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13. ABSTRACT *(Maximum 200 words)*

Psychophysical and theoretical research was conducted on the processes underlying the encoding of relative spatial locations of objects and edges of single objects. Work was done on developing a model of shape representation, called Object Representation by Cores, that is based on previous findings, sponsored by this grant, that the area over which position information is gathered scales with the distance being judged. Experimental work included measuring orientation discrimination thresholds for cone stimuli of various widths and measuring bisection thresholds for stimuli with sinusoidally modulated edges, where both edge modulation frequency and object width were manipulated. Results of both studies verified the key assumption of the model: the scale of the boundariness detector that contributes to perception of object shape covaries with object width. Studies continued on the perception of area. A new line of research was begun on the nature of information observers have about scenes containing multiple objects.

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Human vision; spatial vision, shape perception, localization

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Visual Encoding of Spatial Relations

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31 January 1994

Annual Technical Report for January 1, 199^ to December 31, 1993.

Prepared for

Air Force Office of Scientific Research/NL
Bolling AFB, DC 20332-6448

Objectives

[from the original grant proposal]

Our research focuses on understanding the visual processes that are responsible for encoding the sizes of objects. This work includes study of the basic properties of the size-encoding process and study of how this process interacts with other aspects of spatial vision. Of particular interest is the perceptual linking of regions of the image that appears to occur prior to the judgment of size. We have found that the accuracy of rapid size judgments depends on the similarity and location of background objects presented simultaneously. We infer from this that the ability of an observer to make a rapid and accurate size judgment depends on his initial perceptual organization of the image. Investigation of this organizational process has become an essential component of our research effort, being important in its own right and also helping to place the size-encoding process within the larger structure of visual processing as a whole.

We propose to investigate three aspects of the size-encoding process:
1) the properties of the process specifically devoted to encoding precise distances in the fronto-parallel plane.

2) the interrelationship between the size-encoding process and object representation (i.e., representation of specific regions as belonging to a single object).

3) the relationship between the size-encoding process and the perceived spatial layout of a complex scene.

Status of Research Effort

The past year has been an extension of the first grant year, requested to give the PI some sabbatical time. Research during this year has focused on the following:
1) Further development of our model of object representation, resulting in a substantial manuscript to be submitted to Psychological Review within the coming month.
2) Experimental research testing the basic premise of the model, namely that the perception of an object's shape is determined by boundariness detectors that scale with the width of the object. Results of two studies are given below.

3) Continued research on area perception by a graduate student doing his dissertation research under Dr. Burbeck's supervision.
4) Completed measurements of the shape of the position integration areas reported previously [Burbeck and Hadden, J. Opt. Soc. Am. A 10, 5-15]. Results will be described below.
5) Began work on understanding how information is encoded about scenes containing multiple objects of one or two types, e.g., the leaves and branches of a tree. Our motive here is to begin to understand how background information is encoded.

I. Experimental research on the scaling of object boundariness detectors with object width

We conducted two studies on how object width effects the determination of the object middle. In one study, we used cone-shaped stimuli and had the observers perform an orientation discrimination task in which the task was to compare the orientation of the center of the cone with that of a reference line. We measured orientation discrimination thresholds as a function of cone width. The data are shown in Fig. 1. As predicted by our model, these thresholds increased with increasing object width. Previous studies of the effect of object width on orientation discrimination thresholds used rectangular stimuli and found no effect of width. With a rectangle the edge carries the same orientation information as the center, however, so the observers could use that instead.

In a second study, we measured bisection thresholds for stimuli with sinusoidally modulated edges. Details and results of this study are given in the attached manuscript. They too confirm our hypothesis that the center of an object is defined by boundariness detectors that are at a scale determined by the object width.

II. On the shape of the position integration areas.

In previous study, we had determined that position information is gathered over an area that scales with the separation being encoded. Those measurements only probed the direction parallel to the separation. To complete that investigation, we changed our paradigm slightly and measured the extent of the position integration areas in the direction orthogonal to the separation.

The target stimulus was a pair of dots whose separation was to be judged. In one of the two temporal intervals in a trial, the pair of dots was accompanied by another pair, as shown in Fig. 2. The separation between the background pair was the parameter varied. The effect of these background dots on the perceived target separation was measured. We replicated our previous finding that the perceived target separation is increased by the presence of the background objects (previously we used a pair of lines as the target and a single background line), and that this effect scales with target separation. Further, the effect of the background dots varied systematically with their separation from one another. (They were a constant distance from the test dots in the other direction.) Their effect was greatest when they were closest to one another, but still discriminable. This suggests that the underlying receptive fields are nonlinear, consistent with our previous finding that changing the contrast polarity of the background line has little effect. Their effect was essentially gone when their separation equaled the target separation. Our previous study suggested that the position integration areas extended approximately this distance in the other direction too, making them (most probably) roughly circular.

We have started again to analyze the data from the opposite contrast polarity background line condition using a two stage model. (This was begun in the first grant year and then put on hold during the reduced-effort year.) We anticipate publishing those results with these new ones on the orthogonal extent of the position integration area.

III. Background encoding

The original motivation for the research sponsored by this grant was to further our understanding of how the human visual system encodes spatial relations in a visual scene. Our focus was initially on simple, attended, stimuli, measuring separation discrimination thresholds in most cases. The results of this work led us tentatively to conclude that accurate size or separation judgments can only be made after the relevant region is encoded as a figure. This, in turn, led to the model of object segregation and representation detailed in the accompanying manuscript. This work has led several others in the Computer Science Department here to pursue related work, as indicated below, so its impact has been substantial. The original question of how we encode the spatial layout of a visual scene remains a driving force, however, and we are beginning new work in that direction.

We are now considering the question of what an observer knows about more complex scenes. We begin with a simple stimulus, for example, an array of circles of various sizes, placed randomly on the display. When an observer views this, what is encoded? In this case, the only things that vary are the sizes and positions of the circles. We will begin by focusing on what he knows about the sizes. Preliminary studies indicate that he does not know the particular sizes that are represented, even though every pair is discriminable if viewed separately. But he does know something about the distribution. We are creating these stimuli, presently, and will be measuring what the observer knows about the distribution. This work has interesting ramifications for studies of serial and parallel search, but it may tackle the question of what is encoded about what we think of as "backgrounds", more directly than those studies. We are also working on developing a theoretical basis for this work in terms of distributed properties.

Publications

Written Publications Not Previously Reported

"Cores as the Basis for Object Vision in Medical Images", S. M. Pizer, C. A. Burbeck. *Proc. SPIE Medical Imaging '94: Human Vision*, 1994.

"Human Perception and Computer Image Analysis of Objects in Images", S. M. Pizer, C. A. Burbeck, D. S. Fritch. *Proc. Conference of the Australia Pattern Recognition Society (DICTA)*, 1993.

"General Shape and Specific Detail: Context-dependent Use of Scale in Determining Visual Form", B. S. Morse, S. M. Pizer, and C. A. Burbeck. Submitted to 2nd *International Workshop on Visual Form*, Capri, 1994.

"A Hough-Like Medial Axis Response Function", B. Morse, S. M. Pizer, and C. A. Burbeck. UNC Technical Report TR#91-044, January 1992.

"Object Shape before Boundary Shape: Scale-space Medial Axes", S. M. Pizer, C. Burbeck, J. Coggins, D. Fritsch, B. Morse. Presented at

Shape in Picture, (NATO Advanced Research Workshop), 1992. Accepted in *J. Math Imaging and Vision,* 1993.

Written Papers in Preparation:

Burbeck, Christina A. and Stephen M. Pizer, , "Object Representation by Cores", to be submitted to Psychological Review.

Snyder, Irene and Christina A. Burbeck, "Separate Integration of Luminance and Position in Separation Discrimination", to be submitted to Vision Research.

Professional Personnel Associated with Research Effort

Christina A. Burbeck, Research Associate Professor of Psychology, PI, 20% time, Jan. 1, 1993- Dec. 31, 1993.

Gal Zauberman, undergraduate laboratory assistant, approx. 65% time.

Collaborators who have worked on the above research, but were not funded by this grant:
Stephen M. Pizer, Kenan Professor of Computer Science.
Jannick Rolland, Assistant Research Professor of Computer Science.
Dan Ariely, Graduate Student in Psychology.
Bryan Morse, Graduate Student in Computer Science
Mike Capps, undergraduate programmer

Weekly meetings are held in which this research is discussed in depth by several members of this group. In addition, weekly meetings are held between the PI and several of the individual collaborators. Dr. Pizer has been a particularly valuable collaborator who is deeply involved in this project.

Interactions

Papers Presented at Meetings and Colloquia

As part of the sabbatical leave taken, the PI did not participate in any conferences during the past year. Dr. Pizer gave one invited talk on our joint work:

"Human Perception and Computer Image Analysis of Objects in Images", S. M. Pizer, C. A. Burbeck, D. S. Fritsch. *Proc. Conference of the Australia Pattern Recognition Society (DICTA)*, 1993.

The following abstracts were submitted to conferences for the 1994 year:

"Object Representation by Cores", C. A. Burbeck and S. M. Pizer, Association for Research in Vision and Ophthalmology, Sarasota, Fla., 1994.

"General Shape and Specific Detail: Context-dependent Use of Scale in Determining Visual Form", B. S. Morse, S. M. Pizer, and C. A. Burbeck. Submitted to 2nd *International Workshop on Visual Form*, Capri, 1994.

"Cores as the Basis for Object Vision in Medical Images", S. M. Pizer, C. A. Burbeck. *Proc. SPIE Medical Imaging '94: Human Vision*, 1994.

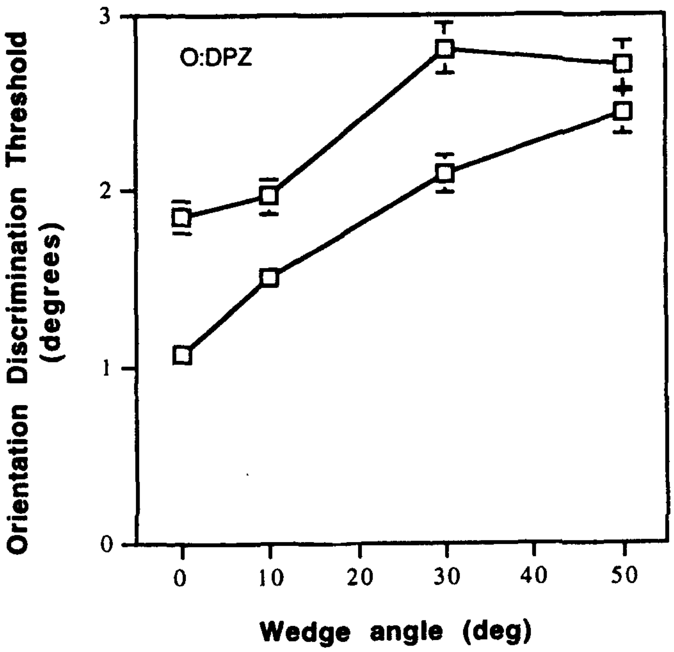
Consultative

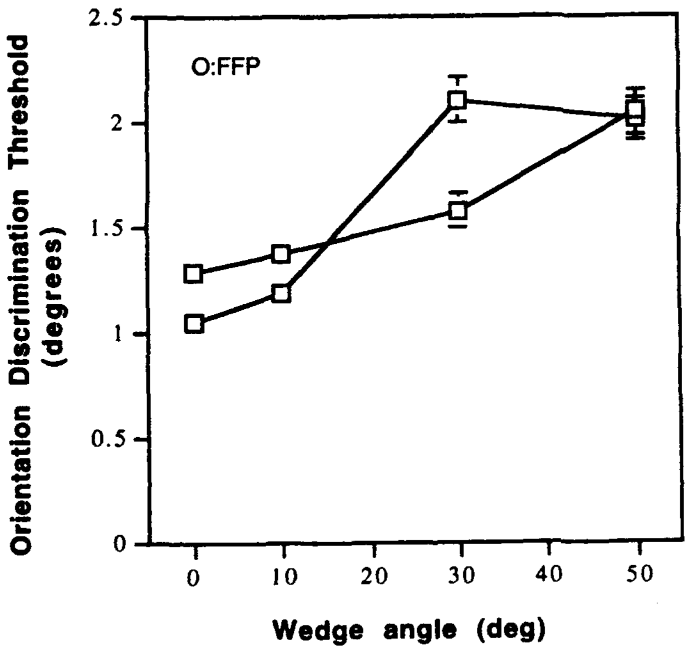
Member, Visual Sciences B study section, NIH.

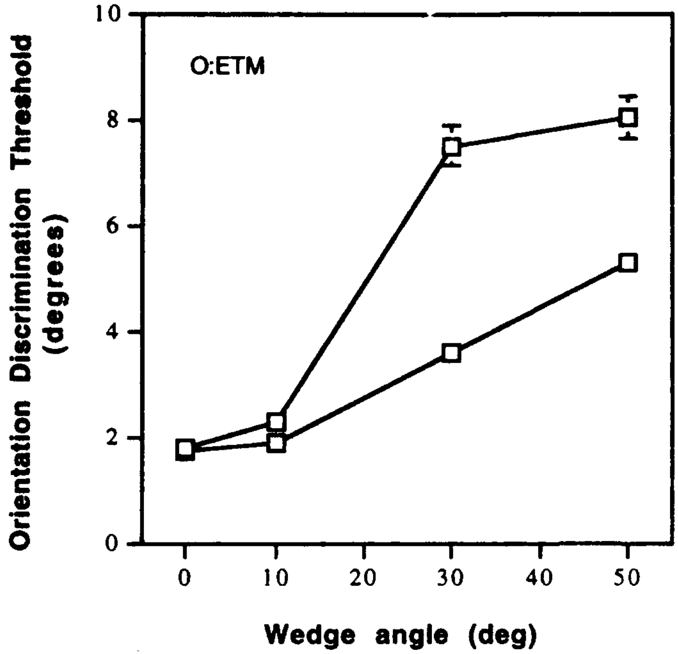
Reviewer for NSF and many journals.

Fig. 1

Orientation discrimination thresholds for cone shaped stimuli of various widths. Each graph shows data for one observer from two conditions, one in which there was random spatial jitter from trial to trial of the x/y location of the reference line stimulus, shown by the open squares, and one in which there was no such jitter, shown by the filled squares.



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Orientation Discrimination Threshold (degrees)
Wedge angle (deg)
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2
4
6
8
10
0
10
20
30
40
50

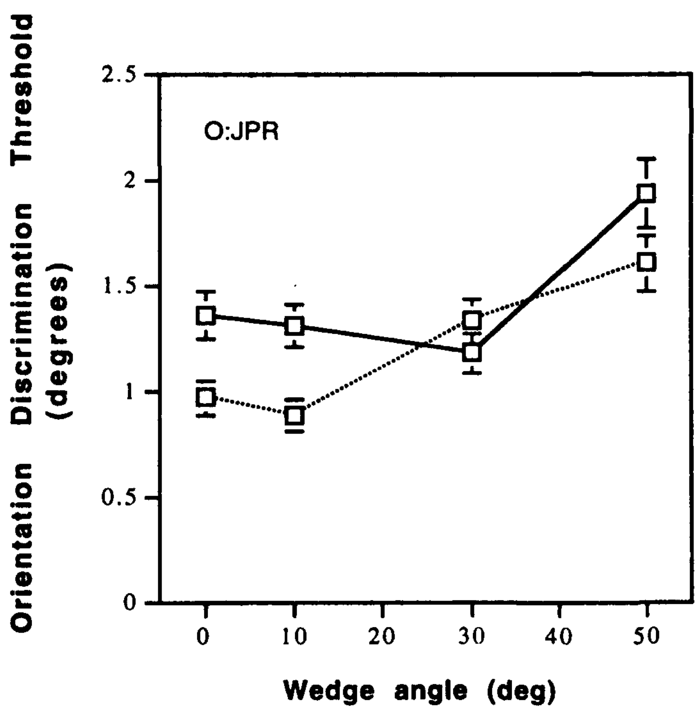
O:JPR
Orientation Discrimination Threshold (degrees)
Wedge angle (deg)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50

Figure 2

a) Sketch of the stimulus. The horizontal distance between the background dots and the left-most target dot was kept constant at half the target separation, a distance at which a large effect was found in the three-line experiments reported previously. b) Results for one observer at three mean target separations: 0.75 deg (shown by squares), 1.5 deg (shown by circles), and 3.0 deg (shown by triangles). ΔPSE indicates the increase in perceived separation of the target pair caused by the presence of the background dots. The range over which the background dots affect the perceived target separation can be seen to scale with the mean target separation.

a)

b)