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The purpose of the research is to (a) develop and test new methods to study the internal visual representation of the shape and surface properties of objects, and the mechanisms that calibrate it, and (b) to use the methods to investigate the representation of contour, shape and surface properties, (c) to use the methods to study the representation of visual space, and (d) visual (re-)calibration mechanisms.

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January 24, 1994

Contracting Officer
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Bolling AFB, DC 20332-6448

Dear Sir or Madam:

The **Annual Technical Report** for AFOSR grant F49620-92-J-0187 (due April 15, 1993) is enclosed.

A no-cost extension for the grant was requested and granted in 1993 and the new termination date for the grant is March 14, 1994. The no-cost extension was requested because of significant delays in delivery of equipment needed to perform the research. The equipment arrived (in December, 1992 and February, 1993), well into the first year of the grant. Consequently, much of the experimental work did not begin until Fall, 1993. This report discusses only work completed before March 14, 1993.

Sincerely yours,

Laurence T. Maloney
Associate Professor

ANNUAL TECHNICAL REPORT

The purpose of the research is to (a) develop and test new methods to study the internal visual representation of the shape and surface properties of objects, and the mechanisms that calibrate it, and (b) to use the methods to investigate the representation of contour, shape and surface properties, (c) to use the methods to study the representation of visual space, and (d) visual (re-)calibration mechanisms.

Background: After a single glance at a scene, a human observer can normally describe the shape and location of objects in the scene, the colors of the objects, and whether the objects are smooth or textured, glossy or dull. Moreover, the observer can do this with one eye closed, while moving, and under a variety of lighting conditions. The sum total of the information about objects, their shapes, locations and surface properties is the observer's *internal visual representation* of the scene. Understanding how the human observer extracts this information from the scene is of great importance. In addtion, it is possible that the observer's internal representation is partly innate and partly learned. That is, a complex visual system likely has mechanisms to calibrate itself and alter its internal structure according to the kinds of visual tasks it typically solves.
The psychophysical methods commonly used to study human vision can be divided into (A) detection/discrimination measurements and (B) methods that require the observer to describe the scene or alter the scene until e.g. two lines are the same lengths. The first class of experiments tell us how little change in the properties of the scene is needed before the observer notices the change. This information is important in its own right, but there is no obvious way to build up a picture of the internal visual representation from simple discrimination measurements. The second class tell us about the observer's internal representation directly – if we believe the observer is accurately reporting what he or she sees. Such methods can produce data that is demonstrably biased or inaccurate.

A. List of Objectives [March 1992 – March March 1993]

- Develop a method [Orthogonality Test] for testing whether a representation is Euclidean.
- Write software needed to apply the Orthogonality Test to color matching space.
- Apply the Orthogonality Test to color matching space.
- Design experiments for the study of contour and shape using a Perturbation Method.
- Select equipment and software that can be use to simulate a high-resolution scene, viewed binocularly and that permits the observer to move in limited ways.
- Write software to perform experiments to study calibration in early vision.
- Modify a Projection CRT to produce a very high intensity CRT for research in perception of surface properties.

B. Status of Research Effort

The objectives above were achieved by March 1993 and represent the status of the research effort as of March 1993. The current status of the Research Effort (January 1994) is considerably advanced beyond that point.

C. Publications Acknowledging the Grant

Meyer, D. E., and Kornblum, S. Editors, Attention & Performance XIV: Synergies in Experimental Psychology, Artificial Intelligence, and Cognitive Neuroscience - A Silver Jubilee. MIT Press, Cambridge, Massachusetts, 1992. Maloney, L. T., Color constancy and color perception: the linear

models framework.

Chan, A. S., Butters, N., Paulsen, J. S., Salmon, D. P., Swenson, M. R., and Maloney, L. T., Assessment of the semantic network in patients with Alzheimer's disease. Journal of Cognitive Neuroscience, 5:2, pp 254-261, 1993.

Young, M., Landy, M. S., & Maloney, L. T., A perturbation analysis of depth perception from combinations of texture and motion cues. *Vision Research*, **11**, 2685-2696, 1993.

Landy, M. S., Maloney, L. T., Johnston, E. B., & Young, M., In defense of weak fusion: Measurement and modeling of depth cue combination. *Under review, Vision Research.*

Wuerger, S. M., Maloney, L. T., & Krauskopf, J., Proximity judgments in color space: test of a Euclidean color geometry. *Under review, Vision Research..*

Wuerger, S. M., Maloney, L. T., & Krauskopf, J., Testing representations of proximity data as a Euclidean metric on an affine space. In R. Duncan Luce [Ed.], *Geometric representations of perceptual phenomena [tentative title].*

D. Personnel

The personnel working on the projects supported by the grant are the PI, Laurence T. Maloney, Associate Professor, NYU, a post-doc, Allen Poirson [color & shape], and a graduate student Alex Hon [visual calibration].

E. Interactions

Consulting

The PI is working with a small company [EOS, Inc. Irvington, NY] on the design and evaluation of medical imaging systems that incorporate some of the ideas resulting from this research. EOS, Inc. and the PI have submitted 4 SBIR/STTR grants to obtain funds to build a general-purpose multispectral camera and develop software needed to assess surface properties of human skin without contact. The immediate applications would be to burn classification and skin lesion classification. AFOSR support from the current grant was crucial to the research on which these applications were based.

Talks acknowledging the grant

Wuerger, S. M., Krauskopf, J., & Maloney, L. T., Euclidean distance in color space does not predict similarity of isoluminant lights. Presented at the Annual Meeting of the Association for Research in Vision and Ophthalmology, Sarasota, Florida, May 1993.

Maloney, L. T., The linear models approach to computing color invariants. In the IEEE Conference on Computer Vision and Pattern Recognition Symposium: "The Roles of Color in Computer Vision" CVPR, New York, June 1993.

Maloney, L. T., Human and machine color perception. Tutorial given at The IEEE Computer Society Conference on Computer Vision and Pattern Recognition, New York, June 1993.

Wuerger, S. M., Maloney, L. T., & Krauskopf, J., Test of a new method for deriving color metrics from similarity judgments. Submitted to the European Conference on Visual Perception, Edinburgh, Scotland, 1993.

Maloney, L. T., Wuerger, S. M., & Krauskopf, J., Color matching judgments and any of three kinds of color proximity judgments cannot be embedded in a common Euclidean space. Conference on Geometric Representations of Perceptual Phenomena. University of California, Irvine, California, July 1993.

A future talk that acknowledges the grant

Maloney, L. T., In defense of weak fusion: Measurement and modeling of depth cue combination. Invited talk presented at the Annual Meeting of the Optical Society of America, Dallas, Texas, October 1994. Abstract: *Technical Digest Series*, (Washington, D. C.: Optical Society of America), 1994, forthcoming.

F. New Discoveries and Accomplishments [as of March, 1993]

- Color matching space is not Euclidean.

- Observers using the Orthogonality Test in color space produce reliable and accurate data. Had the space been Euclidean, it would have been possible to estimate the geometry of color space from a very small number of measurements. Other methods (notably Multidimensional Scaling) require more data, are not as accurate, and do not readily permit testing the validity of the Euclidean representation.

- It was possible to remove the three CRTs from a Electrohome ECP4100 projection television, lengthen the cables connecting then to the projection television and combine the three images of the CRT into a single, very-intense CRT image, about 270 times brighter than an ordinary CRT used in color work. The enlarged gamut of the device will allow testing current hypotheses concerning representation of color and shape-color interaction advanced by the PI and others several years ago. Remaning electrical problems in the device were diagnosed and fixed over the Summer and early Fall of 1993. The device is currently being calibrated and tested for safety.