Assessing the causal role of early visual areas in visual mental imagery

Paolo Bartolomeo, Dounia Hajhajate, Jianghao Liu and Alfredo Spagna

We read with great interest the review by J. Pearson on visual mental imagery (Pearson, J. The human imagination: the cognitive neuroscience of visual mental imagery. *Nat. Rev. Neurosci.* **20**, 624–634 (2019))[1]. The author outlines a model of visual mental imagery based on neuroimaging findings that involves large-scale brain networks spanning prefrontal areas to sensory areas, and that highlights the activation of occipital areas during visual mental imagery. Specifically, the model indicates that it is the "sensory and spatial representations of the imagery content" that would be formed in early visual areas.

However, individuals with acquired brain damage restricted to the occipital cortex typically have perfectly vivid visual mental imagery. For example, a patient with bilateral strokes in the white matter between the occipital and the temporal cortices[2] had severe visual deficits for object form and colour, faces, words and letters but demonstrated perfectly preserved visual mental imagery abilities for these same items[3]. In addition, people with cortical blindness due to bilateral occipital lesions can experience vivid visual mental images[4,5].

By contrast, patients with damage extending anteriorly in the temporal lobe, especially in the left hemisphere, often find themselves unable to build visual mental images[6,7]. Where does the discrepancy between the neuroimaging and neuropsychological findings come from? The neuroimaging results supporting the hypothesis of an implication of early visual areas are correlative in nature, whereas deficits in people with brain injury demonstrate a causal contribution of the lesioned circuits to the relevant cognitive ability (it is true that transcranial magnetic interference on the primary visual cortex was shown to impact visual mental imagery[8], but this effect might depend on modulation of downstream visual areas).

A recent case report[9] provided more specific evidence on the neural bases of visual mental imagery. After a bilateral stroke in the territory of the posterior cerebral artery, an architect, who before the stroke could easily imagine objects and buildings, spontaneously reported to have become unable to visualize items. By comparing his lesion location with those of other individuals with strokes in the same arterial territory, the authors found that the architect had selective damage in the left fusiform gyrus, a region in the ventral temporal cortex. The left temporal location is consistent with previous reports of individuals with impaired mental imagery after stroke[6,7]. During perception, this fusiform region might act as a neural interface between sensory information coming from the occipital cortex and semantic processing in the anterior temporal lobe[10]. In visual mental imagery, it could endow semantic memories with visual information. Taken together, the results from brain-damaged persons invite a revision of the neural model of visual mental imagery proposed by Pearson[1], whereby fronto-parietal networks initiate, modulate and maintain activity in a core left temporal network centred on high-level visual regions in the ventral temporal cortex, with no causal role of early visual cortex.

There is a reply to this letter by Pearson J. *Nat. Rev. Neurosci.* https://doi.org/10.1038/s41583-020-0349-4 (2020).

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Competing interests
The authors declare no competing interests

Reply to: Assessing the causal role of early visual areas in visual mental imagery

Joel Pearson

In a recent review paper[1], I outlined a model of visual mental imagery proposing a reverse visual hierarchy starting from prefrontal areas back to sensory areas.

I would like to thank Paolo Bartolomeo, Dounia Hajhajate, Jianghao Liu and Alfredo Spagna for their correspondence on our Review (The human imagination: the cognitive neuroscience of visual mental imagery. *Nat. Rev. Neurosci.* **20**, 624–634 (2019))[1], which raises some important issues (Assessing the causal role of early visual areas in visual mental imagery. *Nat. Rev. Neurosci.* https://doi.org/10.1038/10.1038/s41583-020-0348-5 (2020))[2].

Neuropsychological work reports that individuals with visual cortex damage can show some imagery-like processes without perception[3,4], while damage to the temporal lobe can correspond to a lack of imagery/memory abilities[5,6]. Further, individuals with aphantasia (no imagery vividness or sensory imagery)[7,8] show normal sensory perception (although this is yet to be tested in detail), suggesting a general dissociation, and has been linked to areas outside of early visual cortex[9]. Based on these reports Bartolomeo et al., suggest a revision to the reverse visual hierarchy model I described, without a causal role of early visual cortex. Here I outline three reasons why this is not required.

Much of the neuropsychological work on imagery is actually correlational, often documented brain injury is correlated with