INSTITUTE FOR COMPUTATIONAL and BIOLOGICAL LEARNING (ICBL)

PRIMARY PARTICIPANTS:

Stephen José **Hanson**, Psych. Rutgers-Newark; Cog. Sci. Rutgers-NB, Info. Sci., NJIT; Advanced Imaging Center, UMDNJ (Principal Investigator and Co-Director)
Mark A. **Gluck**, CMBN Rutgers-Newark (co-Principal Investigator and Co-Director)
Vladimir **Vapnik**, NEC (co-Principal Investigator and Co-Director)

We also include participants and contact personnel for other participating institutions including Rutgers NB-Piscataway, Rutgers-Camden, UMDNJ, NJIT, Princeton, NEC, ATT, Siemens Corporate Research, and Merck Pharmaceuticals (See attachments that follow this document.)

PRIMARY OBJECTIVE:

The *Institute for Computational and Biological Learning* (ICBL) will be an interdisciplinary center for research and training in the learning sciences, encompassing computational, biological,and psychological studies of systems that adapt, extract patterns from high complexity data and in general improve from experience. Core programs include learning theory, neuroinformatics, computational neuroscience of learning and memory, neural-network models, machine learning, human computer interaction and financial/economic modeling. The learning sciences is an emerging interdisciplinary technology, recently recognized by the National Science Foundation (NSF) as a national priority. The NSF announced this year a major multi-disciplinary initiative which will fund approximately five new national **Learning Sciences Centers** with budgets of $3M to $5M a year for up to 10 years, for a total commitment of up to $50,000,000 per center. As envisioned by NSF, these centers will be

> *"large-scale, long-term Centers that will extend the frontiers of knowledge on learning and create the intellectual, organizational, and physical infrastructure needed for the long-term advancement of learning research. Centers will be built around a unifying research focus and will incorporate a diverse, multidisciplinary environment involving appropriate partnerships with academia, industry, all levels of education, and other public and private entities."*

This proposal to the State of New Jersey represents a matching proposal to an initial five-year proposal being submitted simultaneously to NSF by Hanson and Gluck to create a Learning Sciences Center in New Jersey, based at Rutgers University, in response to NSF's Request for Proposals (for details, see http://www.nsf.gov/pubs/2003/nsf03573/nsf03573.htm)

The Rutgers *Institute for Computational and Biological Learning* would, thus, be funded by both NSF and the State of New Jersey with additional funding expecting from the National Institutes of Health (NIH), private foundations, and local industry. It will promote and support synergy and interactive collaboration between two approaches to the learning sciences: **life sciences** and **information technology**. The life sciences component will encompass empirical and theoretical studies of the behavioral and cognitive neuroscience of learning. The information technology component will include mathematical and computational approaches to modeling, analyzing, and exploiting novel artificial learning systems. As described below in more detail, New Jersey is a natural location for a national Learning Sciences Center because of New Jersey's distinctive demonstrated strengths and prior accomplishments at university and industry research programs. Existing and expected external support (including, but not limited to, the NSF Learning Sciences program) provide a clear plan to transition from state to non-state sources of support over the next five years. In addition to core research programs, ICBL will establish novel educational programs (at postgraduate, undergraduate, and K-12 elementary levels), which insure that New Jersey will be a major locus for training future generations of learning researchers. The leadership of the proposed center will span university-industry links, with two co-directors from Rutgers who each have significant prior academic and industry leadership and management experience, and one co-director from industry who is a leading scientific force in Learning Sciences research.

RESEARCH OVERVIEW:

ICBL provides a common and centralized interdisciplinary center that binds diverse research in the learning sciences that share a common need for enhanced computational methods and tools. ICBL's research activities will fall into three main areas, (1) computational neuroscience, (2) mathematics and computer science, and (3) education and training. By drawing diverse--but interlinked--computational programs more closely into the fold of ongoing empirical research, we expect fertile developments in new computational learning theories, models, and methods, as well as a deeper understanding of how biological systems underlie animal and human learning behaviors. These three programs are summarized below, along with current funding:

(1) **System Brain Modeling & Computational Neuroscience** research develops novel methods for **(1.1)** the analysis and characterization of multi-unit electrophysiology data, **(1.2)** the analysis of real-time changes in dynamic human brain activity seen in functional brain imaging during learning, and **(1.3)** neurocomputational simulation models of key brain regions for learning and memory. Through these three research programs, the ICBL will promot and develop novel computational methods to interpret, analyze, and explain the overwhelming deluge of data that result from empirical studies of the neural bases of learning behaviors. These new methods will, in turn, motivate and inform future empirical research in psychology and neuroscience. Current Leverage: $10M from NSF, NIH, and J. S. McDonnell Foundation.

(2) **Computational Learning Theory& Machine Learning** research creates novel approaches to **(2.1)** the mathematics of learning theory and machine learning, including generalization from small samples, estimation vs approximation, use of prior information, high dimensionality and efficient learning algorithms, and **(2.2)** automatic methods for pattern recognition and classification, including object recognition, data mining, archiving and retrieval systems. Current Leverage: $5M from two NSF-ITRs.

(3) **Education and Training** research exploits basic life sciences research and mathematical theories of learning and brain function to develop **(3.1)** novel computer and web-based methods training methods that enhance learning and performance in healthy normal adults and neurologically impaired populations, and **(3.2)** virtual reality to enhance training and provide individual-centered approaches to training children with different inherent learning styles. Current Leverage: $9M from NIH, NINDS, NIHCD, and the Carter Foundation.

As summarized above, these three research areas currently bring in more than $25,000,000 in external federal and private funds to including $7M for Advanced Imaging Center and $1M for a Virtual Reality Lab. Because of the direct relevance of learning research to understanding and treating brain disorders that impair learning, significant future funding is also expected from the NIH's National Institute of Mental Health (NIMH), National Institue for Aging (NIA), and the National Institute for Neurological Disease and Stroke (NINDS). As an interdisciplinary center that integrates basic university research with the industry needs of the local Information Technology (IT) industry and Life Sciences/BioTech industry (especially the pharmaceutical companies), ICBL will have a unique capacity to support and promote cross-institutional research collaboration, leading to further external funds, expanding New Jersey’s potential for industrial, scientific, and educational growth.

While the core of research, training, and educational programs will take place at Rutgers University, we have established cooperation and collaborative alliances with synergistic programs at nearby universities (Columbia, NY and Princeton, NJ), nearby industrial research centers (NEC), and with the numerous pharmaceutical industry research laboratories in New Jersey. Additional international partners include the computational neuroscience centers at University College London (England) and Hebrew University (Israel).

HOW WILL THIS IMPROVE RUTGERS' THE EDUCATIONAL MISSION:

The new institute would create a teaching resource in the computer sciences. NJIT has developed a new school of Computer Sciences which includes Departments of Computer Science and Information Science which would both benefit directly from the new Institute. Rutgers NB would also benefit from having a computational center that could be useful in recruiting. In general, the ICBL will facilitate computational recruitment to Psychology Department, CMBN, Department of Biological Sciences and the Business School as well as various units at UMDNJ at at New Brunswick. Master's programs in computational finance and neural computation would immediately enhance the educational mission at University Heights. Undergraduate training throughout the university will be enhanced by the addition of interdisciplinary courses and advanced research experience opportunities for undergraduates working in the laboratories of ICBL faculty on their undergraduate honors thesis research.

In addition, the ICBL will promote broader educational goals that build on the interdisciplinary scope of the center. These include the development and nation-wide dissemination of novel undergraduate curricula in the learning sciences (in collaboration with Worth/Freeman publishers) along with free web-accessible teaching aids; a new children's science exhibit on "How the brain learns" in collaboration with the Newark Museum (to travel nationally after local exhibition); national dissemination of free mental health information on learning and the brain; summer research internships in ICBL faculty laboratories for underserved urban poor minority high school students from inner-city Newark (in collaboration with Project Seed); and placing ICBL-supported graduate students in these inner-city Newark high schools to provide teacher and student enhancement training (and role models) in math and science classes (in collaboration Rutgers's NSF Center for Learning and Teaching).

NEW JERSEY'S HISTORICAL ROLE IN LEARNING SCIENCES:

For decades, New Jersey has been the epicenter for innovation and development in the learning sciences. Both in academia and industry, New Jersey has initiated, developed and exploited learning research in industry and education creating new jobs, businesses and economic growth in the state since the early 20th century. At Rutgers Saul Amarel and Tom Mitchell (now of CMU) created centers of research in automated design, medical adaptive expert systems and automated tutoring systems. Prof. Amarel especially was responsible for a growth of learning sciences at Rutgers and for supporting key hires in the area of learning[1] in computer science and cognitive science. In the 1940s and 1950s, Jon Von Neumann and Alan Turing at Princeton literally created computer science and some of the first computing devices, focusing on research questions in neuro-informatics, computational neuroscience and machine learning. At ATT Bell Labs and Bellcore in the 1980s and 1990s, research groups explored the learning sciences in the area of neural networks (in which Hanson was instrumental initiating). By the 1990s these had resulted in multiple new applications in control theory, pattern recognition and expert systems. By the 1990s and 2000s basic industry-based research groups in learning were created at Siemens Corporate Research (where Stephen Hanson, co-PI on this grant, headed the

[1] It would be fitting that any new Center in the Learning Sciences spearheaded at Rutgers would, as a debt and tribute to Professor Amarel (who recenlty passed away), would refer to Professor Amarel in the dedication or naming of any such Institute.

Learning Systems Department for 8 years) and NEC, both in Princeton, which developed new theoretical work that revolutionized of learning and statistical theory over the last 10 years. Vladimir Vapnick, at NEC and had also been part of Bell Laboratories and also a Co-PI on this proposal, was the intellectual force behind this work and much of the revolution in Learning Sciences.

Rutgers has also been at the forefront of experimental research in the biological and behavioral study of learning. The Aidekman Center for Molecular and Behavioral Neuroscience (CMBN) opened in 1991 at Rutgers-Newark, co-directed by Paula Tallal. In the last decade, the CMBN has been at the forefront of significant advances in the neuroscience of learning. Paula Tallal's research on the neural basis of language development and disorders has been translated into novel treatments for children with language learning impairments (such as autism, attention deficit disorders, central auditory processing disorders, and reading impairment) that have been shown to significantly improve the life-outcomes of tens of thousands of children. These results led to the development of a new start-up company Scientific Learning Corporation (SLC), co-founded by Tallal and colleagues. SLC began marketing the Fast ForWord® family of products which now is backed up by over 30 patents. To date, over 20,000 children have completed the Fast ForWord training. SLC has been called the first 'cogniceutical' company, focused on developing additional neuroplasticity-based behavioral training programs for patients with other types of language problems, as well as a variety of other neurological or mental problems. Tallal currently collaborates with April Benasich on studying early infant development of cognitive and learning skills. Also at CMBN, Gyorgy Buzsaki's laboratory is world renowned as one of the most productive and influential labs studying the brain systems for memory, with significant implications for understanding sleep and epilepsy. Buzsaki's laboratory, in collaboration with Ken Harris, has developed novel method for recording, analyzing, and interpreting data from hundreds of simultaneously firing neurons. In the late 1990s, Mark Gluck (CMBN) and Catherine Myers (Psychology) founded the Memory Disorders Project at Rutgers-Newark which promotes research and education on human memory disorders, including those resulting from stroke, injury, and disease such as Alzheimer's, Parkinson's, and Schizophrenia. For the last three years they have published a free mental health newsletter, Memory Loss and the Brain, which is also available online at http://www.memorylossonline.com.

Leaving Siemens Corporate Research in Princeton, Stephen Hanson moved to Rutgers-Newark in 1996 to chair the Psychology Department. In the last 8 years, he has largely remade the department, hiring 7 new faculty, and overseeing 3-4 million dollars in new funding each year, including the establishment of a new joint Rutgers-UMD brain imaging Center costing over 7M$. Hanson hired 7 additional young learning researchers including Maria Kozhevnikov who studies spatial learning.

RESEARCH PROGRAM (DETAILED)

The key vision behind ICBL is that computational research in learning theory and empirical research are complementary and interactive. In this way, ICBL provides the computational glue that binds together numerous interdisciplinary research programs at Rutgers-Newark and throughout New Jersey. At present Rutgers is a hotbed of learning sciences activity and faculty. However, there has been suprisingly little organizational structure or central coordination of the vast talent in the learning sciences across Units and campuses. There are at least 10 different units and 6 different campuses that would be involved in the research activity in such a center, as follows:

Faculty	Department/Institution	Learning Research
Stephen J. Hanson	Psychology/Rutgers	Neural Computation/Neuroimaging
Mark Gluck	CMBN/Rutgers	Computational Neuroscience/Neural Computation

Vladimir Vapnik	Learning/NEC	Learning Theory
Maria Kozhenikov	Psychology/Rutgers	Learning and Human Computer Interaction
Bart Rypma	Psychology/Rutgers	Cognitive Neuroscience/Neuroimaging
Ben Martin Bly	Psychology/Rutgers	Cognitive Neuroscience/Neuroimaging
Catherine Myers	Psychology/Rutgers	Computational Neuroscience/Neural Computation
Roberta Schorr	Education/Rutgers	Learning & Education
Gyorgy Buzsaki	CMBN/Rutgers	Computational Neuroscience/Neural Computation
Paula Tallal	CMBN/Rutgers	Cognitive Neuroscience/Neuroimaging
Ken Harris	CMBN/Rutgers	Computational Neuroscience/Neural Computation
Farzam Nadim	Biology Rutgers	Computational Neuroscience/Neural Computation
April Benesich	CMBN/Rutgers	Cognitive Neuroscience/Neuroimaging
David Perlin	PHRI	Molecular Neuroscience/Computational Biology
Marilyn Tremaine	NJIT/Info. Sci.	Human Computer Interaction/the Web
Michael Recce	NJIT/Info. Sci.	Neural Computation/HCI
Jorge Golowasch	NJIT/Math & Biology	Math and Comp. Neuroscience
Glenn Shafer	Business Sch./Rutgers	Machine Learning/Probability Theory
Doug Carroll	Business Sch./Rutgers	Multivariate Methods/Statistical Estimation
Phipps Arabie	Business Sch./Rutgers	Multivariate Methods/Statistical Estimation
Jim Haxby	Psychology/Princeton	Neuroimaging/Obj Recognition
Gil Harman	Philosophy/Princeton	Philosophy of Mind/Cognitive Science
Edwin Williams	Linguistics	Language Acquisition/Cognitive Science
Steve R. Baker	Radiology/UMDNJ	Imaging/Dept. Head Radiology
Bharat Biswal	Radiology/AIC/UMDNJ	Neuroimaging/Biophysics
Haym Hirch	CS/Rutgers	Machine Learning/Datamining
Michael Littman	CS/Rutgers	Machine Learning
Paul Kantor	SCILS/Rutgers	Information Retrieval/Machine Learning

Although it is not possible to review all of the research programs by the participants in the space allotted, we summarize here the main programs that would form the core of the supported research programs. Faculty listed above who are not mentioned further either work in collaboration with the research summarized here, or work on related and synergistic research programs. As noted earlier, ICBL's research activities will fall into three main areas, (1) computational neuroscience, (2) computational learning theory , and (3) education and training, and these are described here in more detail:

(1). COMPUTATIONAL NEUROSCIENCE

1.1. Modeling of Multi-unit Electrophysiology in Spatial Learning Tasks

It is widely believed that the brain processes information through the parallel action of neuronal populations. The question of *how* it does this, however, remained for many years in the realm of speculation. Recently it has become possible to record from large enough numbers of neurons simultaneously, and Gyorgy Buzsaki at Rutgers is one of the small handful of leaders in this area. To test theories of how neuron populations compute and learn, Buzsaki and Harris study the mechanisms of information processing in neuronal circuits, using data collected from large neuronal populations in behaving rodents. A guiding principle for this research is the *cell assembly hypothesis*. Originally proposed over half a century ago by Donald Hebb, this hypothesis states that information is processed in the brain by the *synchronous activity of spatially distributed populations* of neurons, whose activity may be triggered either by sensory input or by internal cognitive factors, which may, in turn, produce motor activity.

Future research will experimentally evaluate assembly activity in neocortex and hippocampus to provide quantitative bounds on the spatial and temporal distribution of assembly activity, to study the effect of pharmacological manipulations on assembly activity, and to examine the relationship of assembly activity during behavior to subsequent sleep. The data required have already been collected by collaborators on the current proposal, or will be collected under empirical research programs supported by the NIH.. However, the complex nature of the questions involved, and the *very large database sizes* involved means that the development of new *advanced mathematical methods* for processing this data is necessary.

1.2. Modeling of Functional Brain Imaging Data During Active Learning Tasks

Individuals survive by making context appropriate responses which depend on accurate perception and interpretation of the behavior of objects and of other individuals. How one learns to intepret the agent-object interaction that constitutes activity in the real world is termed event perception, and this is a major focus of the research of Stephen Hanson. How one parses the continual stream of action encountered throughout the day into distinct events depends upon both the stimulus features of the agents and objects being observed and the knowledge accumulated over time about those agents and objects. That is, event perception depends upon both bottom-up processing (perception of stimulus features) and top-down processing (cognitive biases or expectations). Parsing the "buzzing, booming confusion" of the world into meaningful units (events) requires the brain to be in a constant state of activity, translating physical signals received through the senses into neural representations of the world it encounters. This translation requires the cooperative interchange of data among areas of the brain responsible for cognitive functions such as sensory processing, attention, memory, planning, emotion, and language. Consequently, Hanson's experimental research centers on the process of event perception because this provides a unique opportunity to observe the integration of brain function in real time. This work explores neural correlates of bottom-up and top-down processing as observers engage in event perception. The general approach is to record brain activity while a subject watches taped action sequences. This captures the dynamic nature of brain response to the stimuli encountered in a way not possible with intermittent recording of brain states, which was until recently the most common neuroimaging paradigm.

The event perception paradigm Hanson uses approximates ecological validity by placing the subject in a situation more similar to that encountered during every day life. To the extent that the event perception paradigm offers a means of studying the interaction of brain areas while engaged in a “real-world” task, it also poses a serious methodological challenge. How to capture the dynamic pattern of brain activation in real time? Ideally, what is needed is a methodology that provides both high spatial (mm) and temporal resolution (ms). However, whereas fMRI captures a fine spatial resolution (mm), its temporal resolution (sec) is too coarse for cognitive function. On the other hand, EEG captures a fine temporal resolution (ms), but provides poor spatial estimates. Their response to this challenge comprises the second general goal of this proposal. Specifically, they intend to develop high-resolution methods of analysis that integrate both temporal and spatial information into a single signal using both high field strength fMRI (3T) and high density (64 channel) EEG in order to:

1. develop event perception experiments that engage brain activity across putative bottom-up and top-down processing involved in learning
2. develop fusion methods for time rich signals such as EEG and spatially accurate signals such as fMRI while perserving a high signal to noise ratio
3. demonstrate the interactivity of brain regions that are solving the task of segmenting, encoding, organizing and retrieving event related interpretations of everyday events.

To summarize, Hanson proposes using an experimental task (event perception) that engages the brain in a way that closely resembles "real-world" cognition and learning. In this way they will capture the complex interactivity of the dynamic brain in real time and thereby integrate disparate findings in the extant literature on localized brain function and the nature of learning in the brain. They will analyze the resultant brain activation patterns fusing fMRI and EEG data, a novel method of analysis developed at Rutgers specifically for this purpose.

1.3. Neural Network Models of Brain Regions for Learning and Memory

Mark Gluck and Catherine Myers work to understand the neural bases of learning and memory, using computational models as a bridge between brain and behavior. Their approach has been to work -top-down, starting with connectionist network models that instantiate information-processing theories of the computations required to explain behavior, and then showing how these functions could arise "bottom-up" from the anatomy and physiology of specific brain regions. Through iterative and converging theory development, computational models elucidate the principles of learning and memory at multiple levels of analysis, from behavioral processes through neural circuits.

Gluck and Myers have focused on the neural substrates of associative learning, including both classical and operant conditioning as well as higher forms of learning such as categorization. Through the 1990s, their main emphasis was on models of the hippocampal region (also called the medial temporal lobe in humans) the same brain region studied by Buzsaki and Harris, and the site of early damage in Alzheimer’s disease and epilepsy. More recently, they have studied the basal forebrain (which produces key chemicals for learning lost during aging) and the basal ganglia (which is damaged in Parkinson’s disease), both of which interact with the hippocampal-region during associative learning. Their modeling is intimately linked to parallel empirical research in their laboratory (supported by NSF, NIH, and private foundations) where they collect data to test, inform, and constrain model development using lesion, drug, and electrophysiology studies with animals and neuropsychological and brain imaging studies with humans. With support from the ICBL, Gluck and Myers will integrate and elaborate their previous models into a single “grand unified” neural-network model that incorporates significant details of the physiology and anatomical connectivity of key brain regions for learning noted, and use the model to:

- Selectively disrupt individual structures and cell types within a brain region, leading to novel behavioral assessments for neurological disorders and drugs that alleviate these disorders.
- Compare network unit activity against electrophysiological recordings from neurons in behaving animals, using data from the Buzsaki laboratory.
- Capture temporal aspects of learning such as varied inter-stimulus intervals and inter-trial intervals and the role of theta rhythm on learning, as studied by Buzsaki and Harris.
- Model the distribution and function of different neuromodulator receptor types, a key issue for modeling Alzheimer’s and Parkinson’s disease and for leading the way towards <u>in silico</u> approaches to drug discovery.

Integration of Computational Neuroscience Programs

New computer modeling and simulation results from Gluck and Myers will subsequently motivate further animal research to test predictions and gather further data, including that in the labs of Buzsaki and Harris. Ultimately these models and animal studies will inform applications of these models to more complex human learning paradigms, which will be evaluated through functional brain imaging studies that employ the methodological tools and paradigms developed by Hanson's group. Additional collaboration with local pharmaceutical industry, the East Orange VA hospital, and UMDNJ will center on the needs of clinical populations suffering from memory loss due to Alzheimer's disease, amnesia, Parkinson’s disease, or schizophrenia.

<u>(2). COMPUTATIONAL LEARNING THEORY & MACHINE LEARNING:</u>

2.1. Learning Theory

One of the greatest success stories of the last decades was the development of the theory and methods of machine learning. It started more than 40 years ago, as a version of the classical discriminant analysis, then developed its own theory, which was different from the classical statistics. Three important circumstances led to this success:

1) The significant development of the mathematical foundation of the theory of generalization (the, so-called, VC theory) that led to constructing effective universal learning algorithms for generalization in high dimensional spaces--the Support Vector Machines (SVM)--which in many respects contradicted existing intuition and existing philosophy.
2) The appearance of new real-life problems such as machine vision, information retrieval, and analysis of biological data (e.g. DNA, RNA, microarray data), which required generalization in very high dimensional spaces (10,000-1,000,000).
3) The appearance of new challenges in learning science problems whose solutions are based on methods that go beyond induction inference, such as the problem of learning to act, learning to find the best (worst) elements of the set, learning to outperform the teacher, and so on.

Research in learning theory will focus on new methods driven by Vapnik's new learning theories, especially those related to Support Vector Machines and generalization theory. In this work it will be important to distinguish between the nature of the learning process and their implementations in behavior and neural tissue. Vapnik will work closely with Buzsaki, Gluck, and Hanson so that advances in learning theory can inform the search for biological and behavioral principles for learning, while at the same time, biological and behavioral research on learning systems can inform the methods and paradigms adopted by Vapnick and colleagues doing learning theory research.

NEC in the context of the Learning Sciences Center will develop a SVM chip which will speed up learning in these types machines by 100s or 1000s of times. These developments will create new applications for New Jersey industry in drug discovery, telecommunications and disease diagnostics that will be at the leading edge of future commercial progress.

2.2. Pattern Recognition and Classification

In parallel with Vapnick's research program, and designed to exploit the ongoing developments by NEC, various researchers at ICBL will exploit neural networks for application to various pattern recognition and classification problems. These include the development of automated classifiers for diagnosis in diseases, brain states, business or financial data as well as error recognition and anomaly detection in complex devices. One example is a collaboration between Hanson (Rutgers) and James Haxby (Princeton) involving classification of brain activity that is collected from human subjects who are looking at different kinds of object types (Faces, Houses, Cats, Shoes, Chairs etc.). The nature of the feature values of the codes may provide crucial clues as to how human visual learning can be so rapid, accurate and efficient. In other work, Gluck and Hanson used neural-network models based on models of the hippocampus (based on data and theories from Gluck and Buzsaki's labs), that provided novel approaches to detecting mechanical faults in Navy helicopter gear boxes and water pumps on submarines, research supported by the Office of Naval Research. Data mining will also be a focus of attention within the Learning Sciences Center including use of new algorithms that process extremely high dimensional spaces such in lexical and text applications that characterize commerce with the internet. Web search and control will benefit from the new NEC supercomputer and the various Support Vector Machines developed by Vapnik.

(3). EDUCATIONAL AND TRAINING

3.1 Children at Risk for Learning Disorders.

April Benasich and Paula Tallal have identified new methods and technology for the rehabilitation of language dysfunction in children who are at risk for learning disorders. For example, Paula Tallal's research focuses on the neural basis of language development and disorders. She has shown that linguistic deficits of children with oral and written language learning impairments derives from a more basic neural processing constraint in the rate they process sensory information. This rate processing constraint interferes with the ability to analyze the acoustic waveform of speech, leading to the development of weak and imprecise phonological representations that have serious repercussion on both oral and written language development. As described earlier, Tallal's work has led to a commercial company and product that has proven ability to help tens of thousands of children learn better and overcome learning disabilities. Although many researchers have made significant contributions that advance learning science, few other than Tallal have had the opportunity to see their scientific research also have such direct and immediate clinical and educational implications.

April Benasich is the Principle Investigator and director of the infant component of a major cross-national multi-site *Santa Fe Institute Consortium on Increasing Human Potential*, for which she was awarded almost $3M. She is also the Co-Director of the Carter Center for Neurocognitive Research. In addition to her PhD, Benasich has a BSN in Nursing and fifteen years of medical experience including supervisor in Pediatrics and experience with high-risk infants in the Neonatal Intensive Care Unit. At Rutgers, Dr. Benasich's current research interests focus on perceptual-cognitive abilities (habituation, recognition memory, temporal processing) in high risk or neurologically impaired infants as predictors of later cognitive, linguistic, and behavioral outcomes. Her research program examines the impact of individual differences in early processing abilities, low birthweight, prematurity, and familial genetic contributions on developmental trajectories. At present, she is investigating auditory temporal processing in early infancy (shown to be a major predictor of language impairment and dyslexia in older children). In addition, Dr. Benasich is developing a prototype early assessment battery (including both behavioral and electrophysiological measures), based on previous work in her lab, that will allow evaluation of early cognitive and language development in nonverbal, motor impaired children with early (or genetic) brain insult. Dr. Benasich's basic research seeks to uncover the early neural mechanisms necessary for normal cognitive and language development and she is among the first to link deficits in infant temporal processing to later language and cognitive impairments.

3.1 *Different Learning Styles in Math and Science.*

Recent funding (NSF 10M$) received by Prof. Schorr for training in Math and Science Education complements Prof. Kozhevnikov research on the analysis of individual differences in visual/spatial processing and how these differences affect complex activities, such as learning physics and mathematics, spatial navigation, and mechanical reasoning. Specifically, she is interested in dissociation between visual-object imagery (i.e. pictorial imagery that encodes the literal appearance of individual objects) and spatial imagery (i.e. abstract imagery that encodes spatial relations among objects, the location of objects in space and their movements) and how these different types of imagery are used in different domains (e.g., sciences, visual arts, architecture). In addition, she develops novel ways to train visual-spatial abilities and design learning technologies that accommodate individual differences in imagery and different learning styles. Prof. Kozhevnikov research runs in the Virtual Reality research lab in the Psychology Department and she was a recent recipient of a prestigious NSF CAREER award.

ADDITIONAL INFORMATION

FUNDING LEVERAGE OPPORTUNITIES:

In the last 5 years there has been several programs focused primarily on Learning Science. The most recent program was the Learning and Intelligent Systems (LIS) program at NSF. This program was highly interdisciplinary and presently supports research at CMU, MIT, UCSD to name a few sites of center grants. Recent funding in Learning at NSF as also involved the computer science programs associated with the Information Technology Research Program (ITR) in which we have already received millions of dollars for Brain Imaging Dynamics which fundamentally focuses on learning methods from multivariate brain imaging data. NSF more recently is providing more than 200M$ for Learning sciences Centers. This group is also applying in the first cycle for NSF Center funding, as noted earlier. NIH also has large programs in computation and learning, especially as it relates to the Human Brain Project and Information Sciences. Other groups include DARPA and ONR which have been long term funders of Nerual Network research on this campus. Finally, several foundations, McDonnell, Keck, Pew and J&J all have interests in supporting projects, workshops and long term research in the learning sciences. Given the wide diversity of faculty interests and the high faculty prestige already on the various Campuses, the prospects of receiving an initial training grant should be excellent.

ASSOCIATED RESEARCH GROUPS

There are other proposals that are being made to the Governor's commission on jobs and economic growth that involve learning and would be complementary to elements in this proposal. A proposal by Prof. D. Metaxas on Computational Biomedicine, Imaging and Modeling, is cross-linked to our Learning sciences Institute and as Prof. Metaxas letter of support indicates attached to this proposal, there are many synergistic connections to the existing Advanced Imaging Center and collaborative approaches to imaging and pattern recognition.

LEADERSHIP

The Rutgers component of the ICBL will be directed by three Co-PIs, Dr. **Stephen José Hanson**, chair of Rutgers-Newark Psychology and Professor of Psychology and Information Science (NJIT), co-director of the joint University-Medical (UMDNJ) School Brain Imaging Center, the former director of the Learning Systems Department at SIEMENS Research Center and an editor of the MIT four volume series on Learning: "Computational Learning and Natural Learning Systems", Dr. **Mark A. Gluck**, Associate Professor of Neuroscience at Rutgers-Newark, a former NSF White House PECASE winner (1996), publisher of the "Memory Loss and the Brain" newsletter, co-author of "Gateway to Memory: An Introduction to Neural Network Models of the Hippocampus and Learning," and co-author of a forthcoming new integrative undergraduate textbook on learning and memory. Both PIs have extensive management and organizational experience, as well as many years of working closely and collaboratively with industry and the military; they will build on their past contacts and experience to promote significant private and public sector alliances, locally and nationally, for the ICBL, and Dr. **Vladimir Vapnik** who is both Professor of Computer Science and Statistics at Royal Holloway, University London and Senior Research Scientist at NEC labs in Princeton. Dr. Vapnik is a Humboldt Research Award winner and one of the seminal theorists in Computational and Statistical Learning Theory. Dr. Vapnik has taught and done research in computer science, theoretical and applied statistics for over 30 years. He has published 7 books and over a hundred research papers. His major achievements have been the development of a general theory for minimizing the expected risk of losses using empirical data, and a new type of learning machine called Support Vector Machines that possesses a high level of generalization ability. These techniques have been used to solve many pattern recognition and regression estimation problems and have been applied to the problems of dependency estimation, forecasting, and constructing intelligent machines.

BUDGET AND FINANCIAL LEVERAGE

Budget Scope and Justification

Initial scope of the center would involve recruiting at least one senior faculty and initially up to three junior faculty. These numbers are suggested in order to create a critical mass to bind to the existing units and faculty with interest. Joint appointments between the Center and various units would also facilitate the growth and seeding of the Learning Center. Initially the Center would require office space for adminstration, core faculty, visiting faculty, postdocs and graduate students and space for computational and data acquisition resources (neuroimaging etc.). The initial focus of the center would be in acquiring grant funded expansion and growth through training grants and research funding.

Personnel (5 years)

New faculty: Recruiting 1 new senior faculty and 2 junior faculty	500k$
Postdoctoral Students: 10 @ 2 year Cycles @ 2 Cycles	1.2M$
Graduate Student Research Fellowships (10)	800k$
Administrative Assistant	200k$
Center Manager	400k$
Secretary	150K$

Equipment

4T MAGNET- and Infrastruture	5M$
9T MAGNET for Animal Data Acquisition and Infrastructure	2M$
HIGH PERFORMANCE CLUSTER COMPUTER (500 nodes)	2M$
NEUROSCIENCE DATA ACQUISITION	1M$

Space

Data Acquistion Space (2 Floors)	5 Ksqft	
Office Space	8Ksqft	
Common Space	5Ksqft	
Computation Center	5ksqft	
Data Archive Center	5Ksqft	
Lecture Hall	2Ksqft	
Total SPACE Requirements	25Ksqft (assuming a building or large fraction of a building)	
Estimated Cost		~30M$

Training Program

Initial funding for Graduate exchange from other learning centers: 250K (per year) 1M$ (5 years)

Total: 42.8M$

BIBLIOGRAPHY

Hanson, S. J., Gause, B. & Natelson, B. (2001) The Detection of immunologically significant facotrs for chronic fatigue syndrome using neural network classifiers , Clinical and Diagnoistic Laboratory Immunology. 8, 658-662.

Hanson, S. J., Negishi, M. & Hanson C. (2001), Connectionist Neuroimaging., Emergence in Neural Computation, S. Wertmer (Eds). Kluwer.

Haibo Zhang, Y. Ramanathan, Patricia Soteropoulos, Michael L. Recce and Peter P. Tolias EZ-Retrieve: a web-server for batch retrieval of coordinate-specified human DNA sequences and underscoring putative transcription factor-binding sites Nucleic Acids Research, 2002, Vol. 30, No. 21 e121

Haussler, D. (Consoritum Publication Multi-author) Initial Sequencing and Analysis of the Human Genome," International Human Genome Sequencing Consortium. Nature, 409: 860-921, (2001).

Boian, R., Sharma, A., Merians, A., Burdea, G., Adamovich, S., Recce, M., Tremaine, M. and Poizner, H. Virtual Reality-Based Post Stroke Rehabilitation. Proceedings of Medicine Meets Virtual Reality 2002, January 2002, pp. 64-70.

Kozhevnikov, M., Hegarty, M. & Mayer, R. E. (In Press). Revising the Visualizer /Verbalizer Dimension: Evidence for Two Types of Visualizers. Cognition
and Instruction.

Kozhevnikov, M., Hegarty, M. & Mayer, R. (2002). Visual/spatial abilities in problem solving in physics. In M. Anderson, B. Meyer & P. Olivier (Eds). Diagrammatic representation and reasoning, Springer-Verlag, pp. 155-173.

Kaur, M., Tremaine, M., Wilder, J. and Hung, G. Integration of Gaze and Speech for Multimodal Human-Computer Interaction. Proceedings of the Third International Conference on Information, Communications and Signal Processing, ICICS 2001, Singapore, October 2001, 8 pages.

Myers, C., Kluger, A., Golomb, J., Ferris, S., de Leon, M., Schnirman, G., & Gluck, M. (2002). Hippocampal atrophy disrupts transfer generalization in non-demented elderly. Journal of Geriatric Psychology and Neurology, 15. 82-90.

Tallal, P. (2000) Experimental Studies of Language Learning Impairments: From Research to Remediation, In: Speech and Language Impairments in Children: Causes, Characteristics, Intervention and Outcome, D.V.M. Bishop & L.B. Leonard (Eds.), Hove, UK: Psychology Press, p. 131-155.

Shafer G. and Volk, V. Probability and Finance: It's Only a Game! New York: Wiley, 2001

Vladimir Vapnik, Bounds on Error Expectation for Support Vector Machines. Neural Computation 12:(9): 2013-2036 (2000)

Von Neumann, J. 1958. The Computer and the Brain, Yale Univ. Press, New Haven.

ATTACHMENTS: Number 1: LETTER of SUPPORT AND CROSSLINKING FROM PROF METAXAS

08/15/2003 17:10 7324452914 DIMITRIS METAXAS PAGE 02

THE STATE UNIVERSITY OF NEW JERSEY

RUTGERS

Division of Computer and Information Sciences
Hill Center - Busch Campus • 110 Frelinghuysen Road
Piscataway • New Jersey 08855
732-445-2647 • FAX (732) 445-0537

August 15, 2003

Dear Drs. Hanson and Baker,

I am very enthusiastic about your proposal for an Institute for Computational and Biological Learning (ICBL) and would very much like to establish a strong collaboration between ICBL and my Center for Computational Biomedicine, Imaging and Modeling. Many of the open research problems in your field have a strong image analysis component and we can provide expertise. In addition, our proposed new Center for Cancer Imaging, Structure and Function will deal among others with loss of function as a result of tumor removal and your proposed Institute and already acquired expertise will allow us to pursue synergistically the best possible research results in this area.

Therefore I am very excited I look forward to establishing strong research ties with your group which will only become stronger and result in even more cutting edge research if additional resources from our two proposals to the NJ Commission come to fruition.

As we have agreed we will start our collaboration in early September by working on image analysis problems of common interest and by exchanging visits.

This is indeed a very exciting time in NJ and the creation of complimentary Centers of Research excellence will only result in novel discovery, increased competitiveness and new jobs for New Jersey and is in accordance to the Governor's and Dr Vagelos's plans.

I look forward to our future research collaboration.

Sincerely yours,

Dimitris Metaxas
Director CBIM Center
Prof. of Biomedical Eng. and Computer Science
Rutgers, The State Univ. of New Jersey

ATTACHMENTS Number 2: of Universities/Institutes Contacts

Proposal Name
INSTITUTE for COMPUTATIONAL AND BIOLOGICAL LEARNING.

Participant University / Lab / Company
RUTGERS UNIVERSITY

Primary Contact Name
STEPHEN J. HANSON

Mailing Address
PSYCHOLOGY DEPARTMENT
101 Warren Street
Newark, NJ 07102

Email:

JOSE@PSYCHOLOGY.RUTGERS.EDU

Phone

973-353-5440 x 221

Fax

973-353-1171

Attach CV for the primary contact

ATTACHMENTS Number 2: of Universities/Institutes Contacts

Proposal Name
INSTITUTE for COMPUTATIONAL AND BIOLOGICAL LEARNING.

Participant University / Lab / Company
PRINCETON UNIVERSITY
Primary Contact Name
GILBERT HARMAN

Mailing Address
PHILOSOPHY DEPARTMENT

Email
harman@thought.princeton.edu

Phone

Fax

Attach CV for the primary contact

ATTACHMENTS Number 2: of Universities/Institutes Contacts

Proposal Name
INSTITUTE for COMPUTATIONAL AND BIOLOGICAL LEARNING.

Participant University / Lab / Company
NEC

Primary Contact Name
VLADIMIR VAPNIK

Mailing Address
NEC

Email:
VLAD@NEC-LABS.COM

Phone

Fax

Attach CV for the primary contact