# How Learning to Read Changes the Cortical Networks for Vision and Language

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**Introduction.**

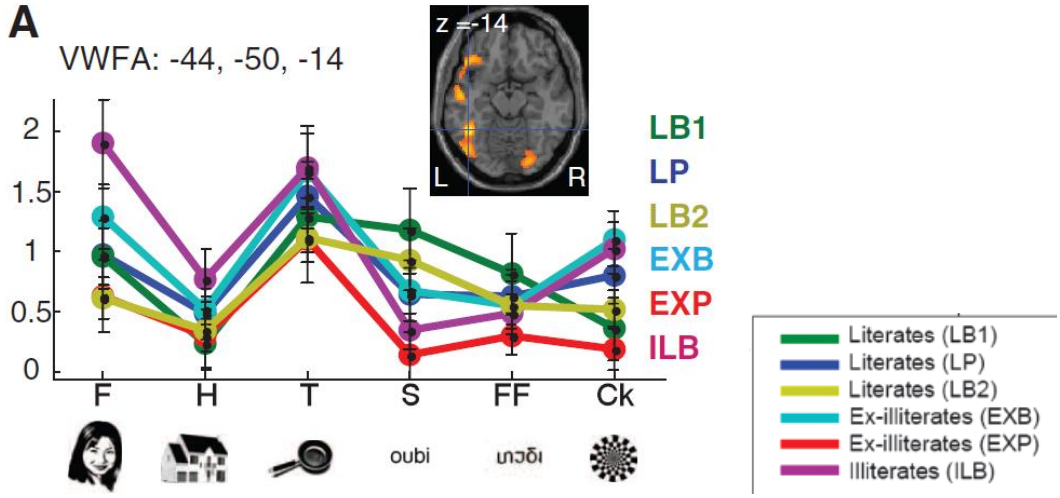
Practically all adult neuroimaging experiments are performed in highly educated college students. The observed brain architecture therefore reflects the influence of culture and education over and above spontaneous brain development (1, 2). Indeed, the acquisition of reading, a major event in children's lives, is now recognized as capable of changing both brain anatomy (3, 4) and brain activation (5–9). In the auditory modality, literacy leads to phonemic awareness, the ability to manipulate the smallest units of spoken language [i.e., phonemes (10)], and alters online speech processing (11–14). At the visual level, developmental neuroimaging studies in normal and dyslexic children show that, with reading acquisition, a specific brain site in left occipito-temporal cortex, which has been termed "visual word form area" (VWFA), starts to respond to orthographic stimuli in the learned script (15–19).

These observations leave many important questions unanswered. First, does literacy primarily lead to cooperative or to competitive effects on cortical processing? Two theoretical positions can be contrasted. The first view, derived from animal studies of environmental enrichment and sensory plasticity, emphasizes that perceptual learning entails beneficial modifications of cortical maps, including sharpened receptive fields and neuronal tuning curves correlated with behavioural improvements (20–22).Without denying these positive effects, the second view emphasizes that reading is a cultural invention too recent to involve dedicated genetic or developmental mechanisms. Thus, during education, reading processes must invade and "recycle" cortical space devoted to evolutionary older functions, opening the possibility that these functions suffer as reading expertise sets in (2, 23). Much like expertise for nonface stimuli induces a reduction in face responses (24–26), reading, which recruits an identical cortical site in all cultures (27), might entail a reorganization of nearby responses to faces, houses, and objects. We thus sought to understand which of these stimuli are processed in the VWFA area before reading and how their cortical representation, which gets refined during the school years (28), is affected by literacy. A second issue is that, at present, most functional imaging studies of illiteracy only contrasted schooled versus unschooled adults. Because these studies did not include "ex-illiterate" adults who did not attend school but learned to read during adulthood, they confounded the effects of schooling and literacy. The only important exception (4) focused solely on how brain anatomy is changed by literacy. In this study, we

separated the functional effects of schooling and literacy by comparing illiterates, ex-illiterates, and adults schooled in childhood.

**Populations studied and verification of literacy level.**
We scanned a total of 63 Portuguese and Brazilian participants. Our sample included 32 unschooled adults (10 illiterates and 22 ex-illiterates with variable reading skills), and 31 schooled and literate adults. The latter group included 11 literate subjects matched to the illiterates in socioeconomic status (SES) (29).
Reading skills were verified through behavioral tasks of letter identification, word and pseudo-word reading (with or without speed pressure), and sentence reading (Fig. 1, fig. S1, and table S1). All tests revealed the same ordering of literacy, from Brazilian illiterates (ILB) to Portuguese ex-illiterates (EXP), Brazilian ex-illiterates (EXB), low-SES Brazilian literates (LB2), Portuguese literates (LP), and Brazilian literates (LB1).
We therefore relied on wholebrain linear regressions with reading performance (number of stimuli read per minute) across all groups to identify the brain regions influenced by literacy. Once identified, each brain site was submitted to restricted comparisons of subgroups to evaluate the effects of schooling and literacy with maximal sensitivity (29). We used three visual runs evaluating cortical responses to faces, houses, tools, letter strings, false fonts, and moving checkerboards, while the participant focused on detecting a target star (fig. S3); and four auditory lexical decision runs with spoken stimuli.

**Results.** Effects of literacy on visual responses in the VWFA to different categories of stimuli.




Questions.

1. Quel est l'intérêt d'étudier des populations d'adultes illettrés et ex-illettrés dans le cadre de la théorie du recyclage neuronal ?
2. Résultats des sujets lettrés (en vert) : comparez le taux d'activation de la VWFA en réponse aux stimuli écrits vs. autres catégories de stimuli visuels : qu'observe –t-on ?
3. Résultats des sujets illettrés (en violet) : comparez le taux d'activation de la VWFA en réponse aux stimuli écrits vs. autres catégories de stimuli visuels : qu'observe –t-on ?
4. Mettez en relation les résultats observés chez les sujets lettrés-illétrés. En quoi les résultats de cette étude soutiennent-ils la théorie du recyclage neuronal ?