02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

PI/PD Name: David H Laidlaw

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

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Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

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PI/PD Name: David Badre

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White

Disability Status:
(Select one or more)
☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☐ None

Citizenship: (Choose one) ☐ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☐

Ethnicity Definition:
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Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

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PI/PD Name: Steven A Sloman

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

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Black or African American. A person having origins in any of the black racial groups of Africa.
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PI/PD Name: Mark J Schnitzer

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

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Black or African American. A person having origins in any of the black racial groups of Africa.
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White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 10-1

NSF 10-551 **06/14/10**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

1047832

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)

OCI - Software Institutes

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/14/2010	5	01110000 OCI	8004	001785542	06/14/2010 3:28pm

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)

050258809

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

Brown University

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Brown University
164 Angell Street
Providence, RI. 029129002

AWARDEE ORGANIZATION CODE (IF KNOWN)

0034017000

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

PERFORMING ORGANIZATION CODE (IF KNOWN)

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS
☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 3,367,185	60 months	01/01/11	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
☐ BEGINNING INVESTIGATOR (GPG I.G.2)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________
PHS Animal Welfare Assurance Number ________
☒ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number **FWA#00004460**
Exemption Subsection ________ or IRB App. Date **Pending**
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT
Computer Science Department

PI/PD POSTAL ADDRESS
Box 1910

Providence, RI 02912
United States

PI/PD FAX NUMBER
401-863-7657

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME David H Laidlaw	PhD	1995	401-354-2819	dhl@cs.brown.edu
CO-PI/PD David Badre	DSc	2005	401-863-2777	David_Badre@brown.edu
CO-PI/PD Steven A Sloman	PhD	1990	401-863-7595	Steven_Sloman@brown.edu
CO-PI/PD				
CO-PI/PD				

Electronic Signature

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 10-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Michael A Kostyshak	Electronic Signature	Jun 14 2010 2:37PM

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
401-863-9328	Michael_Kostyshak@Brown.edu	401-863-7292

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 10-1		FOR NSF USE ONLY
NSF 10-551	06/14/10	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)		
OCI - Software Institutes		1047840

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
06/14/2010	5	01110000 OCI	8004	009214214	06/14/2010 3:29pm

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)
941156365

SHOW PREVIOUS AWARD NO. IF THIS IS
☐ A RENEWAL
☐ AN ACCOMPLISHMENT-BASED RENEWAL

IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE
Stanford University

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
340 Panama Street
STANFORD, CA 94305-6203

AWARDEE ORGANIZATION CODE (IF KNOWN)
0013052000

NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE

ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE

PERFORMING ORGANIZATION CODE (IF KNOWN)

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS ☐ IF THIS IS A PRELIMINARY PROPOSAL
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS THEN CHECK HERE

TITLE OF PROPOSED PROJECT **SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 310,398	60 months	01/01/11	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

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☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
☒ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date 04/08/10
PHS Animal Welfare Assurance Number A3213-01

☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ______
Exemption Subsection ______ or IRB App. Date ______
☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
______
☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT
Biological Sciences / Applied Physics

PI/PD POSTAL ADDRESS
Clark Center Laboratories
Mail Code 5435
Stanford, CA 94305
United States

PI/PD FAX NUMBER
650-723-6132

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Mark J Schnitzer	PhD	1999	650-725-7438	mschnitz@stanford.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

Electronic Signature

1047840

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, lobbying activities (see below), responsible conduct of research, nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 10-1). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

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In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

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(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

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Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

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The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

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Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

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(2) building (and any related equipment) is covered by adequate flood insurance.

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(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF Grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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The undersigned shall require that the language of this certification be included in any award documents for all subawards at all tiers.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
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* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits

David H. Laidlaw (PI), Caroline Ziemkiewicz, Brown University Computer Science;
Steven Sloman (Co-PI), David Badre (Co-PI),
Brown University Cognitive, Linguistic, and Psychological Sciences;
Mark Schnitzer (Co-PI), Stanford Biological Sciences and Applied Physics and
Investigator of the Howard Hughes Medical Institute;
Jeff Chi-Tat Law, Stanford Biological Sciences;
Fritz Drury, Rhode Island School of Design

We propose to develop, test, and deploy software tools for scientific study of brain circuits. The driving scientific application for our research is the study of human brain function and architecture. Major advances in our understanding of how brains work have occurred in recent decades, yet much remains unknown. Network models of the brain are natural because they often reflect both the behavior and the anatomy of the brain. They also provide a valuable abstraction for the huge quantities of imaging data that arise from experimentation. The target user community is brain scientists studying architecture and function of the human brain. Two of the four labs involved in this project are a part of this community.

Our aim is to blend good design and software engineering with research to extend and augment the process using principles derived from perceptual and cognitive psychology. The tools we propose will help brain researchers pose and test hypotheses about networks using input from multiple sources. These sources will include databases of published results about networks, data from their own experiments, and the scientists' hypotheses and working assumptions. Experimental data will include 3D imaging data from functional and diffusion MRI as well as light microscopy.

The software we propose will support the reasoning process by gathering and managing data about networks and connections; gathering and managing imaging and experimental data; providing interactive mechanisms for visually selecting and analyzing portions of the data; and explicitly capturing, recording, and documenting users' scientific reasoning.

Intellectual Merit The intellectual merit of this project is threefold. First, the proposed infrastructure will enable brain scientists to advance their research agendas more efficiently and more quickly by incorporating information from a broader set of sources into their scientific reasoning. Second, computer scientists will advance their understanding of how humans interact with computer systems at the cognitive level and how that can improve those interactions. Third, we anticipate advances in the understanding of human cognition from our cognitive modeling and experimentation.

Broader Impact. This highly interdisciplinary project will demonstrate to undergraduates, graduate students, and postdoctoral scholars how such research can be done. Because the tools will be made widely available, they will potentially benefit of the entire brain science research community. Many other disciplines study linked types of data – gene regulation, protein signaling and even crime and terrorism analysis – and all have the potential to benefit. Any human computer interface that involves reasoning has the potential to be improved by results from this research. Finally, the process of designing and developing effective interfaces for humans to use computers may well be broadly improved.

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*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

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Appendix Items:

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SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits

David H. Laidlaw (PI), Caroline Ziemkiewicz, Brown University Computer Science;
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Fritz Drury, Rhode Island School of Design

a Multidisciplinary Research Agenda

Understanding the human brain is a daunting enterprise. The thousands of brain researchers each face a difficult problem: they have to interpret their voluminous data in the context of everyone else's voluminous data. More details illustrating this pressing need, including specific examples from our labs, are in Sec. b.

We propose to develop software tools to make this enterprise less daunting and more productive. Our experience in the visualization research laboratory within the computer science department at Brown has involved successfully developing software tools in support of numerous scientific users [JDL09a; JYN+09; KOB+08; CJPS+06; Zha06; MCL09]. We have also considered deeply the design and evaluation process of such tools[AJLD08; KAM+08; AJLD05; KL07]. We are well poised to attack this problem.

A significant part of the proposed research will involve incorporating principles of perception and cognition into the design and evaluation of the proposed software. Most software is developed to address relatively low level workflows, but we believe that significant improvements in productivity can be gained by optimizing tools using such principles. Scientists within Brown's Department of cognitive, linguistic, and psychological sciences have a deep understanding of these areas of knowledge and will be instrumental in our software development project. They have knowledge about how scientists think that are developed and specific enough to provide guidance about what functionality to include in the tools and how to design them. This knowledge concerns how scientists test hypotheses, how they represent data, and what kind of neural processing systems they have.

Our development approach will follow a typical spiral software engineering design process, with fast iteration on requirements and prototypes in the beginning and gradually slower iterations solidifying the software as we incorporate feedback and evaluation at multiple levels. Feedback and evaluation will occur at multiple levels including local feedback on sketched designs, focus groups, analysis of video and tracking data, and formal experiments. This evaluation will help us refine not only the tools but also some of the underlying cognitive principles.

The tools will be distributed both in binary and source form. We will endeavor to build a community of users and developers who will help to motivate and realize sustainability.

This effort is clearly an ambitious one. But we have gathered a small group with a large breadth of experience to attack this important problem. While we acknowledge that there is significant risk in what we propose, we believe that the potential rewards balance that risk. Even if we are not completely successful, we believe that the tools will still accelerate brain science as well as adding to human knowledge about how the brain works.

b Need for Visual Analysis of Brain Networks

The human brain is one of the most complex organ in our body. It contains billions of neurons that form interconnected networks at different scales, from small networks with tens of neurons to large networks with long-range connections that span across multiple brain areas. These neural networks are thought to subserve many important functions, from perception, cognition to learning and memory. However, our understanding of the neural basis underlying these brain functions are limited for the following reasons. First, a brain area typically receives both external inputs from other brain areas and internal inputs from within the same area. The inputs fibers from these two sources are both dense and intermingle. Therefore, it is very difficult to study connectivity and dynamics of neural circuits in intact brain. Second, because the brain wiring is extremely complex, researchers often finds it difficult to interpret the data without the help of software tools.

Recent advances in molecular and imaging techniques have opened new possibilities in studying neural connectivity in intact brain. These studies use magnetic resonance imaging or fluorescence microscopy to trace neural connections and provide increasingly detailed information about neuronal wiring from within and between brain areas. Such information is extremely valuable because it allows researchers to study how information from external areas is transformed by intrinsic circuits in a brain area to generate new outputs. However, the amount of data generated from these studies only exacerbates the problems in data analysis. Furthermore, most neuroanatomy software systems display only either external (between brain areas) or internal (within a brain area) connection data. In order to fully understand the function of cortical circuits, we need an interactive visualization tool that displays both internal and external connectivity and allows the user to reduce the complexity by filtering out irrelevant information.

Understanding neural circuits and their function has potentially far-reaching implications in science, medicine, and engineering. The proposed visual analysis tools would have an immediate impact on neuroscience research in interpreting circuits connections that might underlie different aspects of brain function. They also provide a convenient framework for comparing neural connectivity in normal and diseased brains, thus could be used to diagnose neurological diseases and evaluate treatments. In addition, understanding the computational principles that underlie higher brain functions, such as attention, decision formation, learning, and memory, would aid design of artificial intelligence systems. The annual neuroscience meeting draws tens of thousands of researchers studying the brain. A substantial portion of them study networks within the brain directly or would benefit from better understanding collectivity in the context of their research problems.

We illustrate the needs with examples from two of the four labs involved with this research. These examples represent some of the different scales of study that are relevant, and they illustrate some of the different types of analyses and features that are likely to be important.

b.1 Schnitzer Lab Brain Circuit Analysis A research direction in the Schnitzer laboratory at Stanford is the study of neural circuits that underlie sensorimotor learning. A brain area that we are interested in is the prefrontal cortex, which is a polymodal area that receives sensory and reward signals from multiple sources and sends outputs to many cortical and subcortical motor structures to guide behavior. It is suggested that sensorimotor learning occurred as a result of changes in sensory-motor mapping that occurs within the local circuits in the prefrontal cortex.

To form hypothesis about the precise location at which learning occurs, it is important to consider simultaneously the external and internal connections. The visual analysis tools proposed would be particularly useful for this reasoning process because, as opposed to traditional brain visualization tools, it will allow simultaneous visualization of connectivity at multiple levels. The user can, as a result, visualize interactions between external and internal circuits in a common visual framework. The reasoning process can further be aided by selective filtering of irrelevant information (e.g. inputs from auditory cortex in a visual task), and post-hoc reevaluation of the visual reasoning process. This workflow was captured in [BS09] and is shown in Figure 1.

b.2 Badre Lab Brain Circuit Analysis David Badre's lab studies cognitive control, which refers to our ability to plan and guide our behavior based on internally maintained goals. Human cognitive control function is classically associated with the prefrontal cortex (PFC), as damage to this region impairs goal-directed behavior. However, cognitive control function is modulatory rather than transmissive in that the route from sensation to action does not pass obligatorily through PFC. Rather, the distributed representation of goal information in PFC neurons modulates the mappings between inputs and outputs represented elsewhere in the brain. As a consequence, understanding cognitive control function requires studying how PFC operates dynamically within systems-level networks. At least two projects in the lab offer examples of this brain network-level approach to understanding cognitive control function.

(1) Memory requires cognitive control. Consider, for example, trying to remember a specific person's name or an event from your past. In these cases, it is necessary to modulate ongoing retrieval process, supported by regions of medial temporal lobes, in order to increase the probability of retrieving only the name or event you want and not other information. PFC is necessary for such directed retrieval, and it is widely held that PFC supports control of memory via modulation of the MTL. However, the specific

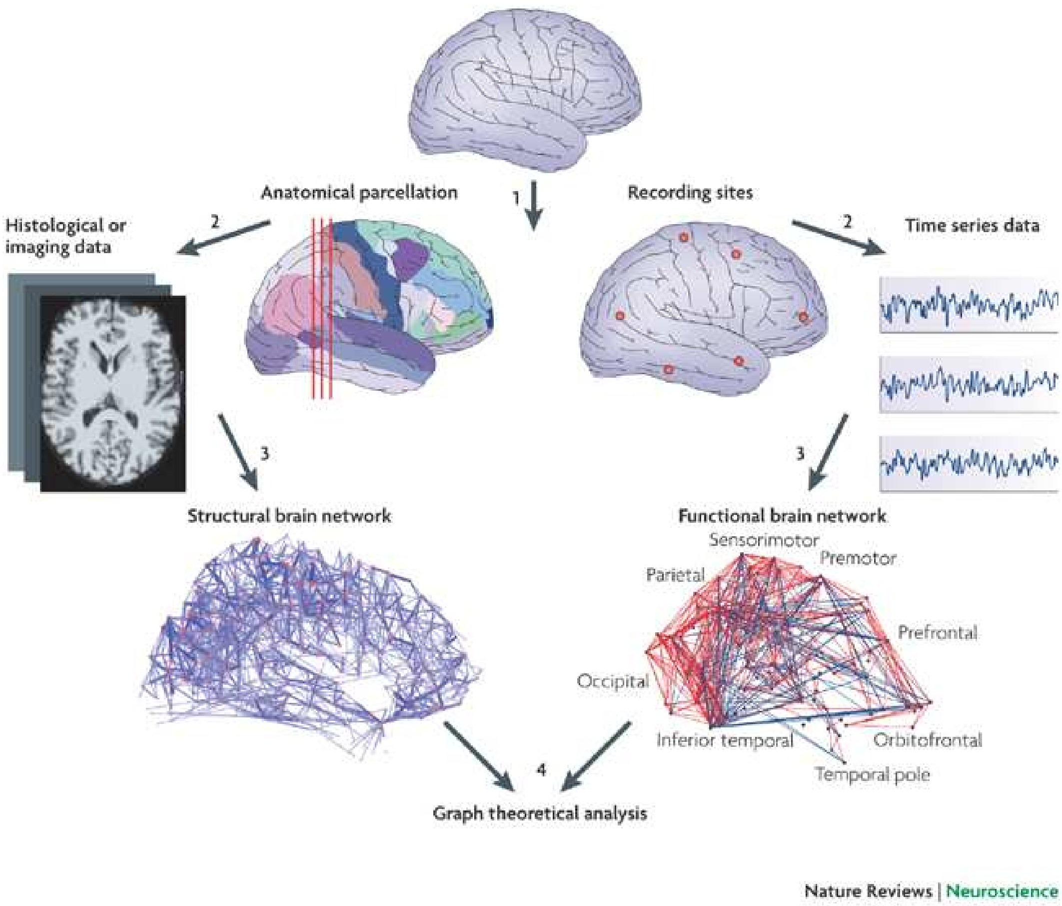

Figure 1: An example of the multi-level workflow of brain network analysis (from [BS09]).

pathways and dynamics by which this modulation occurs remain unknown. Tracer studies in the non-human primate have motivated two candidate polysynaptic pathways from PFC to MTL, one dorsal and one ventral. We are currently using a combined fMRI, effective connectivity, and DTI tractography approach to (a) locate anatomical evidence of dorsal and ventral PFC-MTL pathways in the human brain, (b) assess their differential functional connectivity and dynamics during a strategic retrieval task, and (c) study how certain neurotransmitter systems, like dopamine, may be critical signalers for this circuit.

(2) Ongoing behavior can be expressed at multiple levels of abstraction, from a general goal to a concrete sequence of motor responses. Cognitive control can be required at any of these levels, and growing evidence suggests that rostro-to-caudal frontal cortex may support cognitive control at progressively concrete levels en route to a motor response. Recent data and modeling work in our lab suggests that this hierarchical control architecture may arise from dynamic interactions among a series of nested loops between the basal ganglia and lateral frontal cortex. However, anatomical evidence from non-human primates indicates that frontal-basal ganglia connectivity may differ rostro-caudally, being notably absent at the more rostral extent of PFC. We are currently using a combination of fMRI localization methods, functional connectivity, and DTI tractography in order to more fully characterize the dynamic interactions between basal ganglia and PFC during hierarchical cognitive control tasks.

The proposed tool will be valuable in both of these cases because it will help us mentally merge our circuit diagrams with the intrinsically 3D region and connectivity data that fMRI and diffusion MRI tractography provide. This is a particularly challenging cognitive task, and support for removing as many distractions and other obstacles from the analysis process will help us move forward more quickly and efficiently.

b.3 Some Requirements for Tools These examples, combined with our understanding of visualization tools, of scientific support tools, and of cognition, suggest some specific requirements for the tools we are proposing. First, they need to be able to support reasoning about brain regions and their connections. This support needs to include access to brain region and connectivity knowledge that has already been published. These published data are typically available via several curated databases. Examples of brain connectivity databases are the Brain Architecture Management System (BAMS) [BS07; BDS05], Collations of Connectivity Data on the Macaque Brain (CoCoMac) [K"ot04; SKB+01] and the Functional Anatomy of the Cerebro-Cerebellar System (FACCS) [BLL+05]. Second, this reasoning requires diagramming the regions and connectivity. Third, the diagrams need to handle multiple levels of scale and abstraction. Fourth, users need to be able to interact with imaging data and time course experimental data to support the reasoning. Our examples of imaging data include functional MRI, diffusion MRI, and optical microscopy. Reasoning with these data will involve being able to interact with them in 3-D and understand networks and brain regions both in their anatomical 3-D space and in abstract representations. Similar, but simpler, support will be needed for time course data. Fifth, they need to be able to track and refine their scientific analyses over weeks to years.

c Related Systems and Their Limitations

Relevant existing research and systems span several research areas, research systems, and software products. In the following subsections we break these up into systems for assisted analysis, systems for circuitry exploration, and cognitive-modeling approaches to human-computer interaction,

c.1 Systems for Assisted Analysis Traditionally, visualization enables humans to understand data by representing it visually. More recently, interest in other fundamental visualization issues has emerged. Among others, *Illuminating the Path* [TCoE+05] was written in the context of growing intelligence needs after 2001 and defines the new field of visual analytics as the science of analytical reasoning facilitated by interactive visual interfaces. In addition to defining the term, the booklet establishes the value of such research in the context not only of homeland security but also of any field that involves analysis of complicated and large data.

Recent work in visual analytics can be broadly separated into two categories: theoretical research based on existing cognitive studies and applied work. In the theoretical domain, [Bod] and [PC05] present a five-stage sensemaking model derived through Cognitive Task Analysis (CTA) and verbal protocol experiments with analysts to identify leverage points for visualization. Authors in [RC08] and [ITC08] analyze how users synthesize multiple collections of evidence in a collaborative setting, using a physical, visual medium. Their results, a break-down of analysis tasks with observed frequency/duration and valuable insight into the workflows of collaborative sense making, are useful for deciding which analysis tasks to support. Most of these efforts are not specifically targeted at visualization aided scientific reasoning or, more specifically, visual network analysis but are rather concerned with general tasks pertaining to intelligence analysis. We hypothesize that there are particularities to supporting analysis using visualization systems that are tightly connected to how visualization systems are actually used – a topic current under explored. As such, this proposal plans to complement existent research with low-level task information specific to the proposed domain. A second limitation of current theoretical work is that it was generally restricted to laboratory settings and artificial tasks. The collaborative nature of this proposal will enable us to gather and interpret data from real-life scientific analysis which can both link theoretical research to real applications, and capture and quantify analysis dimensions that are hard to track in artificial settings (e.g., psychological factors such as drive or boredom or long-term temporal effects on analysis).

At the opposite end of the spectrum from theoretical to applied, new applications probe the feature and design space of analysis-support software. Several applications for thought mapping and evidence management use the paradigm of laying out reasoning artifacts on a canvas, either freely or as a tree/graph structure. Such systems include: The Concept Map [CCH+05], MindManager [Min], The Analyst's Notebook [Not07], Visual Links [Vis], The Scalable Reasoning System (SRS) [PMB+07] and The nSpace Sandbox Component [WSP+06]. While useful, the canvas approach is limited: visual vocabulary and interactions are sparse, an automatic layout reduces flexibility while manual layout is cumbersome, usability decreases as the volume of data increases, and, more importantly, problem solving or analysis techniques are minimally supported. Several systems depart from the canvas paradigm. Entity Workspace [BIC06] operates only on textual evidence and uses grouping and linking as an organizing paradigm in a highly structured medium. In HARVEST [GZA06] users can not only visualize existing information, but also construct new analytical knowledge from existing information and apply visualization to it. In [YRW07] and [YXRW] the authors apply similar principles to multi-dimensional visualizations and relate to this proposal by using specific visualization characteristics to drive the organization of evidence. Finally, [EKHW08] departs from conventional methods by structuring analysis as short stories hyperlinked to evidence, a paradigm based on a narrative theory [Fis99] suggesting that people are storytellers and excel at evaluating a story for consistency, detail and structure.

Many of the systems mentioned before are developed and evaluated in the context of intelligence analysis, and as such deal with textual information, large volumes of documents, and temporal or geographic data. Also, few of the systems explore the full range of cognitive principles, ground their design in theoretical and empirical evidence, or aim for thorough evaluation. Most systems don't go beyond the concepts of hypothesis and confirming or disconfirming evidence to structure analysis; they don't aim to convincingly demonstrate that the employed techniques facilitate better analysis either in terms of results or an improved analysis behavior in accordance to normative guidelines. The proposed work has the opportunity to bridge the gap between theory and practice by joining cognitive scientists, visualization experts, and domain specialists ensuring that relevant principles from cognitive psychology are used to design visualization mediums that can be evaluated in concrete scientific settings, with measurable results.

Finally, several approaches have investigated the possibility of recording users' interactions and workflows to facilitate undo operations, next-step recommendations or work-flow reproducibility. VisTrails [CFS+06] records how data sources, filters, visualization methods and visual operations are linked together to produce a useful end-visualization. In [JKMG07] the authors introduce a model of visualization exploration process and a framework to encapsulate, share, and analyze visual explorations. Herr, et al., [HMSA08] describe a taxonomy of architectural and interface issues, identifying design decisions and associated trade-offs. None of these approaches aim to link a visualization workflow to a decisional workflow, which is what we propose in this process.

c.2 Cognitive Modeling in Human Computer Interaction A goal of this project is to improve user performance on brain circuit analysis and other analysis tasks by identifying design principles for computer interfaces that are well aligned with user workflow, including cognitive reasoning and decision-making. If we can predict how users will engage with our software, we can effectively refine its design. A major consideration when undertaking this predictive modeling task is that human actions must be analyzed across many orders of magnitude of time.

In [And02], Anderson argues that we can build successively longer "bridges" across these time scales in understanding, for example, how low-level actions of a student (e.g. eye-tracking across a sheet of paper or computer display) cascade into long-term educational influences. We will support this kind of cascading for analysts using our tool, and will draw on previous research in cognitive modeling architectures in addressing interaction analysis at these multiple time scales. Much of this past research has attempted to create models that predict the performance time of an average user completing a unit task using a proposed user interface. In Project Ernestine [GJA93], for example, researchers showed that a CPM-GOMS cognitive analysis using explicit hierarchical knowledge of user goals and actions can predict user performance on tasks with high accuracy. These predictions were used in evaluating the design of workstation upgrades for telephone operators. Surprisingly, this remains one of the canonical examples of such predictive models. At a lower level, Gluck developed a model (in ACT-R/PM) that predicted student performance on algebra problems based on the distribution of eye movements observed during eye-tracking [Glu99]. These findings support the notion that learning and complex reasoning may be decomposed into small scale, primitive actions, and that we should account for these in our own analysis of user interactions.

In this project, we aim to support hypothesis testing and generation for brain circuit research using cognitive modeling principles. By collecting user data in the form of captured video during usage, logged interaction histories, and eye-tracking, we aim to gain insight about – and build tools to support – the high-level effectiveness of our software. We expect that the processes underlying scientific reasoning and hypothesis formation are significantly more difficult to model than basic interface interactions, like mousing and button presses, to which Fitts's Law and other principles have been applied in predicting user performance. At the same time, if we are successful in modeling user reasoning and problem solving for scientific tasks, the results will be widely beneficial across the fields of scientific computing and visualization, visual analytics, and human computer interaction. This would be a core contribution by creating technology that supports scientific insight and knowledge discovery in a generalized way.

c.3 Circuitry and Network Exploration In computer science, networks of many sorts are abstracted to the concept of graphs. Many techniques [Ead84; DH96; FR91; FLM95; Tun94; LK05; BGHM07] and systems [BST03; Aub03; SMO+03] for displaying general graphs have been developed over the years. The value of this work has been demonstrated by its recent application to a wide range of domains. For example, researchers are able to understand dynamics of communities by visually exploring social networks [Fre00] and biologists can understand protein-interaction and gene regulation networks [SMO+03; HMW+05; ing; DBD+02; JYN+09].

However, research has shown that often general network visualization techniques need to be adjusted to match the particularities of the application domain. For instance, using generic graph-drawing techniques in the context of protein interaction networks yields visualizations that are not intuitive to proteomic researchers: their failure to incorporate protein cellular location and signaling pathway drawing conventions detracts from the visualizations familiarity [Bar; JM03; JYN+09]. In social network visualization exploiting the particular structure of social networks can lead to significantly better visualization [BM02; Fre00] and placing actors randomly on the display can cause misguided interpretations of an actor's role [BMK96].

Moreover, network visualizations have to be integrated into research contexts particular to each domain. For instance, the usefulness of a protein-interaction network is greatly enhanced if the user is allowed to map onto it experimental data [Bar; JYN+09], if the information is hyperlinked to external sources of meta-data, and if certain visual queries, such as highlighting connections pertaining to one protein, are supported.

Network visualization in the domain of brain connectivity is still in its infancy. A few of the online databases hosting connectivity information have developed their own visualization modules [K"ot04]. Others have developed personalized visualizations for specialized brain regions or organisms [wor]. Finally, in [BS09] the authors discuss the opportunity of approaching brain connections from a graph theoretic perspective. These approaches have several drawbacks: they fail to adequately merge findings from network visualization with neuroscientists' intuition; they are limited in scope to singular organisms, brain regions or connection databases; they don't allow users to integrate their own experimental data into the analysis; and they don't offer analysis features such as load/save capabilities, or hypothesis-formation support.

d A Decade of Developing Visual Analysis Tools for Science

Over the last decade, we have developed scientific visualization tools that have taught us a number of lessons about science and about developing tools to support it. Our experience provides us a solid foundation for attacking the proposed problem. In this section we describe a few examples of software we have created and lessons we have learned that we believe will be instrumental to our proposed work.

Brooks describes the principles of such work much better than we can in his paper "The Computer Scientist as Toolsmith II"[Bro96]. A central message is that, "hitching our research to someone else's driving problems, and solving those problems on the owners' terms, leads us to richer computer science research." While there are costs to this sort of approach, there are also benefits; our work has followed this philosophy with good results.

Our experiences with network visualization will help in developing the multi-scale circuit diagramming components of the proposed work. We have studied the workflow associated with protein-interaction networks analysis in the context of high-throughput protein activation experimental data. Proteomic researchers conduct experiments revealing the degree of activation of proteins and wish to relate this data to the body of documented protein interactions from the literature [JYN+09]. Linked views of the signaling network and experimental data, and quick access to the literature and to database information about the proteins and

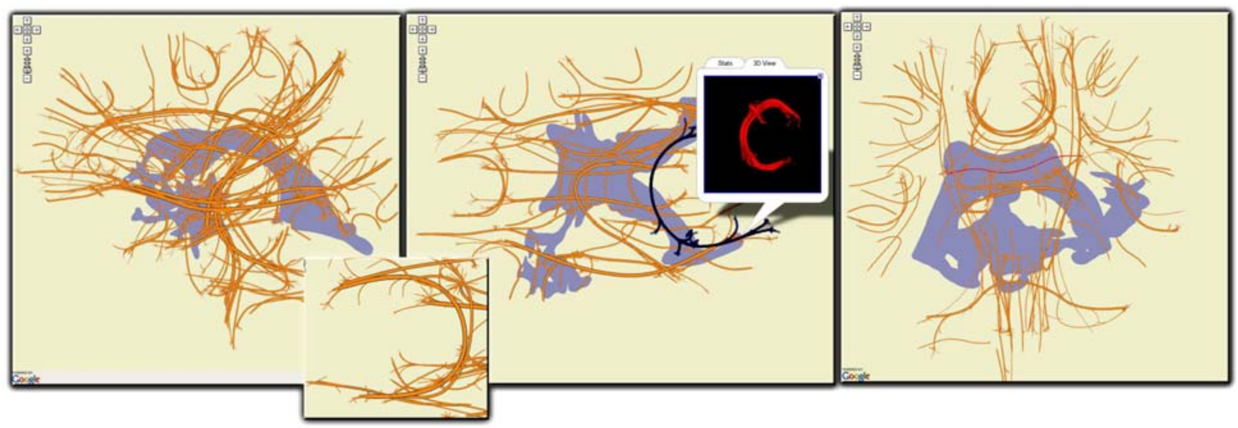

Figure 2: DTI tractography data projected onto the transverse, coronal and sagittal planes. Major tract bundles are represented schematically by their centroid tract; individual tracts in bundles are linked from the centroid bundle to their projected end-points. Bundles can be selected and pre-computed statistical data along with 3D poses of the tract bundle can be displayed.

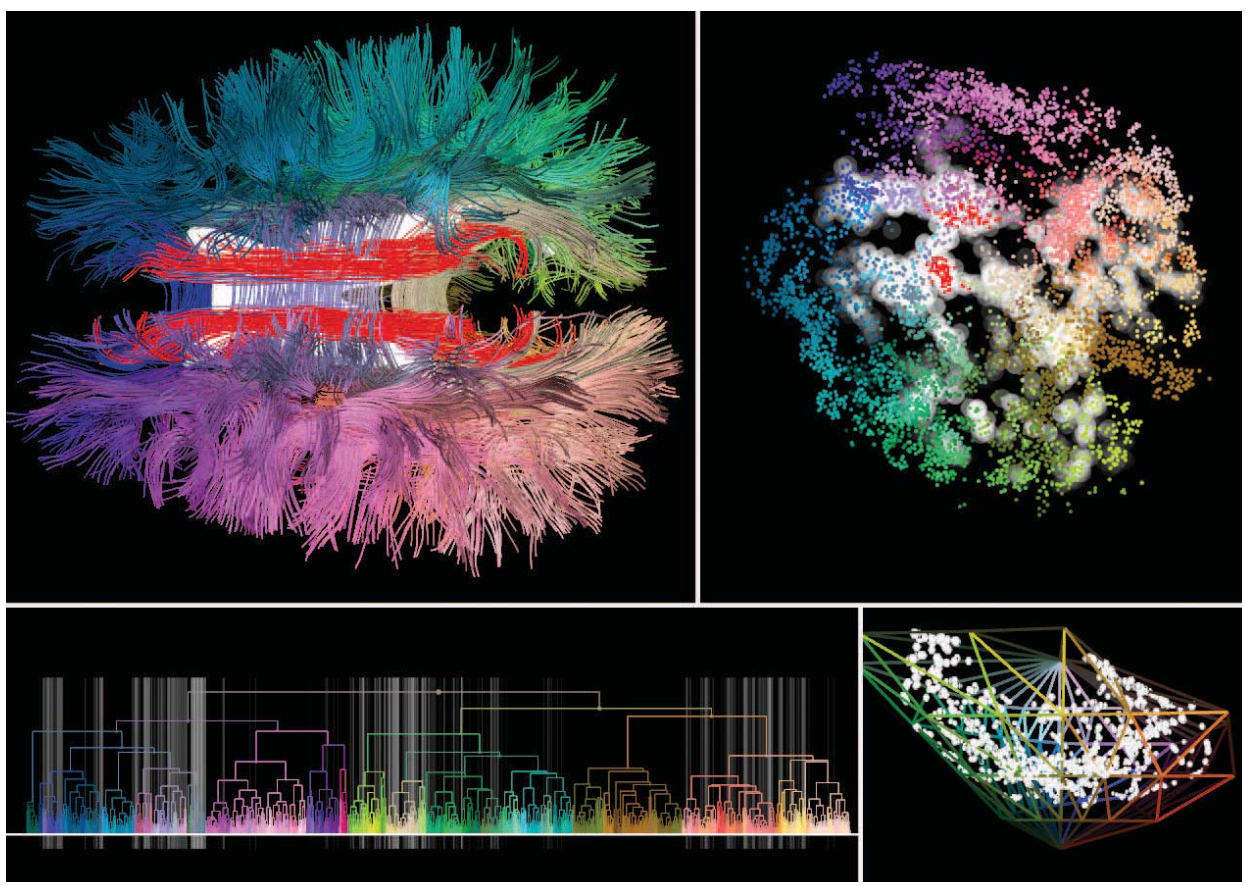

Figure 3: Coordinated DTI tractogram model exploration in lower dimensional visualizations: 2D embedding (upper-right), hierarchical clustering (lower-left), and L*a*b* color embedding (lower-right). A selection of a tract bundle (red) in the hierarchical clustering is mirrored in the other views.

signaling should apply to brain circuit analysis tools. We next describe some specific principles we expect to apply.

One principle is that the network or circuit should be presented in a frame that is relevant to the user. In [JYN+09] we found that placing proteins on a canvas in ways that contradict proteomic researchers' intuition and actual cellular location is counterproductive. Moreover, we found that integrating those networks within a frame that is familiar to the researcher helps the user relate to the network. Fig. 5 shows an example of a protein interaction network scaffolded onto a signaling pathway stylized drawing.

A second principle is that investigating a network at different levels of detail or granularity is beneficial. Fig. 4 illustrates some of our more recent work displaying a protein interaction network as a google-map. In this example, zooming out of the image has the effect of restricting the proteins and interactions that are displayed to the most significant ones, while zooming in allows one to drill into neighborhoods of more obscure proteins.

Third, we found that showing multiple views corresponding to different visual abstractions of the underlying data can help a user understand all of the data more effectively. In [JDL09b] we demonstrate that linking a 3D tractography model of diffusion MRI imagery to abstract low dimensional representations yields an improvement in interaction and data understanding, a technique illustrated in Fig. 3. In Fig. 2 we illustrate additional recent work in which brain tractography is abstracted to schematic projections onto the three principle projection planes. Preliminary results show that this mode of representation, when coupled with the original 3D model, is appreciated by neuroscientists. It also represents a first step in abstracting anatomical features to connectivity information and projecting it onto a meaningful space.

From our preliminary interactions as a group, we hypothesize that these findings will translate to effective brain circuitry analysis tools. The anatomical framework and the inclusion of familiar anatomical landmarks are likely to play an important role in how a user perceives a brain network. Users will want to investigate the network at different levels of granularity depending on their research interests. Coupling abstract network representations to real anatomical data or visualizations of supporting meta-data is likely to improve analysis.

Our experience with developing more imaging-oriented applications will help with the components of the proposed work that deal with microscopy and MRI data. Some representative examples include 3D flow visualization [RPKL06; PRLK05; PHW+05; FRS+03; CRH+10], diffusion MRI visualization and analysis [Zha06; JDL09b; ZDK+01], carpal kinematics analysis [MGL07; MCL09; MDAL04], and even archeology visual analysis [AVLJ00].

Finally, Brown's proximity to RISD provides a wealth of visual design expertise from not only the students but also the faculty, one of whom is an investigator on this proposal. Laidlaw and Drury have taught a "Virtual-Reality Design for Science" class several times, bringing together computer science students, art students, and scientists to explore the process of designing visual and interactive tools to accelerate science. We have documented some of what we have learned in the literature [KKVL05; VAJ+03; AJLD08; KAM+08].

Laidlaw's lab has been one of the leading visualization labs in formal evaluation of visualization methods [LKJ+05; FCL09; PFK+07; DJK+06]. Some of these evaluations were done in collaboration with perceptual psychologists from Sloman and Badre's department. They incorporated some of the kinds of experimental design issues that will be needed to execute our proposed work. Interestingly, these formal evaluations and the "critiques" of of our Brown/RISD class are related – in a sense, they are attempting to solve the same problem of understanding how humans and software interact effectively. This synergy is fascinating and enlightening, but unfortunately rare. We will leverage it in the proposed work.

e Cognitive Optimization: a Novel Approach to Human-Computer Interaction

Development of the software tool will involve an iterative process. An initial prototype will be developed based on software design and cognitive principles. That prototype will be tested first informally and then formally. The results of the testing will shape the next generation of the tool which will also undergo testing and refinement. More details of this process can be found in Sec. f.

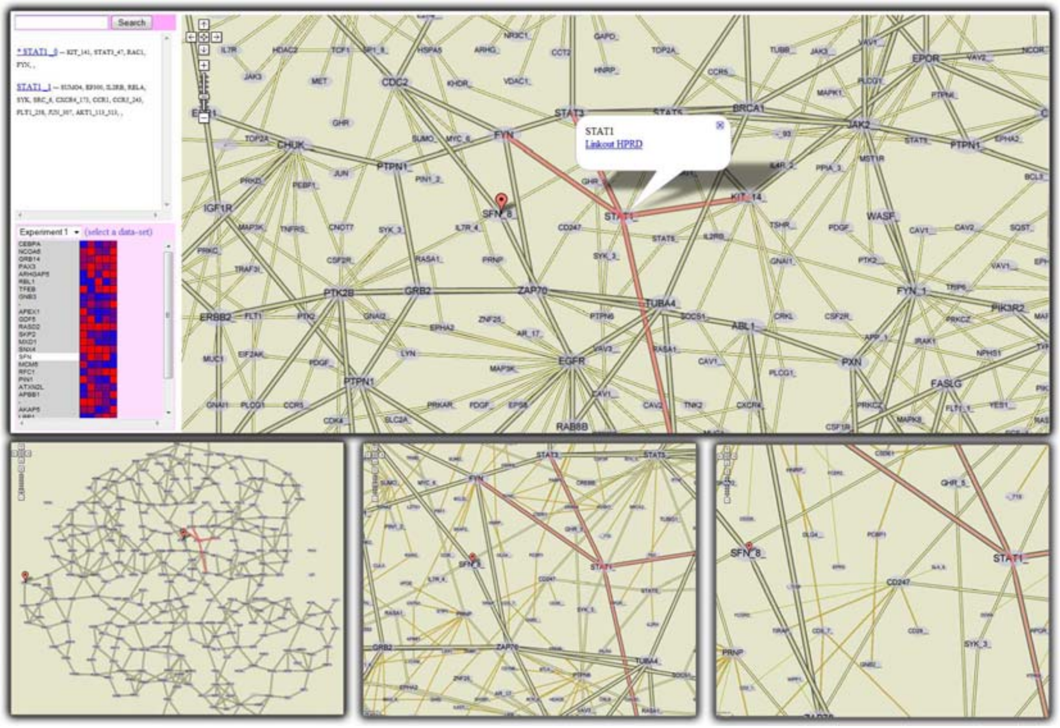

Figure 4: A google map of a protein interaction network. Outer zoom levels reveal only well known proteins and interactions while zooming in brings forth more obscure proteins.

e.1 Prototype Development The cognitive principles that will be used to develop the prototype come in three varieties. First, principles of perception and attention will determine the physical parameters of the display. Second, principles of goal selection will determine the number of tasks made available to the user and their accessibility at any point in time. Third, principles of judgment and reasoning will determine the design of the tool, the information that is on display at any given time, the actions that it makes easy, and the guidance and feedback that it provides.

e.2 The Principles of Perception The software will make available facilities for viewing data, like the network itself, and for performing other tasks (e.g., maintaining history, calculation facilities, note-taking facilities). The designers will have to make decisions about how to display the data (e.g., number of network graphs, network parameters, number of nodes per network) and the number of other functions to include in the display. Note that these are all dynamic entities. They change rapidly over time and they interact constantly.

Recent work in the study of attention has examined the number of objects that can be tracked at any given time [PS88] and the physical parameters that determine the identity of an object [SP99]. These studies present participants with a large number of objects moving in either random or systematically varying directions on screen. Participants' task is to track one or more of the objects; i.e., to maintain the identity of some number of objects as they move about. In some experiments, the objects disappear or become occluded or change in color or size. These experiments reveal the key physical parameters describing how people deploy and distribute attention to maintaining awareness of the existence and behavior of objects as they change over time. From this work, and from older work on the capacity of attention [Pas99], we can draw inferences about how networks should be drawn, the number of nodes and links that should be displayed, and how much changing information about the network can be maintained simultaneously.

e.3 Goal Maintenance Scientific problem solving entails multitasking. The scientist must decide what to look at, recognize patterns in the data, decide which hypotheses to test and actually test them, all

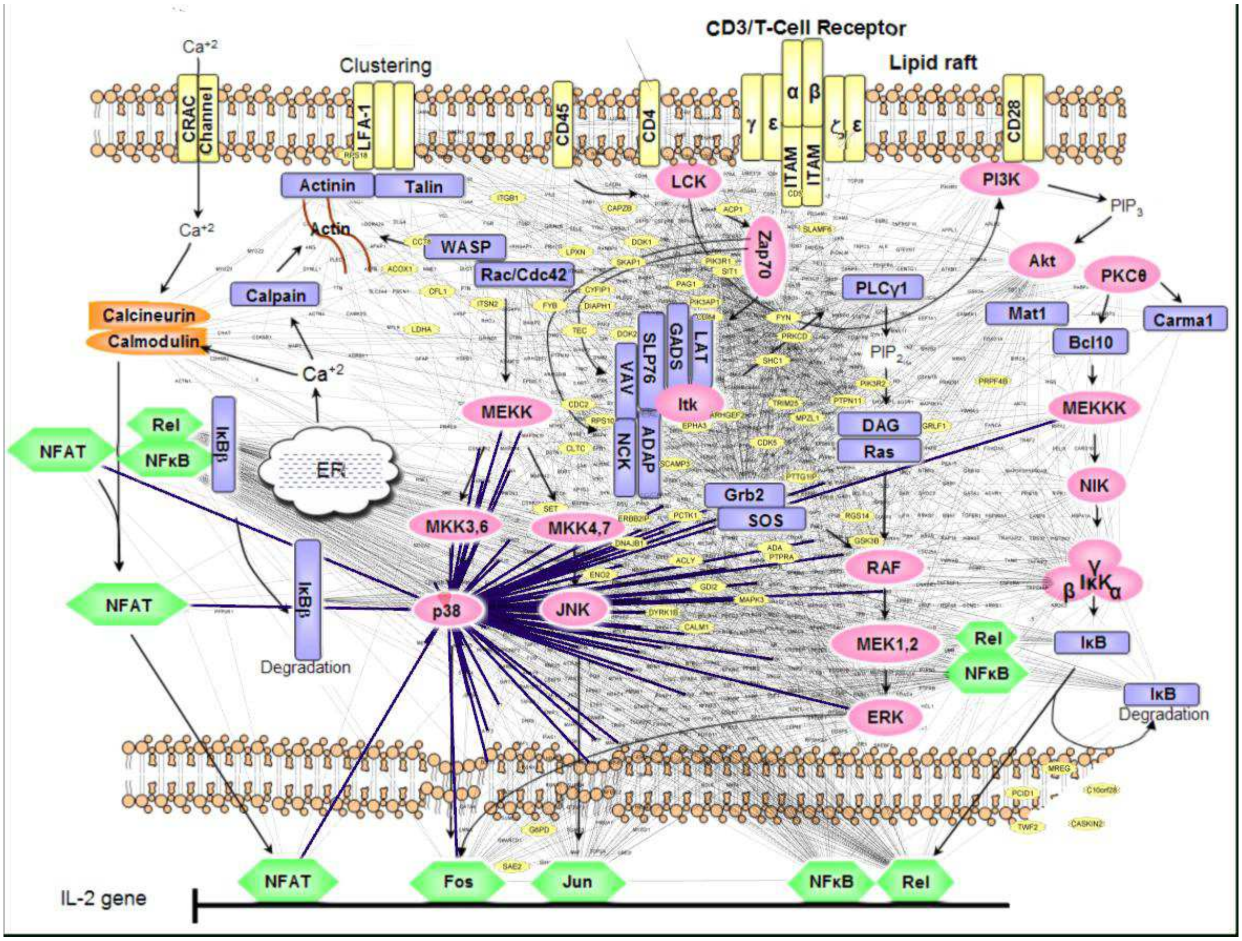

Figure 5: Proteins and interactions extracted from the Human Protein Reference Database are integrated into a stylized signaling pathway model.

the while keeping track of what has been investigated, what has not, any new ideas that come to mind while exploring, while also being mindful of their other everyday concerns. Research has studied the process of multitasking using a variety of paradigms including prospective memory [ME00], task switching [RM95] and goal priming [AD00; BC99].

Several principles have emerged from this work identifying the conditions under which different goals facilitate versus compete with one another. Goals facilitate when they share a larger purpose. For instance, sub-goals of a single task tend to facilitate one another. Goals also facilitate one another when the task performed to pursue them are similar. Otherwise, goals compete. Relations among goals also determine whether they should be pursued simultaneously or sequentially. We will use these principles to determine which tasks to make easily accessible to users and which to put in the background. Moreover, people differ in their ability to juggle multiple pursuits simultaneously. Our system will tune itself to individuals' work styles.

e.4 Hypothesis Testing and Problem Solving At the more abstract level, the software will be designed around three basic principles concerning how users think and solve problems.

First, people have a tendency to be overly myopic in the hypotheses they choose to test [KH87]. This manifests in several ways: we tend to consider only a limited number of hypotheses, failing to consider alternatives; we focus on data that is consistent with the hypothesis we have in mind, neglecting other data; we interpret data in a way that supports our prior hypothesis, failing to appreciate when data are disconfirming.

The most simple and effective way that psychologists have found to reduce this bias is to ask people to "consider the opposite" [LLP84]. That is, simply cuing reasoners to consider an opposing hypothesis when problem solving or interpreting data is often enough to get them to do so. In other words, the psychological roadblock is not always an inability to consider alternative hypotheses, but a meta-cognitive failure to consider doing so. A second remediation method is to ask people to think diagnostically rather than causally [FDS10]. Instead of thinking about a problem in terms of how causes lead to effects (e.g., how does my model of cortical processing lead to this network diagram?), more alternatives are considered when the converse problem is considered (e.g., what is the probability that my model of cortical processing is correct given this network diagram?). Both of these principles can easily be implemented to nudge scientists along.

The second cognitive principle is that people think in terms of mechanisms that operate over time [Slo09]. That is, they break up tasks into functional units. But these functional units do not merely produce specific outputs for given inputs, they do so with known or expected time courses. In that sense, they are causal and not merely computational. Also, these mechanisms come at different scales: some describe operations at microscopic levels and others describe more abstract functional units. In each case, the mechanisms come in structured bundles that can be described as networks or circuits. Mechanisms relate variables of 5 types: causes, disablers, enablers, preventers, and effects. The general form of a mechanism follows that of a structured equation: The effect is a joint function of the other 4 variables. This is not merely a mathematical relation because it obeys a temporal constraint: the effect cannot occur prior to the causes. Moreover, people have a rough idea what the delay should be in the appearance of the effect when the activities of the other variables are known.

This way of thinking is particular helpful as a way for scientists to structure their knowledge of the brain. The brain is studied and described at multiple levels, from the cellular to the systems level. Each level consists of networks of functional units and each functional unit has an expected time course. When a scientist looks at imaging data, he or she does not merely see a visual pattern but rather a dynamic entity that has a purpose, where each pattern of activity exists in the service of some effect. In the canonical case, the activity represents the response to a stimulus that follows a causal chain to arrive at an ultimate effect, a motor response.

The third cognitive principle is that people think in two ways, intuitively and deliberatively [Eva03; Slo96; SW01]. Intuition involves recognizing patterns and coming to conclusions that relies on memory and associative principles like similarity and contiguity. People are not conscious of the process of intuitive reasoning, only of the result. On the other hand, people think deliberatively. They transform symbols over time using executive control mechanisms housed in working memory. People are conscious of both the process and the conclusion of such reasoning.

When solving problems, the two systems of thought have two forms of interaction. For simple problems that can be solved in habitual ways, the normal operation of the system is for the intuitive response to dominate. But if a competing deliberative response comes to mind, then that is what determines performance. A scientist who sees a familiar network configuration will intuitively identify it. But if the context of the observation rules that possibility out, then normally the classification will be abandoned. The second form of interaction concerns problems that require focused thinking over time, like puzzle solving. Such problems are generally solved by a cyclical process in which deliberation offers representations to the intuitive system [NS72]. The intuitive system then tries to find a meaningful pattern in the representation. If it succeeds, then the response is validated by the deliberative system. If it fails, the deliberative system tries to construct a more successful representation.

The distinction between the two forms of thinking will guide the design of the software tool by implementing two sorts of modules. One type will be specialized for intuitive reasoning. It will be much less constrained in the amount of information that it displays and will be designed to afford pattern recognition. The other type will be specialized for deliberation. It will show only a small amount of information at a given time and will facilitate small, analytical reasoning steps.

e.5 Formal Testing After informal testing of the prototype, and at each stage of the tool's development, it will undergo formal user testing. This will involve picking a set of simple, solvable problems concerning brain circuitry and asking a set of novice (probably undergraduate) brain researchers to solve them. Some of the researchers will use the software tool and others will use the software tools that are normally used by researchers in the relevant field. We will make sure that levels of training with the two sets of tools is approximately equivalent. We will choose problems that are challenging but not impossible. Some will be largely analytical in the sense that standard methods can be applied while others will require thinking "outside the box" (insight problems).

We will compare problem solving performance on both types of problems using the different tool sets using a variety of measures: likelihood of solving the problem, reaction time to solve the problem, and quality of solution. We will also obtain qualitative information about performance by querying participants about what they are thinking at regular intervals and tracking their eyes. This will reveal if our software tool is changing basic problem-solving strategy.

f Project Plan and Schedule

We plan to execute our multidisciplinary research agenda over the course of 5 years. The primary output of this project will be a visualization system for the analysis of brain circuitry, with a target audience of brain scientists seeking to understand neural pathways and connectivity. This software will be developed by the Brown group with continual and closely integrated collaboration with the brain research labs. The goal of this tool is to allow researchers to view brain circuits at multiple scales and to support sophisticated analysis of research hypotheses.

In order to maintain a community-driven approach, software development will follow a spiral engineering pattern, with system components and prototypes of increasing functionality deployed for each iteration of the software. These deployments will be to the brain research labs for evaluation and feedback. In addition, interviews and studies of users will be directly used to shape the cognitive models of user reasoning that the Brown group will use to design, modify, and evaluate the system interface. At all points in the development process, collaboration among the research groups will be used to ground design in what is important to users and to incorporate an understanding of the scientific reasoning process into a visual analysis tool.

Timeline

Our plan is divided into five phases. We anticipate that they will correspond to the five years of the proposed work, however there will clearly be some overlap among the phases and some variability in their size. Each phase/year will be driven by multiple evaluatable milestones, e.g., requirements documents, design sketches, design reviews, releases at various scopes, and experiments.

Phase/Year 1: Knowledge sharing, modeling, setup, and interface sketching. In this phase the labs will work together to gather requirements for the software and to develop an initial set of rule sets and user models for the cognitive modeling aspect of the project. This phase will include early testing of the cognitive models to determine whether they accurately predict user behavior and to what degree they are relevant to the analysis needs of the users. During this phase we will iterate on the requirements via sketched interfaces and visualizations; user feedback and cognitive analysis will guide the refinement of the sketches[KAM$^+$08]. A system for capturing user event history, video, and tracking will be developed and combined with a quick prototyping application development system used for several visualization applications [JDL09a]. We will also set up the SourceForge repository, including its bug tracker and forums for developers and users.

Phase/Year 2: Proof of concept design and prototype. An initial software design will be developed based on the requirements gathered in Phase/Year 1. This design will incorporate the highest priority requirements and will be prototyped to demonstrate to the brain scientists that their data is being accurately and understandably displayed, that the interface is usable, and that the system has the potential to show them information or support analysis that was not possible before. The prototype will be made available on SourceForge but without significant publicity. It will be used in our own laboratories to test the interface and the testable cognitive components.

Phase/Year 3: Primary system development cycle. During this main phase of deployment, testing, and design, we will refine our system design through small-scale evaluations within the Laidlaw lab and across the other three labs. This phase will include an iterative series of increasingly complete prototype systems, each of which will be deployed to the brain science labs and evaluated with respect to basic usability, task performance, and how well they support reasoning. Interface evaluation metrics will include completion time and accuracy with simple information-extraction tasks, insight generation, and qualitative feedback from interviews or focus groups. In addition to evaluating the interface, we will also evaluate the cognitive models used to refine and guide interface design. To do so, we will be evaluating the models' predictions of user behaviors and states against actual user data, such as computer interaction logging, video logging, and physiological measures such as eye-tracking data (for attention) and skin conductance response (for affective states). The results of these evaluations will be used to improve our cognitive model, which will subsequently be used to improve system design and responsiveness to the user. Throughout this phase, significant evaluation results and novel aspects of the system will be published in appropriate conferences and journals.

Phase/Year 4: Initial Public and Publicized Release. Iterations on the implementation will be continued into Phase/Year 4 leading up to a public release approximately halfway through the year. This version will include all the intended functionality of the system, including the ability to incorporate and display multiple types of brain connectivity data (fMRI, diffusion fMRI, optical microscopy, and other experimental data); the ability to compare and understand circuits at multiple levels of detail, from cell types to behavior; and finally, should be cognitively optimized to support reasoning and analysis at a high level, rather than just displaying data. During the second half of the year, feedback will be gathered and analyzed more broadly, and community-building efforts utilizing SourceForge mechanisms, for potential developers, and possibly something more user oriented for users who are not developers. User data capture will continue as will internal improvements.

Phase/Year 5: Dissemination. The final system will first be deployed to the brain science labs, with the goal of incorporating its use into ongoing research. Researchers in these labs will observe how the system is used in practice and whether it successfully improves their ability to analyze data and test hypotheses in a real-world setting. At this point we will also release a final version of the system to the public as an open-source distribution, with the source code available via SourceForge and binary installers available through SourceForge and our labs' websites. We will continue to support this release and to log usage data in order to improve the system and better understand how it is used in practice. During this final phase we will also make a choice about the mechanism to be used for sustainability (see next section).

g Outreach, Education, and Sustainability Plan

As described in the timeline, several versions of the system will be deployed to the public as an open-source project via SourceForge, using their public license derived from the GNU General Public License. We have been using this approach for a virtual reality library we are developing with other NSF support (OCI-09-23393). We will also provide binary installers for Windows and Mac so that scientist users can download and use our software. This release will be advertised through blog postings, publications, direct contact, and during conference presentations in order to raise its visibility among the larger visualization, human-computer interaction, and brain science communities. We will also propose to teach tutorials and classes at conferences if there is interest. Additionally, researchers from the brain science labs will be encouraged to use the tool in classes and other educational settings in order to help students understand connectivity in an accessible visual form.

The system will include instructions and easy mechanisms for reporting bugs and providing other feedback. We will address serious maintenance issues as needed. Usage data will be gathered from users if they opt in upon downloading the tool; observation of the tool's use will be undertaken in the brain science labs involved in the proposal. These observations will be used to inform future iterations of the software.

Dr. Laidlaw will be responsible for overseeing the sustainability of the software. Our hope is to interest a company in pursuing SBIR funding to provide continued maintenance, support, and development past the end of the proposed project. An alternative model would be a mechanism like the one that supports ITK through the National Library of Medicine at NIH. If neither of these is possible, we will work to develop open-source community support through the SourceForge repository and its developer and user forums.

h Potential for Broader Use

The success of our proposed research has the potential to be broadly applicable to scientists in many other domains, as well as to software developers and users outside of science. Advances in creating effective visualization interfaces should be applicable to almost any scientific user. Advances in using cognitive optimization as a design and development principle should apply to almost any interactive software tool. Support for reasoning with sketches and networks should be applicable beyond brain networks – not only to disciplines that study networks, but to any analysis oriented problem area.

Applications already under development in Laidlaw's lab illustrate several other scientific domains where similar tools should be valuable, including the study of protein signaling, gene regulation, and possibly their interaction. Other examples of problem domains that might benefit include the study of social networks, epidemiology, and the analysis of large bodies of text.

Our novel "cognitive optimization" approach to supporting analysis systems has the potential to provide valuable input to almost any interactive tool for visual analysis. Because the code implementing it will be available as part of our distribution, it can be extended or applied by other researchers.

This project will provide broad access to a state-of-the-art visualization tool necessary for researching current problems in brain and cognitive science. Our software build and deployment process will allow users to get the most current stable version of our tool on demand or automatically.

Finally, much of the interaction data we collect will be anonymized and made available to the research community. This will be valuable to the research community; our goal is to share the insights we gain from studying user interaction patterns and the effectiveness of visualization techniques. These data will range from low-level eye-tracking and mouse-click logs to high-level information on decision making and concept modeling. This data repository has the potential to help numerous scientific areas within cognitive science and human computer interaction, including decision making, dual-systems research, perception and vision, and user interface optimization.

i A Cohesive Multi-disciplinary Team

We have assembled an excellent team for accomplishing the proposed research. We have recognized experts in cognitive science, neuroscience, computer science, and visual design. Their complementary expertise covers a breadth unusual in such a small group. The problem area of brain science and the research thrust of cognitive optimizing user interfaces are quite synergistic, which helps to reduce the number of disciplines necessary to attack the problem.

Importantly, the faculty investigators have been intellectually engaged with one another for some time. Badre and Sloman are in the same department and Sloman has attended one of Badre's classes. Laidlaw and Sloman are participants in an ongoing working group studying a dual-system model of cognition. Two of Sloman's Ph.D. students attended Laidlaw's "Cognition, Human-Computer Interaction and Visual Analysis" class last year, and one of Laidlaw's students attended two of Sloman's classes this year. Schnitzer provided the inspiration for attacking this problem by contacting Laidlaw several months ago, and they and their groups have been interacting since on what the neuroscience needs are. Laidlaw and Drury have been teaching a class "Virtual-Reality Design for Science" over the last seven years and have learned much about working collaboratively between the design of software and the design of visual and interactive artifacts.

Brown provides a supportive environment for multidisciplinary work such as we propose. The diverse student body is very creative, and we plan to leverage that by involving undergraduates in this research. Brown has porous disciplinary boundaries which permit easy collaboration. Brown's Brain Sciences Institute is an example of a multidisciplinary organization that leverages this easy collaboration; it also provides supportive infrastructure, including biological imaging, centralized talk announcements, small seed funding for new collaborations, undergraduate research opportunities, and multiple examples of successful collaborations.

While admittedly risky, we believe that the proposed work would provide broadly valuable benefits to all the disciplines directly involved, to many other scientific disciplines, to software development and design, and to knowledge workers.

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[WSP+06] W. Wright, D. Schroh, P. Proulx, A. Skaburskis, and B. Cort. The Sandbox for analysis: concepts and methods. In *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 801–810. ACM New York, NY, USA, 2006.

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David H. Laidlaw

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Computer Science
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Email:dhl@cs.brown.edu

Education

1983 Sc.B. in Computer Science, Brown U., Prov., RI, *Topology and Mechanics.* Also completed requirements for an A.B. in Mathematics.
1985 Sc.M. in Computer Science, Brown U., Prov., RI, *Rendering Parametric Surfaces.*
1992 M.S. in Computer Science, Caltech, Pasadena, CA, *Material Classification of Magnetic Resonance VolumeData.*
1995 Ph.D. in Computer Science, Caltech, Pasadena, CA, *Geometric Model Extraction from Magnetic Resonance Volume Data.*

Experience

2008-present Professor, Computer Science Department, Brown University
2003-2008 Associate Professor, Computer Science Department, Brown University
2000-2003 Stephen Robert Assistant Professor, CS Department, Brown University
1998-2000 Assistant Professor, Computer Science Department, Brown University
1996-1998 Senior Research Fellow, Division of Biology, Caltech
1989-1996 Postdoctoral Research Fellow/Research Assistant, Computer Science, Caltech
1989-1993 Consultant Stardent/Advanced Visual Systems
1986-1989 Software Engineer, Stellar Computer
1983-1985 Research Assistant, Computer Science, Brown University

Honors and Awards

1998 Best Panel award at IEEE Visualization
2000 Appointed Stephan Robert Asst. Professor
2001 Best Case Study at IEEE Visualization '01
2001 NSF Career Award
2001 Best Layout and Best Scientific Presentation Exhibit Award at the American Society for Surgery of the Hand Annual meeting '01
2002 Computers and Graphics 2^{nd-}Best Paper
2003 Henry Merritt Wriston Teaching Fellowship
2004 Best Panel award at IEEE Visualization
2005 Best poster award at IEEE Visualization
2006 SIGGRAPH, ACM Student Research Competition, 1st place with PhD student Wenjin Zhou
20071st Place, NSF/Science International Science & Engineering Visualization Challenge, Informational Graphics, with student Misha Kostandov
2008 IEEE VGTC Visualization Technical Achievement Award

Selected Publications

- C. Jackson, D. Acevedo, D. H. Laidlaw, F. Drury, E.Vote, and D. Keefe. Designer-critiqued comparison of 2D vector visualization methods: A pilot study. In SIGGRAPH 2003 Sketches and Applications. IEEE, 2003.
- R. Kosara, C. G. Healey, V. Interrante, D. H. Laidlaw, and C. Ware. Thoughts on user studies: Why, how, and when. Computer Graphics and Applications, July/August 2003.
- C. Jackson, D. Karelitz, S. A. Cannella, and D. H. Laidlaw. The great potato search: The effects of visual context on users feature search and recognition abilities in an IVR scene. In Proceedings of IEEE Visualization, October 2002.
- D. H. Laidlaw, R. M. Kirby, J. S. Davidson, T. S. Miller, M. da Silva, W. H. Warren, M. Tarr, 2005. Comparing 2D Vector Field Visualization Methods, IEEE Transactions on Visualization and Computer Graphics Jan 2005.
- A. Forsberg, J. Chen, D. H. Laidlaw. Computing 3D Vector Field Visualization Methods, IEEE Visualization 2009.

Other Publications

- van Dam, D. H. Laidlaw, and R. M. Simpson (2002). Future interfaces: an IVR progress report, *Computers and Graphics*,
- D. Keefe, D. Acevedo, T. Moscovich, D. H. Laidlaw, J. J. LaViola (2001). CavePainting: A Fully Immersive 3D Artistic Medium and Interactive Experience, Proc. 2001 Symposium on Interactive 3D Graphics.
- van Dam, A. S. Forsberg, J. J. LaViola, and R. M. Simpson (2000). Immersive Virtual Reality for Scientific Visualization: A Progress Report, *IEEE Computer Graphics and Applications*, 20(6), pp. 26-52.
- D. H. Laidlaw (2001), Loose artistic ``textures'' for visualization. IEEE Computer Graphics and Applications, 21(2):6--9.
- Upson, C., Faulhaber, T., Kamins, D., Laidlaw, D. H., Schleigel, D., Vroom, J. Gurwitz, R., and van Dam, A.(1989), The Application Visualization System: A Computational Environment for Scientific Visualization, *Computer Graphics and Applications*, 9(4).

Synergistic Activities

Last year a major revision of a new graduate/undergraduate class, *Interdisciplinary Scientific Visualization*, explored design issues in scientific visualization from two perspectives: illustration and computer science. The course was co-taught with Rhode Island School of Design (RISD) Illustration Department Chairman Fritz Drury. Together we worked with students from both RISD and Brown to design and realize new virtual reality interfaces for exploring 3D time-varying flow. Students learned about communicating and working with researchers across multiple fields. See course web page for more info: http://www.cs.brown.edu/courses/cs237.

Organized panel at Visualization '98 conference on Art and Visualization (best panel at conference). Participated in follow-on Visualization '99 and Visualization '01 panels. All probed issues of interdisciplinary collaborations for visualization.

Co-taught one-day course at premiere computer graphics conference, SIGGRAPH, about using art-based methods for scientific visualization. I led a two-hour session where approximately 80 computer graphics professionals used traditional art media (paint, charcoal, markers, chalk, etc.) to represent multivalued scientific data.

The final publication in c.ii. above describes AVS, a visualization software product that I was a principal developer on at Stellar Computer. It is widely used to process and visualize scientific data from many disciplines.

I have advised and continue to recruit out undergraduates for research projects both at Brown and, previously, at Caltech. Many of the projects have culminated in research publications. Several have been with women in computer science, a traditionally underrepresented group. I organize the Brown Computer Science undergraduate research opportunities web pages.

Collaborators and Other Affiliations

Collaborators and Co-Editors: Eric T. Ahrens, Caltech, Joseph W. Asa, Matthew J. Avalos, Caltech, C. Bajaj, U.Texas, Thomas F. Banchoff, Alan H. Barr, Caltech, Celia F. Brosnan, Albert Einstein College of Medicine, Kristen L. Cook, Caltech, Joseph Crisco, Brown, Bena L. Currin, Caltech, Mary E. Dickinson, Caltech, Paul E. Dimotakis, Caltech, John Donoghue, Brown University, Kurt W. Fleischer, Pixar, Andrew S. Forsberg, Brown, Geoffrey Fox, Felice Frankel, MIT, Scott E. Fraser, Caltech, Yuri M. Goldfeld, Caltech, Galen G. Gornowicz, Dreamworks SKG, Cindy Grimm, Washington U., Donald House, Texas A\&M, Victoria Interrante, U. of Minnesota, Russell E.Jacobs, Caltech, David Kremers, Caltech, Daniel B. Lang, Caltech, H. Marmanis, Brown, Carol Readhead, Cedars Sinai Medical Center, Sharon Swartz, Brown, Jerome Sanes, Brown, Jerry W. Shan, Caltech, Jeffrey M. Silverman, Cedars Sinai Medical
Center, Michael Tarr, Brown, J. Michael Tyszka, City of Hope Medical Center, Colin Ware, U. New Hampshire, William Warren, Brown, Iain Woodhouse, U. Edinburgh

Advisees: Daniel Acevedo-Feliz, Stuart Andrews, Cullen Jackson, Daniel Keefe, R. Michael Kirby, Georgeta Elizabeth Morai, Paul Reitsman, Eileen Vote, Song Zhang.

Advisors: Alan H. Barr, Caltech, Scott E. Fraser, Caltech.

Biographical Sketch: David Badre

Professional Preparation

B.S., 2000, University of Michigan, Biopsychology and Cognitive Science
Ph.D. 2005, MIT, Cognitive Neuroscience

Appointments

2008 - Assistant Professor, Cognitive and Linguistic Sciences and Psychology, Brown University
2005 - 2007 Postdoctoral Fellow, Helen Wills Neuroscience Institute, University of California, Berkeley
2004 - 2005 Visiting Scholar, Department of Psychology, Stanford University

Publications: Relevant to Proposal

Badre, D., Kayser, A. S., and D'Esposito, M. (2010) Frontal cortex and the discovery of abstract action rules. *Neuron,* 66*,* 315-326
Badre, D. and D'Esposito, M. Is the rostro-caudal axis of the frontal lobe hierarchical? (2009). *Nature Reviews Neuroscience*, 10, 659-669.
Badre, D., Hoffman, J., Cooney, J.W., and D'Esposito, M. (2009). Hierarchical cognitive control deficits following damage to the human frontal lobe. *Nature Neuroscience*, 12(4), 515-522.
Badre, D. (2008). Cognitive control, hierarchy, and the rostro-caudal axis of the prefrontal cortex. *Trends in Cognitive Science*, 12(5), 193-200.
Badre, D. and D'Esposito, M. (2007). FMRI evidence for a hierarchical organization of the prefrontal cortex. *Journal of Cognitive Neuroscience*, 19(12), 2082-2099.

Other Publications:

Öztekin, I., Long, N. M., and Badre, D. Optimizing design efficiency of free recall events for fMRI. *Journal of Cognitive Neuroscience*. In Press.
Badre D., and Wagner, A. D. (2007). Left ventrolateral prefrontal cortex contributions to the control of memory. *Neuropsychologia*. 45, 2883-2901.
Badre, D. and Wagner, A. D. (2006). Cognitive and neurobiological mechanisms underlying cognitive flexibility. *Proceedings of the National Academy of Sciences, USA*, 103(18), 7186-7191.
Badre, D., Poldrack, R. A., Paré-Blagoev, E. J., Insler, R., and Wagner, A. D. (2005). Dissociable controlled retrieval and generalized selection mechanisms in ventrolateral prefrontal cortex. *Neuron*, 47, 907-918.
Badre, D. and Wagner, A. D. (2005). Frontal lobe mechanisms that resolve proactive interference. *Cerebral Cortex*, 15(12), 2003-2012.

Synergistic Activities

1) I have developed two courses at Brown that I teach on a routine basis and that are attended by students outside of my immediate department. These are an introductory survey course in Introduction to Cognitive Neuroscience, and an upper level course in functional magnetic resonance imaging methods. The latter course in particular could benefit from additional software applications that will help classroom participation and learning.

2) I am on the editorial board of the journal Cognitive Neuroscience. As a member of the founding board, I've had a role in shaping the direction of that journal.

3) I am an ad hoc reviewer for *Biology Letters (formerly section of Proc. R. Soc. B), Brain and Language,Cerebral Cortex, Cognition, Cognitive, Affective, and Behavioral Neuroscience, Cognitive Neuropsychology, Cognitive Neuroscience, Cognitive Psychology, Experimental Brain Research, European Journal of Neuroscience, Human Brain Mapping, Journal of Cognitive Neuroscience, Journal of the International Neuropsychological Society, Journal of Neurophysiology, Journal of Neuropsychology, Journal of Neuroscience, NeuroImage, Neuron, Neuropsychologia, Neuroscience, Neuroscience Letters, Neuroscience & Biobehavioral Reviews, PLoS ONE, Proceedings of the National Academy of Sciences, USA, Psychological Science, Psychological Bulletin, Psychonomic Bulletin & Review, Social, Cognitive, and Affective Neuroscience, Science, Topics in Cognitive Science, Trends in Neurosciences*; in addition to the NSF Perception, Action, and Cognition and Cognitive Neuroscience panels, the Neurosciences and Mental Health Board, MRC (UK), and the Wellcome Trust (UK).

4) This year, I am co-organizer and co-chair of a symposium on the interaction of cognitive control, decision making, and memory at the upcoming Memory Disorders Research Society meeting in October, 2010.

5) I have served on the colloquium organizing committee for both the Departments of Cognitive and Linguistic Sciences and the Department of Neuroscience at Brown, and so have helped to organize those speaker series in order to enhance the educational experience of students, faculty, and staff in both departments.

Collaborators and Co-Editors

Michael Frank (Brown), *David Laidlaw* (Brown), *Hernando Ombao* (Brown), *Marjorie Solomon* (UC Davis), *Cameron Carter* (UC Davis), *Randy Buckner* (Harvard University), *Kevin Ochsner* (Columbia University), *Margaret Sheridan* (Harvard University), *Martin Albert* (Boston VA), *Mark D'Esposito* (University of California, Berkeley), *Anthony Wagner* (Stanford University).

Graduate Advisors and Postdoctoral Sponsors

Anthony Wagner, Department of Psychology, Stanford University
Mark D'Esposito, Department of Psyhcology, University of California, Berkeley

Thesis Advisor and Postgraduate Scholar Sponsor

Anthony Wagner, Department of Psychology, Stanford University

Postdoctoral Fellows

Current: *Ilke Öztekin* (NYU, PhD in 2008)

Students

Current Graduate Student: *Jennifer Barredo*; Committee Member: *Elizabeth Chrastil, Sophie Lebrecht, Bradley Doll, Adam Darlow, Heida Sigurdardottir (Neuro), Arjun Bansal (Neuro), Kaivon Paroo (Neuro), Hakmook Kang (Biostats).*

STEVEN A. SLOMAN

Professional Preparation

Undergraduate institution: University of Toronto, Psychology, B.Sc., 1986
Graduate Student: Stanford University, Psychology, Ph.D., 1990
Postdoctoral fellow: University of Michigan, Cognition and Perception, 1990-1992

Appointments

2005-	Full Professor, Brown University
1998-2005	Associate Professor, Brown University
1992-1998	Assistant Professor, Brown University

Publications

(1) Five most closely related to proposed project:

Fernbach, P. M., Darlow, A. & Sloman, S. A. (in press). Neglect of alternative causes in predictive but not diagnostic reasoning. Psychological Science.

Darlow, A. & Sloman, S. A. (in press). Two systems of reasoning: Architecture and relation to emotion. Wiley Interdisciplinary Reviews Cognitive Science.

Fernbach, P. M. & Sloman, S. A. (2009). Causal learning with local computations. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35, 678-693.

Sloman, S. A., Barbey, A. K. & Hotaling, J. (2009). A causal model theory of the meaning of *cause*, *enable*, and *prevent*. Cognitive Science, 33, 21-50.

Sloman, S. A. (2005). Causal models: How we think about the world and its alternatives. New York: Oxford University Press.

(2) Five additional publications:

Hagmayer, Y. & Sloman, S. A. (in press). Decision makers conceive of themselves as interveners, not observers. Journal of Experimental Psychology: General.

Barbey, A. K. & Sloman, S. A. (2007). Base-rate respect: From ecological rationality to dual processes. Behavioral and Brain Sciences, 30, 241-254.

Sloman, S. A. & Hagmayer, Y. (2006). The causal psycho-logic of choice. Trends in Cognitive Sciences, 10, 407-412.

Sloman, S. A. & Rips, L. J. (Eds.) (1998) Similarity and symbols in human thinking, Cambridge: MIT Press book.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. Psychological Bulletin, 119, 3-22.

Synergistic Activities

- Associate Editor, Cognition, 2006-
- Associate Editor, Memory and Cognition, 1998-2001.

- Robert J. Glushko Distinguished Visiting Scholar in Cognitive Science, University of California, Berkeley, 2009.
- Joint project on communicating with public about social issues with the firm Cultural Logic, 2004-2006.
- Development of tool to run psychological experiments on the internet with Brown's Scholarly Technology Group.

Collaborators and Other Affiliations

(1) Collaborators

Barbey, Aron, NIH
Bes, Benedicte, University of Toulouse II, France
Bonnefon, Jean-Francois, University of Toulouse II, France
Evans, Jonathan, University of Plymouth, UK
Gronchi, Giorgio, University of Florence, Italy
Hadjichristidis, Constantinos, University of Leeds, UK
Hagmayer, York, University of Göttingen, Germany
Lagnado, David, University College London
Lombrozo, Tania, UC Berkeley
Lucas, Chris, UC Berkeley
Malt, Barbara, Lehigh University
Over, David, Durham University
Walsh, Clare, University of Plymouth, UK

(2) Graduate and Post-Doctoral Advisors

Gordon Bower (Stanford University)
Lance Rips (Northwestern University)
David Rumelhart (inactive)
Amos Tversky (deceased)
Edward E. Smith (Columbia University)

(3) Thesis Advisor and Postgraduate-Scholar Sponsor

Postdoctoral Sponsor: Silvia Gennari, David Lagnado, Emanuel Robinson, Mascha van't Wout, Clare Walsh
Thesis Advisor: Adam Darlow, Philip Fernbach, Gideon Goldin, Ju-Hwa Park, John Santini, Joanna Tai.

Total number of graduate students advised: 6
Total number of postdoctoral scholars advised: 5

Biographical Sketch

Caroline Ziemkiewicz
Researcher
Charlotte Visualization Center
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Charlotte, NC 28223
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http://viscenter.uncc.edu/~caziemki

A. PROFESSIONAL PREPARATION

College/University	Major	Degree &Year
Ithaca College	Computer Science	B.A, 2004
UNC Charlotte	I.T. (Computer Science)	PhD, 2010

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

Researcher, UNC Charlotte, Department of Computer Science (May 2010 – Present)
National Visual Analytics Center Intern, Pacific Northwest National Laboratory, (June-August 2009)

C. PUBLICATIONS

Caroline Ziemkiewicz and Robert Kosara. "Implied Dynamics in Information Visualization," Proceedings of Advanced Visual Interfaces, 215-222, 2010, http://viscenter.uncc.edu/~caziemki/documents/ziemkiewicz10_implied-dynamics.pdf.

Caroline Ziemkiewicz and Robert Kosara. "Preconceptions and Individual Differences in Understanding Visual Metaphors," Computer Graphics Forum, 28, 911–918, 2009, http://viscenter.uncc.edu/~caziemki/documents/ziemkiewicz09_preconceptions.pdf.

Remco Chang, **Caroline Ziemkiewicz**, Tera Green, and William Ribarsky. "Defining Insight for Visual Analytics," IEEE Computer Graphics and Applications, 29, 14–17, 2009, http://viscenter.uncc.edu/~caziemki/documents/cga-viewpoints-insight.pdf.

Caroline Ziemkiewicz and Robert Kosara. "The Shaping of Information by Visual Metaphors," IEEE Transactions on Visualization and Computer Graphics, 14, 1269–1276, 2008, http://viscenter.uncc.edu/~caziemki/documents/ziemkiewicz08_visual-metaphors.pdf.

D. SYNERGISTIC ACTIVITIES

I co-founded UNC Charlotte's student chapter of ACM-W (ACM's Women in Computing) as a project for the STARS Alliance, an organization committed to increasing participation by underrepresented groups in the computing field. I have served as a paper reviewer for the IEEE Information Visualization conference, IEEE Visualization, IEEE Visual Analytics Science and Technology, and IEEE PacificVis. I also served as a student volunteer at IEEE VisWeek for one year and at IEEE Virtual Reality for four years.

COLLABORATORS AND OTHER AFFILIATIONS

Graduate and Postdoctoral Advisors

Robert Kosara (UNC Charlotte)

MARK J. SCHNITZER Assistant Professor, Departments of Biological Sciences and Applied Physics, Stanford University; Investigator, Howard Hughes Medical Institute.
Phone: 650-725-7438   Email: mschnitz@stanford.edu

DEGREES

Harvard University, Cambridge MA	Physics	A.B., *summa cum laude*	1992
Cambridge University, Cambridge, UK	Mathematics	Certificate, Part III	1993
Princeton University, Princeton, NJ	Physics	M.A.	1994
Princeton University, Princeton, NJ	Physics	Ph.D.	1999

RESEARCH EXPERTISE: Optical microscopy, biophotonics **YEARS IN THE FIELD:** 10

RECENT PROFESSIONAL POSITIONS

2008-*present*	Investigator, Howard Hughes Medical Institute.
2003-*present*	Assistant Professor, Dept. of Biological Sciences and Dept. of Applied Physics, Stanford University, Stanford, CA.
1999-2003	Member of Technical Staff, Principal Investigator, Physical Sciences Laboratory, Bell Laboratories, Lucent Technologies, Murray Hill, NJ.

AWARDS AND HONORS

Michael & Kate Bárány Young Investigator Award, Biophysical Society, 2010; NIH Director's Pioneer Award, 2007; Best Methods Paper, American Society of Biomechanics, 2007; Member of The Brilliant 10, Top ten brilliant scientists under age 40, 2007 Popular Science; W.H. Coulter Translational Partner Funding Award, 2006; Terman Fellow, Stanford Univ, 2006; Beckman Translational Research Program Award, 2005; David & Lucille Packard Fellowship in Science & Engineering, 2005; Presidential Early Career Award in Science & Engineering, awarded at White House 6/13/2005; Alfred P. Sloan Research Fellowship, 2005; Klingenstein Fellowship in the Neurosciences, 2004; Young Investigator Award, Beckman Foundation, 2004; Young Investigator Award, Office of Naval Research, Cognitive & Neural Division, 2004; World's Top 100 Innovators under age 35, Technology Review Magazine, 2003; Cutting Edge Basic Research Award (CEBRA), National Institutes of Health, 2003; Young Investigator Award, Human Frontier Science Program, 2002; McKnight Technological Innovations in Neuroscience Award, 2000; Burroughs Wellcome Fellowship, Program in Mathematics and Molecular Biology, 1998-1999; Charlotte Elizabeth Procter Honorific Fellowship, Princeton University, 1997-1998; American Heart Association Predoctoral Fellow, 1996-1998; NSF Predoctoral Fellow, 1993-1996; Winston Churchill Fellowship, 1992-1993; Barry Goldwater Fellowship for Excellence in Science, 1990; United States Physics Team, International Physics Olympiad, 1988.

FIVE RECENT RELEVANT PUBLICATIONS

Mukamel, E.A., Nimmerjahn, A., and Schnitzer, M.J. (2009). "Automated cell sorting for large-scale calcium-imaging studies", **Neuron**, *in press.*

Wilt, B.A., Burns, L.D., Ho, E.T.W., Ghosh, K.K., Mukamel, E.A., and Schnitzer, M.J. (2009). "Advances in Light Microscopy for Neuroscience". **Ann Rev of Neuroscience,** 32:435-506.

Barretto RPJ, Messerschmidt B, Schnitzer MJ. (2009) "*In vivo* fluorescence imaging with high-resolution microlenses". **Nature Methods**. Advance online publication: 14 June 2009.

Flusberg BA, Nimmerjahn A, Cocker ED, Mukamel EA, Barretto RP, Ko TH, Burns LD, Jung JC, Schnitzer MJ. (2008) "High-speed, miniaturized fluorescence microscopy in freely moving mice". **Nature Methods**. 5(11):935-8.

Llewellyn ME, Barretto RPJ, Delp SL & Schnitzer MJ. (2008) Minimally invasive high-speed imaging of sarcomere contractile dynamics in mice and humans. **Nature**. 454: 784-788.

JEFF CHI-TAT LAW
Postdoctoral Fellow, Department of Biology, Stanford University.
Phone: (650) 725-4097; Email: lawj@stanford.edu

DEGREES

B.Eng. 2003	Department of Electrical Engineering, Hong Kong University of Science and Technology, Hong Kong, China
2008	Computational Neuroscience: Vision Course, Cold Spring Harbor Laboratory, New York, USA
Ph.D. 2009	Department of Neuroscience, University of Pennsylvania, Pennsylvania, USA. Ph.D. Advisor: Dr. Joshua Gold

PROFESSIONAL POSITIONS

2010- present	Postdoctoral Fellow, Department of Biology, Stanford University, California, USA

TEACHING EXPERIENCE:

2006	Teaching Assistant, Cellular Neurobiology, University of Pennsylvania

AWARDS AND FELLOWSHIPS:

2000-2003	Dean’s List
2000-2001	Chiap Hua Cheng's Foundation Scholarship
2000-2001	Hong Kong & Kowloon Electrical Appliances Merchants Association Scholarship
2000-2001	MTR Tertiary Scholarship
2001-2002	MTR Tertiary Scholarship
2002-2003	HKTIIT Scholarship
2010	Saul Winegrad Award for Outstanding Dissertation

INVITED PRESENTATIONS:

2008	The Swartz Initiative in Theoretical Neuroscience at Yale Seminar Series: Mechanisms of learning a visual discrimination task.

PUBLICATIONS

Law, C.T. & Gold, J.I. Neural correlates of perceptual learning in a sensory-motor, but not a sensory, cortical area. Nat Neurosci 11, 505-513 (2008).

Gold, J.I., Law, C.T., Connolly, P., & Bennur, S. The relative influences of priors and sensory evidence on an oculomotor decision variable during perceptual learning. J Neurophysiol 100, 2653-2668 (2008).

Law, C.T., & Gold J.I. A reinforcement learning rule can account for both the associative and perceptual learning on a visual discrimination task. Nat Neurosci 12(5), 655-63 (2009).

Law, C.T., & Gold J.I. Shared mechanisms of perceptual learning and decision making. Topics in Cognitive Science 2009 Aug 10 [Epub ahead of print]

Gold JI, Law CT, Connolly P, Bennur S. Relationships between the threshold and slope of psychometric and neurometric functions during perceptual learning: implications for neuronal pooling. J Neurophysiol. 2010 Jan; 103(1):140-54

Budget Justification

A. Senior Personnel

Dr. David Laidlaw is requesting support for 2 months per year of the project. As the PI, he will be responsible for overall management of the multidisciplinary research. His 20 years of experience with interdisciplinary research and his numerous successful collaborations will help to ensure the success of this project. Relevant experience includes a computer science Ph.D. from Caltech, three years of postdoctoral experience in a developmental neurobiology research laboratory, and 10 years as a faculty member in computer science at Brown.

Dr. Steven Sloman is requesting support for 1 month per year of the project. His role will be as a primary source of cognition modeling knowledge and as a user and tester of the software in his own research. Dr. Sloman has a Ph.D. in cognitive science and has been at Brown is a faculty member for many years. He is an active and recognized expert in the areas he will be supporting in the proposed research.

Dr. David Badre is requesting support for 1 month per year of the project. His research involves studying connections within the brain, and he will be one of our early test users. Together with Dr. Schnitzer from Stanford, he motivated the project through contacting Dr. Laidlaw's research group to explore how best to interpret diffusion MRI in the context of studying communication between brain areas.

Professor Fritz Drury, Rhode Island School of Design Professor and former Chair of Department of Illustration will provide consulting advice on visual and interaction design. He and Dr. Laidlaw have taught a class on Virtual-Reality Design for Science several times as well as working together on a number of utilization research projects. This established collaboration has helped the scientific visualization research of Dr. Laidlaw's group on a number of projects. Professor Drury is funded as a consultant (see Section F. Other Direct Costs).

B. Other Personnel

Postdoctoral Fellow: Dr. Laidlaw is requesting full time support for Postdoctoral Fellow Caroline Ziemkiewicz for each year of the project. Her cognitive modeling experience in the context of computer science will make her an ideal assistant on this project. She will assist Dr. Laidlaw in day-to-day management of the project, in particular coordinating among the sites. Dr. Ziemkiewicz will also be responsible for coordinating affiliation activities once S2 I2 institutes are in place.

Bradley Berg, Senior Software Engineer. Dr. Laidlaw is requesting 25% time support for Mr. Berg. Mr. Berg is an expert software engineer, and has been providing support to a number of Dr. Laidlaw's projects for the last 18 months. He has helped to develop a source control and build system for Dr. Laidlaw's research group, and has deployed an upcoming virtual-reality library to Source Forge, an open source software repository. Mr. Berg will also be responsible for creating and running regular tests to ensure that the software is reliable, and for providing installation and infrastructure support for external users. He will also ensure that the software works across platforms and across operating system versions.

Graduate Students: support is requested for 4 to be named graduate students for each year of the project. Two graduate students will work 100% time in Computer Science with Dr. Laidlaw. Two graduate students will work in Cognitive & Linguistic Sciences; one will work 100% for Dr. Sloman and the second 50% for Dr. Badre. The graduate students in computer science will develop the primary software as well as run user experiments to test the efficacy, functionality, and usability of the software. They will also implement the cognition modeling algorithms and evaluate their applicability. The graduate students in cognitive and linguistic sciences will help to provide input on cognitive modeling, together with their faculty advisors, and will supervise and run cognitive tests helping to evaluate the underlying cognitive models. They will also use the software themselves to support their research and to provide feedback on its efficacy. Please note salary support is for stipend only; graduate tuition is included in budget section G.6. Other Direct Costs - Other.

Undergraduate Students: support is requested for three full time undergraduate students each year. One will work in Computer Science with Dr. Laidlaw; the other two will work in Cognitive & Linguistic Sciences (one with Dr. Sloman and one with Dr. Badre). The undergraduate working with Dr. Laidlaw will be responsible for assisting Ph.D. students in developing software. He or she will also assist with the process of affiliating with future S2 I2 institutes. Dr. Laidlaw's lab has a history of including undergraduates in research like this, and many of them have been drawn into the field and gone on to top Ph.D. programs and research careers. The undergraduates working with Dr. Sloman and Dr. Badre will primarily help to run user studies.

C. Fringe Benefits

Fringe Benefits are budgeted at Brown's approved rates which are 30.5% for faculty, post-doctoral, and staff salaries, and 8% for student summer salaries through 30 June 2011. Effective 1 July 2011, the rates are 31.7% for faculty, post-doctoral, and staff salaries, and 8.3% for student summer salaries

D. Equipment

Equipment: funding is requested to acquire a pupil tracking device. Pupil tracking is one of the most accurate indicators of human attention, and tracking it will help to evaluate our cognitive models.

E. Travel

Proposed funding is for attending the annual meeting, visiting research collaborators at Stanford and the future S2I2 institutes, and for attending scientific conferences.

F. Other Direct Costs

Materials and Supplies: $2,500 is requested in the first year for a computer to run experiments.

Consultant Services: Professor Fritz Drury (see additional description in Section A. Senior Personnel).

Computing costs: Brown's Computer Science Department supports the computational needs of this research via the Computing line item on the budget. The department's technical staff acquires and supports high-end graphics workstations for each student, the PI, and within shared lab space. Support includes software installation and maintenance, network access, file backup and restoration, and printing. The amount proposed for each year is calculated at 6.74% of costs projected for the project excluding graduate tuition.

Other: Included on the G.6. Other Direct Costs - Other line is $2,000 each year for experimental participant pay plus Graduate Tuition. Tuition is in the following amounts: $38,836 Year 1; $40,743 Year 2; $42,744 Year 3; $44,844 Year 4; $47,048 Year 5.

G. Indirect Costs

Brown's approved indirect cost rate is used here: 62% MTDC. This rate was approved for Brown University by the U.S. Department of Health and Human Services on January 25, 2010.

Budget Justification

A. Senior Personnel
Prof. Mark J. Schnitzer, PI, 1% (0.12 calendar months) effort
Prof. Mark Schnitzer of Stanford's Departments of Biology and of Applied Physics is a recognized expert in the innovation and application of optical techniques for *in vivo* brain imaging. He has invented two forms of fluorescence microendoscopy for imaging cells lying deep within tissue beyond the optical penetration depth of conventional light microscopy. Based on his initial work, microendoscopy is currently being applied in basic neuroscience research and for minimally invasive imaging in human patients. Schnitzer's core interests now center on using microendoscopy to study neural circuits deep within the living brains of live mice. Prof. Schnitzer will oversee and set priorities for all experimental work and will be responsible for all data interpretation and analysis. He will also be responsible for disseminating our results in a clear and timely fashion through publications and meeting presentations. No funds are requested for salary, which is covered entirely by Schnitzer's employment as an HHMI Investigator.

B. Other Personnel
Jeff Chi-Tat Law*, Postdoctoral Fellow, 50% effort (12 calendar months)*
Dr. Schnitzer is requesting 50% support for postdoc Jeff Chi-Tat Law. Dr. Law has extensive expertise in neural circuits involved in forming perceptual decisions, the underlying computations and how these computations are shaped by experience.. His Ph.D. research in the laboratory of Prof. Gold at the University of Pennsylvania focused on perceptual learning in sensory-motor areas of monkeys. He also is a graduate of the Computational Neuroscience: Vision Course at Cold Spring Harbor Laboratory. As a postdoctoral fellow, Dr. Law is applying his expertise to study modulation of sensory processing using imaging technology created in the Schnitzer group. Dr. Law's research will benefit greatly from the use of tools created in this grant.

C. Fringe Benefits
This budget was constructed for the period 1/01/2011 to 12/31/15. All effort and expenses charged to this project will be for services specific to the project and not for the general support of the academic activities of the faculty or department. Per our negotiated rate agreement with the Office of Naval Research (ONR) on 10/23/2009, the fringe benefit rates are 30.6% for faculty and staff, 21.6% for postdoctoral affiliates, 5% for graduate students, and 8.5% for temporary/casual personnel. The budgeted salary amount for staff includes 8.6% vacation accrual/disability sick leave (DSL) for exempt employees and 7.2% for non-exempt employees. This amount does not exceed total salary. The vacation accrual/DSL rates will be charged at the time of the salary expenditure. No salary will be charged to the award when the employee is on vacation, disability or worker's compensation.

D. Travel
Proposed funding is for attending the annual meeting, visiting research collaborators at Stanford and the future S2I2 institutes, and for attending scientific conferences.

E. Other Direct Costs
Materials and Supplies: $4,000 is requested for each year to cover the costs of wet lab, histological, animal, and optical supplies needed to test the utility and validate the brain visualization approach being created in this grant.

Animals: $3000 is requested for each year to cover costs of animal (mouse) care.

Animal per diem charges at Stanford University reflect the implementation of OMB Circular A-21 and represents full recovery of direct costs of specialized service facilities. The proposed agreement on indirect costs between the Office of Naval Research and Stanford University specifies that animal care charges and services carry a separate indirect cost rate which is excluded from, and does not duplicate, Stanford University's Modified Total Direct Cost (MTDC).

F. Indirect Costs
Stanford University's current Facilities & Administrative Costs rate negotiated on 10/10/2008 with the Office of Naval Research (ONR) is 60%. This rate will be charged to the modified total direct costs base, which excludes the salaries of undergraduate students, subcontracts in excess of $25,000, tuition, and equipment costing more than $5,000 with a useful life in excess of one year.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Laidlaw

Other agencies (including NSF) to which this proposal has

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits
Source of Support: NSF
Total Award Amount: $ 3,367,185 Total Award Period Covered: 01/01/11 – 12/31/15
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: 2.00 Acad: Sumr:0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: IIS:SMALL: Collaborative Research: Supporting BioFlow Knowledge Discovery through A 3D Scientific Visualization Language
Source of Support: NSF
Total Award Amount: $261,596 Total Award Period Covered: 11/01/10 – 10/31/13
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: 0.00 Acad: 0.00 Sumr: .25

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title Functional Kinematics, Morphology and Osteoarthritis of the Thumb CMC Joint
Source of Support: NIH
Total Award Amount: $ 727,877 Total Award Period Covered: 04/01/10 – 03/31/14
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: .08 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: : Neuropathogenesis of clade C HIV in South Africa
Source of Support: NIH
Total Award Amount: $ 555,255.00 Total Award Period Covered: 04/01/09 - 03/31/14
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: .08 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: MRI: Development of a Next-Generation Interactive Virtual-Reality Display Environment for Science
Source of Support: NSF
Total Award Amount: $ 1,999,983.00 Total Award Period Covered: 09/01/09 – 08/31/13
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: 1.00 Acad 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: ImmGen: a gene expression compendium for immune cells
Source of Support: NIH
Total Award Amount: $142,564 Total Award Period Covered: 09/18/07 - 08/31/11
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: 0.10 Acad: 0.00 Sumr: 0.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Laidlaw | Other agencies (including NSF) to which this proposal has

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: 3D multiarticular models of the carpus

Source of Support: NIH

Total Award Amount: $684,982 Total Award Period Covered: 12/01/05 - 11/30/010

Location of Project: Brown University

Person-Months Per Year Committed to the Cal: 1.5 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Age Effects on HIV associated Brain Dysfunction

Source of Support: NIDA/Butler Hospital

Total Award Amount: $144,135 Total Award Period Covered: 09/30/06 - 08/31/11

Location of Project: Brown University

Person-Months Per Year Committed to the Cal: .5 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: IDBR: Hardware and Software Development for 3D Visualization of Rapid Skeletal Motion in Vertebrate Animals

Source of Support: NSF

Total Award Amount: $ 345,486 Total Award Period Covered: 06/01/06 - 05/31/11

Location of Project: Brown University

Person-Months Per Year Committed to the Cal: 1.0 Acad 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Bat Wing Structure and the Aerodynamic Mechanism of Flapping Flight

Source of Support: NSF

Total Award Amount: $ 279,331 Total Award Period Covered: 09/01/07 – 08/31/10

Location of Project: Brown University

Person-Months Per Year Committed to the Cal: 0.5 Acad: 0.00 Sumr: 0.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

NSF Form 1239 (10/99) USE ADDITIONAL SHEETS ANECESSARY

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Laidlaw	Other agencies (including NSF) to which this proposal has

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: MRI+DTI-based tools for analyzing white matter variation

Source of Support: NIH
Total Award Amount: $ 2,038,936 Total Award Period Covered: 09/23/05 - 07/31/10
Location of Project: Brown University
Person-Months Per Year Committed to the Cal: 1.5 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Badre

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Cognitive control and the functional organization of frontal cortex (R01 NS065046)

Source of Support: NIH/NINDS

Total Award Amount: $1,728,019 Total Award Period Covered: 2/15/2010-1/31/2015

Location of Project: Brown University

Person-Months Per Year Committed to the Project. 4.5 Cal: Acad: 1.5 Sumr: 3

Support: ☐ Current ☐ Pending ☒ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Neural basis of the cognitive control of memory (R01 MH090133R2)

Source of Support: NIH/NIMH

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits

Source of Support: NSF

Total Award Amount: $3,367,185 Total Award Period Covered: 1/1/11-12/31/15

Location of Project: Brown University

Person-Months Per Year Committed to the Project. 1.00 Cal: Acad: Sumr: 1.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Steven Sloman

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits

Source of Support: NSF

Total Award Amount: $ 3,367,185 Total Award Period Covered: 01/01/11 - 12/31/15

Location of Project: Brown University

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Designing Consumer Products to Cue Causal Reasoning

Source of Support: Unilever Corporation

Total Award Amount: $ 202,000 Total Award Period Covered: 07/01/10 - 06/30/11

Location of Project: Brown University

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.50

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Schnitzer Other Support

CURRENT SUPPORT

Anonymous Foundation (Schnitzer)	08/01/2007 – 08/31/2010	0.09 Academic
Massively Parallel Brain Imaging	$142,000 current direct costs	0 Summer

This grant helped initiate pilot studies regarding fly brain imaging.

DP1-OD003560-01 (Schnitzer)	09/30/2007 – 07/31/2012	3.42 Academic
NIH Pioneer Award	$500,000 annual direct costs	2.7 Summer
Massively Parallel Brain Imaging		

This project is allowing us to create laser-scanning fluorescence microscopy instrumentation for simultaneous imaging of the brain volumes of ~100 alert flies.

W.M. Keck Foundation (Schnitzer)	01/2008–12/2012	0.09 Academic
Massively Parallel Brain Imaging	$260,000	0 Summer

This project supports our research to create new technologies for imaging Drosophila fly brains.

6822161-01 (Schnitzer)	09/30/08 – 9/29/10	0.09 academic
University of California, Berkeley	$25,000 current direct costs	

Prime Award: 1 PN2 EY018241-01 (Isacoff), NEI/NIH
NDC for the Optical Control of Biological Function

This project concerns the integration of photonic control techniques with microendoscopy imaging.

OPP1015449 (Schnitzer)	5/1/10 – 3/30/11	0.12 Calendar
Bill and Melinda Gates Foundation	$100,000	

Mass-Producible Microscopes for Low-Cost Diagnosis of TB.

This grant supports our effort to build mass producible low cost microscopes for medical use.

CBET-0967257 (Schnitzer)	4/15/10 – 3/31/13	3.0 Calendar
National Science Foundation	$116,945 annual direct costs	

Chip-Scale Ultrashort Pulsed Lasers for Two-Photon Fluorescent Imaging and Sensing

This project supports our research investigating the use of chip-scale ultrashort pulsed lasers in two photon imaging.

PENDING SUPPORT

NSF 10-551 - Software Infrastructure for Sustained Innovation

Prime: Brown University (Laidlaw)	1/1/11 – 12/31/15	0.09 Academic
National Science Foundation	$192,030 total direct costs	

SI2-SSI: Collaborative Research: Cognition-aware Visual Analytics of Brain Circuits

Brown University – General Resources in the Department of Computer Science

The Department of Computer Science provides leading-edge computing technology to all its faculty and students. We have over 500 desktop systems running Linux or Windows Vista. Most of these are custom-built machines configured and assembled by the department's technical staff. Components include dual- or quad-core processors with 2GB or 4GB of memory and dual 19" or single 24" flat-panel monitors. These systems are connected to the department's 1Gb/s switched Ethernet network with access to both Internet1 and Internet2 via the University's fiber-optic backbone. An 802.11g (54Mb/s) wireless network is accessible throughout the department.

The department has two electronic classrooms. One, a banked auditorium, holds seventy-three systems running Linux. This room serves as the primary computer facility for undergraduate computer science students. The other contains twenty-two systems running Microsoft Windows. The layout of this space makes it an ideal room for sections, seminars, and interactive learning. Six research labs further enrich the environment with specialized hardware and advanced workstations from a variety of vendors.

Desktop and research systems are supported by a data center with fully redundant servers that offer a wide range of services. Central file storage is provided by a clustered pair of Network Appliance filers hosting 21TB of RAID-6 disks and an array of Linux servers hosting nearly 27TB of RAID-5 disks. Computational servers in a Sun Grid Engine cluster, all running Linux, include 65 dual-processor, dual-core machines each with 8GB of memory, 16 dual quad-core systems with 24GB each, and a range of more powerful systems offering eight to 24 cores each, and 16 to 96GB of memory, for a total of 108 machines with 484 cores in all. Additional compute cycles are available to the user community through a distributed processing system that allows batch jobs to make use of spare processor cycles on departmental desktop systems.

All research will be done in the Schnitzer laboratories at Stanford. Please find below a summary of the pertinent facilities and resources available to us.

Schnitzer Laboratory:

Laboratory: The Schnitzer laboratory resides at Stanford in the James H. Clark Center for Biomedical Engineering and Sciences. This building is on the campus of the School of Medicine but has a university wide affiliation, as part of Stanford's Bio-X program. We have five lab rooms that exclusively support *in vivo* microscopy (about 1200 sq ft), plus several other lab rooms shared with two other PIs. Of the first five rooms, four are "Imaging rooms". Each of these 4 rooms has a small animal surgery setup plus a large air-table (*e.g.* 12' x 4') on which we construct our custom microscopes. Each of these rooms is acoustically insulated, has multiple electrical circuits, remote-control DC lighting, HEPA filters, minimal air currents, a clean electrical ground for electrophysiology, a metal sink, and is temperature regulated to within 1 deg C. A common lab gas closet supplies to each imaging room 'house' oxygen to for use during surgeries, and house nitrogen for purging the cavities of our Ti:sapphire lasers. Each of these 4 rooms has an exhaust to vent gaseous anesthesia, and a thermally isolated closet for holding laser cooling systems and preventing the heat generated from entering the main room. Our fifth room is a Bio-Safety Level 2 animal prep & surgery room where we have a laminar flow hood for injections of viral vectors into animals. We will also have cell culture facilities here for growing virus.

In addition to these rooms we have 9 bays of standard wet lab space for preparation of solutions, basic chemistry, *etc*. I also have an 8' x 4' air-table in the wet lab for general use stereoscopes and fluorescence microscopes. This is within a common wet lab area shared with two other PIs. In this area for general use there is a fume hood, cold room, centrifuges, vortexers, histology facilities, to which we have shared access. A spectrophotometer and spectrofluorimeter are on order and will have arrived by the time you read this.

Clinical: NA.

Animal: In addition to our own 5 small animal surgery setups within the imaging rooms and animal prep room, there are additional small animal surgery rooms nearby on our floor to which we have access. Down the hall there are regular and BioSafety Level 2 animal holding rooms, which house our mouse colonies. Additional holding rooms are accessible by tunnel in the Stanford University Research Animal Facility, so there is abundant convenient housing nearby for our rats and mice. Technical staff in Stanford's Veterinary Service Center service all the animal holding facilities. Veterinarians are on call 24 hrs a day.

Computer: Each lab member has a wireless-capable laptop computer for data analysis, lab notes, and composition. Each imaging rig has at least one desktop computer for image acquisition, and some have a second computer for acquisition of physiology data. Certain instruments in the lab also have dedicated computers. This includes two spectrometers in the imaging rooms and utility fluorescence microscopes. Our rack-mounted Xserve file server performs nightly back-ups of our lab notes, image and movie data, purchase records, libraries, and other computer files. An application server runs computationally intensive programs for numerical or image analysis and is used with a 23" flat screen to produce movies of our image data. We have ethernet connections in every room and the entire Clark center has wireless connectivity.

Office: The PI has his own office of about 220 sq ft adjacent to the lab. The admin. assistant has her own large cubicle. Each other lab member has his or her own office cubicle adjacent to the lab area. There are color and black & white printers, photocopies, and fax for general use. Additionally, there are "Quiet rooms" around the Clark Center for performing deskwork without interruption.

Other: An electronics shop and machine shop are located down the hall. We also have a shared room in the lab with an electronics bench (oscilloscopes, breadboards, soldering irons, voltmeters) and workbench (lathe, drill-press, dremel, large vice). Staffed machine shops with experienced machinists are in adjacent buildings. Stanford also has several electron microscopy facilities, each equipped with TEM and SEM instruments and run by technical staff, which will be available to us for confirming anatomical features of neuronal tissue.

MAJOR EQUIPMENT: **Instrumentation pertinent to the present grant application is listed below.**

- 6 Ti:sapphire lasers for producing ultra-short pulses for 2-photon excitation - one in each Imaging room.
- 8 air-tables: 6 Newport (1 2' x 4', 12' x 4', 9' x 4', 8' x 4'); 2 TMC (8' x 4').
- 6 sets of major optical components for our custom imaging rigs. These components include trinoculars, eyepieces, fine focus drives, scan lenses, tube lenses, Hg arc lamps (Zeiss, Nikon, Olympus).
- 20 microscope objectives lenses (Zeiss, Olympus, Nikon, Leica).
- 1 upright and 1 inverted fluorescence microscope, each with a variety of objectives, in shared wet lab space
- 1 vibratome for histology, in shared wet lab space (Series 1000, Technical Products).
- 10 oscilloscopes, in the Imaging rooms (Tektronix, Hameg, LeCroy).
- 12 low noise pre-amplifiers with high- and low-pass filters (SRS, Cygnus, Krohn-Hite).
- 4 spectrometers, in two of the imaging rooms, for determination of laser mode-locking (Ocean Optics).
- 3 autocorrelators, for determination of ultra-short pulse widths (APE Gmbh)
- 4 video monitors (3 monochrome CRT, 1 flatscreen, Sony).
- 8 analog CCD (XC-ST70, Sony) and 8 CMOS cameras (Prosilica) for general-purpose videomicroscopy.
- 1 programmable micro-pump, for microfluidic injections (WPI).
- 8 Multi-channel data acquisition cards (5 Mhz, National Instruments) for laser-scanning imaging
- 4 laser shutters (Uniblitz) for shuttering fluorescence excitation
- 5 small animal stereotaxis devices for brain surgeries and precision injections (Kopf, Stoelting, Cartesian Research, custom-made) – distributed among the surgery setups
- 12 micromanipulators, distributed through the Imaging labs, for controlling electrophysiological probes (Sutter).
- 1 microelectrode puller, in the wet labs, for making micropipettes for viral injection or electrical recordings (Sutter P-2000)
- 1 upright microelectrode puller, in the wet labs, for pulling lower impedance glass

electrodes (Kopf).

- 1 electrode beveller, in the wet labs, for preparing micropipettes (Sutter)
- 1 upright and 1 inverted fluorescence microscope, each with a variety of objectives, in shared wet lab space
- 1 vibratome for histology, in shared wet lab space (Series 1000, Technical Products).
- 1 biosafety cabinet, in the animal preparation room, for viral injections (Baxter).

Equipment items available for this project are provided at no direct cost to the sponsor.

MENTORING PLAN FOR POSTDOCTORAL RESEARCHER JEFF LAW

Postdoc Dr. Jeff Law will be involved in the proposed research at a level of 50% effort. Jeff has ~0.5 years of postdoctoral experience in the Stanford group; the mentoring he will receive will be tailored to that of an talented postdoc preparing to enter the US academic job market in the next 2-3 years. Here we describe the mentoring program we have followed to date and will continue to follow towards fostering Jeff's scientific development:

Interdisciplinary Collaboration. Jeff is involved in collaborations with researchers and now laboratories outside his areas of expertise. Overall, our lab's work is heavily interdisciplinary, and so at lab meetings Jeff has key opportunities to present his work to a diverse audience and receive feedback from Professor Schnitzer.

Training in Grant Preparation. Prof. Schnitzer likes to involve each postdoc in the lab in the writing of a grant. This is a good way to convey basic skills in grantsmanship. To support the 50% of Jeff's effort not covered by the present proposal, we plan to write another grant and Jeff will be a major participant in the preparation.

Guidance on Improving Mentoring and Presentation Skills. As a Ph.D. student, Jeff has had opportunities to work closely with junior graduate students. Now as a postdoc, Jeff will be able to participate in the mentoring of one graduate student in the Schnitzer lab. Jeff is also encouraged to gain formal teaching opportunities here at Stanford. As Jeff's postdoctoral work progresses, he will also be encouraged to make presentations at suitable scientific conferences. Additionally, on occasions when Prof. Schnitzer must decline a symposium invitation, he generally sends a postdoc representative from the lab. Jeff is very likely to receive such opportunities for giving major talks, in addition to more standard slide format conference presentations.

Career Counseling and Guidance. Stanford has a regular series of seminars for educating postdocs regarding how to become a Principal Investigator and how to run a scientific laboratory, manage personnel, and write grants, as well as issues in scientific ethics. We encourage Jeff to attend all of these seminars and he does so regularly. In addition to the regular seminars that include ethics, Prof. Schnitzer has occasional discussions with lab members about ethical thinking driven by scientists' core values. This pertains to commonplace issues of authorship, data interpretation, mentoring, control experiments, professional responsibilities, etc. Jeff also has regular meetings with Professor Schnitzer to review both progress on research and towards career goals. Knowing that Jeff is interested in academe, e.g. rather than industry, helps enormously in guiding his steps and providing career advice.

MENTORING PLAN FOR POSTDOCTORAL RESEARCHER CAROLINE ZIEMKIEWICZ

Dr. Caroline Ziemkiewicz will also be involved in the proposed research as part of the Brown group for an expected appointment of two years. Our mentoring plan is designed to aid Dr. Ziemkiewicz in her development of her own long-term research and professional goals and transition her into an independent researcher.

Interdisciplinary Collaboration. Caroline will work closely with students and faculty in our group to pursue a research agenda that branches human-computer interaction, computer science, and cognitive modeling. This research will include regular collaboration with cognitive scientists and scientific domain experts.

Publication and Training in Grant Preparation. Caroline will receive assistance in the process of writing and publishing these results in reputable journals and conferences. She will be involved in preparing further proposals, as a Co-PI or a PI, to garner funding to support work on the project, and we will jointly determine how to appropriately share any resulting awards after her departure.

Career Counseling and Guidance. Dr. Laidlaw will be available to meet with Caroline weekly throughout the period of the mentorship, focusing on her evolving career and research goals. Initially, we will work to define these goals; subsequently we will evaluate whether she is on an appropriate trajectory to reach them. This teleological approach to mentoring naturally supports technical advising on the research itself while preserving the higher-level goals of both the mentee and mentor.

Guidance on Improving Teaching and Presentation Skills. Caroline will participate in the teaching of several relevant classes taught by Dr. Laidlaw, including a course titled "Virtual Reality Design for Science," which is offered jointly with the Rhode Island School of Design and will provide a unique opportunity to learn how to teach in an interdisciplinary environment. She will also lead group discussions in research meetings and will have the opportunity to teach her own computer science course at Brown.

LETTER OF INTENT (LOI) TO THE NATIONAL SCIENCE FOUNDATION

LOI ID	LOI SUBMITED DATE	LOI DUE DATE	PROGRAM SOLICITATION ID
L02169459	**N/A**	**05/10/2010**	**NSF 10-551**

PROGRAM SOLICITATION TITLE

Software Infrastructure for Sustained Innovation

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S)

PRIMARY ORGANIZATION: **Office of CyberInfrastructure**

PROJECT INFORMATION

PROJECT TITLE

SI2-SSI: Cognition-aware Visual Analytics of Brain Circuits

SYNOPSIS

We propose to develop, test, and deploy software tools for scientific study of brain circuits. The driving scientific application for our research is the study of the human brain. Major advances in our understanding of how brains work have occurred in recent decades, yet much remains unknown. Network models of the brain are natural because they often reflect both the behavior and the anatomy of the brain. The target user community is brain scientists studying architecture and function of the human brain. Three of the team are members of this community.

The aim is to use principles of cognition and perception to shape the software tools and then experimental techniques to evaluate the tools' effectiveness. The tools we propose will help brain researchers pose and test hypotheses about networks using input from multiple sources. These sources will include databases of published results about networks, data from their own experiments, and the scientists' hypotheses and working assumptions. Experimental data will include 3D imaging data from functional and diffusion MRI as well as light microscopy.

The software we propose will support the reasoning process by gathering and managing data about networks and connections; providing interactive mechanisms for visually selecting and analyzing portions of the data; and explicitly capturing, recording, and documenting users' scientific reasoning.

While we are targeting this work at brain scientists the research results will be have a broader impact in a number of other domains. In particular, protein signaling, gene regulation, and even crime analysis all involve reasoning about networks using multi-source data.

OTHER COMMENTS

PI/Co-PI TEAM:

David Laidlaw, Dept of Computer Science, Brown University

expertise: scientific visualization, perception, visual design, scientific toolsmithing, interdisciplinary research, mathematics, software engineering, human-computer interaction

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Steven Sloman, Dept of Cognitive and Linguistic Sciences, Brown University

expertise: human reasoning, causal cognitive models, judgment and decision making, computational modeling of cognition, experimental design and analysis, cognitive and neural circuits supporting reasoning and decision making.

David Badre, Dept of Cognitive and Linguistic Sciences, Brown University

expertise: human brain anatomy and architecture, memory theory, cognitive neuroscience of memory and executive function, neuroimaging, human brain anatomy, macaque brain anatomy and architecture

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Mark Schnitzer, Howard Hughes Medical Institute, Depts of Biology and Applied Physics, Stanford University

expertise: neural circuits, optical imaging of neural activity in live and behaving animals, new technology for brain imaging

ORGANIZATION ATTRIBUTE

N/A

POINT OF CONTACT FOR NSF INQUIRIES

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DEPARTMENT: **Computer Science Department**

PROJECT PI INFORMATION

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ORGANIZATION: **Brown University**

SUBMITTER INFORMATION

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TELEPHONE NUMBER: **N/A**

EMAIL ADDRESS: **N/A**

ORGANIZATION: **N/A**

DEPARTMENT: **N/A**

PROJECT SENIOR PERSONNEL

Laidlaw, David, Brown University
Badre, David, Brown University
Sloman, Steven, Brown University
Drury, Fritz, Rhode Island School of Design
Ziemkiewicz, Caroline, Brown University (as of Fall 2010; currently at UNC Charlotte)
Schnitzer, Mark, Stanford University
Law, Jeff, Stanford University

Management and Coordination Plan

The group of researchers who will work on this project is not large. Because of that, a fairly simple management plan is appropriate. In essence, the PI with the assistance of the postdoctoral scholar at Brown will coordinate and manage all of the research efforts. The PI has managed a number of projects of similar scope in the past and found this to be an effective set of mechanisms
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1) Specific Roles

Dr. David Laidlaw, the PI, will be responsible for the overall performance of this research. He will lead the development of the software as well is the cognition modeling process that will be used as an integral part of the design process. He will coordinate among the leaves in each of the other laboratories and with Professor Fritz Drury, the Rhode Island school of design consultant. He will also directly manage the two graduate students, the postdoctoral scholar, an undergraduate research assistant, and a software engineer in his lab.

Postdoctoral scholar Dr. Caroline Ziemkiewicz will devote all of her at effort to this project. She will be particularly involved in the cognitive modeling aspects, but will coordinate among the different labs both Brown and Stanford, will be responsible for affiliation activities as the S2I2 institutes come online, and will mentor the Ph.D. students in the undergraduate. She will also coordinate software development and release efforts in conjunction with the software engineer. Dr. Laidlaw's experience with multidisciplinary projects like this has shown that a postdoctoral scholar is the ideal level of researcher to bridge disciplines in such projects.

Dr. Steven Sloman, together with a Ph.D. student, will advise on cognitive modeling concepts and on their integration into the design process for our software system. He and his group will also utilize the system both as evaluators and as actual end-users. He and his group will be primarily responsible for much of the local user-based testing.

Dr. David Badre, together with a Ph.D. student, will advise on end-user features of the proposed software system. He and his group will also be evaluators as well as end-users of the system. It is expected that he will coordinate with Dr. Sloman in some of the testing efforts.

Dr. Mark Schnitzer, with help from a postdoctoral scholar, will also advise on end-user features, provide input during the requirement gathering phase, provide feedback during the design phase, evaluate prototypes, and use the various versions of the system in his group's research.

Postdoctoral scholar Dr. Jeff Law will assist Dr. Schnitzer in all efforts at Stanford.

Professor Fritz Drury, a faculty member and former chair of the Rhode Island school of design (RISD) Department of illustration, will provide input to the design and interaction process. He will also collaborate in articulating the traditional design process so that the cognitive modeling process of interacting and viewing with diagrams can be effectively informed by the traditional design approaches for creating such diagrams.

2) Management across Labs

The proposed project bridges brain science and computer science, involving three laboratories studying the brain at different scales and one computer science group studying scientific visualization and human computer interaction. The computer science group and two of the brain science groups are members of Brown's Brain Sciences Institute. In addition to providing an organizational structure and exemplars of collaboration, the Institute supports several mechanisms for facilitating collaboration among departments. The PI has also, in other research projects, collaborated successfully with researchers in the same department.

3) Specific Coordination Mechanisms

This project will use a number of mechanisms for coordination and support of collaboration. I'm a day-to-day level, e-mail, video conferencing, and telephone will be our primary means of communication. The PI will maintain a schedule of deliverables which will be developed with the collaborators and which will drive interactions among the groups toward specific measurable milestones with deadlines. These milestones will include design documents, software prototypes, experimental results, research publications, and internal presentations. Concrete deliverables, in the PI's experience, are the most effective way to ensure progress both individually and collectively.

All of the laboratories of Brown are within a five minute walk, and members of the different laboratories routinely attend talks, laboratory meetings, reading groups, and classes across these disciplines. The Stanford researchers will visit Brown if face-to-face interactions become necessary. We will also utilize the annual program meeting at NSF organizes and extended either before or after with an annual meeting of the members of our group. Dr. Ziemkiewicz, the postdoctoral scholar at Brown, will have as a primary goal, successful maintenance of the relationships among the groups.

4) Supporting Budget Items

The primary supporting budget items are personnel salaries. These include most of the costs of the specific coordination mechanisms listed above. Travel is also a supporting budget item, although it is not much higher than it would otherwise be because of the already organized annual NSF meetings. The non-personnel costs of e-mail, video conferencing, and telephone are captured in indirect costs.

Fritz Drury

a. Professional Preparation

BA 1977 Stanford University
MFA 1981 Yale University School of Art

b. Appointments

Rhode Island School of Design, Providence RI
Professor of Illustration, June 2003-present
Department Head, Illustration 2000-2003
Associate Professor of Illustration and Foundation Studies, 1997-2003.
Adjunct Professor of Illustration and Painting 1981-1997.

c. Publications

Drawing Structure and Vision , textbook on drawing technique and tradition, Fritz Drury and Joanne Stryker, anticipated publication, September 2004, Prentice Hall, Upper Saddle River NJ.
Applying the Lessons of Visual Art to the Study of the Brain: abstract for presentation at Winter Conference on Brain Research, January 2004, with Profs David Laidlaw, David Kremers, Russell Jacobs, Arthur Toga.
Designer-critiqued Comparison Of 2D Vector Visualization Methods: A pilot study. In SIGGRAPH 2003 Sketches and Applications. IEEE, 2003. Cullen Jackson, Daniel Acevedo, David H. Laidlaw, Fritz Drury, Eileen Vote, and Daniel Keefe.
New Paintings, Project Room, The Painting Center, NYC October 2002
177th Annual Invitational, National Academy of Design, NYC May 2002
Solo Show, AAA Gallery, NYC, November 1998.
Review in Art in America July 1999, by Nancy Grimes.
Solo Show, "Bedtime Stories", Nancy Moore Gallery, NYC, May, 1997.
Solo Show, Black and Greenberg Gallery, NYC, April 1995.
Solo Show, "Nature", 55 Mercer Gallery, NYC, October 1993.
Review in Art in America, June 1994, by Eleanor Heartney.

d. Synergistic Activities

January 2004, Presentation at Winter Conference on Brain Research, Natural Media and Artistic Process in Scientific Visualization (within the group presentation: Applying Lessons of Visual Art to the study of the Brain).

March-May 2003- advisor to study by Daniel Acevedo and Colin Jackson on the design Visualization icons in relation to perceptual psychology.

September-December 2002, co-taught Interdisciplinary Scientific Visualization at Brown University with Professor David Laidlaw, studying collaboration between artists and scientists in the design of immersive, interactive scientific visualizations.

January- May 2003-Participant in interdisciplinary discussions between Brown University scientists and artists and designers from Rhode Island School of Design on the feasibility of collaborative work on visualization projects.

e. Collaborators and Other Affiliations

(i) Collaborators: Professor David Laidlaw, Department of Computer Science, Brown University, Professor Peter Richardson, Department of Engineering, Brown University, Professor Russell E. Jacobs, California Institute of Technology, Professor Arthur Toga, UCLA School of Medicine, David Kremers, California Institute of Technology, Department of Biology, Artist in Residence, Daniel Keefe, Department of Computer Science, Brown University, Daniel Acevedo, Department of Computer Science, Brown University, Cullen Jackson, Department of Computer Science, Brown University

(ii) Graduate Advisors: Professor William Bailey (emeritus) Yale School of Art, Professor Bernard Chaet (emeritus) Yale School of Art

COLLABORATORS/INDIVIDUALS WITH CONFLICTS OF INTEREST

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Barbey Aron, NIH
Barr AH, Caltech
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Bes Benedicte, University of Toulouse II, France
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