**DANA H. BALLARD**

Born: October 15, 1946  Nationality: United States of America

**GOOGLE SCHOLAR CITATIONS:**

http://scholar.google.com/citations?user=67aYFTQAAAAJ

**EDUCATION:**

B.S., Aeronautics & Astronautics, Massachusetts Inst. of Technology (1967)
M.S., Information & Control Engineering, Michigan (1970)
Ph.D., Information Engineering, U. California at Irvine (1974)


**PROFESSIONAL EXPERIENCE:**

| | |
|---|---|
| 1965-66 | Technical Staff, Lockheed Missiles and Space Co., Sunnyvale, CA |
| 1967-68 | Teaching Assistant, University of Michigan, Ann Arbor, MI |
| 1968-70 | Technical Staff, Autonetics, Anaheim, CA |
| 1970-74 | Research Asst., Pattern Recognition Project, U. California, Irvine, CA |
| 1974-75 | Visiting Consultant, Laboratorio Technol. Biomediche, Rome, Italy |
| 1975-82 | Assistant Professor of Computer Science and Radiology, U. Rochester |
| 1982 | Bridging Leave with Department of Anatomy, U. Rochester |
| 1982-87 | Associate Professor of Computer Science, U. Rochester |
| 1986 | Semester at Institute for Theoretical Physics, U. Cal., Santa Barbara |
| 1987-2006 | Professor of Computer Science, U. Rochester |
| 1987- 2006 | Professor, Center for Visual Science, U. Rochester |
| 1990 | Visiting Consultant, ATR, Kyoto, Japan (summer 1990) |
| 1995-2006 | Professor of Brain and Cognitive Sciences, U. Rochester |
| 2004 | Visiting Professor, IIT Kanpur, Kanpur, India, (January-February) |
| 2006 | Visiting Scholar, University of Sydney, Sydney, Australia |
| 2006- | Professor of Computer Science, University of Texas at Austin, Austin, TX |
| 2006- | Professor in the Center for Perceptual Systems, UT Austin, Austin TX |
| 2011 | Visiting Scholar, Queensland Brain Institute, Brisbane, Australia |
| 2012 | Visiting Scientist, ZiF, Bielefeld, Germany |


**PROFESSIONAL ACTIVITIES:**

1974 Consultant, Actron Industries, Monrovia, CA
1976- NIH Consultant
1984  Consultant, Draper Laboratories, Cambridge, MA
1985  Co-organizer, *Workshop on Cognitive Neuroscience,* Woods Hole, MA
1987 Program Committee, *IEEE Neural Network Conf.,* Boulder, CO
1987 Advisory Committee, *Workshop on Eye Movements in Vision,* U. Mich.
1988- Advisory Bd., Addison-Wesley series *Computation and Neural Systems*
1988-98 Action Editor, *Neural Computation* (MIT Press Journal)
1988- Editorial Bd., *Concepts in Neural Science* (World Scientific Journal)
1989-91 Editorial Bd., *Network*
1991 Program Committee, *CVPR; Int'l. Joint Conf. on Neural Networks*
1991  Instructor, 1-week Active Vision course, Vision Res. Lab., U. Genoa, June 2-9
1992  Participant, NSF Workshop on Computer Vision, Washington, DC, June
1992  Participant, NSF Workshop on Face Recognition, Washington, DC, July
1993  Program Committee, *Int' l. Conf. on Computer V ision*

1994  Co-organizer and Instructor, Workshop on Neurocomputing, Telluride, CO, July
1994  Program Committee, Visual Behaviors Workshop, *CVPR,* Seattle, July 1994
1995  Co-organizer, Telluride Workshop on Neuromorphic Engg., Telluride, CO, July
1996  Organizer, Center for Visual Science Workshop on Neural Models of Behavior
1996- Editorial Bd., *Videre* (on-line computer vision journal; MIT Press)
1999 Associate Editor, *Neural Computation* (MIT Press Journal)
2002-04 Associate Editor, *Perception*
2010  Co-organizer, NETI Workshop, UT Austin, April
2012  Co-organizer, NETI Workshop, UT Austin, April


**HONORS:**

Best Paper Prize, *Int'l. Joint Conf. on Artificial Intelligence,* Detroit, MI, August 1989 ("Reference frames for animate vision").

2013 *ICCV* Test of Time award for "Color Indexing"(1991)

2014 UC Merced Distinguished Cognitive Scientist Award

**DOCTORAL DISSERTATIONS SUPERVISED:**

Cooper, J. C. "Analysis and synthesis of bipedal human movement," PostDoc U. Colorado
Iyer , R., "Muscle models of human walking," (EMC2)
Kit, D., "Image Change Detection,"PostDoc, Northeastern)
Rothkopf, C. A., "Modular models of task based visually guided behavior" (FIAS, Frankfurt)
Shaw, J. " Unifying Perception and Curiosity" (Shaw Technologies)
Gu, X., "A An Equilibrium Point Based Humanoids Control Model" (Towers Perrin)
Yi, W., "Modeling Sequential Behavior based onVisual Routines" (Microsoft)
Sprague, N.R., "Learning to coordinate visual behaviors"(James Madison University)
Yu, C., "Embodied learning from multisensory input"(University of Indiana)
Zhang, Z., "A predictive coding model of the cortex using distributed synchronous spikes"(Fair Isaac Corp.)
Zhu, S., "Learning to cooperate and coordinate"(NEC Labs)
Bayliss, J.D., "Real-time EEG signal analysis in a dynamic environment"(Rochester Institute of Technology)
Salgian, G., "Driving with Visual Routines" (Sarnoff Corporation)
Rao, R.P.N., "Dynamic Appearance-Based Vision" (University of Washington)
Rosca, J.P., "Hierarchical Learning with Procedural Abstraction Mechanisms" (Siemens Corp.Research)
Karlsson, J., "Learning multiple behaviors" (Xerox Webster Research Ctr.)
Sarukkai, R., "Phone sets for speech understanding" (Kurzweil Applied Intelligence, Inc.)
McCallum, A., "Reinforcement learning algorithms" (University of Massachusetts)
Pook, P.K., "Teleassistance: Using deictic gestures to control robot action" (Asian Univ. for Women, Bangladesh)
deSa, V.R., "Unsupervised classification learning from cross-modal environmental structure" (U. California, San Diego)
Wixson, L.E., "Gaze selection for visual search" (David Sarnoff Research Center)
Whitehead, S.D., "Reinforcement learning for the adaptive control of perception and action" (Verizon)
Simard, P.Y., "Learning state space dynamics in recurrent networks" (Microsoft Research)
Hartman, L.B., "Decision theory and the cost of planning" (Canadian Space Agency)

Swain, M.J., "Color indexing" (AthenaHealth, Watertown MA)

Tenenberg, J.D., "Abstraction in planning" (Washington State University)

Bandopadhay, A., "A computational study of rigid motion perception" (independent software consultant)

Shani, U., "A three-dimensional parametric model for the automatic recognition of abdominalanatomy from CAT-scans" (IBM Haifa Research Lab)

Schudy, R.B., "A computer model for extracting moving heart surfaces from four-dimensional cardiac ultrasound data" (Metropolitan College, Boston Univ.)


**DOCTORAL DISSERTATIONS UNDER SUPERVISION:**

Lewis Fishgold, " Combining logical and probabilistic inference"

Leif Johnson, " A model of infant early language learning"

Joseph Cooper, " Hierarchical models of movement control"

Kim Houck, "Sparse code models of motor torques"


**INVITED TALKS: 2010-13**

Oxyopia Colloquium Series in the Vision Science Program at Berkeley, October 2010

Reinforcement Learning Tutorial at the Neural Information Processing Systems Conference, Vancouver Canada, December 2010

Vision Research Centers Annual Meeting, Murramarang, NSW, Australia March 2011

Queensland Brain Institute presentation, Mar 2011

CITEC Summer School Lecture, University of Bielefeld, October 2011

Max Planck Tubingen, Bernstein Center for Computational Neuroscience Symposium on Perception and Action September 2011

COSYNE, Salt Lake City, February 2012

The Gatsby Computational Neuroscience Unit, UCL, London, UK, June 2012

Craik Series Lecture, University of Cambidge, Cambridge, UK, June 2012

Donders Institute, Nijmegen, The Netherlands, June 2012

Hitachi Distinguished Lecture Series, University of Oklahoma, September, 2012

University of Birmingham, Birmingham, UK, September 2012

Universitat Pompeu Fabra, Barcelona, Spain, September 2012

AVA, University of Sussex, Sussex, UK, Spetember, 2012

University of Rochester, Rochester, NY, September 2012

University of Osnabruck, Osnabuck, Gemany, October 2012

ETH, Zurich, November 2012

York University, Toronto, Canada, March 2013

University of Maryland March 2013

Telluride July 2013

University of Rochester CVS 50th, October 2013

Brain Corp. L Jolla San Diego, November 2013

**COURSES:**

CS 378 The Computational Brain

CS 391 Machine Learning

**UNIVERSITY SERVICE:**

Faculty evaluation committee; Explore UT; FirstBytes

**GRANT SUPPORT:**

**Center for Perceptual Systems Training Grant**
Co-PI
Agency: NIH-NEI, $895,260 2012-2017

**Neural Models of Behavior**
PI: Dana Ballard
Agency: NIH (R01 EY019174-14) 5/1/09-5/1/13.
The goal of this research is to develop computational theories of cognitive behavior in complex environments such as driving in order to understand the organization of complex sensori-motor behavior.

**Vision in Natural Tasks**
PI: Mary Hayhoe,

Agency: NIH (R01 EY005729-25) 6/1/03-6/30/13.
The goal of the grant is to understand the way that vision functions in the context of ordinary behavior. The experiments focus on what information is extracted and retained across fixations, whether it is used to guide subsequent eye movements, and how different kinds of information are composed to make up larger behavioral units.

NSF (IIS-0932277) A Real-Time Cognitive Operating System, PI

NIH 1 P41 RR09283 05, A Resource for the Study of Neural Models of Behavior, PI 9/94–8/08.

NIH MH 60624 "Spike Models of Neural Behavior," PI, $650,00, 6/01-6/04

NIH, "Training in Sensory-Motor and Integrative Neurosciences," Trainer (William O'Neill, PI),$1,457,660, 5/00-4/05.

NIH, 1 P41 RR09283 , "A Resource for the Study of Neural Models of Behavior," PI,$3,990,587, 9/94-8/02.

NIH/NEI T32 EY07125, "Training in Visual Science," Trainer (T. Pasternak, PI), $937,300, 9/95-9/00.

NSF, "A Laboratory for Intelligent Multi-Sense Interfaces" (equipment only), co-PI (Randal C.

Nelson, PI), $110,000, 7/99-6/00. NIH Institutional NRSA, "Training in Neuroscience," Trainer (William O'Neill, PI), $843,534,7/89-6/00.

NIH, RO1 EY05729-12, "Visual Processing in Natural Tasks," Co-PI (Mary M. Hayhoe, PI),

$311,479, 12/94-11/99. NSF, CDA-9401142, "Rapid Prototyping of Parallel Robot Vision Systems using Virtual Reality and Systems Simulation," Co-Inv. (Thomas J. LeBlanc, PI), $1,500,000, 9/94–8/99.

NSF, IRI-9406481, "Learning Fixation Routines," PI, $246,276, 9/94–8/97.

NIH, Training Grant for Graduate Students, Trainer (T. Bever, PI), $107,120, 12/91-11/96.

NSF, IRI-8903582, "Animate Robotics Vision," PI, $524,047, 8/92–1/95.

NSF Institutional Infrastructure Program, CDA-8822724, "Parallel Laboratory for Real-Time Vision and Robotics," co-PI (Christopher M. Brown, PI), $1,782,106, 7/89–6/94.

Human Scientific Frontiers Program, "Visuo-Motor Coordination in 3-D Space," co-PI, $248,026, 6/91–5/94.

**PUBLICATIONS**

## Books

Ballard, D.H. *An Introduction to Natural Computation.* Cambridge, MA: MIT Press (A Bradford Book), 1997.
Ballard, D.H. and C.M. Brown. *Computer Vision.* Prentice-Hall, 1982. (Translated into Japanese,

1987.)

Ballard, D.H. *Hierarchic Recognition of Tumors in Chest Radiographs.* Birkhauser-Verlag, 1976.

## Refereed Articles

Rothkopf, C. A. and Ballard D. H. Modular inverse reinforcement learning for visuomotor behavior, Biological Cybernetics, 107(4) 477-490 (2013)

Ballard, D. H.,  and Kit, D., and Rothkopf, C. A., and Sullivan, B., (2013) A Hierarchical Modular Architecture for Embodied Cognition, *Multisensory Research*, 26, 177-204

Sullivan, Brian T., Johnson, L., Rothkopf, Constantin A., Ballard, Dana H., and Hayhoe, Mary, (2012) The role of uncertainty and reward on eye movements in a virtual driving task, Journal of Vision 12 (13) 1-16

Ballard, D. H., and Jehee, J. M. F. (2012) Dynamic coding of signed quantities in cortical feedback circuits, *Frontiers in Perception Science*

Ballard, D. H., and Jehee, J. M. F. (2011) Dual roles for spike signaling in cortical neural populations, *Frontiers in Computational Neuroscience*

Tatler, B. W., Hayhoe, M.M., Land, M. F., and Ballard, D. H. (2011) Eye Guidance in natural vision: Reinterpreing salience, *ournal of Vision*

Rothkopf, C. A., and Ballard, D. H. (2010) Credit assignment in multiple goal embodied visuomotor behavior, *Frontiers in Psychology*

Yi, W. and Ballard, D. H. (2009) Recognizing behavior in hand-eye coordination patterns, *Int. Journal of Humanoid Robotics*

Ballard, D. H. and Hayhoe, M. M.(2009) Modeling the role of task in the control of gaze, *Visual Cognition*, 17, 1185-1204

Rothkopf, C. A., and Ballard, D. H.(2009) Image statistics at the point of gaze during human navigation, *Visual Neuroscience*,26, 81-92

Jehee, J. F. M. and Ballard, D. H.(2009) Predictive Feedback Can Account for Biphasic Responses in the Lateral Geniculate Nucleus, *PLoS Computational Biology*

Rothkopf, C. A., Ballard D. H. and Hayhoe, M. M. (2007) Task and context determine where you look, *Journal of Vision,* 7(14) 1-20

Gu, X., and Ballard, D. H. (2006) An Equilibrium Point based Model Unifying Movement Control in Humanoids, *Robotics: Science and Systems*

Hayhoe, M. M., and Ballard, D. H. (2005) Eye Movements in Natural Behavior, *Trends in Cognitive Science*

Sprague, N. and Ballard, D. H. (2005) Modeling Embodied Visual Behaviors *ACM Transactions on Applied Perception*

W. Yi and D. H. Ballard. Vergence Control in Fixation with Minimal Disparity Information, Proc. 6th International Conference on Cognitive Modeling, pp. 326-330, Pittsburg, July 2004.

Chen Yu and Dana H. Ballard, "A Multimodal Learning Interface for Grounding Spoken Language in Sensorimotor Experience", ACM Transactions on Applied Perception. Vol 1, No 1, 2004.

Chen Yu and Dana H. Ballard, "On the Integration of Grounding Language and Learning Objects", Nineteenth National Conference on Artificial Intelligence (AAAI-04), San Jose, California, July 25-29, 2004.

Chen Yu, Dana H. Ballard and Richard N. Aslin, "The Role of Embodied Intention in Early Lexical Acquisition", 25th Annual Meeting of Cognitive Science Society (CogSci 2003), Boston, MA, July

31 - Aug 2, 2003. [The Marr Prize winner for best student paper ]

Chen Yu and Dana H. Ballard, "A Multimodal Learning Interface for Grounding Spoken Language in Sensory Perceptions", Fifth International Conference on Multimodal Interface (ICMI 2003), Vancouver, Canada, November 5-7, 2003.

Chen Yu and Dana H. Ballard, "A Formal Model of Visual Attention in Embodied language Acquisition", Third Annual Meeting of Vision Science Society (VSS'03), Sarasota, Florida, May 9 - 14th, 2003.

Chen Yu and Dana H. Ballard, "Exploring the Role of Attention in Modeling Embodied Language Acquisition", Fifth International Conference on Cognitive Modeling (ICCM 2003), Bamberg, Germany, April 10 - 12, 2003.

Dana H. Ballard and Chen Yu, "A Multimodal Learning Interface for Word Acquisition", IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'03), Hong Kong, 2003.

Chen Yu, Dana H. Ballard and Shenhuo Zhu, "Attentional Object Spotting by Integrating Multimodal Input", IEEE International Conference on Multimodal Interface (ICMI'02), Pittsburgh, PA, October 14-16, 2002.

Chen Yu and Dana H. Ballard, "Understanding Human Behaviors Based on Eye-head-hand coordination", 2nd Workshop on Biologically Motivated Computer Vision (BMCV2002), Tübingen, Germany, November 22nd - 24th, 2002.

Chen Yu and Dana H. Ballard, "Learning to Recognize Human Action Sequences", IEEE International Conference on Development and Learning (ICDL'02), Cambridge, MA, June 12 - 15, 2002.

Chen Yu and Dana H. Ballard, " Learning Spoken Words from Multisensory Input", International Conference on Signal Processing (ICSP'02), Beijing, CHINA, August 26-30, 2002.

Nathan Sprague and Dana Ballard, "Eye Movements for Reward Maximization", *Advances in Neural Information Processing Systems, 15* , 2003 (draft) .

Nathan Sprague and Dana Ballard, "Multiple-Goal Reinforcement Learning with Modular Sarsa(0)", *IJCAI 2003* , Acapulco, August 2003.

Nathan Sprague and Dana Ballard, "A Visual Control Architecture for a Virtual Humanoid", *IEEE-RAS International Conference on Humanoid Robots* , Tokyo, November 2001.

Sanders, B.J., D.J. Logan, C.J. Duffy, and D.H. Ballard, "A predictive coding model of MST cells," <<in preparation>>.

Zhang, Z. and D.H. Ballard, "Distributed synchrony," submitted for publication. Zhang, Z. and D.H. Ballard, "A single spike model of predictive coding," *Computational Neuroscience Meeting* (CNS*2003), Alicante, Spain, July 2003.

Rao, R., Zelinsky, G., Hayhoe, M., & Ballard, D. (2002). Eye movements in iconic visual search. *Vision Research, 42(11),* 1447-1463.

Shimozaki, S., W.H. Merigan, G.J. Zelinsky, M.M. Hayhoe, and D.H. Ballard, "Spatial memory and saccade targeting deficits from parietal injury," submitted for journal publication (Visual *Cognition).*

Zhu, S. and D.H. Ballard, submitted for conf. publication (Conf. *on Machine Learning,* 2001). Triesch, J., D.H. Ballard, and R.A. Jacobs, "Fast temporal dynamics of visual cue integration," to

appear, *Perception.* Yu, C. and D.H. Ballard, "Exploring the role of attention in modeling embodied language

acquisition," *5th Int'l. Conf. on Cognitive Modeling,* Bamberg, Germany, April 2003. Ballard, D.H. and C. Yu, "A multimodal learning interface for word acquisition," *IEEE Int'l. Conf.*

*on Acoustics, Speech and Signal Processing(ICASSP'03),* Hong Kong, 2003.

Chen Yu and Dana H. Ballard, "Understanding human behaviors based on eye-head-hand coordination," *2nd Workshop on Biologically Motivated Computer Vision* (BMCV2002), Tubingen,

Germany, November 2002.

Yu, C., D.H. Ballard, and S. Zhu, "Attentional object spotting by integrating multimodal input," *IEEE Int'l. Conf. on Multimodal Interface* (ICMI'02), Pittsburgh, PA, October 2002.

Yu, C. and D.H. Ballard, "Learning spoken words from multisensory input," *Int'l. Conf. on Signal Processing* (ICSP'02), Beijing, August 2002.

Yu, C. and D.H. Ballard, "Learning to recognize human action sequences," *IEEE Int'l. Conf. on Development and Learning* (ICDL'02), Cambridge, MA, June 2002.

Rao, R.P.N., G.J. Zelinsky, M.M. Hayhoe, and D.H. Ballard, "Eye movements in iconic visual search," *Vision Research 42,* 11, 1447-1463, 2002.

Zhang, Z. and D.H. Ballard, "Distributed synchrony—Understanding the brain at the single cell level," *Proc., 8th Int'l. Conf. on Neural Information Processing* (ICONIP2001), Shanghai, November 2001.

Zhang, Z. and D.H. Ballard, "Distributed synchrony," *Proc., 10th Annual Computational Neuroscience Meeting* (CNS*2001), San Francisco and Pacific Grove, June-July 2001.

Zuohua Zhang, Dana H. Ballard, *A single spike model of predictive coding,* Computational Neuroscience meeting, 2003

Zuohua Zhang, Dana H. Ballard, *Distributed Synchrony,* poster at Sensory Coding and the Natural Environment conference, 2002.

Zuohua Zhang, Dana H. Ballard, *Distributed Synchrony - Understanding the Brain at the Single Cell Level,* ICONIP2001.

Zuohua Zhang, Dana H. Ballard, *Distributed Synchrony,* Computational Neuroscience 2001, Journal of Neurocomputing, Vol 44-46C, pp 715-720.

Zuohua Zhang, Dana H. Ballard, *Distributed Synchrony* , poster at Neural Information and Coding Workshop (NIC), 2001.

Dana H. Ballard, Zuohua Zhang, *Distributed Synchrony: a Unifying Principle for Neural Signaling,* oral presentation at Society for Neuroscience, Annual Meeting, 2000.

Ballard, Dana H., Zhang, Zuohua, *A synchronous firing model of L G N* , Computational Neuroscience 2000.

Ballard, Dana H., Rao, Rajesh P.N., Zhang, Zuohua, *A Single-spike Model of Predictive Coding,* Journal of neurocomputing, 32-33 (1-4) (2000) pp. 17-23 .

Dana H. Ballard, Zuohua Zhang, and Rajesh P.N. Rao, *Distributed Synchrony: A Probabilistic Model of Neural Signaling,* chapter in *Probabilistic Models of the Brain: Perception and Neural Function,* Eds. Rajesh P.N. Rao, Bruno A. Olshausen and Michael S. Lewicki, MIT press, 2001.

Ballard D. H. , M.M. Hayhoe, G. Salgian and H. Shinoda, "Spatio-temporal organization of behavior, *Spatial Vision 13,* 2, 321-333, 2000.

Ballard, D.H., R.P.N. Rao, and Z. Zhang, "A single-spike model of predictive coding," *J. Neurocomputing,* 2000.

Bayliss, J.D. and D.H. Ballard, "Single trial P300 epoch recognition in a virtual environment," *Neurocomputing,* 2000.

Bayliss, J.D. and D.H. Ballard, "A virtual reality testbed for brain-computer interface research," *IEEE Trans. on Rehabilitation Engineering,* 2000.

Ballard, D.H. and Z. Zhang, "A synchronous firing model of LGN," *Proc., Computational Neuroscience Meeting* (CNS*2000), Brugge, Belgium, July 2000.

Bayliss, J.D. and D.H. Ballard, "Recognizing evoked potentials in a virtual environment," *Advances in Neural Information Processing Systems 12,* 2000.

Bayliss, J.D. and D.H. Ballard, "Single trial P3 epoch recognition in a virtual environment," *Proc., Computational Neuroscience Meeting* (CNS*99), Pittsburgh, PA, July 1999.

Bayliss, J.D. and D.H. Ballard, "Single trial P300 recognition in a virtual environment," *CIMA '99*

*(Soft Computing in Biomedicine),* Rochester, NY, June 1999.

Pelz, J.B., M.M. Hayhoe, D.H. Ballard, A. Shrivastava, J.D. Bayliss, and M. von der Heyde, "Development of a virtual laboratory for the study of complex human behavior," *Proc., SPIE (International Society for Optical Engineering), Vol. 3639B, The Engineering Reality of Virtual Reality,* San Jose, CA, January 1999.

Rao, R.P.N. and D.H. Ballard, "Predictive coding in the visual cortex: A functional interpretation of some extra-classical receptive-field effects," *Nature Neuroscience 2,* 1, 79–87, January 1999.

Magnuson, J., D. Bensinger, M.M. Hayhoe, and D.H. Ballard, "Learning to form visual chunks: On the structure of visuo-spatial working memory, *Proc., 20th Annual Conf., Cognitive Science Society,* M.A. Gernsbacher and S.J. Derry (Eds.), Lawrence Erlbaum, Inc., U. Wisconsin—Madison, August 1998.

Rao, R.P.N. and D.H. Ballard, "Development of localized oriented receptive fields by learning a translation-invariant code for natural images," *Network: Computation in Neural Systems 9,* 2, 219–234, May 1998.

Hayhoe, M.M., D. Bensinger, and D.H. Ballard, "Task constraints in visual working memory," *Vision Research 38,* 1, 125–137, 1998.

Salgian, G. and D.H. Ballard, "Using visual routines to drive in a virtual environment," *Proc., 3rd IFAC Symp. on Intelligent Autonomous Vehicles,* Madrid, Spain, March 1998.

Salgian, G. and D.H. Ballard, "Visual routines for autonomous driving," *Proc., 6th Int'l. Conf. on Computer Vision* (ICCV-98), 876–882, Bombay, India, January 1998.

Sarukkai, R.R. and D.H. Ballard, "Phonetic set indexing for fast lexical access," *IEEE Trans. on Pattern Analysis and Machine Intelligence 20,* 1, 78–82, January 1998.

de Sa, V.R., & Ballard, D. (1998) Category Learning through Multi-Modality Sensing. In *Neural Computation* 10(5)

Ballard, D.H., M.M. Hayhoe, P.K. Pook, and R.P.N. Rao, "Deictic codes for the embodiment of cognition," *Behavioral and Brain Sciences 20,* 4, 723–767, December 1997.

de Sa, V.R., & Ballard, D. (1997). Perceptual Learning from Cross-Modal Feedback. In R. L. Goldstone, P. G. Schyns, & D. L. Medin (Eds.) Psychology of Learning and Motivation, Vol 36. (pp 309-351). San Diego, CA: Academic Press.

Salgian, G. and D.H. Ballard, "Developing autonomous navigation algorithms using photorealistic simulation," *IEEE Conf. on Intelligent Transportation Systems,* 882–887, Boston, MA, November 1997.

Zelinsky, G.J., R.P.N. Rao, M.M. Hayhoe, and D.H. Ballard, "Eye movements reveal the spatiotemporal dynamics of visual search," *Psychological Science 8,* 6, 448–453, November 1997.Sarukkai, R.R. and D.H. Ballard, "Word set probability boosting for improved

spontaneous dialog recognition," *IEEE Trans. on Speech and Audio Processing 5,* 5, 438–450, September 1997.

Rao, R.P.N. and D.H. Ballard, "Dynamic model of visual recognition predicts neural response properties in the visual cortex," *Neural Computation 9,* 4, 721–763, 1997.

Pook, P.K. and D.H. Ballard, "Deictic human/robot interaction," *Robotics and Autonomous Systems 18,* 259–269, 1996.

Rao, R.P.N. and D.H. Ballard, "A computational model of spatial representations that explains object-centered neglect in parietal patients," in J. Bower (Ed.). *Computational Neuroscience '96* (Cambridge, MA, July 1996). Plenum Press, 1996.

Rao, R.P.N. and D.H. Ballard, "Cortico-cortical dynamics and learning during visual recognition: A computational model," in J. Bower (Ed.). *Computational Neuroscience '96* (Cambridge, MA, July 1996). Plenum Press, 1996.

Sarukkai, R.R. and D.H. Ballard, "Improved spontaneous dialogue recognition using dialogue and utterance triggers by adaptive probability boasting," *Proc., Int'l. Conf. on Spoken Language*

*Processing,* Philadelphia, PA, October 1996.

Rosca, J.P. and D.H. Ballard, "Discovery of subroutines in genetic programming," *Video Proc., 13th Nat'l. Conf. on Artificial Intelligence* (AAAI-96), Portland, OR, August 1996.

Rosca, J.P. and D.H. Ballard, "Evolution-based discovery of hierarchical behaviors," *Proc., 13th Nat'l. Conf. on Artificial Intelligence* (AAAI-96) (MIT Press), Portland, OR, August 1996.

Smeets, J.B.J., M.M. Hayhoe, and D.H. Ballard, "Goal-directed arm movements change eye-head coordination," *Experimental Brain Research 109,* 434-440, 1996.

Rao, R.P.N., G. Zelinsky, M.M. Hayhoe, and D.H. Ballard, "Modeling saccadic targeting in visual search," in D. Touretzky, M. Mozer, and M. Hasselmo (Eds.). *Advances in Neural Information Processing Systems 8* (Proc., NIPS 95, Denver, CO, November 1995). Cambridge, MA: MIT Press, 1996.

Sarukkai, R.R. and D.H. Ballard, "A novel word pre-selection method based on phonetic set indexing," *Proc., IEEE Int'l. Conf. on Acoustics, Speech and Signal Processing,* Atlanta, GA, May 1996.

Zelinsky, G.J., R.P.N. Rao, M.M. Hayhoe, and D.H. Ballard, "Eye movements during a realistic search task," abstract, *Invest. Ophthal. Vis. Sci. 37,* 1996.

Rao, R.P.N. and D.H. Ballard, "An active vision architecture based on iconic representations," *AI Journal 78,* 1, 461–505, October 1995.

Ballard, D.H. and R.P.N. Rao, "A computational model of human vision based on visual routines," *Proc., Deutsche Arbeitsgemeinschaft für Mustererkennung* (DAGM) (German Working Group on Pattern Recognition), Bielefeld, Germany, Springer-Verlag, Sept. 1995.

Sarukkai, R.R. and D.H. Ballard, "The distance set representations of speech segments," *Proc., EUROSPEECH '95,* Madrid, Spain, September 1995.

Rao, R.P.N. and D.H. Ballard, "Natural basis functions and topographic memory for face recognition," *Proc., 14th Int'l. Joint Conf. on Artificial Intelligence,* Montréal, August 1995.

Rosca, J.P. and D.H. Ballard, "Causality in genetic programming," *Proc., 6th Int'l. Conf. on Genetic Algorithms* (ICGA6), L. Eshelman (Ed.), Morgan Kaufmann, Pittsburgh, PA, July 1995.

Rao, R.P.N. and D.H. Ballard, "Object indexing using an iconic sparse distributed memory," *Proc., 5th Int'l. Conf. on Computer Vision* (ICCV), Cambridge, MA, June 1995.

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