FINAL REPORT

CENTER OF EXCELLENCE IN MODEL-BASED HUMAN PERFORMANCE

NCC 2-307-S26 PERIOD: 5/1/84 - 2/28/97

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Impact

The Center of Excellence (COE) was created in 1984 to facilitate active collaboration between the scientists at Ames Research Center and the Stanford Psychology Department. As this document will review, over that period of time, the COE served its function well.

Funds from the Center supported a large number of projects over the last ten years. Many of the people who were supported by the Center have gone on to distinguished research careers in government, industry and university. In fact, several of the people currently working at NASA Ames were initially funded by the Center mechanism, which served as a useful vehicle for attracting top quality candidates and supporting their research efforts.

We are grateful for NASA's support over the years. As we reviewed in the reports for each year, the COE budget generally provided a portion of the true costs of the individual research projects. Hence, the funds from the COE were leveraged with funds from industry and other government agencies. In this way, we feel that all parties benefitted greatly from the collaborative spirit and interactive aspects of the COE. The portion of the support from NASA was particularly important in helping members of the COE to set aside the time to publish papers and communicate advances in our understanding of human performance in NASA-related missions.

Technical Accomplishments

The ten annual reports from this grant include a list of the specific papers that were written with support from the grant. The list of publications can be gathered from these annual reports that are already on record. So, tather than repeating that very long list here, it seems more useful to summarize

the impact of the COE by examining the overall pattern of contributions.

The main objective of the COE was to perform advanced research. One measure of our research contributions is to see note the number of papers were published in refereed scientific journals and the number of abstracts contributed to major conferences. This grant supported research that led to roughly 50 papers in distinguished journals (including the **Journal of the Optical Society of America, J. Neuroscience, Vision Research, Nature** and **Science**). In addition, more than 50 conference papers were delivered by the indviduals supported by this grant.

The papers written from the groups of the senior investigators participating in this grant have achieved international prominence. For example, journal articles and conference proceedings from Ahumada, Kaiser, Stone and Watson at Ames, with support from this grant, are among the best-known and most widely cited contributions to the image compression and visual perception. Papers published by Heeger, Rumelhart, Shepard, and Wandell, also supported by this grant, have received very widespread attention in areas ranging from the mathematics of neural networks, the neural basis of vision, and various aspects of color imaging technology. The presence of this grant drew national attention to the high quality of perceptual research being carried out at Ames and Stanford.

A second, important measure of the scientific contribution of this grant is to review how the Center funds helped to launch the scientific careers of a large number of brilliant individual investigators. A fairly complete list of individuals who received support from the NASA grant is shown below. Several things can be learned from examining the list of individuals and their current affiliations.

First, the grant played a useful role in helping Dr. Ahumada and Dr. Watson and other members of the Ames Research Center to recruit talented post-doctoral fellows. Several of the post-doctoral fellows originally recruited through the COE continued to work at NASA for several years (e.g., Stone, Beutter, Perrone and others). Some of these individuals are now members of the technical staff and some are in management positions at Ames.

Second, the grant played a useful role in fostering the career of individuals who went on to work in industry. Dr. Farrell, Dr. Tiana, Dr. Samadani, and Dr. Pavel occupy management positions at industrial research labs. Their experience and training within the COE was helpful to them in their career development. Hence, the COE served as a means of training people

for important industrial positions in the digital imaging field, and fostered an industry-goverment-academia partnership that is often hard to achieve.

Third, the COE also had a national impact. Professor Nachmias (from Penn) is a member of the National Academy of Sciences and he participated in the Center for two years. Professor Pelli is a distinguished research scientist on the East Coast, and he too visited the Center. Professor Cowan is well known for his work in color technology, and he was a key participant at a conference organized by Ames on the issues of color display technologies in the cockpit. By serving as a mechanism to include scientists of national prominence, the center enriched the intellectual life of all participants and helped both the training function and to inspire new research directions that appeared in published journal articles.

Finally, the grant played a very helpful role in developing the research careers of many individuals who went on to join academia. Professor Brainard, Professor Perrone, Professor Heeger, Dr. Chichilnisky (Salk) and Professor Shiffrar were all supported while graduate students or post-docs by the COE. This is an extremely distinguished list of research scientists. As a group, they would form a leading powerful academic department. That the COE played an important role in training these scientists is perhaps the most important measure of the success of the program.

In conclusion, NASA should be proud of the important contribution made by supporting the activities of this Center of Excellence. The quality of the research, the training function, and the outcomes all suggest that the funds were invested wisely and will benefit both the scientific understanind of perception and the national agenda of training scientists and managers in computational human factors research.

NASA - MSFC TECHNOLOGY REPORT

1a NAME OF CONTRACTOR/ SUBCONTRACTOR	c. CONTRACT NUMBER	2a. NAME OF GOVERNMENT PRIME CONTRACTOR	c. CONTRACT NUMBER	3 TYPE OF REPORT (check one)
STANFORD UNIVERSITY	NCC 2-307-S26	NASA AMES RES CENTER	NCC 2-307-S26	☐ INTERIM ☒ FINAL
b. ADDRESS (include Zip Code) DEPT OF PSYCHOLOGY STANFORD, CA 94305-2130	d. AWARD DATE (YYMMDD) 5/1/84	b. ADDRESS (include Zip Code) MOFFETT FIELD, CA 94035	d. AWARD DATE (YYMMDD) 5/1/84	4 REPORTING PERIOD (YYMMDD) FROM 5/1/84 TO 2/28/97

SECTION I ☐ NEW TECHNOLOGY NFS 18-52-227-70

5. "REPORTABLE ITEMS": (if "none" so state)

a. NAME OF INNOVATOR(S) (LAST, FIRST, M.I.)	b. TITLE OF DISCLOSURE
NONE	

SECTION II ☐ PATENT RIGHTS FAR 18-52.227-11

7. "SUBJECT INVENTIONS" (if "none" so state)

a. NAME OF INNOVATOR(S) (LAST, FIRST, M.I.)	b. TITLE OF DISCLOSURE
NONE	

SECTION IA - SUBCONTRACTS (*Containing a "Patent Rights" clause*)

6. SUBCONTRACTS AWARDED BY CONTRACTOR/SUBCONTRACTOR. (If "none" so state)

a. NAME OF SUBCONTRACTORS	b. ADDRESS (include Zip Code)	c. SUBCONTRACT NO.(S)	d. DESCRIPTION OF WORK TO BE PERFORMED UNDER SUBCONTRACT(S)	e. SUBCONTRACT DATES (YYMMDD)	
				AWARD	EST. COMPL
NONE					

SECTION III - CERTIFICATION

8 CERTIFICATION OF REPORT BY CONTRACTOR/SUBCONTRACTOR

a. NAME OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL (LAST, FIRST, M.I.)

WILLIAMS, PEGGY A.

b. TITLE

GRANTS OFFICER

c. I CERTIFY THAT THE CONTRACTOR HAS THE REQUIRED PROCEDURES FOR PROMPT IDENTIFICATION AND TIMELY DISCLOSURE OF (PLEASE CHECK): ☐ (REPORTABLE ITEMS) ☐ (SUBJECT INVENTIONS), AND THAT SUCH PROCEDURES HAVE BEEN FOLLOWED, AND THAT THIS REPORT IS COMPLETE AND ACCURATE.

SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL

DATE (YYMMDD)

Individuals supported by the COE

J. Farrell (Hewlett-Packard Labs); D. Varner (Brooks Air Force Base); R. Shepard (Stanford); M. Pavel (ATT Labs); J. Perrone (New Zealand); A. Ahumada (NASA); A. Watson (NASA); D. Brainard (UC Santa Barbara); K. Nielsen (M.D.); D. Pelli (NYU); W. Cowan (U. Waterloo); J. Nachmias (U Penn.); M. Kaiser (NASA); E. Chichilnisky (Salk Institute); D. Rumelhart (Stanford); R. Remington (NASA); D. Heeger (Stanford); A. Poirson (Stanford); C. Tiana (FLIR Systems); M. Rosekind (Unknown); K. Mosier (Unknown); M. Shiffrar (Rutgers); C. Graeber (NASA); R. Samadani (EFI); B. Beutter (NASA); L. Stone (NASA); B. Wandell (Stanford)

NASA - MSFC TECHNOLOGY REPORT

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SECTION I ☐ NEW TECHNOLOGY NFS 18-52-227-70

5. "REPORTABLE ITEMS": (if "none" so state) NONE

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SECTION II ☐ PATENT RIGHTS FAR 18-52.227-11

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WILLIAMS, PEGGY A.

b. TITLE
GRANTS OFFICER

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SIGNATURE OF AUTHORIZED CONTRACTOR/SUBCONTRACTOR OFFICIAL

DATE (YYMMDD)

BIBLIOGRAPHY

Ahumada, A. J. Jr., "Putting the noise of the visual system back in the picture," Journal of the Optical Society of America A, vol. 4, pp. 2372-2378, 1987. nonlinear theories of detection, discrimination, and masking

Ahumada, A. J. Jr., "Learning receptor positions," in Computational Models of Visual Processing, ed. M. Landy and J. A. Movshon, pp. 23-34, MIT Press, Cambridge, MA, 1991.

Ahumada, A. J. Jr. and J. B. Mulligan, "Learning in interpolation networks for irregular sampling: Some convergence properties," Applied Vision: Optical Society of America Technical Digest Series, vol. 16, pp. 24-27, 1989.

Ahumada, A. J. Jr. and A. Poirson, "Cone sampling array models," Journal of the Optical Society of America A, vol. 4, pp. 1493-1502, 1987.

Ahumada, A. J. Jr. and K. Turano, "Calibration of a visual system with receptor drop-out," in Exploratory Vision: The Active Eye, ed. M. Landy, L. T. Maloney, M. Pavel, pp. 157-168, Springer-Verlag, New York, 1995.

Ahumada, A. J. Jr. and J. I. Yellott, Jr., "Reconstructing irregularly sampled images by neural networks," in Human Vision, Visual Processing, and Digital Display, ed. B. E. Rogowitz, Proc. 1077, pp. 228-235, SPIE, Bellingham, WA, 1989.

Bauml, K. H. and B. A. Wandell, "Color appearance of mixture gratings," Vision Research, vol. 36, pp. 2849-2864, 1996.

Bennett, C. T., W. W. Johnson, J. A. Perrone, and A. V. Phatak, "Synthetic perspective optical flow: Influence on pilot control task," Proceedings of the Spatial Displays and Spatial Instruments Conference and Workshop, pp. 40.1-40.9, 1989.

Brainard, D. H., "Calibration of a computer controlled color monitor," Color Research and Applications, vol. 14, no. 1, pp. 23-24, 1989.

Brainard, D. H. and B. A. Wandell, "Analysis of the retinex theory of color vision," Journal of the Optical Society of America A, vol. 3, no. 10, pp. 1651-1661, 1986.

Reprinted in Color (Physics-based Vision/ Principles & Practice), G.E. Healey, S.A. Shafter, & L.B. Wolff, eds., Jones and Bartlett Publishers, Boston, MA., 1992.

Brainard, D. and B. A. Wandell, The color analysis package, 1987.

Brainard, D. H., B. A. Wandell, and W. B. Cowan, "Black Light: How Sensors filter spectral variation of the illuminant," IEEE Transactions on Biomedical Engineering, vol. 36, no. 1, pp. 140-149, 1989.

Brainard, D. H. and B. A. Wandell, "Calibrated processing of image color," Color Research and Applications, 1990.

Brainard, D. H. and B. A. Wandell, "A bilinear model of the illuminant's effect on color appearance," in Computational Models of Visual Processing, ed. M. Landy and J. A. Movshon, MIT Press, Cambridge MA,, 1991.

Brainard, D. H. and B. A. Wandell, "Asymmetric color matching: how color appearance depends on the illuminant," Journal of the Optical Society of America A, vol. 9, no. 9, pp. 1433-1448, 1992.

Brainard, D. H., B. A. Wandell, and E. J. Chichilnisky, "Color constancy: From physics to appearance," Current Directions in Psychological Science, vol. 2, no. 5, pp. 165-170, 1993.

Carlton, E. H. and R. N. Shepard, "Psychologically simple motions as geodesic paths: I. Asymmetric objects," Journal of Mathematical Psychology, vol. 34, pp. 127-188, 1990.

Chichilnisky, E. J., B. A. Wandell, and D. J. Heeger, "Functional Segregation of Color and Motion Perception Examined in Motion Nulling," Vision Research, vol. 33, no. 15, pp. 2113-2125, 1993.

Chichilnisky, E. J. and B. A. Wandell, "Photoreceptor sensitivity," Vision Research, vol. 35, pp. 239-254, 1995.

Cunningham, H. A., "Aiming error under transformed spatial mappings suggests a structure for visual-motor maps," Journal of Experimental Psychology: Human Perception and Performance, vol. 15, pp. 493-506, 1989.

Carlton, E. H. and R. N. Shepard, "Psychologically simple motions as geodesic paths: II. Symmetric objects," Journal of Mathematical Psychology.

Farrell, J. E. and B. A. Wandell, "Scanner Linearity," Journal of Electronic Imaging, vol. 2, no. 3, pp. 225-230, 1993.

Foyle, D. C., A. J. Ahumada, J. Larimer, and B. T. Sweet, "Enhanced/synthetic vision systems: Human factors research and implications for future systems," SAE Transactions: Journal of Aerospace, vol. 101, pp. 1734-1741, 1992.

Heeger, D., "Model for the extraction of image flow," Journal of the Optical Society of America A, vol. 4, no. 8, pp. 1455-1471, 1987.

Heeger, D., "Optical flow using spatiotemporal filters," International Journal of Computer Vision, vol. 1, no. 4, pp. 270-302, 1988.

Heeger, D. J. and A. D. Jepson, "Subspace methods for recovering rigid motion I: Algorithm and implementation," International Journal of Computer Vision, vol. 7, no. 2, pp. 95-117, 1992.

Heeger, D. J. and A. Jepson, "Subspace methods for recovering rigid motion II: Theory," International Journal of Computer Vision, 1992.

Heeger, D. J. and E. P. Simoncelli, in Spatial Vision in Humans and Robots, ed. M. Jenkin, Cambridge University Press, New York, 1992.

Hong, S., Modeling of Rapid Symmetry Perception, Doctoral Dissertation, Stanford University, Stanford, CA, 1991.

Jepson, A. D. and D. J. Heeger, A fast subspace algorithm for recovering rigid motion, Proceedings of IEEE Workshop on Visual Motion, pp. 124-131, Princeton, NJ, 1991.

Jepson, A. D. and D. J. Heeger, "Linear subspace methods for recovering translation direction," in Spatial Vision in Humans and Robots, ed. M Jenkin, Cambridge University Press, New York, NY, 1992.

Larimer, J., M. Pavel, A. Ahumada, and B. Sweet, "Engineering a visual system for seeing through fog," SAE 22nd International Conference on Environmental Systems, Seattle, WA, 1992.

Maloney, L. T. and B. A. Wandell, "Color constancy: A method for recovering surface spectral reflectance," Journal of the Optical Society of America A, vol. 3, no. 1, pp. 29-33, 1986.

Reprinted in: Image Understanding, S. Ullman and W. Richards, eds., pp. 215-224. Ablex Publishing: Norwood, NJ, 1989. And in Color (Physics-based Vision/ Principles & Practice), G.E. Healey, S.A. Shafter, & L.B. Wolff, eds., Jones and Bartlett Publishers, Boston, MA., 1992.

Maloney, Larry T., "Calibrating a linear visual system by comparision of inputs across camera/eye movements," Applied Vision: Opt. Soc. Am. Tech. Digest Series, vol. 16, pp. 28-31, 1989.

Maloney, L. T. and A. J. Ahumada, Jr., "Learning by assertion: Two methods for calibrating a linear visual system," Neural Computation, vol. 1, pp. 392-401, 1989.

Marimont, D. H. and Brian A. Wandell, "Matching color images: The effects of axial chromatic aberration," Journal of the Optical Society of America, vol. 11, no. 12, pp. 3113-3122, 1994.

Martin, R. A., A. J. Ahumada, Jr., and J. O. Larimer, "Color matrix display simulation based upon luminance and chromatic contrast sensitivity of early vision," in Human Vision, Visual Processing, and Digital Display III, ed. B. E. Rogowitz, Proc. 1666, pp. 336-342, SPIE, Bellingham, WA, 1992.

McBeath, M. K., The influence of depth cues on velocity of apparent motion, 1989.

McBeath, M. K. and R. N. Shepard, "Apparent Motion between shapes differing in location and orientation: A window technique for estimating path curvature," in Perception and Psychophysics.

McBeath, M. K., "The rising fastball: Baseball's impossible pitch," Perception, 1990.

McBeath, M. K., K. Morikawa, and M. K. Kaiser, "Perceptual bias for forward-facing motion," Psychological Science, vol. 3, no. 6, pp. 362-367, 1992.

Mosier, K. L., "Expert decision-making strategies," Proceedings of the Sixth International Symposium on Aviation Psychology, Columbus, OH, 1991.

Mulligan, J. B. and A. J. Ahumada, Jr., "Principled Halftoning Based on Models of Human Vision," in Human Vision, Visual Processing, and Digital Display III, ed. B. E. Rogowitz, Proc. 1666, pp. 109-121, SPIE, Bellingham, WA, 1992.

Nielsen, K. R. K., A. B. Watson, and A. J. Ahumada, Jr., "Application of a computable model of human spatial vision to phase discrimination," Journal of the Optical Society of America A, vol. 2, pp. 1600-1606, 1985.

Used a computable model of human spatial vision to make predictions for phase-discrimination experiments. In the model, cross correlation of the stimuli with an array of sensors produces feature vectors that are operated on by a position-uncertain ideal observer to simulate detection and discrimination experiments.

Nielsen, K. R. K. and B. A. Wandell, Analysis of spatial vision models, 1987.

Pavel, M., M. A. Gluck, and V. Henkle, "Constraints on adaptive networks for modeling human generalization," Advances in Neural Network Information Processing Systems, Morgan Kaufmann, Los Altos, CA, 1989.

Pavel, M., J. Larimer, and A. Ahumada, "Sensor fusion for synthetic vision," in AIAA Computing in Aerospace 8: A Collection of Technical Papers, vol. CP9110-1, pp. 164-173, AIAA, Washington, DC, 1991.

Pavel, M., J. Larimer, and A. J. Ahumada, Jr., "Sensor Fusion for Synthetic Vision," in Society for Information Display Digest of Technical Papers, ed. J. Morreale, pp. 475-478, Society for Information Display, Playa del Rey, CA, 1992.

Perrone, J. A., "Visual slant underestimation: a general model," Perception, vol. 11, pp. 641-654, 1982.

Perrone, J. A., "Visual slant misperception and the "black-hole" landing situation," NASA Technical Memorandum, vol. 858661, 1983.

Perrone, J. A., "Anistropic responses to motion toward and away from the eye," Perception and Psychophysics, vol. 39, no. 1, pp. 1-8, 1986.

Perrone, J. A., "In search of the elusive flow field," Proceedings of the Workshop on Visual Motion, pp. 181-188, Computer Society of the IEEE, Washington DC, 1989.

Perrone, J. A., "Simple technique for optical flow estimation," Journal of the Optical Society of America A, vol. 7, no. 2, pp. 264-278, 1990.

Perrone, J. A., "The perception of surface layout during low-level flight," Workshop on the Visually Guided Control of Movement, pp. 40.1-40.9, 1990.

Perrone, J. A., "Model for the computation of self-motion in biological systems," Journal of the Optical Society of America A, vol. 9, no. 2, pp. 177-194, 1992.

Perrone, J. A. and P. Wenderoth, "Visual slant underestimation," Proceedings of spatial displays and spatial instruments conference and workshop, pp. 8.1-8.9, Washington, D. C, 1989.

Poirson, A. B., Appearance and Detection of Colored Patterns, Doctoral Dissertation, Stanford University, Stanford, CA, 1991.

Poirson, A. B. and B. A. Wandell, "Task-dependent color discrimination," Journal of the Optical Society of America A, vol. 7, no. 4, pp. 776-782, 1990.

Poirson, A. B. and B. A. Wandell, "The ellipsoidal representation of spectral sensitivity," Vision Research, vol. 30, no. 4, pp. 647-652, 1990.

Poirson, A. B., B. A. Wandell, D. Varner, and D. H. Brainard, "Surface characterizations of color thresholds," Journal of the Optical Society of America A, vol. 7, pp. 783-789, 1990.

Poirson, A. B. and B. A. Wandell, "The appearance of colored patterns: pattern-color separability," Journal of the Optical Society of America A, vol. 10, no. 12, pp. 2458-2470, 1993.

Poirson, A. B. and B. A. Wandell, "Pattern-color separable pathways predict sensitivity to simple colored patterns," Vision Research, 1995.

Rosekind, M. R., B. Townsend, M. Rountree, L. Connell, D. Yost, C. Graeber, R. C. Spinweber, D. F. Dinges, and W. C. Dement, "Modification of the medilog 9000-ii recorder to reduce 400 hz noise in the cockpit environment," Sleep Research, vol. 19, p. 377, 1990.

Rosekind, M. R., D. Yost, M. Rountree, B. Welsh, S. Cohen, W. F. Seidel, and W. C. Dement, "Laboratory investigation of sleepiness in night shift workers," Sleep Research, vol. 19, p. 403, 1990.

Shepard, R. N., "Internal representation of universal regularities: A challenge for connections," in Neural Connections, Mental Computation, ed. L. Nadel, L. A. Cooper, P. Culicover, R. M. Harnish, MIT Press/ Bradford Books, Cambridge, MA, 1989.

Shiffrar, M. M. and J. J. Freyd, "Apparent motion of the human body," Psychological Science, 1990.

Shiffrar, M. M. and R. N. Shepard, "Comparisons of cube rotations about axes inclined relative to the environment or to the cube," Journal of Experimental Psychology: Human Perception and Performance, 1990.

Tominaga, S. and B. A. Wandell, "Component estimation of surface spectral reflectance," Journal of the Optical Society of America A, vol. 7, no. 2, pp. 312-317, 1990.

Reprinted in Color (Physics-based Vision/ Principles & Practice), G.E. Healey, S.A. Shafter, & L.B. Wolff, eds., Jones and Bartlett Publishers, Boston, MA., 1992.

Tominaga, S. and B. A. Wandell, "The standard surface reflectance model and illuminant estimation," Journal of the Optical Society of America A, vol. 6, no. 4, pp. 576-584, 1989.

Wandell, B. A., "The synthesis and analysis of color images," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. PAMI-9, no. 1, pp. 2-13, 1986.

Wandell, B. A., "Computational Methods for Color Constancy," in Frontiers of Visual Science, ed. National Research Council Committee on Vision, National Academy Press, Washington D.C., 1987.

Wandell, B. A. and D. H. Brainard, "Towards cross-media color reproduction," Applied Vision: Optical Society of America Technical Digest Series, vol. 16, pp. 132-137, 1989.

Watson, A. B., K. R. K. Nielsen, A. Poirson, A. Fitzhugh, A. Bilson, K. Ngugen, and A. J. Ahumada, Jr., "Use of a raster framebuffer in vision research," Behavioral Research Methods, Instrumentation, and Computers, vol. 18, no. 6, pp. 587-594, 1986.

Watson, A. B., "Efficiency of a model human image code," Journal of the Optical Society of America A, vol. 4, no. 12, pp. 2401-2417, 1987.

Watson, A. B., "The ideal observer concept as a modeling tool," in Frontiers of Visual Science, ed. Committee on Vision, National Academy of Sciences, pp. 32-37, National Academy Press, 1987.