

CURRICULUM VITAE

Norberto M. Grzywacz

February 6, 2004

General Information

Education

- 1981-1984 Doctoral thesis in biophysics of photoreceptors under the supervision of Professor Peter Hillman. The work was part of a program reserved to the 10% top students of the Hebrew University of Jerusalem.
- 1980 Complementary studies in biology at the Hebrew University of Jerusalem.
- 1975-1979 Undergraduate studies in physics and mathematics at the Hebrew University of Jerusalem; received degree with honors.

Professional Career

- 2003- Director of the Center for Vision Science and Technology, University of Southern California, USC.
- 2003-2004 Fellow of the USC Center for Interdisciplinary Research.
- 2001- Professor, Department of Biomedical Engineering, USC.
- 2001- Professor, Neuroscience Graduate Program, USC.
- 1994-2001 Senior Scientist at the Smith-Kettlewell Eye Research Institute (SKERI).
- 1993-1994 Scientist at SKERI.
- 1991-1993 Associate Scientist at SKERI.
- 1987-1990 Research Scientist at the Center for Biological Information Processing of the Massachusetts Institute of Technology (MIT).

1985-1986 Postdoctoral fellow in Professor Tomaso Poggio's group at MIT.

Research Interests

- Mechanisms of Retinal Directional Selectivity
- Representation of Information in Retinal Ganglion Cells
- Development of Retinal Receptive Fields
- Optimal Processing Principles for Retinal Function
- Computation and Psychophysics of Motion Perception

Grant-Related Activity

Participation in Grant Reviewing Committees

2004 Reviewer for the Air Force Office of Scientific Research.

2000-2004 Regular Reviewer for the National Eye Institute, Central Visual Processes Study Section, National Institutes of Health.

1999 Ad Hoc Reviewer for the National Eye Institute, Visual Sciences B Study Section, National Institutes of Health.

1996-1999 External Reviewer for the National Eye Institute, Visual Sciences B Study Section, National Institutes of Health.

1993 External Reviewer for the National Institute of Mental Health, National Institutes of Health.

1991 External Reviewer for the Basic Research Foundation of The Israel Academy of Sciences and Humanities.

- 1990 Advisory Consultant to the National Institute of Neurological and Communicative Disorders and Stroke, National Institutes of Health.
- 1989- External Reviewer for the National Science Foundation Program in Sensory Physiology and Perception.

Awards and Grants Received

- 2003 Faculty Fellowship from the Interdisciplinary Research Center, USC, \$ 50,000.
- 1996-2007 Principal Investigator in a Grant from the National Eye Institute (R01 EY11170). Title: "Development of Complex Retinal Receptive Fields." Total Direct Costs: \$ 1,026,167.
- 1991-2006 Principal Investigator in a Grant from the National Eye Institute.(R01 EY08921). Title from 1991 to 2001: "Facilitation and Inhibition in Directional Selectivity." Title from 2001 to 2006: "Correlation Among Retinal Directionally Selective Cells." Total Direct Costs: \$ 614,548 from 1991 to 1996, \$ 971,153 from 1996-2001, \$1,250,000 from 2001-2006.
- 1994-2003 Travel Grants from the Generalitat Valenciana, Community of Valencia, Spain.
- 1994 The Kettlewell Chair, SKERI, \$ 50,000.
- 1992-1998 Co-Principal Investigator in a Grant from the Air Force Office of Scientific Research (F49620-95-1-0265). Title: "Visual Processing of Object Velocity and Acceleration." Total Direct Costs: \$ 301,818 from 1992-1995 and \$ 339,504 from 1995-1998.

- 1990-1993 Sub-Contractor in a Grant from the Office of Naval Research (N00014-91-J-1280). Title: "Theoretical and Experimental Determination of the Robust Biological Mechanism of Retinal Directional Selectivity." Total Direct Costs: \$ 116,451.
- 1988 Honorable Mention for the Marr Prize of the International Conference on Computer Vision.
- 1988-1990 Principal Investigator in a Grant from the National Science Foundation (BNS-8809528). Title: "The Computation of Direction Selectivity in the Retina." Total Direct Costs: \$ 97,900.
- 1987-1988 Fairchild Fellowship.
- 1987-1989 Co-Principal Investigator in a Grant from the Sloan Foundation (87-1-19). Title: "Computation of Motion and Stereo: From Theory to Biophysics." Total Direct Costs: \$ 121,996.
- 1986-1988 Co-Principal Investigator in a Equipment Grant from the Office of Naval Research (N00014-86-G-0152). Title: "Computation of Stereo, Motion, and Color." Total Direct Costs: \$ 205,576.
- 1985-1986 Bantrell Postdoctoral Fellowship.

Teaching Experience

Courses

- 2004- Developer and Coordinator of "Late Visual Processes," an inter-school, interdisciplinary graduate course at USC.

- 2004- Developer and Coordinator of "Early Visual Processes," an inter-school, interdisciplinary graduate course at USC.
- 2003 Lecturer at the graduate course "Advanced Studies of the Nervous System" at the Department of Biomedical Engineering, USC.
- 2003 Lecturer at the undergraduate course "Control and Communication in the Nervous System" at the Department of Biomedical Engineering, USC.
- 2002-2003 Coordinator of the Neurolunch, a graduate seminar of the Neuroscience Graduate Program at USC.
- 2002- Lecturer at the graduate course "Computational Vision" at the Department of Biomedical Engineering, USC.
- 1999-2001 Lecturer at the doctorate course "Neurobiology and Neurotechnology" at the University of Alicante, Alicante, Spain.
- 1999-2001 Lecturer at the doctorate course "The Neurobiology of Vision" at the University of Alicante, Alicante, Spain.
- 1999 Lecturer at the course "Visual Neuroscience" at the Gulbenkian Institute, Oeiras, Portugal.
- 1998 Principal Lecturer at the winter course "The Physics of Light and the Evolution of the Eye" at the University of Alicante, Alicante, Spain.
- 1997 Principal Lecturer at the summer course "The Physics of Light and the Evolution of the Eye" at the University of Alicante, Alicante, Spain.
- 1996 Invited Lecturer at the "Seminar of Introduction to Neurotecnology," Universidad de Murcia, Cartagena, Spain.

- 1995-1996 Principal Lecturer at the summer course "Vision in Brains and Computers" at the University of Alicante, Alicante, Spain.
- 1994-1995 Principal Lecturer at the summer course "Models of Retinal Function" at the University of Alicante, Alicante, Spain.
- 1992- Organizer of the "Wet" Neuroscience Journal Club at SKERI.
- 1990 Invited lecturer in the summer course "Methods in Computational Neuroscience" at the Marine Biological Laboratories in Woods Hole.
- 1989 Invited lecturer in the Cold Spring Harbor Summer Course in Computational Neuroscience at the Cold Spring Harbor Biological Laboratories.
- 1989 Coordinator of the activity "The Electric Head: From Proteins to EEG" of the Independent Activities Period of MIT.
- 1987-1990 Lecturer in the course "Vision in Brains and Computers" of the Harvard University Extension School.
- 1987-1990 Organizer of the weekly seminar of MIT's Center for Biological Information Processing.
- 1985-1986 Invited lecturer in the Neurobiology course of the Harvard University Extension School.
- 1980-1984 Instructor at the following courses of The Hebrew University of Jerusalem:
- Electronics for biologists.
 - Statistics for biologists.
 - General Physiology.
 - Sensory Physiology.

Ph.D. Students and Postdoctoral Fellows Supervised.

- 2004- Dr. Eun-Jin Lee, postdoctoral fellow
- 2004- Mr. Manoj Raghuraman
- 2003- Ms. Susmita Chatterjee, graduate student at USC
- 2003- Dr. Mónica Padilla
- 2002- Mr. Jeff Wurfel, graduate student at USC
- 2001- Mr. Joaquín Rapela, graduate student at USC
- 2000- Dr. José Barraza, postdoctoral fellow
- 1997- Dr. Rosario Balboa, postdoctoral fellow
- 1996- Dr. David Merwine, postdoctoral fellow
- 1996-2000 Dr. Lynette Nguyen, postdoctoral fellow
- 1997-2000 Dr. David Ascher, postdoctoral fellow
- 1996-1997 Dr. Preeti Verghese, postdoctoral fellow
- 1995-1997 Dr. Mark Pettet, postdoctoral fellow
- 1995-1997 Dr. Rosario Balboa, who completed her doctorate at the University of Alicante, Spain
- 1994-1998 Dr. José Vicente Guardiola, who completed his doctorate at the University of Alicante, Spain
- 1992-1995 Dr. Julie Harris, postdoctoral fellow
- 1992-1994 Dr. Pierre-Yves Burgi, postdoctoral fellow
- 1991-1995 Dr. Evelyne Sernagor, postdoctoral fellow
- 1989-1995 Mr. Jim Smith, graduate student at MIT
- 1987-1992 Dr. Lyle Borg-Graham, who completed his doctorate at MIT.

Orals and Dissertation Committees.

- 2003 Dong Song; Doctorate Committee at USC

- 2003 Ran Carmi; Doctorate Committee at USC
- 2003 Mircea Nicolescu; Doctorate Committee at USC
- 2003 Echo Wei; Doctorate Committee at USC
- 2002 Eric Ortega; Doctorate Committee at USC.
- 2002 Chunhong Zhou; Doctorate Committee at USC
- 1998 Davis Barch; Orals at University of California at Berkeley
- 1998 Dr. José Vicente Guardiola; Chairman of Doctorate Committee at the University of Alicante, Spain
- 1997 Dr. David Ascher; Doctorate Committee at Brown University at Providence, Rhode Island
- 1997 Dr. Rosario Balboa; Chairman of Doctorate Committee at the University of Alicante, Spain
- 1994 Dr. Magdalena Garcia; Doctorate Committee at the University of Alicante, Spain
- 1993 Julie Scott; Orals at University of California at Berkeley

Scientific Activity

Chairing and Organization of Sections and Workshops in Scientific Meetings

- 2004 Co-Organizer of the meeting “Vision at Spring in Alicante,” University of Alicante, Spain.
- 2002 Co-Organizer of the Fall Provost’s Neuroscience Symposium “The Perceiving Organism: Interdisciplinary Vistas in Vision,” USC.
- 2002- Co-Organizer of the USC Vision Symposium.

- 2000 Chairperson of the Directional Selectivity session at the FASEB meeting, Copper Mountain, Colorado.
- 1998 Co-Organizer of the Workshop on Retinal Adaptation at SKERI.
- 1997- Co-Organizer of the Club HEBB, a discussion group for systems neurosciences co-sponsored by SKERI, Stanford University, and the University of California at San Francisco, Berkeley, and Davis.
- 1997 Chairperson of the Cholinergic Amacrine Cells' session in the meeting of the Association for Research in Vision and Ophthalmology (ARVO).
- 1996 Chairperson of the Retinal Ganglion Cells' session in the meeting of the Association for Research in Vision and Ophthalmology (ARVO).
- 1996 Co-Organizer of the Workshop on Object Recognition at SKERI.
- 1991 Organizer of the Workshop "Quantitative Models of Retinal Function" in the Third meeting of the International Brain Research Organization (IBRO).
- 1991 Chairperson of the Retinal Circuitry session in the meeting of the Association for Research in Vision and Ophthalmology (ARVO).

Scientific Meeting Refereeing

Neural Information Processing Systems: Natural and Synthetic

Journal Refereeing

Applied Optics

Biological Cybernetics

Computer

European Journal of Neuroscience

Experimental Brain Research

Journal of Comparative Neurology

Journal of European Neuroscience

Journal of General Physiology

Journal of Neurophysiology

Journal of Neuroscience

Journal of the Optical Society of America

Journal of Physiology

Journal of Visual Communication and Image Representation

Nature

Nature Neuroscience

Neural Computation

Neuron

Perception

Perception and Psychophysics

Proceedings of the National Academy USA

Psychological Reviews

Science

Spatial Vision

Synapse

Visual Neuroscience

Vision Research

Affiliation in Scientific Societies

The Israel Association for Eye Research.
 The Association for Research in Vision and Ophthalmology.
 The Society for Neuroscience.
 Optical Society of America.
 American Institute of Physics.
 International Brain Research Organization

Selected List of Invited Lectures

2004 Seminar at the Neuroscience Graduate Program, University of Southern California.

2004 Invited talk at the 29th Annual Interdisciplinary Conference, Jackson Hole, Wyoming.

2003 Lecture at the Centro de Estudios Interdisciplinarios of the Universidad Nacional, Bogotá, Colombia.

2002 Lecture at the Workshop on Advanced Methods of Physiological System Modeling, Marina del Rey, CA.

2002 Lecture at the Gordon Conference on Coding and Natural Scenes, Mount Holyoke College, MA.

2001 Seminar at the Department of Ophthalmology, The Mount Sinai School of Medicine, New York, New York.

2000 Seminar at the Division of Biology, California Institute of Technology, Pasadena, California.

2000 Seminar at the Department of Bioengineering at the University of Pennsylvania, Philadelphia, Pennsylvania.

2000 Seminar at the Department of Biomedical Engineering at the University of Southern California, Los Angeles, California.

- 2000 Seminar at the Department of Anatomy & Neurobiology, Boston University School of Medicine, Boston, Massachusetts.
- 2000 Vision Seminar of the Department of Neuroscience, University of California at Davis, Davis, California.
- 1999 Invited talk at the RINVA'99 meeting on Biotechnology, University of Valladolid, Valladolid, Spain.
- 1999 Invited talk at the Conference of the Spanish Society of Histology, Alicante, Spain.
- 1998 Invited talk at the FASEB meeting's session on Retinal Development, Falls River, Vermont.
- 1998 Seminar at the Department of Anatomy and Neurobiology, Medical School, Saint Louis University, Saint Louis, Missouri.
- 1998 Invited talk at the RINVA'98 meeting on Biotechnology, University of Valladolid, Valladolid, Spain.
- 1997 Two Invited Talks at the Workshop "Machine Vision Meets Machine Learning" at the Newton Institute of Cambridge University, Cambridge, United Kingdom.
- 1997 Seminar at the Department of Psychology, Nottingham University, Nottingham, United Kingdom.
- 1997 Seminar at the Department of Languages and Information Systems, University of Alicante, Alicante, Spain.
- 1996 Colloquium of the Department of Information Technology and Computation, University of Alicante, Alicante, Spain.
- 1996 Neuroscience-Group Seminar, University of Newcastle Upon Tyne, Newcastle Upon Tyne, United Kingdom.
- 1996 Vision Seminar of the Department of Neuroscience, University of California at Davis, Davis, California.

- 1996 Talk at the Retinal Neuroanatomy Group, University of Pennsylvania, Philadelphia, Pennsylvania.
- 1996 Colloquium of the Institute for Research in Cognitive Science at the University of Pennsylvania, Philadelphia, Pennsylvania.
- 1996 Invited talk at the FASEB meeting's workshop on Computational Approaches to Retinal Research, Falls River, Vermont.
- 1996 Seminar of the Stanford Associated Perception Students, Stanford University, Stanford, California.
- 1996 Craik Club Seminar, Cambridge University, Cambridge, United Kingdom.
- 1996 Rank Mini-Symposium on Visual Motion Analysis, Lake District, United Kingdom.
- 1996 Oxyopia, University of California at Berkeley, Berkeley, California.
- 1996 Seminar of the Neurobiology Research Center, University of Alabama at Birmingham, Birmingham, Alabama.
- 1995 Invited Talk at the Conference of the Spanish Association of Artificial Intelligence, Alicante, Spain
- 1995 Seminar at the Institute of Neuroscience, School of Medicine, University of Alicante, Alicante, Spain
- 1995 Friday Seminar, Department of Molecular and Cell Biology, University of California at Berkeley, Berkeley, California
- 1995 Breakfast Seminar, Vision Group, School of Medicine, University of California at San Francisco, San Francisco, California
- 1994 Seminar to the Vision Group at the NASA-Ames Research Center, Moffet-Field, California

- 1994 Seminar at the Department of Information Technology and Computation, University of Alicante, Alicante, Spain
- 1994 Seminar at the Institute of Neuroscience, School of Medicine, University of Alicante, Alicante, Spain
- 1993 Science Writer's Seminar for the 25th Anniversary of the National Eye Institute, Exploratorium, San Francisco, California.
- 1993 Workshop on Dendritic Processing of Synaptic Information, Max-Planck-Institut für Biologische Kybernetik, Tübingen, Germany.
- 1993 Seminar of the Department of Psychology, Stanford University, Stanford, California.
- 1993 Seminar of the Neurobiology Research Center, University of Alabama at Birmingham, Birmingham, Alabama.
- 1992 Seminar to the Vision Group at the NASA-Ames Research Center, Moffet-Field, California
- 1991 Oxyopia, University of California at Berkeley, Berkeley, California.
- 1991 Seminar of the Department of Biomedical Engineering, Boston University, Boston, Massachusetts.
- 1990 Seminar at the Graduate Program of Neurobiology and Behavior, State University of New York at Stony Brook, Stony Brook, New York.
- 1990 Seminar at the Department of Biomedical Engineering, Johns Hopkins University, Baltimore, Maryland
- 1990 Seminar at the Department of Psychology, University of California at San Diego, San Diego, California.
- 1990 Seminar at the Department of Neuroscience, University of Pennsylvania, Philadelphia, Pennsylvania.

- 1990 Thursday Colloquium, SKERI, San Francisco, California.
- 1990 Friday Seminar, Biological Laboratories, Harvard University, Cambridge, Massachusetts.
- 1990 Seminar of the Department of Biology, Brandeis University, Waltham, Massachusetts.
- 1989 Cold Spring Harbor Workshop on Neural Computation, Co-Sponsored by ONR, Cold Spring Harbor, New York.
- 1989 Neural Information Processing Seminar, Division of Applied Sciences, Harvard University, Cambridge, Massachusetts.
- 1988 ONR Neural and Electronic Networks Workshop, Woods Hole, Massachusetts.
- 1988 Thursday Colloquium, SKERI, San Francisco, California.
- 1987 DARPA Neural Network Study, Bedford, Massachusetts.
- 1987 Vision Seminar, Artificial Intelligence Laboratory, MIT, Cambridge, Massachusetts.
- 1986 Meeting on Organization of Structure and Function in the Brain, Bad Homburg, Germany.
- 1986 Friday Seminar, Biological Laboratories, Harvard University, Cambridge, Massachusetts.
- 1986 Lunch Seminar, Whitaker College, MIT, Cambridge, Massachusetts.
- 1985 Conference on Nonlinear Processes in Neurobiology, Weizmann Institute, Rehovot, Israel.
- 1985 Lunch Seminar, Whitaker College, MIT, Cambridge, Massachusetts.
- 1985 Workshop on Neurobiological Noise Analysis, The Neurosciences Institute, New York, New York.
- 1984 "Nervous" Seminar, Department of Neurobiology, The Hebrew University of Jerusalem, Jerusalem, Israel.

1984 ``Nervous" Seminar, Department of Physiology, Tel Aviv University, Tel Aviv, Israel

Institutional Work

2003- Director of the Center for Vision Science and Technology, USC.

2003- Admissions Committee, Department of Biomedical Engineering, USC.

2002- Executive Committee, Neuroscience Graduate Program, USC.

2002- Chairman of the Curriculum Committee, Neuroscience Graduate Program, USC.

2002- Research Committee, School of Engineering, USC.

1992-1995 Chairman of the Colloquia Committee of SKERI.

1992-1993 Chairman of the Central-Computer Committee of SKERI.

1991-2001 Chairman of the Library Committee of SKERI.

Publications

Books

Grzywacz, N.M., and F. Escolano (2002) *Vision in Brains and Computers*. MIT Press, Cambridge, Massachusetts, USA. In Preparation.

Publications in Scientific Journals

Zucker, C.L., B. Elinger, and N.M. Grzywacz (2003) GABA_B Receptors in the Cholinergic Circuitry of the Rabbit Retina. *J. Comp. Neurol.* In Press.

Balboa, R.M., and N.M. Grzywacz (2003) Power Spectra and Distribution of Contrasts of Natural Images from Different Habitats. *Vision Res.* **43**, 2527-2537.

Vaina, L.M., N.M. Grzywacz, P. Saiviroonporn, M. LeMay, D.C. Bienfang, and A. Cowey (2003) Can Spatial and Temporal Motion Integration Compensate for Deficits in Local Motion Mechanisms? *Neuropsychologia*, **41**, 1817–1836.

Barraza, J.F., and N.M. Grzywacz (2003). Local Computation of Angular Velocity in Rotational Visual Motion. *J. Opt. Soc. Am. A.* **20**, 1382-1390.

Grzywacz, N.M., and J. de Juan (2003) Sensory Adaptation as Kalman Filtering: Theory and Illustration with Contrast Adaptation. *Network: Comput. Neural Syst.* **14**, 465-482.

Grzywacz, N.M., R.M. Balboa, and C.W. Tyler (2002). Reply to a Letter by Ruderman. *Vision Res.*, **42**, 2803-2805.

- Barraza, J.F., and N.M. Grzywacz (2002). Temporal Coherence in Visual Rotation. *Vision Res.*, **42**, 2463-2569.
- Barraza, J.F., and N.M. Grzywacz (2002). Angular Velocity in the Perception of Visual Rotation. *Vision Res.*, **42**, 2457-2562.
- Garcia, M., N.M. Grzywacz, and J. De Juan (2002) Interocular Effect of Intravitreal Injection of 6-Hydroxydopamine and Dopamine on Spinule Formation in Teleost Retina. *Histology and Histopathology*, **17**, 721-729.
- Grzywacz, N.M., and R.M. Balboa (2002) A Bayesian Framework for Sensory Adaptation. *Neural Computation*, **14**, 543-559.
- Balboa, R.M., C.W. Tyler, and N.M. Grzywacz (2001) Occlusions Contribute to Scaling in Natural Images. *Vision Res.*, **41**, 955-964.
- Ascher, D., and N.M. Grzywacz (2000) A Bayesian Model For the Measurement of Visual Velocity. *Vision Res.* **40**, 3427-3434
- Burgi, P.Y., A.L. Yuille, and N.M. Grzywacz (2000) Probabilistic Motion Estimation Based on Temporal Coherence. *Neural Computation*, **12**, 1839-1867.
- Balboa, R.M., and N.M. Grzywacz (2000) Occlusions and Their Relationship With the Distribution of Contrasts in Natural Images. *Vision Res.*, **40**, 2661-2669.
- Balboa, R.M., and N.M. Grzywacz (2000) The Minimal Local-Asperity Hypothesis of Early Retinal Lateral Inhibition. *Neural Computation*, **12**, 1485-1517.
- Verghese, P., S.P. McKee, and N.M. Grzywacz (2000) Stimulus Configuration Determines the Detectability of Motion Signals in Noise. *J. Opt. Soc. Am. A.* **17**, 1525-1534.
- Ascher, D., and N.M. Grzywacz (2000) A Bayesian Model of Temporal Frequency Masking. *Vision Res.* **40**, 2219-2232.
- Grzywacz, N.M., and E. Sernagor (2000) Spontaneous Activity in

- Developing Turtle Retinal Ganglion Cells: Statistical Analysis. *Visual Neurosci.* **17**, 229-241.
- Balboa, R.M., and N.M. Grzywacz (2000) The Role of Early Retinal Lateral Inhibition: More Than Maximizing Luminance Information. *Visual Neurosci.* **17**, 77-89.
- Nguyen, L.T., J. de Juan, M. Mejia, and N.M. Grzywacz (2000) Localization of Choline Acetyltransferase in the Developing and Adult Turtle Retinas. *J. Comp. Neurol.* **420**, 512-526.
- Nguyen, L.T., and N.M. Grzywacz (2000) Co-Localization of Choline Acetyltransferase and GABA in the Developing and Adult Turtle Retinas. *J. Comp. Neurol.* **420**, 527-538.
- Sernagor, E., and N.M. Grzywacz (1999) Spontaneous Activity in Developing Turtle Retinal Ganglion Cells: Pharmacological Studies. *J. Neurosci.* **19**, 3874-3887.
- Vergheze, P., S.N.J. Watamaniuk, S.P. McKee, and N.M. Grzywacz (1999) Local Motion Detectors Cannot Account for the Detectability of an Extended Trajectory in Noise. *Vision Res.* **39**, 19-30.
- Merwine, D.K., N.M. Grzywacz, D.S. Tjepkes, and F.R. Amthor (1998) Non-Monotonic Contrast Behavior in Directionally Selective Ganglion Cells and Evidence for Its Dependence on Their GABAergic Input. *Visual Neurosci.* **15**, 1129-1136.
- Grzywacz, N.M., D.K. Merwine, and F.R. Amthor (1998) Complementary Roles of Two Excitatory Pathways in Retinal Directional Selectivity. *Visual Neurosci.* **15**, 1119-1127.
- Grzywacz, N.M., F.R. Amthor, and D.K. Merwine (1998) Necessity of ACh for Retinal Directionally Selective Responses to Drifting Gratings in Rabbit. *J. Physiol. Lond.* **512**, 575-581.
- Burgi, P.Y., and N.M. Grzywacz (1998) A Biophysical Model for the Developmental Time Course of Retinal Orientation Selectivity.

Vision Res. **38**, 2787-2800.

- Pettet, M.W., S.P. McKee, and N.M. Grzywacz (1998) Constraints on Long Range Interactions Mediating Contour Detection. *Vision Res.* **38**, 865-879.
- Yuille, A.L., P.Y. Burgi, and N.M. Grzywacz (1998) Visual Motion Estimation and Prediction: A Probabilistic Network Model for Temporal Coherence. *The Proceedings of the Sixth International Conference on Computer Vision*, Sponsored by IEEE Computer Society. 973-978.
- Grzywacz, N.M., and P.Y. Burgi (1998) Toward a Biophysically Plausible Bidirectional Hebbian Rule. *Neural Computation*, **10**, 499-520.
- Burgi, P.Y., and N.M. Grzywacz (1997) Possible Roles of Spontaneous Waves and Dendritic Growth for Retinal Receptive Field Development. *Neural Computation*, **9**, 533-553.
- Grzywacz, N.M., J.S. Tootle, and F.R. Amthor (1997) Is the Input to a GABAergic or Cholinergic Synapse the Sole Asymmetry in Rabbit's Retinal Directional Selectivity? *Visual Neurosci.* **14**, 39-54.
- Sernagor, E., and N.M. Grzywacz (1996) Influence of Spontaneous Activity and Visual Experience on Developing Retinal Receptive Fields. *Current Biol.* **6**, 1503-1508.
- Amthor, F.R., N.M. Grzywacz, and D.K. Merwine (1996) Extra Receptive Field Motion Facilitation in On-Off Directionally Selective Ganglion Cells of the Rabbit Retina. *Visual Neurosci.* **13**, 303-309.
- Smith, R.D., N.M. Grzywacz, and L. Borg-Graham (1996) Is the Input to a GABAergic Synapse the Sole Asymmetry in Turtle's Retinal Directional Selectivity? *Visual Neurosci.* **13**, 423-439.
- Sernagor, E., and N.M. Grzywacz (1995) Emergence of Complex Receptive Field Properties of Ganglion Cells in the Developing Turtle

- Retina. *J. Neurophysiol.* **73**, 1355-1364.
- Merwine, D.K., F.R. Amthor, and N.M. Grzywacz (1995) The Interaction Between Center and Surround in Rabbit Retinal Ganglion Cells. *J. Neurophysiol.* **73**, 1547-1567.
- Grzywacz, N.M., N.J. Watamaniuk, and S.P. McKee (1995) Temporal Coherence Theory for the Detection and Measurement of Visual Motion. *Vision Res.* **35**, 3183-3203.
- Burgi, P.Y., and N.M. Grzywacz (1994) Model Based on Extracellular Potassium for Spontaneous Synchronous Activity in Developing Retinas. *Neural Computation*, **6**, 982-1002.
- Grzywacz, N.M., F.R. Amthor, and D.K. Merwine (1994) Directional Hyperacuity in Ganglion Cells of the Rabbit Retina. *Visual Neurosci.* **11**, 1019-1025.
- Watamaniuk, N.J., S.P. McKee, and N.M. Grzywacz (1994) Detecting a Trajectory Embedded in Random-Direction Motion Noise. *Vision Res.* **35**, 65-77.
- Burgi, P.Y., and N.M. Grzywacz (1994) Model for Pharmacological Basis of Spontaneous Synchronous Activity in Developing Retinas. *J. Neurosci.* **14**, 7426-7439.
- Vaina, L.M., N.M. Grzywacz, and R. Kikinis (1994) Segregation of Computations Underlying Perception of Motion Discontinuity and Coherence. *Neuroreport*, **5**, 2289-2294.
- Watamaniuk, S., N.M. Grzywacz, and A.L. Yuille (1993) Dependence of Speed and Direction Perception on Cinematogram Dot Density. *Vision Res.* **33**, 849-859.
- Grzywacz, N.M. (1993) Commentary on 'The Computational Brain,' a book by P.S. Churchland, and Sejnowski, T.J. *Quarterly Reviews of Biol.* **68**, 457.
- Amthor, F.R., and N.M. Grzywacz (1993) Inhibition in Directionally

- Selective Ganglion Cells of the Rabbit Retina. *J. Neurophysiol.* **69**, 2174-2187.
- Grzywacz, N.M., and F.R. Amthor (1993) Facilitation in Directionally Selective Ganglion Cells of the Rabbit Retina. *J. Neurophysiol.* **69**, 2188-2199.
- Grzywacz, N.M., F.R. Amthor, and L.J. Borg-Graham (1993) Does Synaptic Facilitation Mediate Motion Facilitation in the Retina?, in *Computation and Neural Systems 1992*, F.H. Eeckman and J.M. Bower (Eds.), 159-163. Kluwer Academic Press, Boston, Massachusetts, USA.
- Smith, J.A., and N.M. Grzywacz (1993) A Local Model for Transparent Motions Based on Spatio-Temporal Filtering, in *Computation and Neural Systems 1992*, F.H. Eeckman and J.M. Bower (Eds.), 177-181. Kluwer Academic Press, Boston, Massachusetts, USA.
- Grzywacz, N.M., P. Hillman, and B. Knight (1992) Response Transfer Functions of *Limulus* Ventral Photoreceptors: Interpretation in Terms of Transduction Mechanisms. *Biol. Cybern.* **66**, 429-435.
- Grzywacz, N.M., P. Hillman, and B. Knight (1992) Amplitudes of Unit Events in *Limulus* Photoreceptors Are Modulated from an Input that Resembles the Overall Response. *Biol. Cybern.* **66**, 437-441.
- Vaina, L.M., and N.M. Grzywacz (1992) Testing Computational Theories of Motion Discontinuities: A Psychophysical Study, in *Lecture Notes in Computer Science*, Vol. 588, G. Sandini (Ed.), 212-216. Springer-Verlag, Berlin, Germany.
- Vaina, L.M., and N.M. Grzywacz (1992) Structure from Motion With Impaired Early Motion Computations, in *Sensor Fusion V*, the SPIE Proceedings Series, 1828, P.S. Schenker (Ed.), 309-319. Boston, Massachusetts, USA.
- Amthor, F.R., and N.M. Grzywacz (1991) Nonlinearity of the Inhibition

- Underlying Retinal Directional Selectivity. *Vis. Neurosci.* **6**, 197-206.
- Grzywacz, N.M., and A.L. Yuille (1990) A Model for the Estimate of Local Image Velocity by Cells in the Visual Cortex. *Proc. R. Soc. Lond. B*, **239**, 129-161.
- Hildreth, E.C., N.M. Grzywacz, E.H. Adelson, and V.K. Inada (1990) The Perceptual Buildup of Three-Dimensional Structure from Motion. *Perception and Psychophysics*, **48**, 19-36.
- Vaina, L.M., N.M. Grzywacz, and M. LeMay (1990) Structure from Motion with Impaired Local-Speed and Global Motion-Field Computations. *Neural Computation*, **2**, 416-432.
- Grzywacz, N.M., F.R. Amthor, and L.A. Mistler (1990) Applicability of Quadratic and Threshold Models to Motion Discrimination in the Rabbit Retina. *Biol. Cybern.* **64**, 41-49.
- Grzywacz, N.M., J.A. Smith, and A.L. Yuille (1989) A Common Theoretical Framework for Visual Motion's Spatial and Temporal Coherence. *The Proceedings of the IEEE Workshop on Visual Motion*. Irvine, California, USA. 148-155.
- Grzywacz, N.M., and F.R. Amthor (1989) A Computationally Robust Anatomical Model for Retinal Directional Selectivity, in *Advances in Neural Information Processing Systems*, Vol. 1, D.S. Touretzky (Ed.), 477-484. Morgan Kaufman Publishers, Palo Alto, California, USA.
- Hildreth, E.C., N.M. Grzywacz, V.K. Inada, and E.H. Adelson (1989) The Perceptual Buildup of Three-Dimensional Structure from Motion. *MIT Artificial Intelligence Memo*, **1141**, 1-36.
- Yuille, A.L., and N.M. Grzywacz (1989) A Mathematical Analysis of the Motion Coherence Theory. *International Journal of Computer Vision*, **3**, 155-175.

- Yuille, A.L., and N.M. Grzywacz (1989) A Winner-Take-All Mechanism Based on Presynaptic Inhibition Feedback. *Neural Computation*, **1**, 334-347.
- Yuille, A.L., and N.M. Grzywacz (1988) A Computational Theory for the Perception of Coherent Visual Motion. *Nature*, **333**, 71-74.
- Grzywacz, N.M., and P. Hillman (1988) Biophysical Evidence that Light Adaptation in *Limulus* Photoreceptors Is Due to a Negative Feedback. *Biophys. J.* **53**, 337-348.
- Grzywacz, N.M., P. Hillman, and B.W. Knight (1988) The Quantal Source of Area Supralinearity of Flash Responses in *Limulus* Photoreceptors. *J. Gen. Physiol.* **91**, 659-684.
- Grzywacz, N.M., and A.L. Yuille (1988) Massively Parallel Implementations of Theories for Apparent Motion. *Spatial Vision*, **3**, 15-44.
- Yuille, A.L., and N.M. Grzywacz (1988) The Motion Coherence Theory. *The Proceedings of the Second International Conference on Computer Vision*, Sponsored by IEEE Computer Society. Tampa, Florida, USA. 344-353.
- Grzywacz, N.M., and E.C. Hildreth (1987) Incremental Rigidity Scheme for Recovering Structure from Motion: Position-Based Versus Velocity-Based Formulations. *J. Opt. Soc. Am. A*, **4**, 503-518.
- Grzywacz, N.M., and C. Koch (1987) Functional Properties of Models for Direction Selectivity in the Retina. *Synapse*, **1**, 417-434.
- Grzywacz, N.M., and A.L. Yuille (1987) Massively Parallel Implementations of Theories for Apparent Motion. *MIT Artificial Intelligence Memo*, **888**, 1-38.
- Hildreth, E.C., and N.M. Grzywacz (1986) The Incremental Rigidity Scheme for Recovering Structure from Motion: Position vs. Velocity Based Formulations. *Proceedings of the ACM Workshop on Motion:*

Representation and Control. North Carolina, USA. 137-143.

Grzywacz, N.M., and A.L. Yuille (1986) Motion Correspondence and Analog Networks, in *Neural Networks for Computing*, the AIP Conference Proceedings, 151, J.S. Denker (Ed.), 200-205. Snowbird, Utah, USA.

Grzywacz, N.M., and E.C. Hildreth (1985) The Incremental Rigidity Scheme for Recovering Structure from Motion: Position vs. Velocity Based Formulations. *MIT Artificial Intelligence Memo*, **845**, 1-53.

Grzywacz, N.M., and P. Hillman (1985) Statistical Test of Linearity of Photoreceptor Transduction Process: *Limulus* Passes Others Fail. *Proc. Natl. Acad. Sci. USA*, **82**, 232-235.

Book Chapters

Grzywacz, N.M., and M. Padilla (2004) Neural Control, in the *Encyclopedia of Biomedical Engineering*, M. Khoo (Ed.). Wiley. In Press.

Grzywacz, N.M., and D.K. Merwine (2003) Neural Basis of Motion Perception, in the *Encyclopedia of Cognitive Science*, Vol. 3, 86-98. Macmillan Press, Cambridge, United Kingdom.

Grzywacz, N.M., and D.K. Merwine (2003) Directional Selectivity, in the *Handbook of Brain Theory and Neural Networks, Second Edition*, M.A. Arbib (Ed.), 354-358. MIT Press, Cambridge, Massachusetts, USA.

Grzywacz, N.M. (1998) Introduction to Motion Coherence and Grouping, in *High-Level Motion Processing – Computational, Neurobiological, and Psychophysical Perspectives*, T. Watanabe (Ed.), 185-186. MIT Press, Cambridge, Massachusetts, USA.

Vaina, L.M., N.M. Grzywacz, M. LeMay, D. Bienfang, and E. Wolpaw

- (1998) Perception of Motion Discontinuities in Patients With Selective Motion Deficits, in *High-Level Motion Processing – Computational, Neurobiological, and Psychophysical Perspectives*, T. Watanabe (Ed.), 213-247. MIT Press, Cambridge, Massachusetts, USA.
- Yuille, A.L., and N.M. Grzywacz (1998) A Theoretical Framework for Visual Motion, in *High-Level Motion Processing – Computational, Neurobiological, and Psychophysical Perspectives*, T. Watanabe (Ed.), 187-211. MIT Press, Cambridge, Massachusetts, USA.
- Grzywacz, N.M., E. Sernagor, and F.R. Amthor (1995) Directional Selectivity in the Retina, in *The Handbook of Brain Theory and Neural Networks*, M.A. Arbib (Ed.), 312-314. MIT Press, Cambridge, Massachusetts, USA.
- Grzywacz, N.M., and A.M. Norcia (1995) Directional Selectivity in the Cortex, in *The Handbook of Brain Theory and Neural Networks*, M.A. Arbib (Ed.), 309-311. MIT Press, Cambridge, Massachusetts, USA.
- Grzywacz, N.M., J.M. Harris, and F.R. Amthor (1994) Computational and Neural Constraints for the Measurement of Local Visual Motion, in *Visual Detection of Motion*, A.T. Smith and R.J. Snowden (Eds.), 19-50. Academic Press, San Diego, California, USA.
- Amthor, F.R., and N.M. Grzywacz (1993) Directional Selectivity in Vertebrate Retinal Ganglion Cells, in *Visual Motion and Its Role in the Stabilization of Gaze*, Reviews of Oculomotor Research, Vol. 5, F. Miles and J. Wallman (Eds.), 79-100. Elsevier, Amsterdam, The Netherlands.
- Borg-Graham, L.J., and N.M. Grzywacz (1992) A Model of the Direction Selectivity Circuit in Retina: Transformations by Neurons Singly and in Concert, in *Single Neuron Computation*, T. McKenna, J. Davis,

and S.F. Zornetzer (Eds.), 347-375. Academic Press, Orlando, Florida, USA.

Grzywacz, N.M. (1991) Commentary on 'The Computation of Lightness by the Primate Retina', in *From Retina to Neocortex: The Early Papers of David Marr*, L.M. Vaina (Ed.), 223-229. MIT Press, Cambridge, Massachusetts, USA.

Grzywacz, N.M., and A.L. Yuille (1991) Theories for the Visual Perception of Local Velocity and Coherent Motion, in *Computational Models of Visual Processing*, M.S. Landy and J.A. Movshon (Eds.), 231-252. MIT Press, Cambridge, Massachusetts, USA.

Grzywacz, N.M., and T. Poggio (1990) Computation of Motion by Real Neurons, in *An Introduction to Neural and Electronic Networks*, S.F. Zornetzer, J.L. Davis, and C. Lau (Eds.), 379-403. Academic Press, Orlando, Florida, USA.

Grzywacz, N.M., E.C. Hildreth, V.K. Inada, and E.H. Adelson (1987) The Temporal Integration of 3-D Structure from Motion: A Computational and Psychophysical Study, in *Organization of Neural Networks*, W. von Seelen, G. Shaw, and U.M. Leinhos (Eds.), 239-259. VCH Publishers, Weinheim, FRG.

Papers Submitted for Publication or in Preparation

Amthor, F.R., and N.M. Grzywacz (2004) Robust Directional Computation in On-Off Directionally Selective Ganglion Cells of Rabbit Retina. Submitted for Publication.

Grzywacz, N.M., H. Ögmen, and F.R. Amthor (2004) Biophysical Model for the Robust Directional Selectivity in the Rabbit's Retina. Submitted for Publication.

- Amthor, F.R., and N.M. Grzywacz (2004) Organization of Dendritic Contacts between Starburst Amacrine and Directionally Selective Ganglion Cells of the Rabbit Retina. Submitted for Publication.
- Amthor, F.R., and N.M. Grzywacz (2004) Cross Covariance of Activity between Starburst Amacrine and On-Off Directionally Selective Ganglion Cells in the Rabbit Retina. Submitted for Publication.
- De Juan, J., E. Sernagor, J.V. Guardiola, and N.M. Grzywacz (2004) Ultrastructural Changes in the Neonatal Turtle Retina Following Dark Rearing and Nicotinic Blockade. Submitted for Publication.
- Guardiola, J.V., J., De Juan, and N.M. Grzywacz (2004) Ultrastructural Substrates of the Emergence of Electrical Activity in the Turtle's Embryonic Retina. Submitted for Publication.
- Grzywacz, N.M., and C.L. Zucker (2004) Modeling Starburst Cells' GABA_B Receptors and Their Putative Role in Motion Sensitivity. Submitted for Publication.
- Wurfel, J., Barraza, J.F., and N.M. Grzywacz (2004) Measurement of Rate of Expansion in the Perception of Radial Motion. Submitted for Publication.
- Liu, F., D.K. Merwine, and N.M. Grzywacz (2004) Statistically Robust Signal Detection in Spontaneous Noisy Neural Traces. In Preparation.
- Barraza, J.F., and N.M. Grzywacz (2004) Parametric Decomposition of Optic Flows by Humans. In Preparation.
- Wurfel, J., J.F. Barraza, and N.M. Grzywacz (2004) Necessity of Sufficiently Rich Stimuli for Parametric Measurements from Optic Flows. In Preparation.

Abstract of Papers Presented at Scientific Meetings

- Grzywacz, N.M. (2003) Retinal Contrast Adaptation as Kalman Filtering. *Invest. Ophthalmol. Vis. Sci.* **44**.
- Barraza, J.F., and N.M. Grzywacz (2003) Parametric Decomposition of Complex Motion by Humans. *Abstracts of the Vision Sciences Society*.
- Wurfel, J., J.F. Barraza, and N.M. Grzywacz (2003) Measurement of Rate of Expansion in the Perception of Radial Motion. *Abstracts of the Vision Sciences Society*.
- Barraza, J.F., and N.M. Grzywacz (2002) Fine Discrimination of Angular Velocity Despite Poor Localization of Center of Rotation. *Abstracts of the Vision Sciences Society*. **227**.
- Barraza, J.F., and N.M. Grzywacz (2001) Discrimination of Angular Velocity in Humans. *Invest. Ophthalmol. Vis. Sci.* **42**, S870.
- Amthor, F.R., and N.M. Grzywacz (2001) Synchronous Firing Is Stimulus Dependent in Directionally Selective (DS) and non-DS Rabbit Retinal Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **42**, S677.
- Balboa, R.M., and N.M. Grzywacz (2001) Power Spectra and Distribution of Contrasts of Natural Images from Different Habitats. *Invest. Ophthalmol. Vis. Sci.* **42**, S615.
- Merwine, D.K., and N.M. Grzywacz (2000) Two Modes of Propagation of Spontaneous Waves in the Turtle's Neonatal Retina. *Invest. Ophthalmol. Vis. Sci.* **41**, S935.
- Guardiola, J.V., J. de Juan, and N.M. Grzywacz (2000) Development of the Synapse in the Turtle's Retina. *Invest. Ophthalmol. Vis. Sci.* **41**, S848.
- Grzywacz, N.M. (2000) Retinal Development and Thoughts on Retinal Transplantation. *Proceedings of the Jampolsky Festschrift*.

- Merwine, D.K., L.T. Nguyen, J. de Juan, and N.M. Grzywacz (1999) Acetylcholine's Roles in Retinal Development. *Proceedings of the Conference of the Spanish Society of Histology*.
- Amthor, F.R., N.M. Grzywacz, and R.F. Dacheux (1999) Whole Cell Patch Clamp Recordings of On-Off Directionally Selective Rabbit Retinal Ganglion Cells to Photic and Current Inputs. *Invest. Ophthalmol. Vis. Sci.* **40**, S589.
- Guardiola, J.V., J. de Juan, and N.M. Grzywacz (1999) Development of the Immunoreactivity to Synaptophysin in the Turtle Retina. *Invest. Ophthalmol. Vis. Sci.* **40**, S458.
- Balboa, R.M., and N.M. Grzywacz (1999) Biological Evidence for an Ecological-Based Theory of Early Retinal Lateral Inhibition. *Invest. Ophthalmol. Vis. Sci.* **40**, S386.
- Ascher, D., and N.M. Grzywacz (1999) A Bayesian Model of Temporal Frequency Masking. *Invest. Ophthalmol. Vis. Sci.* **40**, S45.
- Nguyen, L.T., and N.M. Grzywacz (1998) Early Co-Localization of Choline Acetyltransferase and GABA in the Developing Turtle Retina. *Soc. Neurosci. Abst.* **24**, 2090.
- Merwine, D.K., N.M. Grzywacz, and F.R. Amthor (1998) Persistent Effects of Dark Rearing on the Development of Turtle Retinal Ganglion Cells. *Soc. Neurosci. Abst.* **24**, 1518.
- Zucker, C.L., B. Ehinger, and N.M. Grzywacz (1998) GABA_B Receptors Are Localized to Starburst Amacrine and Ganglion Cells in the Rabbit Retina. *Soc. Neurosci. Abst.* **24**, 136.
- Grzywacz, N.M., and L.T. Nguyen (1998) A Transient Cholinergic Population of Cells in the Developing Turtle Retina. *Soc. Neurosci. Abst.* **24**, 63.
- Amthor, F.R., and N.M. Grzywacz (1998) Stimulus-Dependent Firing Correlation Between Directionally Selective (DS) and Non-DS

- Rabbit Retinal Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **39**, S562.
- Balboa, R.M., and N.M. Grzywacz (1998) The Minimal Local-Asperity Theory of Retinal Lateral Inhibition. *Invest. Ophthalmol. Vis. Sci.* **39**, S562.
- Grzywacz, N.M., F.R. Amthor, and D.K. Merwine (1998) Necessity of Acetylcholine for Retinal Directionally Selective Responses to Drifting Gratings. *Invest. Ophthalmol. Vis. Sci.* **39**, S432.
- Grzywacz, N.M., D.K. Merwine, D.S. Tjepkes, and F.R. Amthor (1997) Roles of Two Excitatory Pathways in Retinal Directional Selectivity. *Soc. Neurosci. Abst.* **23**, 1960.
- Merwine, D.K., N.M. Grzywacz, D.S. Tjepkes, and F.R. Amthor (1997) Non-monotonic Contrast Dependence of Preferred-Direction Responses in On-Off Directionally Selective Cells of Rabbit Retina. *Soc. Neurosci. Abst.* **23**, 1960.
- Nguyen, L.T., M. Mejia, and N.M. Grzywacz (1997) Co-localization of ACh and GABA in the Adult and Developing Turtle Retinas. *Soc. Neurosci. Abst.* **23**, 1262.
- Balboa, R.M., J. de Juan, and N.M. Grzywacz (1997) Discrepancy Between Biology and the Predictive Coding Theory of Lateral Inhibition Based on the Statistics of Natural Scenes. *Invest. Ophthalmol. Vis. Sci.* **38**, S1017.
- Amthor, F.R., N.M. Grzywacz, K.T. Keyser, and R.F. Dacheux (1997) Contribution of Cholinergic Amacrine Cells to Directional Selectivity in Rabbit Retinal Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **38**, S949.
- Grzywacz, N.M., L.T. Nguyen, M. Mejia, and J. de Juan (1997) Development of Cholinergic Neurons in the Turtle Retina. *Invest. Ophthalmol. Vis. Sci.* **38**, S948.

- Verghese, P., S.P. McKee, and N.M. Grzywacz (1997) Stimulus Configuration Determines the Detectability of Motion Signals in Noise. *Invest. Ophthalmol. Vis. Sci.* **38**, S215.
- Guardiola, J.V., E. Sernagor, J. de Juan, and N.M. Grzywacz (1997) Histological Changes in Turtles' Neonatal Retinas by Nicotinic Blockade. *Invest. Ophthalmol. Vis. Sci.* **38**, S37.
- Sernagor, E., and N.M. Grzywacz (1996) Control of Developing Retinal Receptive Fields by Spontaneous Activity and Visual Experience. *Brain Res. Association Abst., Great Britain.*
- De Juan, J., N.M. Grzywacz, J.V. Guardiola, and E. Sernagor (1996) Coincidence of Synaptogenesis and Emergence of Spontaneous and Light-Evoked Activity in Embryonic Turtle Retina. *Invest. Ophthalmol. Vis. Sci.* **37**, 634.
- Grzywacz, N.M., F.R. Amthor, and D.K. Merwine (1996) Pharmacological Evidence for Two Asymmetric Pathways in Rabbit Retinal Directional Selectivity. *Invest. Ophthalmol. Vis. Sci.* **37**, 689.
- Pettet, M.W., S.P. McKee, and N.M. Grzywacz (1996) Smoothness Constrains Long-Range Interactions Mediating Contour Detection. *Invest. Ophthalmol. Vis. Sci.* **37**, 954.
- Ascher, D., L. Welch, and N.M. Grzywacz (1996) Integration Across Spatial Frequency Channels in Speed Discrimination. *Soc. Neurosci. Abst.* **22**, 886.
- Verghese, P., S.N.J. Watamaniuk, S.P. McKee, and N.M. Grzywacz (1996) Evaluating a Simple Model for Detecting Visual Signals in Noise. *J. Opt. Soc. Am. A* **13**.
- De Juan, J., N.M. Grzywacz, J.V. Guardiola, and E. Sernagor (1995) Anatomical and Physiological Dark-Rearing Induced Changes in Turtle Retinal Development. *Invest. Ophthalmol. Vis. Sci.* **36**, 60.
- Grzywacz, N.M., F.R. Amthor, and R.F. Dacheux (1995) Are Cholinergic

Synapses to Directionally Selective Ganglion Cells Spatially Asymmetric? *Invest. Ophthalmol. Vis. Sci.* **36**, 865.

Burgi, P.Y., and N.M. Grzywacz (1995) A Neurophysiological Model of the Early Development of Retinal Orientation Selectivity. *Perception*, **24**, 20.

Amthor, F.R., and N.M. Grzywacz (1995) Morphological and Physiological Basis of Starburst-ACh Amacrine Input to Directionally Selective (DS) Ganglion Cells in Rabbit Retina. *Soc. Neurosci. Abst.* **21**, 508.

Hamer, R.D., Tyler, C.W., and N.M. Grzywacz (1995) A Full Range Linear Model of the Activation Stages of Vertebrate Phototransduction. *Soc. Neurosci. Abst.* **21**, 510.

Sernagor, E., and N.M. Grzywacz (1995) Shaping of Receptive Field Properties in Developing Retinal Ganglion Cells in the Absence of Early Cholinergic Spontaneous Activity. *Soc. Neurosci. Abst.* **21**, 1503.

Amthor, F.R., C.W. Oyster, and N.M. Grzywacz (1994) Retinal Coverage and Physiological Inputs to Directionally Selective Rabbit Retinal Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **35**, 2056.

Sernagor, E., and N.M. Grzywacz (1994) Synaptic Connections Involved in the Spontaneous Correlated Bursts in the Developing Turtle Retina. *Invest. Ophthalmol. Vis. Sci.* **35**, 2125.

Burgi, P.Y., and N.M. Grzywacz (1994) Does Prenatal Development of Ganglion-Cell Receptive Fields Depend on Spontaneous Activity and Hebbian Processes? *Invest. Ophthalmol. Vis. Sci.* **35**, 2126.

Grzywacz, N.M., and P.Y. Burgi (1994) A Hebbian Rule Consistent With Physiology and Producing Sharp Refinement of Organization. *CNS*1994 Abst.* **3**, 18.

Burgi, P.Y., and N.M. Grzywacz (1994) Hebbian Processes and

Spontaneous Waves of Activity Could Lead to the Emergence of Complex Retinal Receptive Fields. *CNS*1994* Abst. **3**, 38.

Amthor, F.R., and N.M. Grzywacz (1994) Morphological and Physiological Basis of Starburst-ACh Amacrine Input to Directionally Selective (DS) Ganglion Cells in Rabbit Retina. *Soc. Neurosci. Abst.* **20**, 217.

Grzywacz, N.M., and E. Sernagor (1994) Development of Directional Selectivity in Turtle Retina: Physiology and Model. *Soc. Neurosci. Abst.* **20**, 1470.

Sernagor, E., and N.M. Grzywacz (1994) Role of Early Spontaneous Activity and Visual Experience in Shaping Complex Receptive Field Properties of Ganglion Cells in the Developing Retina. *Soc. Neurosci. Abst.* **20**, 1470.

Grzywacz, N.M., and F.R. Amthor (1993) Tests of an Asymmetric Amacrine Cell Model for Retinal Directional Selectivity. *Invest. Ophthalmol. Vis. Sci.* **34**, 1292.

Vaina, L.M., N.M. Grzywacz, and R. Kikinis (1993) Hierarchical Organization of Computations Involved in the Extraction of Motion Discontinuity and Coherence: Evidence from Patients With Unilateral Occipital-Parietal Lesions. *Invest. Ophthalmol. Vis. Sci.* **34**, 1033.

Burgi, P.Y., and N.M. Grzywacz (1993) A Biophysical Model of Synchronous Bursts of Activity in Ganglion Cells of the Developing Retina. *Invest. Ophthalmol. Vis. Sci.* **34**, 1155.

Sernagor, E., and N.M. Grzywacz (1993) Cellular Mechanisms Underlying Spontaneous Correlated Activity in the Turtle Embryonic Retina. *Invest. Ophthalmol. Vis. Sci.* **34**, 1156.

Sernagor, E., and N.M. Grzywacz (1993) Emergence of Isotropic and Anisotropic Receptive-Field Properties in the Developing Turtle Retina. *Soc. Neurosci. Abst.* **19**, 53.

- Burgi, P.Y., and N.M. Grzywacz (1993) Model for Initiation and Propagation of Waves of Action Potentials in Developing Retinas. *Soc. Neurosci. Abst.* **19**, 239.
- Grzywacz, N.M., F.R. Amthor, and D.K. Merwine (1993) Extra Receptive Field Facilitation in Rabbit's Retinal Directional Selectivity. *Soc. Neurosci. Abst.* **19**, 1258.
- Amthor, F.R., and N.M. Grzywacz (1992) Response of Rabbit Directionally Selective Ganglion Cells to Moving Gratings and Plaids. *Invest. Ophthalmol. Vis. Sci.* **33**, 907.
- Grzywacz, N.M. (1992) One-Path Model for Contrast-Independent Perception of Fourier and Non-Fourier Motions. *Invest. Ophthalmol. Vis. Sci.* **33**, 954.
- Smith, J.A., N.M. Grzywacz, and E.C. Hildreth (1992) A Spatio-Temporal Filter Model for Transparent Motions. *Invest. Ophthalmol. Vis. Sci.* **33**, 1137.
- Grzywacz, N.M., and F.R. Amthor (1992) Quantitative Fits of an Amacrine Model of Directional Selectivity to Rabbit Data. *Soc. Neurosci. Abst.* **18**, 393.
- Borg-Graham, L., and N.M. Grzywacz (1991) Whole-Cell Patch Recordings and Analysis of the Input onto Turtle Directionally Selective (DS) Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **32**, 1090.
- Grzywacz, N.M., and L. Borg-Graham (1991) Model of Retinal Directional Selectivity Based on Amacrine Input/Output Asymmetry. *Invest. Ophthalmol. Vis. Sci.* **32**, 1131.
- Merwine, D.K., F.R. Amthor, and N.M. Grzywacz (1991) Characteristics of Divisive Ganglion Cell Surround Inhibition in the Rabbit Retina. *Invest. Ophthalmol. Vis. Sci.* **32**, 1132.
- Smith, R.D., N.M. Grzywacz, and L. Borg-Graham (1991) Picrotoxin's

- Effect on Contrast Dependence of Turtle Retinal Directional Selectivity. *Invest. Ophthalmol. Vis. Sci.* **32**, 1263.
- Grzywacz, N.M., V. Torre, R. Winslow, P. Sterling, and J.D. Victor (1991) Workshop- Quantitative Models of Retinal Function. *IBRO Abst.* **3**, 10.
- Vaina, L.M., N.M. Grzywacz, and M. LeMay (1991) Spared High-Level Motion Perception in Patients With Impaired Low-Level Motion Mechanisms. *IBRO Abst.* **3**, 182.
- Borg-Graham, L.J., and N.M. Grzywacz (1991) Directionally Selective (DS) Synaptic Input to DS Ganglion Cells in Turtle Retina. *IBRO Abst.* **3**, 392.
- Grzywacz, N.M., and F.R. Amthor (1991) Independent ON and OFF Computations of Retinal Directional Selectivity in Rabbit. *Soc. Neurosci. Abst.* **17**, 344.
- Smith, R.D., N.M. Grzywacz, and L.J. Borg-Graham (1991) GABA and Facilitation in Turtle Retinal Directional Selectivity. *Soc. Neurosci. Abst.* **17**, 1376.
- Borg-Graham L.J., and N.M. Grzywacz (1991) Distinguishing Models of Directional Selectivity With Patch Clamp Recordings from an Isolated Retina Preparation of Turtle. *Soc. Neurosci. Abst.* **17**, 1376.
- Amthor, F.R., and N.M. Grzywacz (1990) ON-OFF Directionally Selective Ganglion Cells Are Inhibited by Two Distinct Mechanisms in Rabbit Retina. *Invest. Ophthalmol. Vis. Sci.* **31**, 115.
- Merwine, D.K., F.R. Amthor, and N.M. Grzywacz (1990) Ganglion Cell Surround Inhibition Is Divisive, Not Linear, in Rabbit Retina. *Invest. Ophthalmol. Vis. Sci.* **31**, 115.
- Borg-Graham, L., and N.M. Grzywacz (1990) An Isolated Turtle Retina Preparation Allowing Direct Approach to Ganglion Cells and Photoreceptors, and Transmitted Light-Microscopy. *Invest.*

- Ophthalmol. Vis. Sci.* **31**, 211.
- Vaina, L.M., N.M. Grzywacz, A. Choi, M. LeMay, and D.C. Bienfang (1990) Selective Deficits of Measurement and Integration of Motion in Patients With Lesions Involving the Visual Cortex. *Invest. Ophthalmol. Vis. Sci.* **31**, 523.
- Grzywacz, N.M., and F.R. Amthor (1989) An Anatomical Hypothesis for the Synaptic Circuitry Underlying Retinal Directional Selectivity. *Invest. Ophthalmol. Vis. Sci.* **30**, 63.
- Yuille, A.L., and N.M. Grzywacz (1989) A Model for the Estimate of Local Image Velocity by Cells in the Visual Cortex. *Invest. Ophthalmol. Vis. Sci.* **30**, 425.
- Grzywacz, N.M., and F.R. Amthor (1989) Facilitation in ON-OFF Directionally Selective Ganglion Cells of the Rabbit Retina. *Soc. Neurosci. Abst.* **15**, 969.
- Grzywacz, N.M., B. Knight, and P. Hillman (1989) Adaptation in *Limulus* Photoreceptors: Unit Event Size Shows a Simple Dynamic Relation to Cell Response. *Perception.* **18**, 485.
- Amthor, F.R., and N.M. Grzywacz (1988) The Time Course of Inhibition and the Velocity Independence of Direction Selectivity in the Rabbit Retina. *Invest. Ophthalmol. Vis. Sci.* **29**, 225.
- Yuille, A.L., and N.M. Grzywacz (1988) A Computational Theory for the Perception of Coherent Visual Motion. *Invest. Ophthalmol. Vis. Sci.* **29**, 252.
- Grzywacz, N.M., F.R. Amthor, and L. Borg-Graham (1988) The Inhibition of Direction Selective Ganglion Cells in the Rabbit Retina Has Both Hyperpolarizing and Shunting Components. *Invest. Ophthalmol. Vis. Sci.* **29**, 294.
- Grzywacz, N.M., and F.R. Amthor (1988) What Are the Directionally Selective Subunits of Rabbit Retinal Ganglion Cells? *Soc. Neurosci.*

Abst. **14**, 603.

- Grzywacz, N.M. (1987) Interactions Between Minimal Mapping and Inertia in Long-Range Apparent Motion. *Invest. Ophthalmol. Vis. Sci.* **28**, 300.
- Amthor, F.R., L.A. Mistler, and N.M. Grzywacz (1987) Experimental Analysis of the Nonlinear Mechanism of Direction Selectivity in Rabbit Retinal Ganglion Cells. *Invest. Ophthalmol. Vis. Sci.* **28**, 405.
- Amthor, F.R., N.M. Grzywacz, and L.A. Mistler (1987) The Mechanism of Direction Selectivity in Rabbit Retinal Ganglion Cells. *Soc. Neurosci. Abst.* **13**, 293.16.
- Inada, V.K., E.C. Hildreth, N.M. Grzywacz, and E.H. Adelson (1986) The Effects of Temporal and Spatial Extents on the Recovery of Structure from Motion. *Invest. Ophthalmol. Vis. Sci.* **27**, 142.
- Grzywacz, N.M. (1986) Properties of Generalized Minimal Mapping Theories for Apparent Motion. *J. Opt. Soc. Am. A* **3**, P72.
- Grzywacz, N.M., C. Koch, and L.A. Mistler (1986) A Comparison of the Nonlinear Properties of the Shunting Inhibition and the Threshold Models for Direction Selectivity in the Retina. *Soc. Neurosci. Abst.* **12**, 114.1.
- Grzywacz, N.M., and E.C. Hildreth (1985) Recovering Three-Dimensional Structure from Motion Using Positions vs. Velocities. *Technical Digest of the Optical Society of America Meeting*, 61.
- Grzywacz, N.M., and C. Koch (1985) The Use of Volterra Series Expansion to Characterize Direction Selectivity. *Soc. Neurosci. Abst.* **11**, 103.1
- Grzywacz, N.M., P. Hillman, and B.W. Knight (1985) A Study of the Bump-Rate Transfer Function in *Limulus* Ventral Photoreceptors. *Invest. Ophthalmol. Vis. Sci.* **26**, 113.