



UNIVERSITY *of* ROCHESTER

A stylized graphic of a human head in profile, facing right. The interior of the head is filled with a complex network of white lines, circles, and squares, representing neural connections and cognitive processes. The background is a gradient of blue and green.

Brain & Cognitive Sciences

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TABLE OF CONTENTS

	page number	
	about the department of brain and cognitive sciences	1
	overview of research programs	3
	the graduate program in brain and cognitive sciences	5
<u>BRAIN and</u>	research resources and facilities	8
<u>COGNITIVE</u>	faculty in brain and cognitive sciences	9
<u>SCIENCES</u>	associated faculty in other departments	29
	our graduate students	31
	our former students	33
	associated departments and programs	38

ABOUT THE DEPARTMENT OF BRAIN AND COGNITIVE SCIENCES

Members of the Department of Brain and Cognitive Sciences study how we see and hear, move, learn and remember, reason, and produce and understand spoken and signed languages, and how these remarkable capabilities depend upon the workings of the brain. We also study how these capabilities develop during infancy and childhood, and how the brain matures and becomes organized to perform complex behavior.

Advances in various branches of the biological sciences and in computer science, along with striking progress in the behavioral sciences during the last 25 years, have fundamentally altered the way we approach the study of these perceptual and cognitive skills. The disciplines of computer science and neuroscience, both of which have enjoyed explosive growth, have profoundly influenced the scientific study of thinking, perception, learning and memory, and language, have fueled the emergence of the field of cognitive science. The recognition that what the brain does is analyze information (i.e., it is a computer), and resulting efforts to represent its function in formal computational models, have brought powerful new insights to our understanding of visual perception, language and reasoning. At the same time, it has become increasingly clear that the brain is a very special computer—that its biology imposes powerful constraints on the kinds of computation undertaken, and (given many possible formal ways to organize a particular behavior) the particular method adopted. These developments, together with major advances in the behavioral analysis of perception and cognition, have provided us with marvelous new opportunities for understanding the brain and behavior.

The emergence of the Brain and Cognitive Sciences as strong new academic disciplines is recognized in the founding of the Department of Brain and Cognitive Sciences at the University of Rochester. The Department is home to 19 Faculty with primary appointments and to closely associated faculty with primary appointments in other departments. Our faculty and their research programs are a major intellectual force, with national and international reputations in several fields. Our research spans a large domain and straddles several disciplines in the behavioral and neural, and computational sciences, but all our work is connected by the idea that to understand behavior we must study not only behavior but also the processes—both neural and computational—that underlie it. The importance of this work is recognized both in the numerous honors conferred on faculty, and in their great success in attracting funds to support their research (principally from the National Institutes of Health and the National Science Foundation). Our commitment to research also means a commitment to train future research workers, and here too we have an outstanding record, attracting students of the highest caliber into our graduate program and investing heavily in them while they work with us. Undergraduates too have a major place in this new enterprise: we believe very strongly that study of the Brain and Cognitive Sciences provides a superb general intellectual training, and a marvelous opportunity for students to engage themselves in research work with faculty and learn the logic of scientific enquiry. This conviction is reflected in the structure of our undergraduate programs, which offer students a wide range of opportunities to explore the breadth and depth of our discipline.

Our Department provides a focus for studying cognition, complex behavior, and brain function. But we also recognize this pursuit as an interdisciplinary endeavor, and the Department and its members have strong ties to associated programs in other academic departments and centers, notably computer science, Linguistics, Music, Visual Science, and several neuroscience departments in the Medical Center.

It is important to point out that students with interests in one or more of these associated programs can take courses and obtain research experiences with faculty in any of these units, while maintaining a primary connection to the graduate program in Brain and Cognitive Sciences

OVERVIEW OF RESEARCH PROGRAMS

Our research spans a large domain and straddles several disciplines in the cognitive, computational and neural sciences. All of it is connected by the idea that to understand behavior we must study the processes – both neural and computational – that underlie it. While the Faculty have active research programs on many topics, in several areas the department, in conjunction with the surrounding University community, has notable concentrations of strength. Some of these concentrations of expertise are in specific perceptual or cognitive systems; others cover broader theoretical issues that cut across systems and species.

Perception and Action

One large group of faculty and students focuses their research on understanding the organization and function of the visual system. Members of this group use a range of perceptual, physiological, anatomical, and computational methods to investigate the optics of the eye, signal processing in the retina and at higher levels in the visual pathway, and the mechanisms underlying the perception of color, motion, shape, and other attributes of visual images. Many investigators also study the integration of visual perception with memory and motor organization. The Center for Visual Science, an interdisciplinary research unit to which many faculty, fellows and students in the department belong, provides the focus for research on vision, drawing us together with scientists from the departments of Computer Science, Ophthalmology, Neurobiology and Anatomy, Neurology, and the Institute of Optics.

Language Processing and Acquisition

A second constellation of faculty and students studies the nature of language processing and acquisition. This research spans a broad set of topics, ranging from the perception of speech sounds and words, the production and comprehension of spoken and written language, and the acquisition of spoken languages by young children and adults, to investigations of the structure, processing, and acquisition of signed languages. The Center for Language Sciences, an interdisciplinary research unit associated with the Department of Brain and Cognitive Sciences, brings together our own faculty, fellows, and students with language scientists from the Departments of Linguistics, Computer Science, and Philosophy.

Learning, Development and Neural Plasticity

The study of learning and plasticity during development cuts across domains and links those who study perception, language, and neurobiology. Faculty and students working on a variety of different systems share an interest in the mechanisms of learning and plasticity, and explore these mechanisms using behavioral, computational, and neuroscientific methods. The research ranges from investigating the development of perception and language in human infants and adults, and the acquisition of bird song in finches and sparrows, to the measurement and modeling of the neural and computational mechanisms that underlie developmental plasticity, Hebbian learning, and critical periods in the development of the brain and behavior.

Cognitive Neuroscience

Research programs in the broad domain of cognitive neuroscience offer students in the Department an opportunity to stress neurobiological approaches to cognition in their research, while developing a perspective strongly shaped by the department's emphasis on combining behavioral, computational, and neural investigations. Faculty in this area seek to understand complex cognitive processes in terms of their underlying neural mechanisms. Their investigations employ a variety of complementary tools to understand the neural bases of visual perception, sensory integration and motor planning, language acquisition, and learning and memory. Behavioral and psychophysical studies identify the tasks and functions performed by the brain during cognition. Brain-imaging (fMRI) studies identify regions of the brain engaged in cognitive processes, and neurobiological studies explore how their cellular and molecular properties relate to behavioral measures of cognition.

Computation, Cognition and the Brain

Several faculty and students focus on the use of mathematical analysis and computational modeling to the study of brain and behavior. Significant progress in our field requires and emphasis on theoretical frameworks and findings, we believe, can best be achieved through computational methods. Members of our department study the Brain & Cognitive Sciences from a wide variety of perspectives. Some researchers seek to understand information processing by individual neurons and groups of neurons organized into circuits. Other researchers seek to understand human behavior through computational frameworks constrained by what we know about people's mental abilities. And still other researchers seek to create artificial intelligence by developing new data structures and algorithms. An unusual aspect of BCS is the large number of members whose research interests reflect two or more of these perspectives. We often conduct our research in collaboration with colleagues in the Department of Computer Science and with other members of the Center for Computation and the Brain.

THE GRADUATE PROGRAM IN BRAIN AND COGNITIVE SCIENCES

Our Approach

Graduate education is a central part of academic life in the department. All of our faculty are invested in research structured to include graduate students as essential partners. Graduate students in the department are our junior colleagues and future peers—people who enrich our academic lives as much as we enrich theirs—and we commit a great deal to their training.

The essence of our graduate program is training for research in the disciplines that constitute the brain and cognitive sciences. Initially a student's research is likely to be undertaken with close guidance from a member of the faculty, but we expect and encourage students to develop rapidly into independent researchers, and to become major contributors to the intellectual life of the department. We attach great importance to the collegiality of contact among graduate students, postdoctoral fellows and faculty, and the department does much to foster this by encouraging students to work with several faculty members, concurrently or sequentially, and with one another.

We also greatly value the public discussion of our science, and through a range of research meetings, colloquia and lecture series sponsored by the department and other centers with which it is associated, students and faculty are regularly brought together. We encourage students to discuss their work in the larger scientific community, and the department supports students' attendance at scientific meetings.

The Ph.D. Program

The explosive growth of the Brain and Cognitive Sciences results in large part from their

capacity to draw on techniques and inspiration from a range of disciplines. The domain is quintessentially interdisciplinary, and for this reason our Ph.D. program emphasizes training in the range of research methods that drive the field. While our focus is always on behavior and the brain activity that underlies it, we encourage students to undertake projects in several laboratories that use different research methods, and we provide courses that introduce students to the range of methods we use (see below). At the same time, we do not expect students to master all domains, and we recognize that disciplinary specialization is necessary and desirable, so we try to ensure that while all become familiar with a range of methods, each develops real expertise in those that best serve the chosen field of specialization.

In providing a program that is both broad and deep, we draw not only on our own resources but also on those of associated research centers and departments, and it is not uncommon for graduate students seeking to understand particular aspects of behavior to undertake projects with faculty and students from outside the department; conversely, our faculty often work very closely with graduate students from other programs and departments. This fluidity of our program is one of its greatest strengths, and we work hard to maintain it.

Although research training is paramount, we recognize that we are training future academics, many of whom will combine teaching with research. All graduate students therefore also undertake some teaching, usually as assistants to faculty in lecture or laboratory courses.

The Curriculum

Because students come to the Brain and Cognitive Sciences with a wide range of backgrounds, the curriculum offers a broad base

designed to introduce students to parts of the domain they might not previously have studied, and to prepare them for advanced work. This core curriculum covers a range of topics in perception, action, cognition, language, learning and development, each examined from the perspectives of behavioral, computational and neural science. The methods students master for approaching their own research may vary. However, as preparation for entering a highly interdisciplinary field, all students must acquire some expertise in at least two of these approaches. Students also take advanced courses and seminars in one or more areas of specialization.

At all stages of their graduate careers, students are heavily engaged in research. Generally students complete most of their course work during the first two years. During the third year students take a qualifying exam covering the scholarly literature surrounding their area of specialization, and thereafter typically devote themselves fully to their research. The PhD. is awarded upon the completion of a dissertation that describes original research in the field. The Department does not offer a program leading to a master's degree.

These requirements are summarized below.

1. Core Courses: four of the following, with at least one from each pair:

Language
Cognition

Sensory Systems
Perception & Action

Cellular or Systems Neuroscience
Developmental Cognitive Neuroscience

2. Experimental Design and Statistics

3. Training in at least two research methodologies, selected from the following:

Behavioral Science
Computational Modeling
Neuroscience

Expertise in a methodology is achieved by taking BCS methods course or by petitioning to satisfy the requirement through research experience.

4. Supervised research throughout the program

5. Advanced courses as needed to achieve scholarly background and specialized expertise

6. Qualifying exam in area of specialization

7. Supervised experience as teachers or teaching assistants

8. Doctoral dissertation

For general information about graduate studies at the University of Rochester and for descriptions of all graduate course offerings at the University, please visit

<http://www.rochester.edu/GradBulletin/>

Admission and Financial Support

Students admitted to the program come from a variety of backgrounds, some in disciplines closely related to ours, (e.g. psychology, neuroscience, computer science, cognitive science, linguistics), others in branches of the natural sciences or engineering that are less obviously relevant to our domain. This richness of backgrounds is a source of great strength to the program, because our students bring to it new ways of thinking about scientific problems. Although we do not stipulate the kinds of backgrounds students should have, we do expect applicants for admission to have outstanding academic records, and to be able to demonstrate their capacity for formal thinking and clear expression of ideas.

All students admitted to the program are offered graduate fellowships that provide a competitive 12-month stipend, and cover the costs of tuition and other fees. Support is guaranteed for four years subject to satisfactory academic progress. The department does not

distinguish teaching fellows and research assistants: all students are provided with a fellowship to support their research training, and all contribute to the department's teaching by serving as teaching assistants or teachers of small classes. Students may be asked to serve as teaching assistants for one course each year during tenure of their fellowships, but in recent practice the load has been less than this. Where appropriate, students are encouraged to seek personal fellowships from bodies such as the National Science Foundation or the National Institutes of Health, for this brings distinction both to the student and the Department; however, admission to the program is never contingent on students securing their own funds.

To apply for admission to the graduate program, you must submit an application electronically through the department's web page at:

<http://www.bcs.rochester.edu/graduate/guidelines.html#application>

As a courtesy to the applicants of the Department of Brain and Cognitive Sciences, the department has waived the University of

Rochester application fee. If you are applying to other graduate departments at the University of Rochester, please check their application process. Not all departments will waive the application fee.

The closing date for applications for admission is January 1. We cannot guarantee to consider applications received later than that date. Applicants may be invited to visit the department for interview. Decisions on all applications will be made before April 1. The department accepts students only for fulltime Ph.D. study and beginning only in the fall semester.

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RESEARCH RESOURCES AND FACILITIES

The Department occupies approximately 40,000 square feet of laboratory and office space in Meliora Hall, a modern building close to the heart of the University's River Campus. Individual laboratories are well equipped with facilities and instruments that meet more specialized needs. These range from a molecular biology laboratory and a neurochemistry laboratory, to laboratories that provide a variety of instruments for delivering visual stimuli (for example, laser interferometers and image computers, including a virtual reality engine and helmet-mounted display system), and a range of sophisticated systems for measuring various behaviors and physiological responses. These include several devices for monitoring eye-movements during perceptual, cognitive, and visuomotor tasks, and physiological recording systems that monitor activity of single neurons or groups of neurons. In other domains laboratories are equipped for the analysis and synthesis of speech, and for recording and analyzing the gestures in signed languages. Most laboratories have sophisticated real-time computing systems for controlling experiments.

Members of BCS have direct access to computer support. BCS employs a systems administrator who manages all of the department's computing resources, provides hardware & software support for departmental computers, and offers advice and technical assistance.

In addition to the resources available in Meliora Hall, members of the Department have access to a shared machine shop, staffed by skilled technicians, and to University resources such as the Optical Fabrication and Testing Facility. Other special resources, such as a state-of-the-art 3T magnet for structural and functional MRI, are available for re-search use at the Rochester Center for Brain Imaging, or in various labs and centers within the Medical School complex, which is a five-minute walk from Meliora Hall.

FACULTY IN BRAIN AND COGNITIVE SCIENCES

The faculty are active both as researchers and as teachers. These roles are inseparably linked: we have a strong obligation to advance knowledge in the brain and cognitive sciences, to impart that knowledge to students and to train them in the methods and formalisms we use. Our investment in students is not altruistic: teaching helps us enlarge our academic horizons and clarify our thinking, and through projects students undertake with us it binds us to the next generation of thinkers who will shape our own and other fields.

The focus of the faculty's work is behavior and its dependence on neural and cognitive mechanisms. The multi-disciplinary nature of the domain is reflected in our backgrounds. Among the 20 faculty with primary appointments in the Department of Brain and Cognitive Sciences, we find doctoral degrees in Biology, Cognitive Science, Computer Science, Experimental Psychology, and Physiology-Neurobiology. The following paragraphs provide brief overviews of the research programs of our primary faculty.

Richard Aslin (Ph.D., University of Minnesota, 1975)

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My research over the past decade has been focused on the rapid learning of sequences of events in the auditory domain and spatial configurations of visual elements in complex scenes. This statistical learning mechanism, which is both highly susceptible to environmental inputs and constrained by innate biases, enables adults, children, and infants to group sounds based solely on the distributional information (conditional probabilities) of elements contained in the sound stream or in visual scenes. We have also used a serial reaction time task to study the on-line processing of sequential statistics and fMRI to study the neural correlates of statistical learning. Complementing fMRI studies of adults is a new brain imaging technique, called Near-Infrared Spectroscopy, that can assess the neural correlates of language and visual processing, including statistical learning, in young infants. Finally, we are using a head-mounted camera and eye-tracker to study how infants view natural scenes, particularly during language learning.

In addition to studying infant development, I am also interested in behavioral and neural plasticity

in adults, particularly in the domain of language (speech perception and the lexicon). We have employed a Bayesian approach to studies of cue-reliability in speech, artificial lexicon paradigms for studying word learning, and eye-tracking in the visual-world paradigm to study dialect adaptation and context effects in lexical competition. Recent work using fMRI provides compelling evidence that lexical competition has a neural signature when newly learned words are associated with specific perceptual properties. Future work will explore these issues as well as more basic questions about neural coding of speech categories and semantic categories in spoken word recognition.

Relevant Publications

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speakers' referential intentions. Developmental Science, 14, 925-934.

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Shukla, M., White, K. S., & Aslin, R. N. (2011). Prosody guides the rapid mapping of auditory word forms onto visual objects in 6-mo-old infants. Proceedings of the National Academy of Sciences, 108, 6038-6043.

White, K. S. & Aslin, R. N. (2011). Adaptation to novel accents in toddlers. Developmental Science, 14, 372-384.

Hunt, R. H. & Aslin, R. N. (2010). Category induction via distributional analysis: Evidence from a serial reaction time task. Journal of Memory and Language, 62, 98-112.

Gebhart, A. L., Aslin, R. N., & Newport, E. L. (2009). Changing structures in mid-stream: Learning along the statistical garden path. Cognitive Science, 33, 1087-1116.

Clayards, M. A., Tanenhaus, M. K., Aslin, R. N., & Jacobs, R. A. (2008). Perception of speech reflects optimal use of probabilistic speech cues. Cognition, 108, 804-809.

Maye, J., Aslin, R. N., & Tanenhaus, M. K. (2008). The weckud wetch of the wast: Lexical adaptation to a novel accent. Cognitive Science, 32, 543-562.

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Pirog Reville, K., Aslin, R. N., Tanenhaus, M. K., & Bavelier, D. (2008). Neural correlates of partial lexical activation. Proceedings of the National Academy of Sciences, 105, 13110-13114.

Daphne Bavelier (Ph.D., Massachusetts Institute of Technology, 1992)

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A distinctive feature of the human brain is its capacity to learn and adapt to an ever-changing

environment. What are the factors that promote such learning and brain plasticity? Are some parts of our nervous system more plastic than others, making some skills easier to acquire? Answers to these questions are central to basic science, education, clinical rehabilitation, and aging.

To address these questions, my laboratory uses a multidisciplinary approach (behavior, brain imaging, eye tracking) to study how individuals learn and adapt to changes in experience, whether induced by nature (deafness) or training (playing video games).

This work highlights that, although possible, brain plasticity is highly specific. For example, life-long deafness enhances only one aspect of vision: peripheral visual attention. The consequences of that one change range from enhanced visual search abilities to differences in reading patterns, providing valuable information for deaf education.

Plasticity induced by training also shows high specificity, with individuals typically improving on the trained task but not on other, even closely related, tasks. This critically limits the benefits of training. Recently, however, we have discovered that playing certain types of video games induces a vast array of improvements in vision, decision-making and cognition that extend well beyond the specific tasks in the game. A training regimen whose benefits are so broad is scientifically unprecedented, and provides a unique opportunity to identify factors that underlie learning and brain plasticity. This work also has profound social implications, since more than 90% of youngsters now play video games.

Relevant Publications

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- Hall, M.L. & Bavelier, D. (2011). Short-term memory stages in sign versus speech: The source of the serial span discrepancy. Cognition. Epub 2011 Mar 29.
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Jessica Cantlon (Ph.D. Duke University, 2007)

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What do the minds of monkeys, children, and adult humans have in common? One answer to this question that stems from my research is: math. Although adult humans have an extremely sophisticated repertoire of mathematical faculties, a subset of those skills is shared by other members of the animal kingdom and emerges early in human development, before children learn math in school. Using a diverse set of methods (both behavioral and neuroscientific) and subject populations (preschool children, adults, and non-human primates), my research has demonstrated that the cognitive and brain signatures of basic mathematical skills are comparable in adult humans, pre-school children, and non-human primates. Broadly speaking, this research indicates that certain conceptual abilities

are cognitive vestiges of our shared evolutionary history with other animals.

One aim of my research is to discover whether the same cognitive mechanisms govern certain semantic judgments in human and non-human animals. My studies have demonstrated that adult humans, pre-school children, and monkeys share capacities for numerical abstraction, numerical comparison, addition, and subtraction. This set of abilities is comparable between species not only in its gross output (e.g., an ability to enumerate), but also in its underlying principles. We have found that the nonverbal mathematical behaviors of adult humans, pre-school children, and non-human primates obey the same cognitive laws (e.g., Weber's law, the semantic congruity effect). These findings indicate a common basis for numerical reasoning in our shared evolutionary history with non-human animals.

If there is a true evolutionary connection between the cognitive abilities of human and non-human animals then we might expect that common brain systems underlie these abilities throughout development. Using functional magnetic resonance imaging (fMRI), we have found that a brain region identified as a critical substrate for mathematical cognition in adult humans and non-human primates (the intraparietal sulcus) is also engaged by pre-school children (~4 years of age) during non-symbolic numerical processing (i.e., judgments of visual arrays of dots). In addition, regions of inferior frontal cortex are recruited by pre-school children (together with the intraparietal sulcus) as they learn uniquely human numerical symbols. This research has prompted the hypothesis that the recruitment of inferior frontal cortex by young children during symbolic numerical processing serves to link modern human numerical concepts with the evolutionarily primitive numerical system of the intraparietal sulcus.

Current studies aim to investigate the organization of a wide variety of conceptual systems (e.g., math, reading, music, logic) across species and stages of development. We are using cognitive and neuroimaging methods (fMRI) to investigate

the organization of concepts in preschool children, school-age children, adults, and non-human primates to identify their common cognitive and neural mechanisms as well as those that are uniquely human. The ultimate goal of this research program is to integrate cognitive and neuroimaging studies of adults, children, and non-human primates to advance our understanding of the origins of the human mind.

Relevant Publications

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Gregory DeAngelis (Ph.D. University of California Berkeley, 1992)

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My laboratory studies cortical circuits that mediate visual perception and visually guided behavior. This work involves a creative fusion of the disciplines of neurophysiology, psychology, and computation. Monkeys are trained to perform demanding discrimination tasks, and we record from single or multiple neurons in visual cortex during performance of these tasks. This allows us to directly compare the ability of neurons to discriminate between different sensory stimuli with the ability of the behaving animal to make the same discrimination. This approach also allows us to examine the relationship between neuronal activity and perceptual decisions (independent of the physical stimulus). In addition, the techniques of electrical microstimulation and/or reversible inactivation are used to establish causal links between physiology and behavior. Computational modeling plays an important role in interpreting results and making predictions for future experiments.

Our research currently has two main foci: 1) Neural mechanisms of depth perception. The image formed on each retina is a two-dimensional projection of the three-dimensional (3D) world. Objects at different depths project onto slightly disparate points on the two retinas, and the brain is able to extract these binocular disparities from the retinal images and construct a vivid sensation of depth. My lab studies the mechanisms by which binocular disparity information is en-

coded, processed, and read out by the brain in order to perceive depth and compute 3D surface structure. We are beginning to elucidate the brain areas that contribute to stereoscopic depth perception under specific task conditions, although much remains to be learned about this interesting cognitive process. We have also recently discovered a population of neurons that combines visual motion with eye movement signals to code depth from motion parallax, and future work will focus on how depth cues from disparity and motion parallax are integrated by neurons. 2) Sensory integration for perception of self-motion and object motion. To accurately perceive our own motion through space, and in turn the motion of objects relative to our own trajectory, we integrate information from the visual and vestibular systems. Integrating information across different sensory systems is a fundamental issue in systems neuroscience. Using a 3D virtual reality system to provide monkeys with naturalistic combinations of visual stimuli and inertial motion, we are studying how cortical neurons integrate visual and vestibular signals to compute one's direction of heading through 3D space. We are also exploring the neural computations by which the brain compensates for self-motion to judge the motion of objects in space. An overarching goal is to develop a detailed neurobiological account of Bayesian optimal cue integration.

Relevant Publications

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vestibular cues during self-motion perception. Journal of Neuroscience, 29: 15601-15612.

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Benjamin Hayden (Ph.D. U.C. Berkeley, 2005)

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We are constantly confronted with choices: What should we eat? How should we allocate our time? Where should we go next? Should we follow a safe path or a risky one that offers a potentially larger payoff? The brain has evolved sophisticated machinery to balance competing interests to make beneficial choices. Our lab wants to know how the brain solves these problems - and why it fails so often. Specifically, we are interested in identifying the neural calculations that promote good decision-making, especially when rewards are involved. To do this, our lab records the activity of single neurons during actual choices.

Our lab is particularly interested in the problem of self-control. Some people have an easy time quitting smoking, saving their pennies, and resisting doughnuts. Others don't. What accounts for these differences? Self-control is a cognitive skill that allows us to resist urges and delay gratification. We are particularly interested in understanding the role of neurons in the anterior cingulate cortex, among other frontal lobe structures, in providing inhibitory brain signals to brain regions responsible for urges. Deficiencies in self-control characterize addiction, obsessive-compulsive disorder, Tourette Syndrome, and many other disorders, so we hope that studying how self-control works will give us further insight into the etiology of these diseases.

Our research falls under the general purview of the emerging field of neuroeconomics. Like other scientists in this field, we seek to use neuroscience to guide theories about how people make economic decisions and to use economic theory to guide our understanding of the brain. We are particularly interested in the influence of risk, ambiguity, and delays on value judgments. We are also interested in applying the rich insights of foraging theory to neuroscience. In doing so, we can provide a solid foundation for fields that study decision-making, and derive fresh tools for

solving some of the most important philosophical questions humans have asked: What does it mean for us to choose freely? How much control do we really have? What distinguishes what happens from what could have happened?

We are also interested in fictive learning. We often think about outcomes that could have happened but did not. How does the brain's reward circuitry deal with these counterfactual, or fictive rewards? We have showed that a capacity for counterfactual thought is not limited to humans, but is shared with other animals. We have also found that neurons in one reward structure, the anterior cingulate cortex, treat these rewards largely the same way they treat actual experienced rewards. Now we want to know how these abstract reward signals are constructed. We plan to use single unit electrode recordings to study the role of several brain structures in recognizing and responding to fictive rewards, to develop a more complete picture of reward processing in general.

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Robert Jacobs (Ph.D., University of Massachusetts, 1990)

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My lab uses both human experimentation and computational modeling to study the roles of learning, memory, and decision-making in perception and cognition. We believe that both methodologies are needed to form and evaluate comprehensive theories of human thought and behavior.

One focus of our research is on how people take advantage of the redundancies that exist in typical perceptual environments. Redundancies exist in both multisensory environments – where a person might receive visual, auditory, and tactile information about the shape and location of an object – and in purely visual environments – where a person might receive multiple visual

cues such as binocular, motion, and shading cues to an object's identity. What strategies do people use to combine information provided by multiple sensory modalities or multiple visual cues? Are these strategies optimal from statistical (e.g., maximum likelihood or Bayesian) perspectives? Can people learn new strategies in an experience-dependent manner? Experimental and computational studies are conducted to address these questions.

A second focus of our research is on how to best train people to learn to acquire perceptual skills. Efficient and effective training is important because many scientific disciplines require experts to possess advanced perceptual skills in limited domains (consider a radiologist examining x-ray images). We study differences in perceptual behaviors between domain experts and novices, and study training procedures that will allow novices to quickly acquire the perceptual skills of experts

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Florian Jaeger (PH.D., Stanford University, 2006)

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Research in the Human Language Processing Lab focuses on language processing in production and comprehension. In particular, we are interested in (a) the extent to which speaker and comprehenders use probabilistic information to communicate efficiently (ideal speaker models; communication through noisy channels), (b) how language users integrate different information sources (cues) during incremental language processing (cue integration; interactive models), and (c) how the relevant probability distributions over linguistic structures are acquired and maintained throughout adult life (language acquisition and adaptation).

To this end, we draw on insights from probability theory, information theory, machine learning, and Bayesian inference to develop models of human language processing. For example, we might ask what would be theoretically or mathematically optimal for communication, and then compare the optimal solution to human behavior, where these behaviors range from articulatory and phonological planning to syntactic planning and beyond (e.g. discourse planning). Similarly, we employ hierarchical Bayesian models to understand implicit learning and linguistics adaptation in adult language users. For example, speakers and listeners might continuously adapt their phonetic, phonological, and syntactic expectations to individual speakers, groups of speakers, and situations. We're also interested in understanding how such possible adaptation might relate to how we build social identities.

Other work in the lab studies processing preferences in production and comprehension beyond those linked to communicative efficiency. For example, how do speakers deal with the task demands during production to maintain fluency (effects of syntactic planning, lexical retrieval, scope of planning, etc.)? We also explore how such processing preferences affect acquisition and, ultimately, typological distributions across languages of the world.

To study these questions we use both corpus studies and laboratory experiments. Corpora of spontaneous speech have the advantage that speakers are recorded under more ecologically valid conditions, but they don't yield balanced data. We use modern statistical modeling to tackle this problem by controlling for the influence of many factors at the same time. Other questions are better addressed by more directly controlled experiments. We use standard methods such as eye-tracking, self-paced reading, picture descriptions, sentence recall, artificial language learning, etc. To reach a more diverse community of participants, we frequently run our experiments over the web

Relevant Publications

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- Levy, R. & Jaeger, T.F. (2006) Speakers optimize information density through syntactic reduction. Proceedings of NIPS 19, 849-856.

David C. Knill (Ph.D., Brown University, 1990)

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"We do not see optical images in an optical space, but we perceive the bodies round about us in their many and sensuous qualities."

Ernst Mach, 1897

Mach's quote, taken from a short monograph on sensation and perception, states very beautifully the basic phenomenon of vision - that our perceptions are comprised of descriptions of the world, not of the energy patterns directly available to our senses. A central puzzle in vision is how the brain infers properties of the world from the sensory data. Research in my lab focuses on two aspects of the vision problem: how the human visual system perceptually infers physical and geometric properties of the world from image data and how the brain uses visual information about the world to control motor behavior, such as reaching for and grasping objects. Answering these questions requires understanding the relationships between visual processing, the structure of visual information and the information demands of the tasks subserved by vision. Research in my lab, therefore, takes an integrative approach that combines mathematical analysis and psychophysical experimentation.

One central problem being studied in my lab is how the visual system perceives the 3-D shapes and layouts of surfaces in a scene. Our theoretical work in this area focuses on analyzing how regularities in the world help to structure the information provided by different cues and how multiple cues should (ideally) be integrated to generate percepts of 3-D surface geometry. The results of this "computational" analysis guide psychophysical investigations into how the visual system uses the information provided by different cues to infer 3-D scene structure. We have applied this approach to a number of specific problems, including the perception of 3-D object motion from the motion of cast shadows, the perception of surface shape from contours, the perception of surface shape from texture and the perception of shape from shading. We are currently studying how the visual system integrates the information from different cues to generate a unified percept of surface shape. This work attempts to relate theoretical analyses of ideal cue integration strategies to the strategies used by human observers as revealed by psychophysical studies.

A second general problem domain being investigated in my lab is how the human brain uses visual information to control motor behavior, particularly prehension movements (reaching for and grasping objects). The lab contains a 3-D display system for generating a virtual world with which subjects can interact, a robot arm for automatically placing real targets in an experiment and a real-time 3-D sensing system for recording subjects' finger, hand and arm movements during execution of a reaching task. By artificially perturbing parts of the virtual 3-D world during a prehension movement, we are able to study how the human brain uses visual information to control the movement. One problem currently being investigated is how the brain integrates different visual cues to the 3-D position, orientation and shape of objects to control reaching and grasping movements and whether the integration strategies for motor control differ from those discovered for perception. An-

other is how the brain combines information about the 3-D geometry of a target object with visual feed-back from the moving hand to control prehension movements. This work allows us to close the loop between perception and action and allows us to study visual processing in the context of a natural task for which it has evolved.

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Schrater, P., Knill, D. C. and Simoncelli, E. (2000) Mechanisms of visual motion detection, Nature Neuroscience, 3 (1), 64 - 68.

Brad Mahon (PhD, Harvard University, 2009)

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My principal research focus is on how concepts of common objects are represented and organized in the brain. Most of this research is focused on how concepts are accessed from visual input and how those concepts then interface with other systems, such as the motor system controlling the hands, or language. So for instance, you might look at a glass sitting on the table, and think to yourself that it looks slippery, or reach out to grasp it, or you might say 'hand me the glass.' Each of these simple abilities is subserved by dissociable brain systems and is susceptible to selective impairment after brain damage. How is all of this information represented and accessed in the healthy brain, and what happens after the brain is damaged? If a patient loses the ability to use objects according to their function, what happens to linguistic or perceptual knowledge about those objects? Can knowledge that is lost after brain damage be 're-learned,' and if so, what are the neural mechanisms that underlie brain reorganization?

A central focus of my research is on how brain damage may affect what people know about objects, the timecourse of recovery after brain damage, and the plasticity of brain function that underlies recovery. We use fMRI and behavioral measures to address these issues, and study healthy and brain damaged adults. Our theoretical approach emphasizes network level analyses of fMRI datasets, along with behavioral tests that are designed to isolate different cognitive components of complex tasks. We then relate brain activity to performance across different tests in

order to parcellate out the contribution of different brain regions to behavior.

We work in close collaboration with faculty in the Department of Neurosurgery in order to be able to test patients before and after surgery (both behaviorally and using fMRI). Ongoing projects in collaboration with Neurosurgery include studying the effects of surgery for removal of temporal- and parietal-lobe tumors, changes in retinotopic maps in early visual cortex after tumor-induced compression of the optic chiasm, and the long-term effects on language abilities of temporal lobectomy for treatment of epilepsy. We also study healthy adults using fMRI to answer cognitive neuroscientific questions about the organization of object knowledge in the brain. Ongoing projects with healthy subjects include studying how information about different semantic categories is carried by different spatial frequencies in the visual input, and how language areas interact with visual areas during object naming.

Relevant Publications

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Elissa Newport (Ph.D., University of Pennsylvania, 1975)

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It is well known that different types of learners differ in the kinds of patterned environmental stimuli they can acquire, and in the times of life at which such learning can best occur. Finches and sparrows learn their own species' songs more readily than other patterned auditory stimuli, but only during a narrowly circumscribed

period of early development. My own work has shown that similar limits of type and time of learning govern the acquisition of languages in humans. But we know relatively little about the nature of such learning, and about the mechanisms that underlie both the ease of learning under certain circumstances and the difficulty of learning under others.

My research focuses on language acquisition, as a prime example of such constrained learning. One set of projects examines the roles of linguistic input and the maturational state of the learner in the acquisition of English and of American Sign Language. I am studying the differences among learners who are first immersed in the language at different ages, and also the similarities in language learning found in young learners despite linguistic environments of quite different degrees of complexity and consistency. A second set of projects examines these phenomena using miniature language learning, compared with the learning of nonlinguistic patterns, in the laboratory. A third line of work attempts to model the underlying learning mechanisms, to try to explain why language learning might have these properties. Finally, we also investigate natural language acquisition around the world, including the formation of young creole languages and the acquisition of well-established spoken and signed languages in various countries.

Relevant Publications

Fedzechkina, M, Jaeger, T.F., & Newport, E.L. (2011). Functional biases in language learning: Evidence from word order and case-marking interaction. In L. Carlson, C. Hölscher, & T. Shipley (Eds.), Proceedings of the 33rd Annual Conference of the Cognitive Science Society. Austin, TX: Cognitive Science Society.

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Newport, E.L. (1990) Maturation constraints on language learning. Cognitive Science, *14*, 1128.

Ernie Nordeen (Ph.D., University of California, Irvine, 1982)

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I employ molecular, pharmacological, anatomical and behavioral approaches to investigate neural mechanisms underlying vocal learning and plasticity in songbirds. One aspect of my work aims to characterize synaptic changes related to the encoding of auditory memories used as templates for vocal learning. These studies focus on cellular substrates of learning within a striatal-thalamic-cortical circuit specifically implicated in avian song. I also am interested in how diffuse neuromodulatory systems (e.g. dopaminergic cell groups) regulate synaptic processes related to learning. Finally, I also employ the avian song system as a model in which to study neural substrates for adaptive sensorimotor plasticity.

Relevant Publications

Nordeen, K.W., and E.J. Nordeen (2010) Deafening-induced vocal deterioration in adult songbirds is reversed by disrupting a basal ganglia-forebrain circuit. J. Neurosci; *30*:7392-400.

Nordeen, E.J., Holtzman, D.A., and Nordeen, K.W. (2009) Increased Fos expression among midbrain dopaminergic cell groups during birdsong tutoring. Eur. J. Neurosci; *30*: 662-70.

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Hein, A., Sridharan, A., Nordeen, K.W and Nordeen, E.J (2007) Characterization of cell types expressing CaMKII within the avian basal ganglia. Brain Research, *1155*: 125-133.

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Kathy Nordeen (Ph.D., University of California, Irvine, 1982)

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One of the most important functions of the nervous system is to store information and produce adaptive behaviors that reflect prior experience. To uncover circuits and cellular mechanisms that can foster rapid and accurate learning, we use molecular, pharmacological, anatomical and behavioral approaches to investigate neural mechanisms underlying vocal learning and plasticity in songbirds. Like humans, songbirds exhibit strong innate preferences for reproducing vocalizations typical of their own species, and learning occurs quickly if these stimuli are heard at an appropriate age.

Recent work indicates that some of the same neural pathways, transmitter systems, and bio-

chemical cascades linked generally to reinforcement-based learning also are critical for vocal learning. One aspect of our work aims to characterize biochemical and synaptic changes related to the encoding of auditory memories used as templates for vocal imitation. Currently, several studies are focused on elucidating the role of basal ganglia pathways, NMDA receptors, and dopaminergic neuromodulatory systems on establishing song-related memories that will later serve as the target for vocal development. We also employ the avian song system as a model in which to study mechanisms that enable adaptive sensorimotor plasticity in adulthood. The broad aim of our research program is to uncover biological processes that underlie learning and regulate its efficiency.

Relevant Publications

- Nordeen, K.W. and E.J. Nordeen (2008) Circuits and Cellular Mechanisms of Sensory Acquisition. In: H.P. Zeigler and P. Marler (eds.) Neuroscience of Birdsong. Cambridge University Press, Cambridge, pp. 256-270.
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Heinrich, J.E., Singh, T.D., Sohrabji, F., Nordeen, K.W., & Nordeen, E.J. (2002). Developmental and hormonal regulation of NR2A mRNA in forebrain regions controlling avian vocal learning. Journal of Neurobiology, 51, 149-159.

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Alexandre Pouget (Ph.D., University of California, San Diego, 1994)

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The goal of our research is to uncover general principles of representation and computation in neural circuits. Most computations of interest, such as recognizing an object or making a decision, are performed in the presence of high uncertainty. Recent behavioral work in humans and animals has shown that the nervous system handles this uncertainty near optimally, which is to say that the brain represents probability distributions over variables of interest, and combine these distributions according to the laws of statistical inference. The goal of our work is to understand how these inferences are performed at the neuronal level using a type of neural code known as population code. We apply our theory to a variety of domain, including decision making,

multisensory integration, early visual processing and perceptual learning.

Relevant Publications

Moreno-Bote, R., Knill, D.C., and Pouget, A. (2011) Bayesian sampling in visual perception. Proceedings of the National Academy of Science. 26;108(30):12491-6.

Bejjanki, V.R., Lu, Z.L., Beck, J.M., and Pouget, A. (2011) Perceptual learning as improved probabilistic inference in early sensory areas. Nature Neuroscience. 14(5):642-8.

Ma, W.J., Navalpakkam, V., Beck, J., van den Berg, R. and Pouget, A. (2011) Behavior and neural basis of near-optimal visual search. Nature Neuroscience. 14(6):783-90.

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Ted Supalla (Ph.D., University of California, San Diego, 1982)

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The study of signed languages of the world, particularly those which have emerged naturally within communities of deaf people, provides unusual insight into the way humans process and develop communication systems. From such research we are beginning to learn that, to a surprising degree, the structure of languages and the processes by which they are formed are the same for spoken and signed languages, and are therefore constrained by factors that cross input and output modalities.

My research involves three main lines of work. First, I am interested in universals of language, including the comparison between spoken languages and signed languages, as well as the similarities and differences among sign languages themselves. In this research I conduct linguistic analyses of American Sign Language (ASL), particularly its morphology, and I also analyze related structures in 20 different sign languages in North and South America, Europe, Asia, and Africa.

Second, I am interested in grammaticalization of gestural features during early stages in the formation of signed languages. Part of this work examines the continuum from nonlinguistic gesture to gestural language, comparing gesture as used by hearing people, "home sign" systems devised within families who have deaf members, and full sign languages such as ASL, to determine where and how linguistic properties appear in the evolution from nonlinguistic to linguistic use of the same modalities. In historical linguistic work, I am reconstructing the grammar of ASL in the late 19th and early 20th centuries. Comparisons of early and modern ASL, and also among other young versus well-developed sign languages around the world, can provide an understanding of how languages form and change, and whether the processes of language change for sign languages are the same as those for spoken languages.

Third, I am interested in the online processing of ASL, including studies of sentence comprehension and memory as well as fMRI studies asking what parts of the brain are activated during visual gestural language processing.

Relevant Publications

- Supalla, T. and Clark, P. (in press) Sign Language Archeology: Understanding History and Evolution of American Sign Language. Gallaudet University Press.
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Duje Tadin (Ph.D., Vanderbilt University, 2004)

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Visual perception is the biggest and, arguably, the most important part of our sensory experience. Roughly, a half of the cortex is involved in visual processing, but we are only beginning to understand the complex and highly efficient processes that are behind our seemingly effortless ability to experience and understand our visual world. In my research, I use psychophysics, transcranial magnetic stimulation (TMS), fMRI, and eye-tracking to investigate neural mechanisms of visual perception in normal and special populations. Current topics include motion perception, binocular rivalry, visual awareness, contextual interactions, perceptual learning, visual adaptation, attention and temporal dynamics of vision. My behavioral work has revealed several counter-intuitive characteristics of human motion perception and linked these findings with cortical center-surround mechanisms. Follow-up work investigated temporal and spatial properties of center-surround interactions across visual submodalities in normal, schizophrenic and stroke patient populations. Another line of my research uses binocular rivalry, visual crowding and attention as experimental methods for studying the characteristics of visual awareness. Combined use of rigorous psychophysical methods and TMS allows me to make causal inferences about the neural mechanisms of visual perception. These lines of research are supplemented with related investigations of visual processing in special populations, including schizophrenic patients, low-vision children and older adults.

Relevant Publications

Glasser, D.M., Tsui, J., Pack, C.C. & Tadin, D. (2011) Perceptual and neural consequences of rapid motion adaptation. Proceedings of the National Academy of Sciences U. S. A.

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Michael K. Tanenhaus (Ph.D., Columbia University, 1978)

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My research focuses on the mechanisms underlying real-time language comprehension, spanning the traditional subfields of speech perception, word recognition, sentence processing, and interactive conversation. As we are listening or reading, we develop interpretations without waiting until the ends of words, phrases or sentences. This process requires continuous coordination of different types of linguistic and nonlinguistic information. Moreover, the sequential nature of the input means that numerous temporary ambiguities routinely arise.

Much of my research has used ambiguity resolution as a vehicle for examining how information is coordinated during real-time language processing, addressing questions such as: (a) how is information from different linguistic subsystems represented, accessed, and combined; (b) how are linguistic and conceptual representations integrated and how do they interact during processing; and (c) to what extent is language processing accomplished by specialized modules that operate according to principles unique to language (as contrasted with more general principles of information integration common to other perceptual and cognitive domains). A particular focus of this work has been on lexical representation and processing within a constraint-based framework. My research examining these issues makes use of a variety of experimental methods and computational models.

Most recently, my students and I have pioneered the use of light-weight head-mounted eye-tracking as a methodology for monitoring spoken language comprehension. Participants follow spoken instructions to manipulate real or computer displayed objects (e.g., Put the candle that's on the towel into the box). Eye movements to the objects are precisely time-locked to relevant information in the instruction as it unfolds, mak-

ing it possible to study real-time comprehension of spoken language with natural tasks. The methodology is currently being applied to issues in spoken word recognition, syntactic and semantic processing, anaphora resolution, and a variety of issues in experimental pragmatics, including interactive comprehension.

Two large-scale projects are underway. The first project examines spoken word recognition in continuous speech, using English as well as artificial languages, and a combination of experimentation and modeling. Recent work has traced the time course of lexical access, resolving outstanding issues about lexical competition and validating a quantitative linking hypothesis between lexical activation and fixations. Work underway is examining the effects of subcategorical phonetic variation on lexical access, integrating classical issues in speech perception into investigations of lexical access. The second project examines syntactic, semantic and pragmatic processing in natural contexts, including unscripted interactive conversation. This work is aimed at bridging two broad traditions in language performance: (1) the “language-as-product” approach which focuses on the recovery (or creation) of context invariant linguistic structure in an utterance and (2) the “language-as-action” approach which views language processing as inextricably bound to a particular time and place, with speakers and hearers cooperating to create context-specific representations. Ongoing work focuses on how multiple sources of information, including prosody, goals and intentions, and action based affordances are used to construct and dynamically update referential domains.

Relevant Publications

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- Arnold, J.A., Tanenhaus, M.K., Altmann, R.J. & Fagnano, M. (2004) The old and, thee, uh, new:

Disfluency and reference resolution.
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Chambers, C.G., Tanenhaus, M.K. & Magnuson, J.S. (2004) Action-based affordances and syntactic ambiguity resolution. Journal of Experimental Psychology: Learning, Memory & Cognition. 30, 687-969.

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M. & Sedivy, J.E. (1995). Integration of visual and linguistic information in spoken language comprehension. Science, 268, 1632-1634

Other Primary BCS Faculty Members-
Not Accepting Graduate Students:

Robert Chapman (Ph.D., Brown University, 1960)

James Ison (Ph.D., University of Michigan, 1960)

Carol Kellogg (Ph.D., University of Rochester, 1970)

Peter Lennie (Ph.D., University of Cambridge, 1972)

Walter Makous (Ph.D., Brown University, 1964)

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OUR GRADUATE STUDENTS

Students in our Ph.D. program come from a wide range of backgrounds, and work in a range of different domains within the brain and cognitive sciences, but all seek to understand behavior, and how it depends on underlying mechanisms.

To make it easier to appreciate the variety of students' backgrounds and interests we offer here snapshots of five who are at different stages in their careers, who came to the program with different back-grounds and expectations, and whose research falls in different parts of our domain.

Sarah Davis is a fifth-year graduate student studying probability learning in infancy, early language acquisition and language organization in the brain with Elissa Newport and Richard Aslin. She came to Rochester with a B.A in Psychology and a B.A. in Music from Amherst College.

"When I first looked at graduate programs, I wasn't at all certain what specific research questions I wanted to focus on and so I needed the flexibility to explore my options. During my discussions with faculty and students it became clear that the BCS department was the kind of place where I would be encouraged to experience a wide range of research topics and methods. Working with multiple faculty members, even across departments, on a range of questions is not at all unusual here. In fact, in the past year I have been able to take advantage of the highly collaborative and supportive nature of the department to work on two very different projects. An additional draw that Rochester had for me was the proximity of the Eastman School of Music. My undergraduate research had focused mainly on topics in music cognition, and it was important to me that I

be able to continue to explore these interests. The close ties between BCS and the theory department at Eastman have allowed me to continue to take classes in music cognition, discuss ideas, and attend the music cognition symposia that take place twice each semester. The freedom for intellectual development and strong support from the academic community that I have experienced here in Rochester is exactly what I had hoped for."

Kevin Dieter is a fourth-year graduate student studying visual motion perception. He came to Rochester after earning a B.A. in Cognitive Science from Johns Hopkins University.

"My attention was first drawn to Rochester because of its reputation for excellence both as a whole institution and in the particular field of vision science. What I learned when I visited is that this excellence stemmed not only from talented individuals, but from a strong and supportive community with an unparalleled desire to solve problems through collaboration rather than competition. The diversity of research questions and approaches utilized at Rochester also ensure me that I will be well prepared to study whatever research questions I eventually settle on. As a new student, it was extremely comforting to arrive knowing that there was a whole community waiting to support me. And I know that in the future this same community will foster my curiosity and lead me towards exciting discovery."

Ting Qian is a third-year graduate student studying computational modeling and language. He came to Rochester as an undergraduate junior and decided to continue his studies here after earning a B.S. in BCS.

“Rochester was my top choice for graduate school. While many people speak of Rochester as the best example of a flexible and collaborative research environment, I did not realize how it was truly different until I visited several other places. At one place, the professor threw at me a list of projects that I should consider taking on if I were to become his student. Fortunately, I chose to stay at Rochester, and I have been able to put my best efforts into research directions that speak to my genuine scientific curiosity. I have enjoyed the freedom of frequently sitting in meetings of other labs, chatting with professors just to discuss half-baked research ideas, and collaborating with other graduate students/friends on topics that we are interested in. I cannot ask for a better graduate program.”

Bobby Emerson is a second-year graduate student studying how children’s brain support the development of math and reading concepts. He came to Rochester after earning a B.A. in Psychology and Linguistics from the University of North Carolina at Chapel Hill.

“Rochester seemed like the perfect storm of research resources, academic environment, and brilliant people. I was also drawn to the program because it was built to accommodate multiple projects in different labs and foster collaborations.

When I first decided I wanted to complete my Ph.D., the most important part of the experience, at least to me, was the ability to fill my research toolbox with a variety of techniques in data collection, analysis, and teaching. Rochester offered me a diverse collection of tools to help make me a competitive researcher, capable of addressing a large variety of interesting research questions. Taken as a whole, that meant Rochester more than met my requirements, but what really stood out was the way students are funded. At many universities, funding for research is tied to the lab you choose which puts pressure on the student to do only the research that fits into their lab’s research. Rochester was unique in the fact that student funding comes from the department, allowing students to freely move about between labs and put together projects that sparked the interest of multiple labs. In the year that I’ve been a graduate student, this collaborative spirit has been invaluable.”

OUR FORMER STUDENTS

Graduate training provided by the department equips students for research and teaching careers in the range of disciplines that constitute the brain and cognitive sciences. We see this in the topics of the Ph.D.s recently awarded to students working with our faculty, and in the appointments these graduates hold subsequently:

2011

Carbary, Kathleen “Syntactic priming, message formaticum, and successful communication in unscripted dialogue” Assistant Professor, Columbia Basin College

Klein, Natalie “Convention and cognition: Weak definite noun phrases”

2010

Austin, Alison “When children learn more than what they are taught: Regularization in child and adult learners” Postdoctoral Fellow, University of Connecticut

Bardhan, Neil “Adults’ self-directed learning of an artificial lexicon” Postdoctoral Fellow, Max Planck Institute

Frank, Austin “Integrating linguistic, motor and perceptual information in language production” Postdoctoral Fellow, Haskins Laboratories, New Haven, Connecticut

Li, Renjie “The effects of action video game playing on low level vision” Data Analyst, Blizzard Entertainment

Reeder, Patricia “Distributional cues to grammatical categorization: Acquiring categories in a miniature artificial grammar” Postdoctoral Fellow, University of Rochester

2009

Bejjanki, Vikranth Rao “Computing the face of uncertainty: From neurons to behavior” Postdoctoral Fellow, University of Rochester

2008

Clayards, Meghan “The ideal listener: Making optimal use of acoustic-phonetic cues for word recognition” Assistant Professor, McGill University

Faber, Benjamin “Learning hierarchies: acquiring hierarchical structure from miniature artificial languages” Assistant Professor, College of St. Benedict and St. John’s University

Green, Christopher Shawn “The effects of action video game experience on perceptual decision making” Assistant Professor, University of Wisconsin-Madison

Greenwald, Hal “Getting a grip on 3-D surface orientation: Binocular vision, cue integration and computation” Senior Artificial Intelligence Engineer, MITRE

Jovancevic, Jelena “Control of attention and gaze in complex environments” Postdoctoral Fellow, University of Pittsburgh

Masharov, Mikhail “Reference resolution and discourse salience” Research Assistant, University of Dundee

Rothkopf, Constantin “Modular models of task based visually guided behavior” Postdoctoral Fellow, Frankfurt Institute for Advanced Studies

2007

Campana, Ellen “Natural versus standardized approaches to spoken system design: A comparison using the dual-task paradigm” Assistant Professor, Arizona State University

Michel, Melchi “Statistical mechanisms and constraints in perceptual learning: What can we learn?” Assistant Professor, Rutgers University

Pirog, Kathleen “Examining the unspoken word recognition: Semantic representation and integration” Postdoctoral Fellow, Georgia Institute of Technology

2006

Brimijoin, Wm. Owen “Auditory receptive fields and responses to frequency modulation in single units in the auditory mid-brain and thalamus of the bat”. Career Development Fellow, Medical Research Council's Institute for Hearing Research, Glasgow, Scotland

Ivanenko, Volodymyr “Cue-dependent and cue invariant mechanisms in perception and perceptual learning” Postdoctoral Fellow, Smith-Kettlewell Eye Research Institute

Sohn, Jeong-Woo “Action value and motor sequence representation in the primate medial frontal cortex” Postdoctoral Fellow, University of Pittsburgh

Sussman, Rachel “Verb-instrument information during on-line processing” Postdoctoral Fellow, University of Wisconsin-Madison

Wonnacott, Elizabeth “Acquiring argument structure from the input distribution: A miniature language study” Postdoctoral Fellow, University of Oxford.

2005

Brown-Schmidt, Sarah “Language processing in conversation” Assistant Professor, University of Illinois, Urbana Champaign

Creel, Sarah “The role of talker variation in lexical access” Assistant Professor, University of California, San Diego

Droll, Jason “How tasks demands and prior knowledge control eye movements, visual attention and use of working memory” Postdoctoral Fellow, University of California, Santa Barbara

2004

McMurray, Bob “Within-category variation is used in spoken word recognition: Temporal integration at two time scales” Assistant Professor, University of Iowa

2003

Atkins, Joseph E. “Experience-dependent visual cue integration based on consistencies and discrepancies between visual and haptic percepts” Research Scientist, Colby College

Boutla, Mrim “Cognitive mechanisms underlying capacity limits in working memory: Insights from American Sign Language” Assistant Director, Career Development Center, Indiana University

Coppola, Marie “The emergence of grammatical categories in home sign: Evidence from family-based gesture systems in Nicaragua” Assistant Professor, University of Connecticut

Deneve, Sophie “Optimal estimations and computations with population codes by interconnected cortical networks” Faculty Member, Centre National de la Recherche Scientifique, France

Dominguez, Melissa “Developing Vision” Research Associate, McMaster University

Heinrich, Julie “Neural correlates of the sensitive period for avian song learning” Research Associate, University of Notre Dame

Hofer, Heidi “Implications of the trichromatic mosaic for color vision” Assistant Professor, University of Houston

Hudson, Carla L. “Pidgins, Creoles, and learners: How children and adults contribute to the formation of Creole languages” Associate Professor, University of British Columbia

Koo, Daniel S. “On the nature of phonological representations and processing strategies in deaf users of English” Postdoctoral Fellow, Gallaudet University

Scott, Luisa “Mechanisms of neural and vocal plasticity in the adult song bird” Postdoctoral Fellow, University of Texas, Austin

Thompson, Susan P. “The role of transitional probability in the induction of the phrases of a miniature artificial language” Assistant Professor, Monroe Community College

2002

Eigsti, Inge-Marie “Word learning and memory functions in young children with autism” Assistant Professor, University of Connecticut.

Hunt, Ruskin H. “The induction of categories from distributionally defined contexts: Evidence from a serial reaction time task” Postdoctoral Fellow, University of Minnesota

Schneider, Keith “On visual prior entry” Assistant Professor, York University

2001

Chambers, Craig G. “The dynamic construction of referential domains” Associate Professor, University of Toronto

Coady, Jeffrey A. “The development of sensitivity to probabilistic phonotactic structure: Implications for children’s lexical representations” Assistant Professor, Boston University

Hanna, Joy E. “The effects of linguistic form, common ground, and perspective on domains of referential interpretation” Assistant Professor, Oberlin College

Magnuson, James S. “The microstructure of spoken word recognition” Associate Professor, University of Connecticut

Ross, Danielle S. “Disentangling the nature-nurture interaction in the language acquisition process: Evidence from deaf children of hearing parents exposed to non-native input” Regular Fellow, Centers for Disease Control

Ward, Bonnie “Characterizing the relationship between brain space and avian vocal learning” Postdoctoral Fellow, University of Oxford

1999

Fine, Ione “Perceptual learning for discriminating complex gratings” Associate Professor, University of Washington

Juliano, Cornell W. “Frequency effects on syntactic ambiguity resolution during sentence processing” Industrial Design Specialist, Xerox Corporation

Müller, James R. “Gain controls and pattern-selectivity in striate cortex [VI]” Postdoctoral Fellow, Stanford University

1998

Bensinger, David G. “Visual working memory in the context of ongoing natural behaviors” Information Technology Consultant, Self-employed

Etzel, Barbara Ann "Adult female-specific environment related SI: Role reproductive hormones during different periods of development" Associate Professor, Finger Lakes Community College

Rudolph, Kirsten K. "Motion and form perception following lesions of areas MT/MST and V4 in the Macaque monkey" Research Scientist, Visionics, Corp.

1997

Basham, Mark E. "The role of NMDA receptors in zebra finch song learning" Assistant Professor, Regis University

Li, Andrea "Color and brightness in texture segmentation" Assistant Professor, Psychology, Queens College City University of New York

Pollak, Seth David "Early experience and cognitive processing of emotional cues in maltreated children" Professor, University of Wisconsin, Madison

Saffran, Jenny R. "Statistical learning of syntactic structure: Mechanisms and constraint" Professor, University of Wisconsin, Madison

Straub, Kathleen "The production of prosodic cues and their role in the comprehension of syntactically ambiguous sentences" Chief Scientist, Human Factors International

Webb, Rebecca "Linguistic features of metaphoric gestures" Visiting Instructor, University of Rochester

1996

Bowen, G. Peter "Modification of the acoustic startle reflex by complex sensory prestimuli: The roles of the auditory and visual cortical areas" Associate Professor, Wayland Baptist University

Karn, Keith "Human perception, cognition and action" Adjunct Assistant Professor, Center for Visual Science

Maurer, Gail "The role of implicit arguments in sentence processing" Associate Professor, State University of New York, Buffalo

Mintz, Toben H. "The roles of linguistic input and innate mechanisms in children's acquisition of grammatical categories" Associate Professor, University of Southern California

Montserrat Sanz Yagüe, María "Telicity, objects and the mapping onto predicate types. A crosslinguistic study of the role of syntax in processing" Associate Professor, Kobe City University of Foreign Studies

Pelz, Jeff "Visual representations in a visuomotor task" Professor, Rochester Institute of Technology

Spivey, Michael J "Integration of visual and linguistic information in real-time and in real-space" Professor, University California Merced

1995

Burek, Michael "Regulation of neuron number during sexual differentiation of the avian brain" Merck Pharmaceuticals

Cameron, Leslie "Factors determining the latency of saccadic eye movements" Associate Professor, Carthage College

Choi, SuJean "The function of noradrenergic projections to the hypothalamus is altered during adolescent development in the male rat" Assistant Professor, Marquette University

Goldowsky, Boris "Learning structured systems from imperfect information" Director of Engineering and Development, Information Please

Lachter, Joel “Processing of unattended objects in vision” National Research Council Fellow, NASA Ames Research Center

Lin, Daniel “The effects of neonatal exposure to cocaine on responsiveness to rewarding stimuli in young adult rats” Postdoctoral Fellow, The Scripps Research Institute

1994

Aamodt, Sandra M. “Activation and expression of the N-methyl-D-aspartate receptor during the sensitive period for avian song learning” Freelance Science Writer

Galvin, Susan J. “The spatial grain of motion perception in human peripheral vision” Lecturer, University of Otago, New Zealand

Shenkman, Kenneth “Structure sensitivity and language processing in adult learners of Eng-

lish” Vice President and Chief Technology Officer, Genesis Technology Group, Inc.

1993

Jandreau, S. “Sentence meaning and discourse meaning” Senior Technologist, Language Technologies, Inc.

Möller, Per “Influence of color on motion segmentation” Postdoctoral Fellow, University of Newcastle upon Tyne, England

Skoczenski, Ann “The development of position sensitivity in the infant visual system: Evoked potentials, motion and blur” Associate Professor, University of Massachusetts Medical School

Trueswell, John “The use of verb-based sub-categorization and thematic role information in sentence processing” Professor, University of Pennsylvania

ASSOCIATED DEPARTMENTS AND PROGRAMS

Faculty and students in the Department of Brain and Cognitive Sciences have strong ties to several other departments and programs within the University.

The **DEPARTMENT OF COMPUTER SCIENCE** has 20 full-time faculty and about 45 graduate students. Its programs are particularly strong in the areas of computer vision and robotics, knowledge representation and natural language understanding, systems software for parallel computing, and the theory of computation. It enjoys strong collaborative contacts with faculty in several other departments, and has a major involvement in the cognitive sciences at the University.

The **DEPARTMENT OF LINGUISTICS** operates in close cooperation with the Center for Language Sciences (CLS), which serves as the focus of a distinguished interdisciplinary community with research and teaching interests in natural language. Faculty within the Department of Linguistics have expertise in syntax, semantics, phonology, and morphology. The linguistics faculty actively participate in research and training in computational linguistics and psycholinguistics. In addition, they play a central role in teaching and advising students of linguistics and the language sciences from the following Ph.D. programs: computer science, brain and cognitive sciences, and philosophy.

The **GRADUATE NEUROSCIENCE PROGRAM** draws together more than 60 faculty in nearly 15 departments in the School of Medicine and Dentistry and in the College (The Department of Brain and Cognitive Sciences is one of these). In this multidisciplinary program, students examine the organization and function of the nervous system on several levels. The program is formally constituted to provide graduate training leading to the Ph.D.

in neuroscience, but it also offers a range of activities (for example, seminars and journal clubs) which bring together neuroscientists from all of the participating departments and disciplines.

The **DEPARTMENT OF NEUROBIOLOGY AND ANATOMY**, within the School of Medicine and Dentistry, maintains strong commitments to research as well as to graduate, medical, and undergraduate education. Over 30 faculty with primary and secondary appointments in the Department are actively engaged in research on the structure and function of the nervous system across a variety of levels of inquiry. Areas of interest cover a broad spectrum, with a strong emphasis on the neurobiology of sensory-motor systems, neuroengineering and computational neuroscience, and also including cell signaling and transmission, development and aging, neurobiology of disease, and learning and plasticity.

The **CENTER FOR LANGUAGE** Sciences draws together faculty and students with a common interest in natural languages, including an understanding of the linguistic structure, processing and production, and acquisition of both spoken and signed languages. Members of the Center come from four departments in the University and employ the methods of behavioral research, theoretical linguistics, computational modeling, philosophical analysis, and neurolinguistic studies to investigate how languages of the world are formed, processed, and learned.

The **CENTER FOR VISUAL SCIENCE** promotes research on vision by bringing together scientists from a variety of disciplines. Members of the Center, drawn from five departments within the University, employ a variety of approaches (psychophysical, computational, physiological, anatomical, optical, and

clinical) to study a range of problems, including the optical limits on visual performance, the neural analysis of spatiotemporal and chromatic information, cortical mechanisms of motion perception, the neural control of eye movements, and visuomotor coordination.

The **ROCHESTER CENTER FOR BRAIN IMAGING** provides researchers interested in brain structure and function with a state-of-the-art 3T Siemens magnet for basic and clinical research on humans and non-human primates. Researchers from many departments in Arts, Sciences & Engineering as well as the School of Medicine conduct studies

using BOLD imaging to assess neural correlates of brain activity, volumetric analyses of brain anatomy, and Diffusion Tensor Imaging of fiber tracts.

The **DEPARTMENT OF MUSIC THEORY** at the Eastman School of Music provides instruction in music theory at all degree levels. Faculty and graduate students in the department study many kinds of music from a variety of perspectives. In partnership with the Department of Brain and Cognitive Sciences, the theory department actively supports study and research in music cognition. n sentence processing”