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Our brains continuously transform the sensory information we encounter into meaningful perceptions. Thus, points of lights turn into colorful three dimensional structures, often carrying some emotional significance when perceived to match a memory stored image. What transforms the apparently meaningless patterns of light into familiar shapes? How does the brain organize the incoming information and transform physical entities into perceptual objects? We try to understand brain processes involved in visual transformations, such as encoding sequences of line points into curves, curves into shapes, and shapes into recognizable images. Though these processes are mostly visual, we find they also make use of more general brain functions, such as information chunking, learning and memory, that are employed by other brain faculties. Transforming light into images may not be a very different task from transforming sound waves into music or ideas into thoughts.

Toward achieving the goal of understanding human vision we use psychophysical methods, in an attempt to quantify perceptual and cognitive abilities. Though human brains are not accessible for direct activity measurements, much of its logic can be uncovered by measuring human performance in well controlled settings. For example, our inability to discriminate between some color mixtures (red+green = yellow) puts constraints on models of color processing, and detailed experiments can be carried out to further understand the

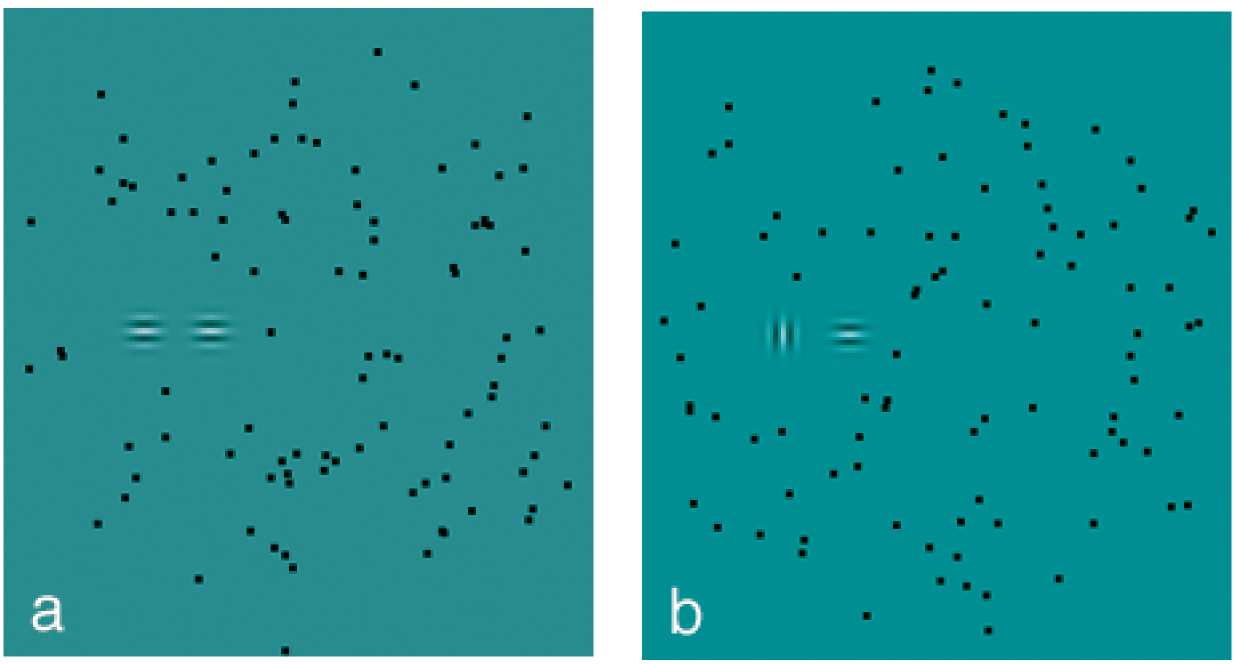

Fig. 1 *Visual objects we perceive are generated by subconscious processes that select the relevant image parts defining the object. Selection is based on "perceptual organization" laws making use of geometrical relationships and stored associations (experience). In a typical environment multiple objects compete for conscious access, with only one object gaining access at a given time. Here, movement of the black dots puts the visual system into a "limited access" mode, slowing down the competition. As a result, the two aligned Gabor patches (a) tend to disappear and re-appear together while the orthogonal patches (b) compete. To experience the effect download a demo from www.weizmann.ac.il/~masagi/MIB and fixate your eyes steadily at the center of the rotating sphere (Bonneh, Cooperman & Sagi, 2001).*

way we see colors. In a similar way, we try to understand processes involved in pattern vision, by manipulating specific shape components. We design computer generated displays aimed at testing human performance on well defined detection and discrimination tasks, with targets being carefully selected to probe brain processes such as image segmentation, perceptual organization, learning, attention and mental imagery.

As our visual system is constructed from many interacting modules, each dealing with a different aspect of the visual task, we made a strategic decision to start from relatively simple low level processes involved in image segmentation. These processes, probably residing at the entrance stage of the visual cortex, were believed to be devoid of cognitive intervention, and indeed we could successfully model their performance on texture segmentation and perceptual grouping tasks by using simple localized image-analyzers with lateral excitatory and inhibitory interactions. The architecture of these interactions was explored using contrast detection tasks. However, it became evident that performance on these texture tasks improves with time, pointing toward learning effects. Further experiments provided evidence for a genuine learning process, probably governed by associative rules, occurring at an early stage of visual processing. Our extended knowledge of segmentation processes contributed here to develop an understanding of the learning process and to quantify some learning abilities. Recently we could also demonstrate a cognitive modulation of lateral interactions by using mental imagery (as in trying to imagine a visual object).

Current research emphasizes global processes within early vision and plasticity of the system. The visual system is studied using a neuronal network approach with basic units (receptive fields) having mutual excitatory and inhibitory interactions. In the experiments, we measure local contrast discrimination thresholds when the target's visual context (neighboring stimuli) is manipulated. The results show a nontrivial dependence on the number of context elements, with spatial oscillations. Of particular interest the stability of local network nodes in the absence of context, even with extended periods of practice. This stability is lost when contextual elements are present, with the local node entering a 'learning' mode. We also find a strong dependency on the relevance of the visual context for the task, pointing toward selection processes (attention) that modulate the efficacy of network connections. Attention seems to have a critical role in the generation of memory traces leading to long-term modifications of connectivity.

Selected Publications

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