Visual Imagery and Visual Perception:

The Role of Memory and Conscious Awareness

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Introduction

This review addresses several aspects of visual imagery, as an example for the interactions between perception, memory and consciousness[1]. Visual imagery is the natural ability to invent or recreate an experience that resembles the experience of actually perceiving an object or an event, in the absence of retinal input. Visual imagery and perception share several functional properties, and apparently share common underlying brain structures. The involvement of cortical structures common to visual imagery and perception is supported by studies on evoked potentials (Farah et al., 1988), regional cerebral blood flow (Goldenberg et al., 1989), positron emission tomography (Kosslyn et al., 1993; Kosslyn et al., 1995; Roland et al., 1987; Roland and Gulyas, 1995), and functional magnetic resonance imaging (Bihan et al., 1993). Neuropsychological case studies provide support for the hypothesis that visual imagery and perception share the same neural substrate (Bisiach and Luzzatti, 1978; Mehta et al., 1992), yet brain-damaged patients with double dissociation between imagery and perception may reflect the fact that the visual areas subserving visual imagery are a subset of those active in visual perception (Behrmann et al., 1992; Jankowiak et al., 1992). Data indicating activity in early visual areas during visual imagery suggest that identical visual areas subserve both systems (Bihan et al., 1993; Kosslyn et al., 1995). However, these areas are not activated during visual imagery in all subjects, and are activated mainly by tasks that require high-resolution images (Roland and Gulyas, 1994; Sakai and Miyashita, 1994).

The effect of visual imagery on visual perception is controversial. Many studies show that imagery interferes with perceptual processes. An early study by Perky (1910) has demonstrated that when subjects were told to imagine looking at an object (such as a banana) on a supposedly blank screen while actually being shown a faint picture of the object, the object was not seen (Perky, 1910). Segal and Fusella (1970) have found that

[1] What we mean by consciousness in this chapter is the ordinary language sense of the relation between an observer and a phenomenon; someone is aware of something.

perceptual sensitivity was maximally reduced when the modality of the image matched that of the target - it was harder to detect a faint geometric form when imagining a visual scene than when imagining a familiar sound (Segal and Fusella, 1970). Craver-Lemley and Reeves (1987) have explored the imagery-induced interference (so called 'Perky effect') with a vernier acuity task. Imagery of vertical or horizontal lines affected performance, but only when the image overlapped or was very close to the target (Craver-Lemley and Reeves, 1987). Imagery reduces visual acuity by reducing sensitivity - that is, imagery reduces the target energy in the region of the visual field where the images are located (Craver-Lemley and Reeves, 1992).

Can visual imagery facilitate visual perception? Neisser (1976) has proposed that images generally function as perceptual "anticipations" - imagining an object would speed up perception by initiating the appropriate perceptual processes in advance (Neisser, 1976). Farah (1985) has shown that subjects were more accurate in detecting letters (H or T) when images of the letters matched the targets in both shape and location, relative to the control condition, in which detection was performed without imagery (Farah, 1985). However, the facilitation effect was probably due to a spatially localized shift of criterion rather than to a change in sensitivity (Farah, 1989). Thus, facilitation may reflect processes other than changes in visual sensitivity. McDermott and Roediger (1994) have reported that imagery can promote priming on implicit memory tests. Imagery produced selective facilitation - imagining *pictures* primed picture fragment identification but not word fragment completion, whereas imagining *words* primed word fragment completion but not picture fragment identification (McDermott and Roediger, 1994).

Recently, we have explored, psychophysically, the interactions between visual imagery and visual perception, using a lateral masking detection paradigm (Ishai and Sagi 1995, 1996a, 1996b). We review here results showing that imagery-induced facilitation and interference are memory dependent: image generation from long-term memory (LTM) interferes with perception, while on short-term memory (STM) tasks facilitation can be obtained. We discuss the implication for memory representation, and the role of conscious awareness.

Imagery-Induced Facilitation is Mediated by Short-Term Memory

The psychophysical paradigm was a detection task of a foveal Gabor target, flanked by Gabor masks placed at different eccentricities (for a detailed description of the experimental procedure see Ishai and Sagi 1995, 1996b). Observers were instructed to perform the detection task under three different conditions: perception condition, in which the target was flanked by the masks; control condition, in which the masks were excluded; and imagery condition, in which observers were instructed to imagine the absent Gabor masks while detecting the isolated target. Each experiment included alternating tasks of either perception followed by control, or perception followed by imagery. The stimulus is shown in Figure 1. The results were surprising. As was previously reported, the presence of the flanking masks at an optimal distance enhanced the detection of the target (Polat and Sagi, 1993). As figure 2 shows, in the perception condition a threshold reduction was seen. In the control condition, where no masks were presented, contrast thresholds were slightly higher than the baseline threshold. In the imagery condition, where observers were imagining the absent masks, a threshold reduction was obtained (Ishai and Sagi, 1996b). It is worth mentioning that the only difference between the control and imagery conditions was the instruction to imagine the previously presented masks (physically, in both conditions the same stimulus was presented, i.e. a single Gabor target). The imagery instruction had a surprising effect of reducing target threshold. When observers were aware of the flanking masks in the imagery experiment, they were able to detect the target better, yet when awareness was not required during the control experiments, the perceived masks had no effect on target threshold.

The imagery-induced facilitation shares similar characteristics with the perceptual enhancement and is subserved by a stimulus-specific short-term memory (Ishai and Sagi 1995, 1996b). The memory trace is specific to the orientation of the stimulus, as well as to the eye used in the task. When a vertical target is flanked by horizontal masks, no facilitation is obtained in both perception and imagery tasks. Moreover, when the perceptual task is performed with one eye covered and the imagery task with the other eye covered, the imagery-induced facilitation disappears (Ishai and Sagi 1995, 1996b). The imagery-induced facilitation is based on recent memory established a few minutes prior to the imagery task. Introducing a delay period, longer than 5 minutes, between the perceptual and imagery tasks reduces the imagery-induced facilitation (Ishai and Sagi, 1995). The necessity of performing the perceptual task before the imagery task, together with the stimulus-specificity of the effect, indicate the involvement of short-term memory. Interestingly, the existence of this low-level memory system, which stores the images and enables re-activation of quasi-pictorial representations by top-down processes, is exposed only when conscious awareness is required.

Imagery-Induced Interference is Mediated by Long-Term Memory

Using the lateral masking paradigm we have found an imagery-induced facilitation, yet no interference (e.g. Perky effect) was seen, even when observers imagined Gabor stimuli on top of the Gabor target (Ishai and Sagi 1995, 1996b). In an attempt to obtain an imagery-induced interference, we introduced a new experimental procedure. Observers had to detect a vertical Gabor target under three conditions: control, imagery of vertical lines, and imagery of horizontal lines. Before the imagery experiments, observers were presented with a picture of vertical and horizontal lines. Surprisingly, an orientation-specific interference was seen: imagery of vertical lines elevated target threshold, yet imagery of horizontal lines had no effect on target threshold (Ishai and Sagi, 1996a). Note, again, that the only difference between the imagery and control conditions was the instruction to the observer. This Perky effect could have been due to the imaginary lines, as opposed to the imaginary Gabor stimuli, or, alternatively, could have been due to the experimental procedure - generation of line images from LTM, as opposed to STM. To test this hypothesis, additional experiments were designed. Observers had to detect a Gabor target with *vertical lines* superimposed on it in the perception condition, to detect an isolated target in the control condition, and to imagine the absent lines in the imagery condition. Each experiment included alternating tasks of either perception followed by control, or perception followed by imagery. The results show that the presence of the lines in the perceptual task increased target threshold, yet imagery of the absent lines had no effect on target threshold (Ishai and Sagi, 1996a). Thus, when the imaginary lines were generated from STM, as opposed to LTM, no interference was seen. Interestingly, when observers detected a vertical target in the presence of *horizontal* lines in the perception conditions, and were instructed to imagine *vertical* lines in the following imagery task, a threshold elevation was obtained (Ishai and Sagi, 1996b). These results indicate an interactions between STM and LTM.

It is possible that the lines create an excitatory trace in STM, balancing the inhibitory effect of generating images from LTM. Is this additivity specific for imaginary lines, or is it a general characteristic of visual memory systems? To test the additivity hypothesis, observers performed the detection task of a vertical Gabor target, flanked by peripheral Gabor masks at a distance of 3λ [previously we have shown that the optimal target-to-mask distance created an excitatory trace that subserved the imagery-induced facilitation (Ishai and Sagi 1995, 1996b)]. In the following imagery task, observers imagined vertical lines. The results were surprising: while the standard enhancement was obtained in the perception condition, imagery of vertical lines did not have a suppressive effect on target threshold, although the task required image generation from LTM (Ishai and Sagi, 1996a).

It seems that indeed some mechanisms of comparing and subtracting the present input and the representation in LTM are involved - when an excitatory trace is created in STM, the suppressive effect of generating images from LTM is reduced. When the imagery task is purely based on LTM, the maximal interference is seen. A summary of the results from the imaginary lines experiments is shown in Figure 3. These findings imply interactions between actual inputs and stored representations, which may subserve object recognition. Moreover, the differences between image generation from LTM, as opposed to STM, and the differences between lines and Gabor stimuli, suggest that short-term visual memory maintains low-level descriptions, while long-term visual memory preserves structural descriptions.

Summary

Using alternating tasks of perception followed by control, or perception followed by imagery, we have exposed a low-level memory system that subserves the imagery-induced facilitation (Ishai and Sagi 1995, 1996b). In our experiments the only difference between control and imagery conditions was the instruction given to observers. While in the control task detection of an isolated Gabor target was required, in the imagery task also awareness to the previously presented flanking masks was necessary. Surprisingly, we have discovered a stimulus-specific STM trace that enables reduction in target threshold only in the imagery tasks. The memory trace was accumulated during the perceptual tasks (Ishai and Sagi 1995, 1996b), yet only the imagery instruction enabled access to this trace. In order for visual imagery to facilitate visual perception conscious awareness of observers to the perceptual input is needed.

An imagery-induced interference was obtained when observers generated line images from LTM, but not STM (Ishai and Sagi, 1996a). The differences between lines and Gabor stimuli, as well as the differences between image generation from LTM and STM, support the idea of two types of representation in visual memory. In STM tasks the visual system utilizes low-level representations (Gabor), while in LTM tasks structural descriptions of common objects (lines) are dominant. These two representations are interfaced at some visual processing module, maybe at the so called 'visual sketch-pad' (Baddeley, 1986).

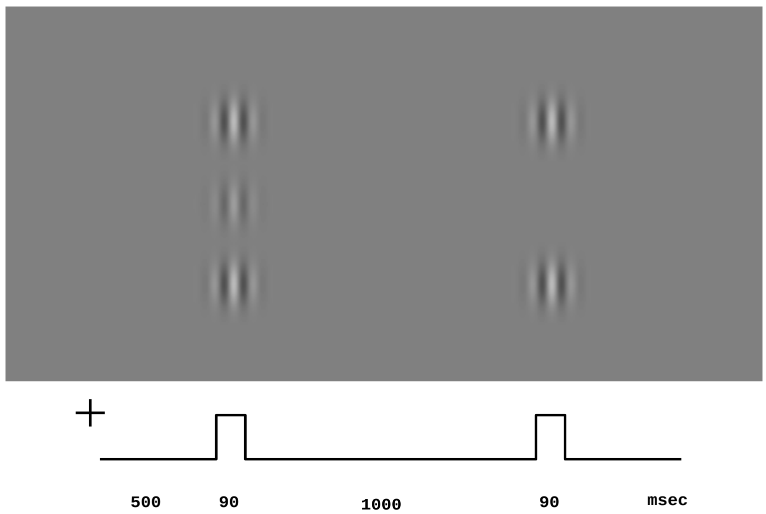
We have suggested that our data provide psychophysical evidence for the involvement of early visual areas in visual imagery, due to low-level features of the effect: orientation-specificity, monocularity and locality (Ishai and Sagi 1995, 1996b). Crick and Koch (1995) have hypothesized, based on macaque monkey neuroanatomy and human psychophysics, that there is no conscious visual awareness in the primary visual area V1. However, they note that these "...ideas would not be disproved if it were shown convincingly that (for some people) V1 is activated during visual imagery tasks. There is no obvious reason why such top-down effect should not reach V1. Such V1 activity would not by itself prove that people are directly aware of it" (Crick and Koch 1995, p. 123). We believe that visual imagery can influence low-level perceptual processes when conscious awareness is involved. Further physiological and neuroimaging studies are needed to elucidate the neural correlates of visual awareness.

Figures

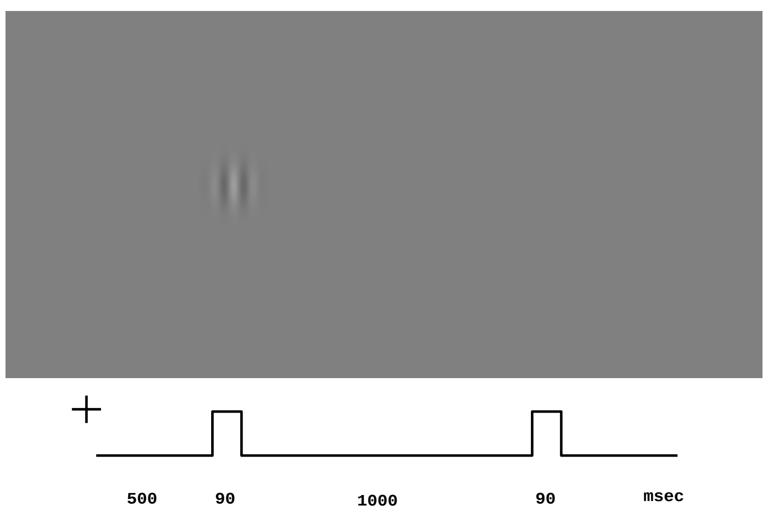
Figure 1 Temporal sequence of a trial. **A)** A foveal Gabor target flanked by two high-contrast Gabor masks, at a distance of 3λ, used for the perception condition. Observers had to detect the target in the presence of the peripheral masks. **B)** An isolated Gabor target used for the control and imagery conditions. In the imagery experiments observers detected the isolated target while imagining the absent peripheral masks.

Figure 2 Enhancement area, averaged across six observers. The area from 2 to 12λ was computed for each session. The imagery-induced facilitation was 50% relative to the perceptual enhancement. In control condition contrast threshold was slightly higher than baseline threshold, due to the lack of any cue on the screen.

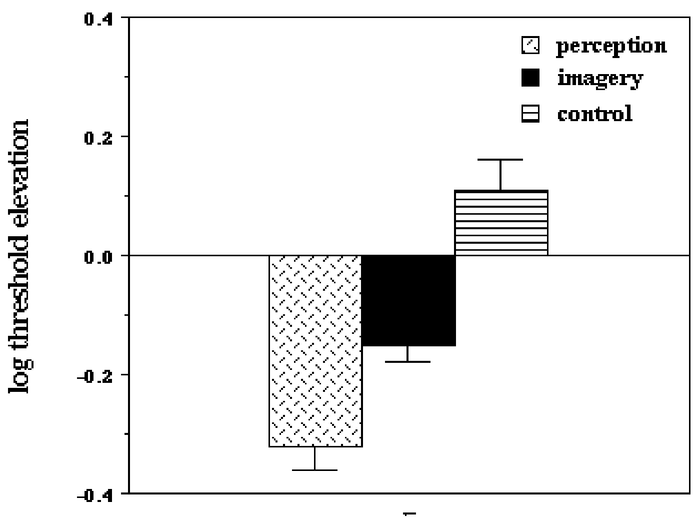
Figure 3 Effects of imaginary vertical lines on target threshold of a vertical Gabor signal. Imagery-induced interference was maximal when line images were generated from long-term memory. Excitatory trace in short-term memory (produced by either lines or Gabor stimuli) reduced the effect.



A



B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0.2
0.0
-0.2
-0.4
log threshold elevation
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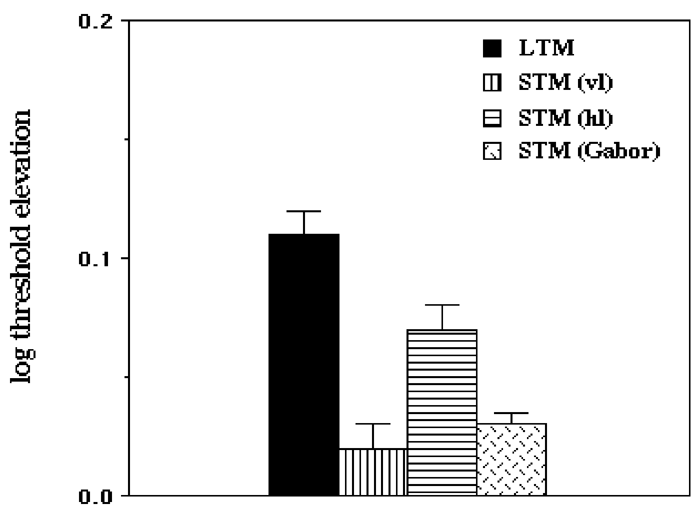
control


0.2
0.1
0.0
log threshold elevation
LTM
STM (vl)
STM (hl)
STM (Gabor)

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