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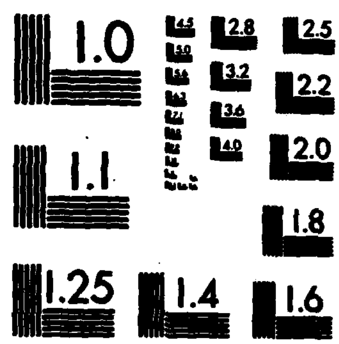


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We continue to study the spatial and temporal characteristics of relative spatial localization, seeking to establish conditions in which it can be isolated from the processes underlying the detection of motion and form. Thus far we have found that stabilizing the retinal image degrades localization accuracy by a factor of 2, and further that this degradation does not result from a reduction in the apparent contrast of the stimulus. Drifting the stimulus slowly at a velocity known to restore contrast sensitivity to normal (unstabilized) values does not improve localization accuracy noticeably. However, localization accuracy is restored to normal if the otherwise-stabilized stimulus is moved rapidly. We have also found that localization accuracy improves with increasing contrast for contrasts significantly above the detection threshold, supporting our hypothesis that location and detection are parallel visual processes. We have also found that localization accuracy is as good at large object separations as it is at very small separations (the vernier acuity range where sensitivity is known to be extremely acute). Thus, spatial localization is

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not primarily a foveal function that is degraded elsewhere, but rather a general visual ability. Further, there is evidence that localization is done by several distinct sub-processes, each of which is optimally sensitive to a different range of object separations. There is also some indication that the mechanisms underlying localization of widely separated targets are qualitatively different from those underlying visual acuity. Future directions for research include 1) using a reaction-time paradigm to explore the temporal characteristics of the spatial localization process, and 2) using stimuli that are localized in both the frequency and space domains to investigate the spatial characteristics of this process.

AFOSR Contract Number F49620-82-K-0024
Annual Technical Report
July 1984

# FY-1984 ANNUAL REPORT

# SPATIOTEMPORAL CHARACTERISTICS OF VISUAL LOCALIZATION

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## I. RESEARCH OBJECTIVES

We are continuing to study the spatial and temporal characteristics of relative spatial localization, seeking to establish conditions in which it can be isolated from those processes underlying the detection of motion and form. Specifically, we are studying

- The role of eye movements in spatial localization
- The effects of contrast on spatial localization
- The relationship between spatial localization and motion detection.

## II. STATUS OF RESEARCH

### A. Development of Laboratory Facilities

We have continued to expand and develop the hardware and software capabilities of the visual display system used for this project. The (Apple) microcomputer now operates in parallel with a 68000-based board, which greatly increases the computational and storage capabilities of the system. The high degree of flexibility of this system, along with its inherent simplicity has made it an extremely powerful and useable tool. The PI and her assistant are both skilled in its use and a naive user can quickly learn the system. Because of the simple and yet powerful nature of this system, SRI has funded another laboratory for the PI that is equipped with the same set-up. Although the duplicate system is used primarily for another research project, this replication of laboratories is extremely helpful in reducing downtime and providing scheduling flexibility.

### B. Effects of Eye Movements in Spatial Localization

We have continued research on the effects of eye movement since the last annual report. In particular, improved image stabilization has enabled us to determine that image stabilization does indeed elevate thresholds for relative spatial localization, by approximately a factor of two. Furthermore, we have shown that this threshold elevation is not the result of a reduction in the apparent contrast of the stimulus: drifting the retinal image at slow rates (known to restore contrast sensitivity to normal values) does not improve localization accuracy significantly. However, moving the stimulus more rapidly--either in a smooth continuous motion, or abruptly between two retinal locations--restores localization of the otherwise-stabilized stimulus to normal (unstabilized) values. These results suggest that rapid eye movements are essential to normal spatial localization.

We have also found that relative spatial localization with an unstabilized stimulus is not impaired by stimulus motion, supporting the idea that localization and motion are independent processes.

## C. Comparison of Localization of Widely Separated Targets and Visual Acuity

Although an early study of visual acuity by Keesey (J. Opt. Soc. Am., 50, 769, 1960) reported that stabilization has no effect on accuracy, we find that stabilization elevates thresholds for localization of widely separated objects by a factor of two. We are exploring this discrepancy and are seeking ways to determine whether fundamental differences exist in the processes underlying spatial localization at different object separations. We have found that localization accuracy is as good at large object separations as it is at very small ones (the hyperacuity region). Therefore, there is no single localization mechanism that is optimal at small separations and less sensitive at larger separations. Localization of widely separated objects is clearly an interesting and important visual ability in its own right.

## D. Temporal Characteristics of Spatial Localization

Repeated attempts to measure spatial localization as a function of stimulus duration suggest that stimulus duration is not the critical variable. Visual processing seems to continue for some time after the stimulus has been turned off, even when a masking stimulus is presented at the offset of the localization stimulus. Our studies suggest that reaction time data may be of considerably more interest in investigating this very slow visual process. (It is common for the subject to respond several seconds after the stimulus has been presented.) We anticipate implementing a cued-response reaction time paradigm to explore the timing of this process.

## E. Effects of Stimulus Contrast

We are measuring the effects of stimulus contrast on spatial localization. Thus far we have found that localization accuracy continues to improve at contrasts several times greater than the detection threshold, even when the subject makes localization judgments only on those trials in which he clearly sees both lines of the two-line stimulus. This result is analogous to the classical result by Tolhurst (J. Phys. 231, 385-402, 1973) on the separation of motion and form. Just as a moving object can be detected at contrasts at which its motion cannot be seen, so an object can be detected at contrasts at which its location cannot be accurately determined.

Because of its theoretical significance, this result is being investigated particularly carefully. Specifically, we are checking to ensure that accuracy does not improve because high-frequency elements of the square bars are becoming visible. To do this, we use raised sine bars of low nominal spatial frequency. The result holds. However, one property of sine bars is that the effective width of the bar increases as contrast increases. As a check on the effect of increasing bar width, localization accuracy is also being measured with bars of various widths as a function of contrast. Preliminary data on this suggest that width is not a factor over the relevant range of bar widths. It is probable that we will be able to conclude unequivocally that the localization mechanism has a different contrast response function than does the detection mechanism.

### F. Spatial Sensitivity of the Spatial Localization Process

Our results on localization accuracy with square bars and with raised sine bars suggest that localization of widely separated objects is based either on the low-frequency content of the targets or on the mean of the light distribution. (A similar result has been reported for a visual acuity task [Watt, Morgan, and Ward, *Invest. Ophth.* 1, 66 (1983)]. We will be exploring this question further, measuring localization accuracy with segments of high-frequency sine wave gratings in place of bars to distinguish between an explanation based on a spatial frequency description and one based on a light distribution description of the stimulus.

## III. PUBLICATIONS

### A. Publications in the Past Year Supported by this Grant

"Independence of orientation and size in spatial discriminations," with D. Regan, *J. Opt. Soc. Am.* 73, 1691-1694 (1983).

"On the role of retinal image motion in relative spatial localization," in press, *Vision Research*.

"Separate channels for the analysis of form and location", in preparation, *J. Physiol*.

"A comparison of spatial localization at small and large object separations", in preparation, *J. Opt. Soc. Am.*

### B. Other Publications in the Past Year

"Critical problems in spatial vision", with D. H. Kelly, *CRC Critical Reviews in Biomedical Engineering*, Vol. 10, 125-177, 1984.

"Role of local adaptation in the fading of stabilized images," with D.H. Kelly, *J. Opt. Soc. Am.* A 1, 216-220, (1984).

"On isolating the properties of local adaptation in human vision," submitted to *J. Physiol. London*.

## IV. PROFESSIONAL PERSONNEL

Christina A. Burbeck

## V. NEW DISCOVERIES AND SPECIFIC APPLICATIONS

- Rapid eye movements or rapid stimulus movements are essential for optimal spatial localization. This suggests that careful fixation and the suppression of large saccades may impair localization performance.
- Over a large range of velocities, stimulus motion does not degrade relative spatial localization accuracy.
- Contrast detection and localization are identifiably different processes. Localization accuracy continues to improve at contrasts well above detection threshold.

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