we investigated the performance of illiterate subjects and matched literate controls on a visual-motor integration task that captures aspects of the visual-motor components in reading and writing and requires minimal memory and visual processing resources. Participants were instructed to touch a red target among 79 yellow distractors uniformly distributed over a touch screen. Because the target and distractor shape was simple and identical (square), any differences in visual search strategies between literacy groups should emerge in such a task. Thus, we hypothesized that if the acquisition and practice of reading and writing skills significantly influence visual scanning, then the literate response times would be shorter than that of the illiterate subjects, primarily in the condition of detecting a target presented on the left side of the computer screen.

MATERIALS AND METHODS

Participants

Forty-one right-handed native Portuguese speaking female volunteers with the same socio-cultural background participated in this study (Portuguese is read from left to right). Subjects were recruited with the help of local authorities and by word-of-mouth. The literate group included 20 subjects (mean age (±std) = 69.7 ± 5.5 years; mean literacy level = 3.6 ± 1.1 years) and the illiterate group 21 subjects (mean age = 70.5 ± 4.1 years; no significant age differences between groups, $P = .36$) matched for age. Informed consent was obtained from all participants in compliance with the Helsinki Declaration. All participants were prescreened according to the standard procedures outlined by Reis and collaborators (Reis et al., 2003). In brief, the subjects underwent a semi-structured socio-cultural interview that probes the level of literacy, the reasons for receiving formal education (or not), the literacy level and profession of the parents, past, and present occupation of the subject; as well as reading and writing habits of literate subjects. According to our criteria, a subject is considered illiterate if he or she has not received any schooling (formal or informal) exclusively for well-defined socio-cultural reasons, have never received any literacy training, and did not have any reading or writing skills (Reis et al., 2003). In order to ensure that the illiterate subjects did not have any literacy knowledge, all subjects were also screened with a grapheme-phoneme association task (reading common words such as "hospital" and some random letters). The literacy level of literate subjects was determined based on self-reported number of school years. In addition, the literate subjects were evaluated with a short text, which was read by the subjects, in combination with six comprehension questions. Finally, all participants were screened with a clinical interview in order to exclude any disease potentially affecting the central nervous system. In order to rule out neuropsychological dysfunction, all subjects were evaluated with a short neuropsychological battery (Reis et al., 2003). For further details concerning the screening procedures see Reis et al. (2003).

The handedness of the subjects was assessed by a 14-item questionnaire adapted from the Edinburgh Inventory (Oldfield, 1971) and by the pegboard task (Lafayette-Instrument-Company, 1985). There was no significant difference between groups, as measured by the questionnaire (mean score: literates = $13.4 \pm .76$; illiterates = $13.5 \pm .68$; $P = .79$) or the pegboard task (mean score: literates = 6.0 ± 5.4; illiterates = 4.2 ± 5.6; $P = .40$).

Experimental Procedures

The computerized visual-motor integration task was run on a laptop (Toshiba, Satellite M30-604), with the stimulus being displayed on a color touch-screen (LG, Flatron L15105F, 38 cm, 17″). On each trial, eighty squares (10×10 mm^2) were presented, uniformly distributed over the screen under the constraint that each quadrant included 20 squares. All squares were yellow except the target square, which was colored red (Fig. 1). The participants were seated ~60 cm centrally in front of the touch screen with their (right or left) index finger resting at the center of the screen (marked as cross-hair). On each trial, the subjects were required to touch the target by means of their index finger as rapidly as possible. One hundred and sixty trials were created with the target appearing randomly in the four quadrants: on 80 trials the target appeared on the left side of the screen, and on 80 trials the target appeared on right side, randomly intermixed. On each trial, after touching the target, the participant returned the index finger to the center of the touch-screen, and the next trial was initiated. The execution time was measured as the time between the onset of the target stimulus and the manual detection of the target. The experiment included four conditions: right and left response hand as well as right and left side target localization on the screen. Half of the subjects started with their right hand and the other half with their left hand, with alternation of hand every 20 trials. All subjects took part in a training session with both hands before the experiment was initiated.

RESULTS

The mean execution time for each subject and experimental condition was calculated. Execution times two standard deviations above or below the mean for each subject and condition were excluded from the statistical analysis. Longer execution times were classified as lapses of attention or

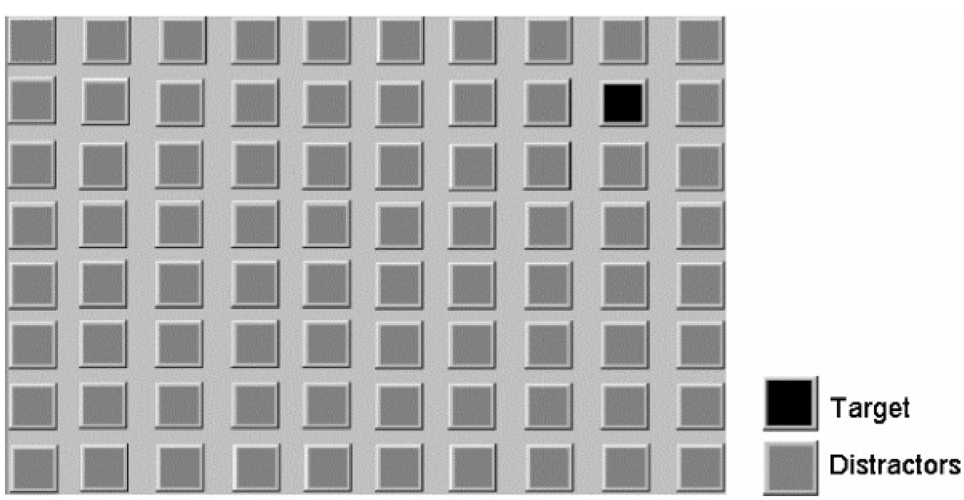

Fig. 1. The Visuo-motor Integration Task.

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concentration, whereas short execution times were classified as anticipatory responses. In total, approximately 5% of the trials were excluded per subject (a mean of 5.4% in the illiterate group and 4.6% in the literate group).

The mean execution times were analyzed with repeated-measures ANOVA including the factors: (1) Literacy group (illiterate/literate) as a between-subject factor; (2) Hand of execution (right/left); and (3) Side of the screen (right/left) as within-subject factors. The analysis showed a significant group effect [$F(1,39) = 7.6$; $P = .009$; the illiterate group performed slower than the literate group], and a significant hand effect [$F(1,39) = 15.5$; $P < .001$; touching the target with the right hand was faster than with the left]. The side of screen effect [$F(1,39) = 1.0$; $P = .33$], the interaction between group and execution hand [$F(1,39) = .2$; $P = .66$] as well as the interaction between execution hand and side of the screen [$F(1,39) = 2.0$; $P = .17$] were not significant. However, the interaction between group and side of the screen was significant [$F(1,39) = 7.6$; $P = .009$]. Scheffé post-hoc comparison revealed that the literate participants were faster on touching targets on the left side of the screen compared to the right ($P < .001$), whereas the performance of illiterate participants was not affected by which side of the screen the target was displayed ($P = .66$). In addition, the three-way interaction was marginally significant [$F(1,39) = 3.8$; $P = .06$; see Fig. 2].

To further understand the interaction between literacy group, execution hand, and presentation side, we performed two separate analyses for each reading group, including the same within factors as mentioned previously. In the illiterate group, we observed a significant hand effect [$F(1,20) = 4.5$; $P = .05$; $\chi^2 = .18$; performance with the right hand was faster than the left hand], no significant presentation side effect [$F(1,20) = 1.1$; $P = .30$; $\chi^2 = .05$] and a significant interaction between execution hand and presentation side [$F(1,20) = 4.2$; $P = .05$; $\chi^2 = .17$]. A post-hoc Scheffé test revealed that the illiterate subjects performed equally well with both hands on the right side of the screen. However, on the left side of the screen, the illiterate subjects were significantly slower when they used the left hand compared to the right ($P = .02$). In contrast, the literate group showed a significant execution hand effect [$F(1,19) = 15.8$; $P < .001$; $\chi^2 = .46$; execution with the right hand was always faster than with the left], a significant screen presentation side effect [$F(1,19) = 12.2$; $P = .003$; $\chi^2 = .39$; targets presented on the left side were always touched faster than targets presented on the right]. There was no significant interaction between execution hand and screen presentation side [$F(1,19) = .2$; $P = .63$; $\chi^2 = .01$]. Finally, all correlations between the pegboard laterality measure and the investigated execution times tested were nonsignificant for both groups ($P > .5$).

DISCUSSION

The study of literacy effects on cognition and its corresponding neurobiological basis is an important research topic in order to understand the interaction between neurobiological and cultural factors on the outcome of cognitive development and learning. In our work, the acquisition of reading and writing skills and other cognitive skills, for example during formal education, serves as a model for structured

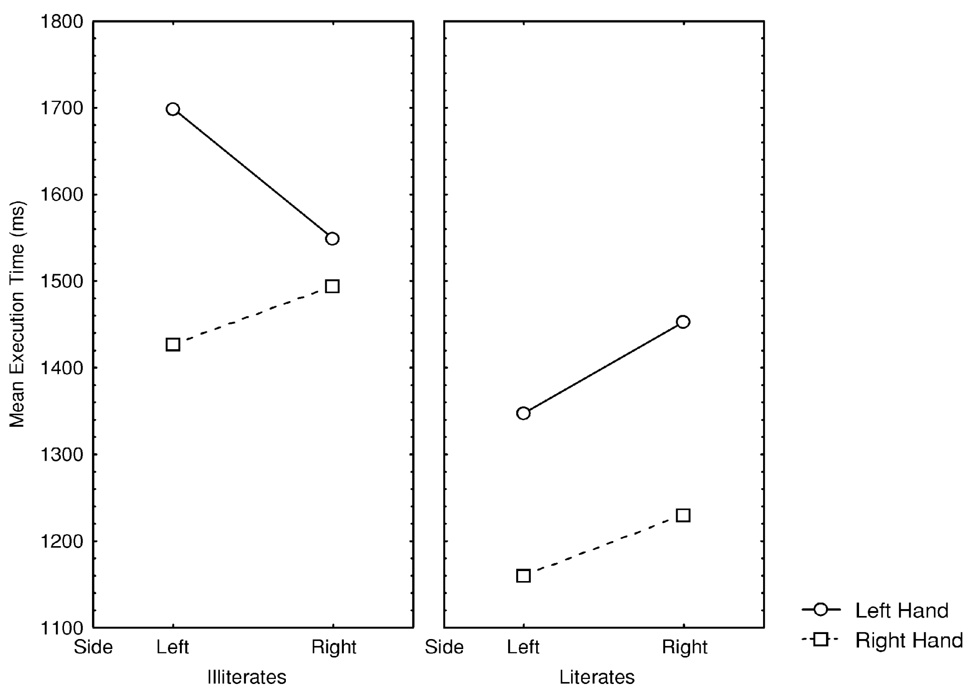

Fig. 2. Three-way interaction between literacy group, hand of execution, and side of the screen for execution times (ms).

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cultural transmission (Petersson & Reis, 2006; Petersson et al., 2001). Human cognition is ultimately a product of prior structure generated by (neuro) biological evolution in interaction with development, learning, and cultural transmission. In this context, it is important to establish proper models to disentangle this complex set of interactions. This line of research addresses important theoretical questions and important practical issues when it comes to the neuropsychological assessment of illiterate or lowly educated subjects.

In this study we investigated whether the acquisition of reading and writing skills influences a particular non-verbal cognitive domain, particularly in tasks that involve visual scanning processes. The results of our experiment showed that the literate group was faster when the target was presented on the left of the screen compared to the right and showed an advantage of the right over the left hand independent of the presentation side. Overall this result suggests that literate subjects employ a systematic visual scanning strategy. On the other hand, the illiterate group demonstrated a less systematic scanning pattern and, as a consequence, a slower overall execution time. Illiterate performance was dependent on the execution hand: when the target was localized on the right side of the screen, the execution time was similar for both the right and the left hand, whereas it was significantly slower in detecting a target with the left hand compared to the right when the target was presented on the left of the screen. In another words, illiterate subjects performed equally well with the right hand on both sides of the screen, whereas their performance with the left hand was slower for targets presented on the left side of the screen. Although both groups presented a right hand advantage, the analysis of the magnitude effects revealed that the hand and the side of screen effect were stronger in the literate ($\chi^2 = .46$ and $\chi^2 = .39$, respectively) compared to the illiterate group ($\chi^2 = .18$ and $\chi^2 = .05$, respectively). Overall, the observed effects suggest that literate subjects showed a scanning pattern more in agreement with a behavior modulated by reading and writing skills (in the case of Portuguese, left to right). Similar type of effects have been documented with respect to various non-verbal tasks such as the Benton Visual Retention Test (Byrd et al., 2005; Le Carret et al., 2003), stick figure copying (Matute et al., 2000), and a target detection task (Ostrosky-Solis et al., 1991) as well as two-dimensional immediate object naming tasks (Reis et al., 2006; Reis et al., 2001). Moreover, there is an on-going discussion about the impact of reading direction on the detection of visual stimuli and that reading systems can bias the visual scanning behavior under certain circumstances (Chokron & Imbert, 1993; Mishking & Forgays, 1952; Zivotofsky, 2004). Overall, the results of these studies in combination with our findings provide evidence that reading habits modulate the preferred visual scanning behavior, which can play a role in visual-motor integration skills.

The act of reading and writing in an alphabetic language engages cognitive processes related to the systematic scanning of space and motor integration. Consistent with this idea, our results suggest that visual scanning, detection, and pointing at non-linguistic targets are modulated by the acquisition of reading and writing skills. These results represent new evidence of the effects of literacy on cognition, and they are important for neuropsychological tasks selection and results interpretation for subjects without literacy skills or low literacy levels.

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