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R. N. Aslin

Visual Imagery, Neural Basis of

Human thought makes use of different forms of mental representation; some language-like and some more visual or spatial. The term 'mental imagery' refers to the latter. It plays a central role in many cognitive abilities, from creative problem solving to strategies for improving memory. This article will review the current state of knowledge on the neural bases of mental imagery, beginning with the controversies in cognitive psychology that motivated the neuroscience research.

1. Imagery, Verbal Thought, and Perception

Much of the early history of imagery research was devoted to discriminating imagery from verbal thought, and characterizing some of its differences in functional information-processing terms. Allan Paivio (e.g., 1971) addressed these issues within the context of memory research. He demonstrated that, in ostensibly verbal learning tasks, imagery affected memory encoding. Though a program of research in which subjects learned words, which either lent themselves to concrete images or not (e.g., banana vs. vacation), with or without imagery instructions, he gathered evidence in support of a 'dual coding hypothesis.' According to this hypothesis, imagery and language are two distinct forms of mental representation. Imagery was therefore helpful in verbal memory tasks because, in effect, it doubled the number of representations being stored.

A challenge to this view came from Zenon Pylyshyn (1973), who questioned the computational feasibility of storing visual images, and raised a number of issues concerning the role of imagery phenomenology in the information processing that underlies thought. This challenge brought an empirical response from Stephen Kosslyn (e.g., 1978), who devised experimental tasks in which the visual-spatial properties of images could be shown to affect subjects' information processing. For example, when subjects focus their attention on one location within an image, and then shift to a different location, the time taken to shift is directly proportional to the imagined distance (Kosslyn et al. 1978). Findings from the laboratory of Roger Shepard also supported the visual-spatial nature of imagery. In mental image rotation experiments, images took more time to rotate through larger angles (Cooper and Shepard 1973).

As evidence accumulated that imagery is a distinct form of mental representation from linguistic or propositional thought, the question of its relation to visual perception came to force. Early work on this topic was pioneered by Ron Finke (e.g., 1980), who demonstrated many detailed and striking similarities between mental images and percepts. For example, he reported that mental images had similar-shaped fields of resolution to the perceptual visual field.

2. Image Representation: Insights from Neuroscience

The relation between imagery and perception can also be assessed in terms of their respective neural substrates. Indeed, many of the alternative interpretations that plagued the purely behavioral approaches to

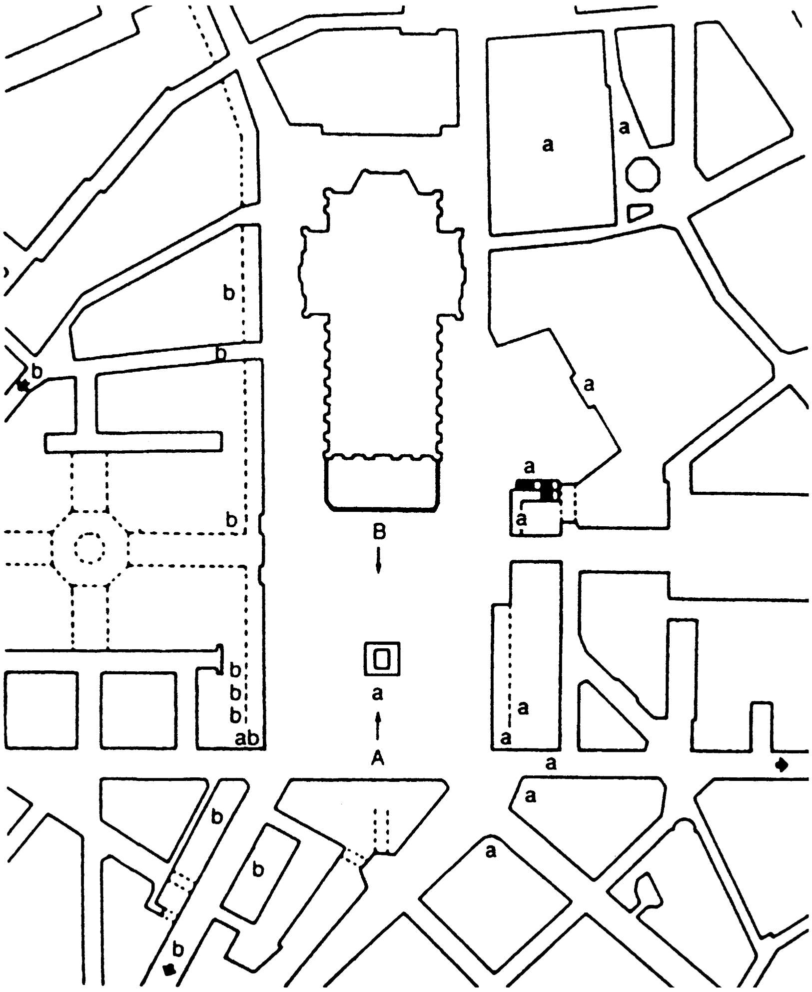

Figure 1
A map of the Piazza Del Duomo in Milan. When patients with left neglect were asked to imagine themselves standing at point A looking toward the cathedral, and to report what they saw in their 'mind's eye,' the locations they mentioned were those marked with 'a.' When they repeated the procedure from the vantage point B, they then mentioned the locations marked with a 'b.' (Source: Farah M J 1999 The neural basis of mental imagery. In: Gazzaniga M S (ed.) *The New Cognitive Neurosciences*. MIT Press, Cambridge, MA.)

mental imagery did not apply to the neural data. An initial review of the literature on imagery and the brain, motivated by the need for more decisive evidence concerning the imagery–perception relation, uncovered a variety of relevant findings (Farah 1988). These included numerous findings of parallel impairments of imagery and perception after brain damage, which suggest that the same underlying representations are needed for both.

In one of the best-known demonstrations of parallel impairments in imagery and perception. Bisiach and Luzzatti (1978) found that patients with hemispatial neglect for visual stimuli also neglected the contralesional sides of their mental images (that is, the side of their image opposite the side of their brain lesion). Their two right-parietal-damaged patients were asked to imagine a well-known square in Milan, shown in Fig. 1. When they were asked to describe the scene from vantage point A on the map, they tended to name more landmarks on the cast side of the square (marked with lower case a's in the figure); that is, they named the landmarks on the right side of the imagined scene. When they were then asked to imagine the square from the opposite vantage point, marked B on the map, they reported many of the landmarks previously omitted (because these were now on the right side of

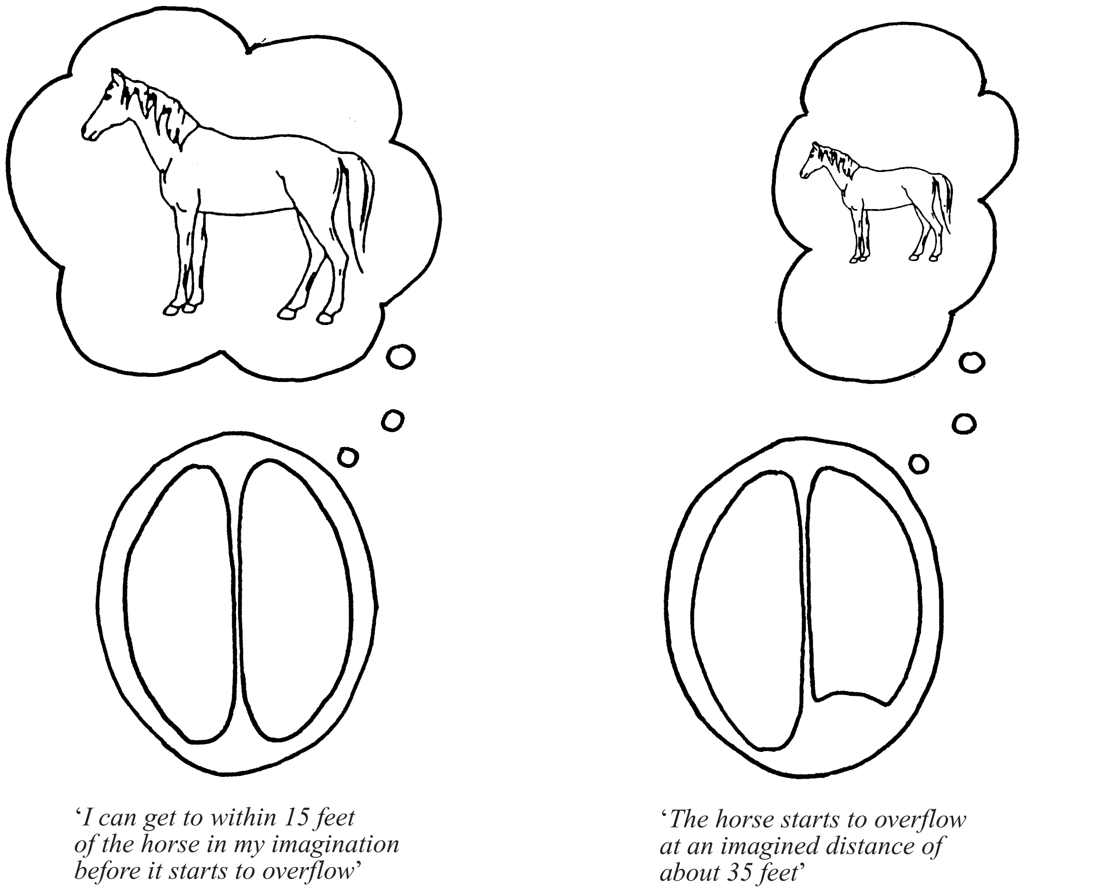

Figure 2
Depiction of the effects of unilateral occipital lobectomy on the visual angle of the mind's eye. (Source: Farah M J 1999 The neural basis of mental imagery. In: Gazzaniga M S (ed.) *The New Cognitive Neurosciences*. MIT Press, Cambridge, MA.)

the image) and omitted some of those previously reported.

Imagery and perception also share representations at relatively early stages of visual processing. This point was demonstrated by a patient with blindness in half of her visual field following occipital resection (Farah et al. 1992). If mental imagery consists of activating representations in the occipital lobe, then it should be impossible to form images in regions of the visual field that are blind due to occipital lobe destruction. This predicts a reduced maximum image size, or visual angle of the mind's eye, in this patient. By asking her to report the distance of imagined objects such as a horse, breadbox, or ruler when they are visualized as close as possible without 'overflowing' her imaginal visual field, one could compute the visual angle of that field before and after her surgery. It was found that the size of her biggest possible image was reduced after surgery, as represented in Fig. 2. Furthermore, the separate measurement of maximal image size in the vertical and horizontal dimensions showed that only the horizontal dimension of her imagery field was reduced significantly. These results provide strong evidence for the use of occipital visual representations during imagery.

The results of functional neuroimaging studies in normal subjects have been, on the whole, supportive of shared representations for visual mental images and percepts. Early studies with event-related potentials (e.g., Farah et al. 1989) and SPECT (e.g., Goldenberg et al. 1989) implicated a cortical visual locus and, as newer methods allowed better localization, it has been possible to test far more specific hypotheses concerning the precise areas within visual cortex that are recruited for mental imagery (Kosslyn and Ochsner 1994; Roland and Gulyas 1994).

3. Brain Systems for Image Generation

If imagery consists of activating some of the same cortical visual areas used for perception, this raises the question of how these representations become activated in the absence of a stimulus. Whereas one cannot see a familiar object without recognizing it, one can think about familiar objects without inexorably calling to mind a visual mental image. This suggests that the activation of visual representations in imagery is a separate voluntary process, needed for image generation but not for visual perception and object recognition.

Neuropsychological evidence for such a process comes from patients whose perception and general memory are preserved, but who cannot visualize objects or scenes from memory. This is the profile of abilities that would be expected given an impairment of image generation *per se*. A number of such cases have been reported in the neurological literature, with lesions generally being located in the posterior left hemisphere. In one such case (Farah et al. 1988), the imagery impairment was demonstrated in a number of ways, including a sentence verification task developed by Eddy and Glass (1981). Half of the sentences required the use of visual imagery to verify them (e.g., 'A grapefruit is larger than a cantaloupe'), and half did not (e.g., 'The US government functions under a two-party system'). Eddy and Glass had shown that normal subjects find the two sets of questions to be of equal difficulty (as did right-hemisphere-damaged control subjects tested by Farah et al. 1988), and that performance on the imagery questions was impaired selectively by visual interference, thus validating them as imagery questions. RM showed a selective deficit for imagery on this validated task: He performed virtually perfectly on the nonimagery questions, and performed significantly worse on the imagery questions.

RM was also tested on imagery for the colors of objects, using black and white drawings of characteristically-colored objects (e.g., a cactus, an ear of corn) for which he was to select the appropriate colored pencil. His imagery was further tested with drawing tasks. By these measures, too, his imagery was poor, despite adequate color perception and object recognition ability.

In subsequent years, a small number of additional cases of image generation deficit have been reported (e.g., Goldenberg 1992, Grossi et al. 1986, Riddoch 1991), as well as similar but weaker dissociations in subgroups of patients in group studies (Bowers et al. 1991, Goldenberg 1989, Goldenberg and Artner 1991, Stangalino et al. 1995).

What parts of the brain carry out image generation? This question has evoked controversy. Although mental imagery was for many years assumed to be a function of the right hemisphere, Ehrlichman and Barrett (1983) pointed out that there was no direct evidence for this assumption. Most of the patient-based research supports a left-hemisphere basis for image generation (see Tippett 1992, Trojano and Grossi 1994 for reviews; see Sergent 1990 for a different position). However, for questions of localization, we can also turn to functional neuroimaging.

Not all neuroimaging studies of visual imagery are appropriate for localizing image generation *per se*. The study must be designed in a way that can isolate this process, separated from perceptual and memory processing more generally. A large number of studies do meet this criterion, including those done with ERP, SPECT, PET and fMRI (see Farah 1999 for a review); in most cases, but not all, foci of activity are observed in the left inferior temporo-occipital region.

Although the bulk of evidence favors a left-hemisphere superiority for image generation, it also suggests that in most individuals both hemispheres possess some image generation ability. This hypothesis explains both the rarity of cases of image generation deficit after brain damage, as well as the asymmetries observed in neuroimaging studies, and the fact that when impairments are observed after damage, the left or dominant hemisphere is implicated.

See also: Imagery versus Propositional Reasoning; Mental Imagery, Psychology of; Perception: Philosophical Aspects; Perceptual Organization; Vision, Psychology of; Visual Perception, Neural Basis of; Visual System in the Brain

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M. J. Farah

Visual Images in the Media

Effects in the media of the visual image (i.e., a reproduced sight) are central to a debate which typically contrasts the properties of image and word. Here, that debate is tracked across three key areas: child literacy and education, commercial and political persuasion, and issues surrounding news.

1. Visual Images vs. the Word

The world is filled with visual images. Images appear on television and movie screens, billboards, posters, magazines, newspapers, and computer monitors. Increasingly, it is argued that the word, once the dominant medium, is being supplanted by the image. Civilization has taken, in Mitchell's phrase, a 'pictorial turn' (Mitchell 1994).

The visual image has been the subject of research across a range of academic disciplines. In recent years, the emphasis has moved away from theories of art towards a psychosocial perspective that draws on research from semiotics, branches of psychology, sociology and communications, and cultural theory (see *Semiotics*; *Mass Media: Introduction and Schools of Thought*; *Media Effects*; *British Cultural Studies*).

In part, this research has been driven by a longstanding debate over the social implications of the image. Often, this has centered on controversies that surround certain visual media; most prominently, racial and gender stereotyping, sexually-explicit material, and violence as depicted on television, film, and in computer games (see *Mass Media, Representations in*; *Pornography*; *Violence and Media*; *Media Effects*; *Computers and Society*). However, this debate has also been advanced as an opposition between the qualities and social effects of the word or text, and those of the image, with the former typically being privileged over the latter.

1.1 History of the Debate

The premise on which this debate turns is the superiority of text over image, a bias informed by an intellectual tradition that stretches back centuries (for a detailed discussion, see Stephens 1998). The Bible, in associating the Word with creation in Genesis, while forbidding the production of the 'graven image or any likeness', has long been used to support this presumption. Even as the image has established itself at the center of Western culture, writers and philosophers from Plato to contemporary thinkers have remained critical of the qualities and effects of the image compared with those of the word.

This intellectual antipathy is prompted by a series of overlapping concerns. Partly, it is founded on a longstanding suspicion of verisimilitude. In one view, such a capturing of likeness evokes a high degree of 'truth.' It is this perspective that typically reflects a traditional, although now contested, history of art as the progress of visual reproduction towards an ever more accurate reflection of the natural world, an ideal established by the Romans, and one that finds its most perfect expression in the photographic process.

However, verisimilitude has also driven a more negative perspective; that what the visual image offers is not truth but seductive illusion. A painter, Plato

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