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Literacy acquisition reduces the influence of automatic holistic processing of faces and houses

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HIGHLIGHTS

- Holistic processing of faces and houses were studied through composite face tasks.
- Illiterates, ex-illiterates and literates were tested.
- Illiterates were consistently more holistic in dealing with faces and houses.
- Literacy has a broad effect on visual processing style.

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ABSTRACT

Writing was invented too recently to have influenced the human genome. Consequently, reading acquisition must rely on partial recycling of pre-existing brain systems. Prior fMRI evidence showed that in literates a left-hemispheric visual region increases its activation to written strings relative to illiterates and reduces its response to faces. Increasing literacy also leads to a stronger right-hemispheric lateralization for faces. Here, we evaluated whether this reorganization of the brain's face system has behavioral consequences for the processing of non-linguistic visual stimuli. Three groups of adult illiterates, ex-illiterates and literates were tested with the sequential composite face paradigm that evaluates the automaticity with which faces are processed as wholes. Illiterates were consistently more holistic than participants with reading experience in dealing with faces. A second experiment replicated this effect with both faces and houses. Brain reorganization induced by literacy seems to reduce the influence of automatic holistic processing of faces and houses by enabling the use of a more analytic and flexible processing strategy, at least when holistic processing is detrimental to the task.

1. Introduction

Learning to read leads to the development of a strong response to written materials in the left fusiform gyrus, in the "visual word form area" (*VWFA*, e.g. [8,11]). Here, we examine whether it also has consequences outside the language domain. In a recent fMRI study comparing illiterate to literate adults [13], we showed that at the VWFA site, learning to read competes with the cortical representation of other visual objects, especially faces. With increasing literacy, cortical responses to faces decrease slightly in the left fusiform region while increasing strongly in the right fusiform face area (*FFA*). Thus, right-hemispheric lateralization for faces is increased in literates compared to illiterates. Further developmental studies corroborate a tight link between reading acquisition and changes in face processing [6,15,20,25,31,32,38].

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These observations support the existence of competition between the VWFA and FFA [10,11,39], with some displacement of fusiform face-sensitive areas toward the right hemisphere. A similar theoretical perspective [4,33] espouses interplay between cooperation and competition between distributed circuits for face and word recognition.

However it remains unknown whether this brain reorganization has behavioral consequences. Here, we investigate whether face processing is affected by literacy, and particularly whether holistic processing is changed. It is generally accepted that faces are processed differently than other objects, relying considerably on "holistic" processing of the whole face configuration [e.g. 28]. Under the simple view that the right FFA encodes configuration while the left fusiform gyrus encodes features [e.g. 5], one might predict that the stronger right-hemispheric lateralization for face processing with literacy implies a more holistic processing of faces.

However, such tuning might be flexible and dynamic [19,26], and the depth with which a face is holistically encoded may depend on the nature of the task [17,34]. By training the left fusiform gyrus to process letters and their combinations, literacy may enhance an analytic mode of visual processing which would generalize to processing of other visual categories represented at this and nearby cortical sites, thus bringing more flexibility to face processing. Accordingly literate adults would more easily adopt an analytic mode of face processing if the task requires it, while illiterate adults would systematically adopt what may be the default or privileged mode of processing faces in adults, namely holistic processing (this matures as early as after 4 years of experience with faces [14]).

To evaluate these two hypotheses we compared holistic processing in adult illiterates, literates, and ex-illiterates. In Experiment 1, all stimuli were made out of faces. In Experiment 2, we compared faces to another object category, namely houses.

In both experiments participants had to determine if the bottom halves of two sequentially presented composite images were the same while trying to ignore the top halves.

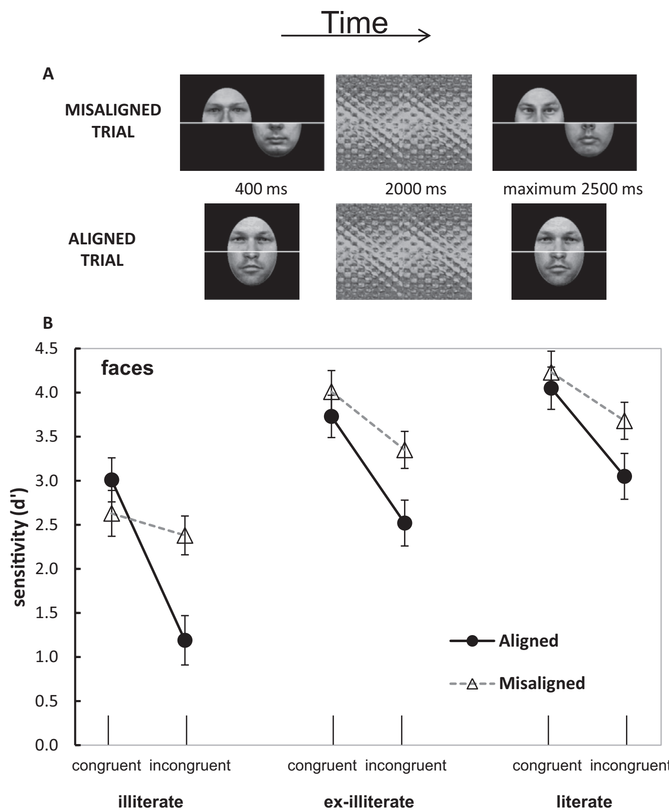

Fig. 1. Design and results of Experiment 1 (faces). (A) Experimental design. Participants were asked to say aloud if the bottom part of the test face was either the same or different from the study face. (B) Results. Average *d'* scores (error bars SEM) for aligned and misaligned, congruent and incongruent trials, separately by group. Lines provide a graphic depiction of congruency effect/HP index for aligned (black line) and misaligned (gray line) conditions.

2. Experiment 1: composite face task

2.1. Materials and methods

2.1.1. Participants

Three groups of 22 participants each were examined: literates (16 females; average age 54.7 ± 13.2 yrs), ex-illiterates (16 females; average age 54.8 ± 7.8 yrs), and illiterates (16 females; average age 56.1 ± 12.3 yrs). All were recruited through non-governmental agencies participating to social projects in a small town on the outskirts of Lisbon, Portugal. They were matched as closely as possible on cultural and socio-economic characteristics, and came from similar households. All had normal or corrected-to-normal visual acuity (Snellen chart for illiterates) and were fully functional in their daily lives. Ex-illiterates and illiterates had received no early schooling during childhood. Among them, we considered as ex-illiterates those who had fulfilled adult alphabetization courses, while illiterates were still unable to read even simple words (but could identify some letters; see Supplementary Table 1 for results on letter identification and reading tests). Literate participants had benefited from regular education (including literacy) at an early age and were all normal readers. All participants gave their informed consent (the consent form was read aloud and explained to illiterates) which is archived by the first author. The experiment was approved by the Deontological Committee – Faculty of Psychology (University of Lisbon) and conformed to the Declaration of Helsinki.

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2.1.2. Material

Stimuli were constructed from 28 male faces (8 for training) from the MPI face database [44], converted to gray scale and cut in half. Stimuli were composites made out of the top- and bottom-half of different faces. A line separated face halves. To eliminate cues derived from the shape of the head or chin, we presented faces inside an oval within a black rectangle (see Fig. 1A).

For the sequential matching task (of bottom-halves) we used the complete design, with four types of trials: congruent *same* (both halves of study and test faces were identical), congruent *different* (both halves of study and test faces were different), incongruent *same* (only the bottom halves of the study and test faces were identical, the top halves were different) and incongruent *different* (only the bottom halves of the study and test faces were different, the top halves were identical). Study and test faces were either both aligned (bottom and top halves were spatially aligned) or both misaligned (bottom halves were spatially offset from the top halves); we used strongly misaligned faces to facilitate attention to the target part.

Two aligned and two misaligned blocks were counterbalanced and followed interactive training. Each block comprised 80 trials, 40 congruent and 40 incongruent (in both cases, half *same* and half *different*).

2.1.3. Procedure

On each trial, a fixation cross appeared in the center of the screen for 500 ms followed by a study face shown for 400 ms. After a 2000 ms mask stimulus, a test face appeared. Participants were instructed to match the bottom parts of the composites while ignoring the top parts. They had to say aloud if the bottom part of the test