Visual Perception & Psychophysics

Department of
Neurobiology

Prof. Dov Sagi

Dr. Yoram Bonneh,
Dr. Alexander Cooperman,
Nitzan Censor, Sharon Gilad,
Tomer Livne, Ido Zak

972 8 934 3747
FAX 972 8 934 4131
Dov.Sagi@weizmann.ac.il
www.weizmann.ac.il/~masagi

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, decision making, learning and memory that are employed by other brain faculties.

Perceiving images from light may not be very different from perceiving music from sound or from the creation of mental concepts from information external to the brain.

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 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, memory and decision.

As visual perception involves many interacting processes, each dealing with a somewhat 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

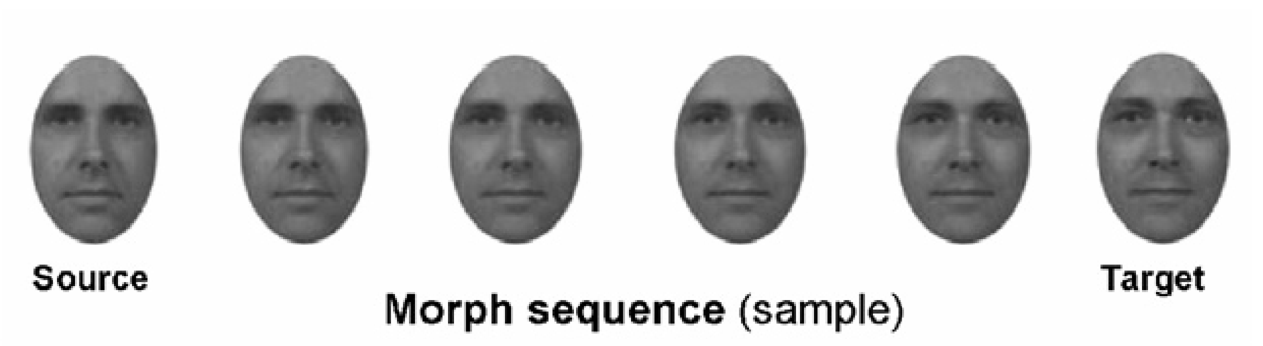

__Fig. 1__ In one experiment we exposed observers to many presentations of face stimuli which were gradually changed between presentations from one face (source) to another (target). These presentations (0.2 sec each) were separated by presentations of other faces. Local differences within the sequence were largely unnoticed. Experimental results showed that such an exposure dramatically change our memory and perception of the experienced faces. Source and target faces which were initially perceived to be different were judged to be the same after training and their identities were confused. Such a result was not obtained with random ordering of stimuli. We believe that such confusion takes place in real life when we are exposed to gradual changes of aging people, or more generally to gradual changes in cognitive concepts as in art and culture (Preminger, Sagi & Tsodyks, Vision Research 2007). The experimental results motivated a new model for learning in neuronal networks (Blumenfeld, Preminger, Sagi & Tsodyks, Neuron 2006).

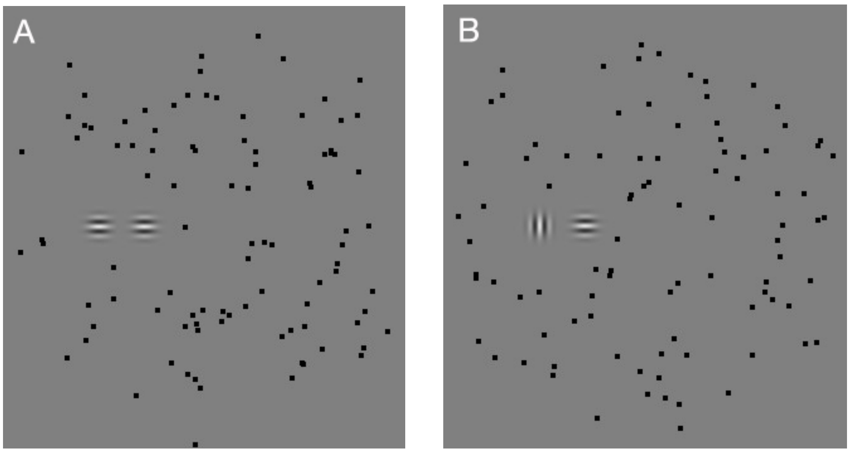

Fig. 2 *Visual objects we perceive are generated by subconscious processes that select the relevant image parts defining the object. Selection is based on "perceptual organization" laws that make use of geometrical relationships and stored associations (experience). In a typical environment multiple 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 on the left (a) tend to disappear and re-appear together while the orthogonal patches on the right (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).*

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. Such interactions underlie our ability to group local perceptual elements to form low-level visual objects. Recently we were able to show that such objects have an important role in perceptual crowding, a well known visual effect which limits our ability to identify form (e.g. a letter) in the presence of neighboring elements (such as when a letter is embedded in a word). In the psychophysical experiments, we measure local contrast and orientation discrimination-thresholds when the target's visual context (neighboring stimuli) is manipulated. The results show a nontrivial dependence of detection and discrimination on spatial context.

Of particular interest is the stability of local network nodes in the absence of interacting visual objects, even with extended periods of practice. This stability is lost when contextual elements are present, with the local nodes 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. Using psychophysical and electrophysiological (EEG) we study the different processes taking part in perceptual learning, including memory consolidation, the transition between the immediate perceptual activity and long-term memory, with a particular emphasize on the role of sleep in memory stabilization. Our recent results show that sleep has a particularly important role in consolidating the results of efficient learning before reaching saturation due to over training. Overall, these results show that the visual system is constantly rewired to accommodate behaviorally relevant changes in the environment.

Selected publications

D. Sagi and B. Julesz (1985) ``Where" and ``What" in Vision. Science, 228, 1217-1219.

D. Sagi and B. Julesz (1987) Short-Range Limitation on Detection of Feature Differences. Spatial Vision, 2, 39-49.

B.S. Rubenstein and D. Sagi (1990) Spatial variability as a limiting factor in texture discrimination tasks: Implication for performance asymmetries. Journal of the Optical Society of America A, 7, 1632-1643.

A. Karni and D. Sagi (1991) Where practice makes perfect in texture discrimination: Evidence for primary visual cortex plasticity. Proceedings of the National Academy of Sciences USA, 88, 4966-4970.

U. Polat and D. Sagi (1993) Lateral interactions between spatial channels: suppression and facilitation revealed by lateral masking experiments. Vision Research, 33, 993-997.

D. Sagi and D. Tanne (1994) Perceptual learning: Learning to see. Current Opinion in Neurobiology, 4, 155-159.

U. Polat and D. Sagi (1994) Spatial interactions in human vision: from near to far via experience dependent cascades of connections. Proc National Academy of Sciences USA, 91, 1206-1209.

A. Karni, D. Tanne, B.S. Rubenstein, J.J.M. Askenasy and D. Sagi (1994) Dependence on REM sleep of overnight improvement of a perceptual skill. Science, 265, 679-682.

A. Ishai and D. Sagi (1995) Common Mechanisms of Visual Imagery and Perception. Science, 268, 1772-1774.

A. Gorea and D. Sagi (2000) Failure to handle more than one internal representation in visual detection tasks. Proceedings of the National Academy of Sciences USA, 97, 12380-12384.

Y. Bonneh, A. Cooperman and D. Sagi (2001) Motion induced blindness in normal observers. Nature, 411, 798-801.

E. Freeman, D. Sagi and J. Driver (2001) Lateral Interactions between Targets and Flankers in Low-Level Vision Require Attention to the Flankers. Nature Neuroscience, 4, 1032-1036.

B. Zenger and D. Sagi (2002) Plasticity of low level visual networks. In: M. Fahle and T. Poggio (Eds.), Textbook on `Perceptual Learning' (pp 177-196). MIT press, Boston.

Y. Adini, D. Sagi and M. Tsodyks (2002) Context enabled learning in the human visual system. Nature, 415, 790-793.

U. Polat, T. Ma-Naim, M. Belkin, D. Sagi (2004) Improving vision in adult amblyopia by perceptual learning. Proceedings of the National Academy of Sciences USA, 101, 6692-7.

A. Gorea and D. Sagi (2004) On decision and attention. In: Itti, Rees and Tsotso (Eds), Neurobiology of Attention. Academic press / Elsevier.

R. Shani and D. Sagi (2005) Eccentricity effects on lateral interactions. Vision Research, 45, 2009-2024.

M. Katkov, M. Tsodyks and D. Sagi (2006) Analysis of a two-alternative force-choice Signal Detection Theory model. J Math Psychol, 50.

M. Katkov, M. Tsodyks and D. Sagi (2006) Singularities in the inverse modeling of 2AFC contrast discrimination data. Vision Research, 46, 259-266.

B. Blumenfeld, S. Preminger, D. Sagi and M. Tsodyks (2006) Dynamics of Memory Associations in Networks with Novelty-Facilitated Synaptic Plasticity. Neuron, 52, 383-394.

T. Livne and D. Sagi (2007) Configuration influence on crowding. J of Vision, 7(2):4, 1-12.

S. Preminger, D. Sagi and M. Tsodyks (2007) The Effect of Novel Associations on Long-term Memory of Perceptual Objects. Vision Research, 47, 965-973.

N. Censor and D. Sagi (2008) Short training enables long-term resistance to perceptual adaptation induced by intensive testing. Vision Research, 48.

D. Sagi (2008) Contextual interactions in visual perception. In L.R. Squire (Editor-in-Chief), The New Encyclopedia of Neuroscience. Elsevier.

Acknowledgements

D.S. is incumbent of the George Zlotowski Professorial Chair.

The research supported by The Basic Research Foundation administered by the Israel Academy of Sciences and Humanities, The Levine trust , Benoziyo center for Neurobiology, The Nella and Leon Benoziyo Center for Neurological Diseases, The Rosenmayer foundation.