Neuropsychologia 53 (2014) 94–103

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Imaging 'top-down' mobilization of visual information: A case study in a posterior split-brain patient

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ARTICLE INFO

Article history:
Received 11 June 2013
Received in revised form
10 November 2013
Accepted 14 November 2013
Available online 21 November 2013

Keywords:
Top-down
EEG
Behavior
Split-brain
Inter-hemispheric transfer
Anterior cingulate cortex

ABSTRACT

During visual perception, automatic bottom-up and controlled top-down processes occur simultaneously and interact in a complex way, making them difficult to isolate and characterize. In rare neurological conditions, such a dissociation can be achieved more easily. In the present work, we studied a patient (AC) with a posterior lesion of the corpus callosum (CC), using a combination of behavioural, structural MRI and high-density scalp EEG measures. Given the complete disruption of the posterior half of the CC, we speculated that inter-hemispheric transfer of visual information was only possible through top-down mobilization across the preserved anterior segment of the CC. We designed a matching-to-sample visual task during which this patient was randomly presented with two successive numerical targets (T1 and T2) flashed with either a short or a long stimulus-onset asynchrony (SOA), each presented within one visual hemifield (HF). Intra-hemispheric processing of visual stimuli was essentially preserved. In sharp contrast, patient's performance was massively impaired during inter-HFs trials with a short-SOA, confirming the lack of fast inter-hemispheric transfer. Crucially, patient AC spontaneously improved his performance in inter-HFs trials with a long-SOA. This behavioral improvement was correlated with a mid-frontal ERP effect occurring during the T1–T2 interval, concomitant with an increase of functional connectivity of this region with distant areas including occipital regions. These results put to light a slow, non-automatic, and frontally mediated route of inter-hemispheric transfer dependent on top-down control.

1. Introduction

Perception is conceived and theorized as a complex combination of early feed-forward events followed by and rapidly associated with late top-down and recurrent processes. The precise characterization of those elementary mechanisms and their interactions remains a major challenge for psychology and neuroscience. Moreover the impact of various factors such as attention, strategy, learning, motivation or conscious access on bottom-up and top-down processing remains largely debated (Gilbert & Li, 2013). In this context, the exploration of patients suffering from unusual brain lesions may be particularly relevant in order to dissociate these two modes of processing, which are inevitably entangled in healthy subjects. Along those lines, in the present work, we studied a posterior split-brain patient, which allowed us to isolate and characterize both behaviorally and electrophysiologically a pure top-down mobilization of visual information through the preserved anterior portion of the corpus callosum.

1.1. Two routes of inter-hemispheric transfer of visual information

In the intact brain, the inter-hemispheric transfer of information relative to lateralized visual stimuli may proceed through either posterior or anterior sectors of the corpus callosum (Tomita, Ohbayashi, Nakahara, Hasegawa, & Miyashita, 1999). Posterior transfer between sensory cortices is an early, fast and bottom-up process impossible to inhibit through executive control. In contrast, anterior transfer occurs later, supports a more abstract non-sensory format of information, and is subject to top-down task-dependent influences (for a recent review see Van der Knaap & Van der Ham, 2011).

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0028-3932/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.neuropsychologia.2013.11.009

Such dissociation is best illustrated through the study of patients with posterior callosal lesions, in which one may observe both the loss of fast bottom-up transfer, and indices of a slower top-down transfer. Note that selective anterior lesions do not provide symmetrical evidence, as an intact posterior callosum is sufficient to ensure full and immediate access to information to both hemispheres. To give an illustration directly relevant to the paradigm used in the present study, a patient with a small splenial lesion responded rapidly but at chance level when asked to perceptually compare digits presented in opposite HFs (Cohen & Dehaene, 1996). In contrast, she was way above chance when comparing a digit and a set of dots, a task inducing a semantic encoding of stimuli, and allowing the transfer of abstract numerical information through the spared anterior callosum. Similarly, when attempting to read left-HF digits, a task requiring their transfer to the left hemisphere, she performed above chance through a slow guessing strategy, with semantic proximity errors attesting of the transfer of abstract numerical information.

This distinction between two routes of inter-hemispheric transfer is also supported by similar evidence involving visuo-motor information. Thus, (Blangero, Khan, Rode, Rossetti, & Pisella, 2011) explored automatic and intentional visuo-motor abilities in two patients suffering from optic ataxia following lesions to their posterior parietal cortex (PPC). In one experimental condition (trans-saccadic remapping), a visual target was presented laterally to fixation in the contralesional HF, and then disappeared. Patients had then to touch the memorized target position on the tactile-screen, either directly (no transfer required), or after a saccade on a new fixation position in the opposite HF (trans-saccadic remapping across HFs). This fast and automatic inter-hemispheric transfer of visual information was found respected in both patients. In sharp contrast when patients were engaged in an anti-reaching task requiring them to touch manually the screen on a mirror-position of the laterally presented target, they were massively impaired. This suggests that intentional transfer of visuo-motor information relies on a pathway anterior to PPC, most probably engaging the frontal regions and the anterior region of corpus callosum.

Neuropsychological evidence is congruent with data gathered in monkeys. In a seminal study Gazzaniga studied 5 chiasm-sectioned

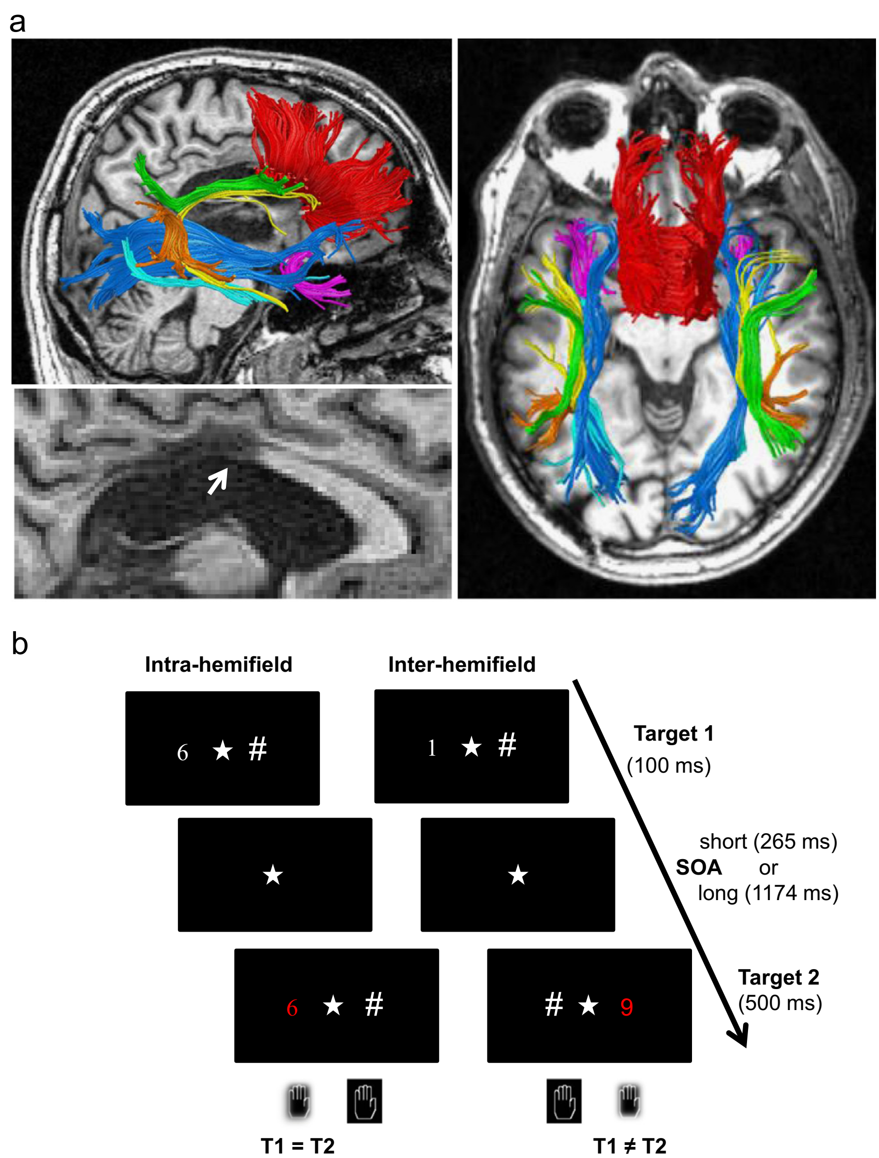

Fig. 1. Callosal lesion and experimental design. (a) T1-weighted structural MRI and DTI reconstruction of the major intra-hemispheric pathways (the 3 segments of the arcuate fasciculus (green, yellow, orange), the inferior fronto-occipital (dark blue), inferior longitudinal (light blue), and uncinate (purple) fasciculi) and the corpus callosum (red), showing the full destruction of the posterior callosum. The lesion appears as a hypointense area in the bottom left panel (arrow). (b) The experimental paradigm consisted in flashing successively two lateral digits, with a short or a long SOA, in a matching-to-sample task with manual responses. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)