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:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

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).

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: Benjamin J Raphael

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:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

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).

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: 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 ☒

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:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

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).

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

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COLLABORATORS/INDIVIDUALS WITH CONFLICTS OF INTEREST

Acevedo D, KAUST
Agler Jim, University of California, San Diego
Ahrens ET, CMU
Akelman E, Brown University
Albert Martin, Boston VA/BU
Bafna Vineet (University of California, San Diego)
Ballard, J. William, University of New South Wales
Barbey, Aron, NIH
Barr AH, Caltech
Barredo Jennifer, Brown
Bashir Ali (Pacific Biosciences)
Bellemare-Pelletier, A., Dana-Farber Cancer Institute 450 Brookline Avenue Boston, MA
Benjamin Flusberg, Pacific Biosciences
Bennett J, UCHSC
Bennur, Sharath, University of Pennsylvania
Bes, Benedicte, University of Toulouse II, France
Best, J.A., University of California San Diego, Division of Biological Sciences 9500 Gilman Dr. La Jolla, CA
Bezman, N.A., University of California, San Francisco Department of Microbiology & Immunology 513 Parnassus Avenue, San Francisco
Bogunovic, M., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Boller R, NASA Goddard Space Flight Center
Bonnefon, Jean-Francois, University of Toulouse II, France
Boussy, Ian, Loyola University
Bower, Gordon (Stanford University)
Bowman D, Virginia Polytechnic Institute & State University
Bragdon A, Microsoft
Braun S, NASA Goddard Space Flight Center
Brennan, P., Brigham and Women's Hospital, Rheumatology, Immunology and Allergy 75 Francis Street Boston, MA
Brennan-Krohn T, Providence VA Hospital and Butler Hospital
Brenner, M., Brigham and Women's Hospital, Rheumatology, Immunology and Allergy 75 Francis Street Boston, MA
Breuer KS, Brown University
Brossay L, Brown University
Brown M, UCHSC
Brown, Alice, Mother of 3 boys
Brown, B., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Bryan, Bruce, High School Biology Teacher
Buckner Randy, Harvard University
Butkiewicz Thomas, UNC Charlotte/University of New Hampshire (Co-author)
Butner Scott, Pacific Northwest National Laboratory (Internship mentor)
Cabeen R, Brown University
Cai H, Brown University
Callan-Jones AC, unknown
Cao L, Brown University
Carter Cameron, UC Davis
Chang Remco, UNC Charlotte/Tufts University (Co-author)

Chen J, Southern Mississippi University
Chow, A., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Cipolletta, D., Harvard Medical School Division of Microbiology & Immunobiology 77 Avenue Louis Pasteur Boston, MA
Clark RC, Flinders University (Australia)
Clark, Andrew, Cornell University
Cohen R, Brown University
Cohen, N., Brigham and Women's Hospital, Rheumatology, Immunology and Allergy 75 Francis Street Boston, MA
Collins Colin (Vancouver Prostate Center)
Collins, J., Boston University Department of Biomedical Engineering 44 Cummington Street Boston, MA
Conley J, Brigham and Women's Hospital
Connolly P, University of Pennsylvania
Coop K, Miriam Hospital
Corboy J, UCHSC
Correia S, Providence VA Hospital and Butler Hospital
Costello, J., Boston University Department of Biomedical Engineering 44 Cummington Street Boston, MA
Crisco JJ, Brown University
Curran Kent, UNC Charlotte (Dissertation committee)
D'Esposito Mark, University of California, Berkeley
Darlow, Adam, Brown U
David SP, Brown University
Demiralp C, Brown University
Ding Li (Washington University, St. Louis)
Doedens, A.L., University of California San Diego, Division of Biological Sciences 9500 Gilman Dr. La Jolla, CA
Dou Wenwen, UNC Charlotte (Co-author)
Drury F, Rhode Island School of Design
E. Smith, Edward, (Columbia University)
Elpek, K., Dana-Farber Cancer Institute 450 Brookline Avenue Boston, MA
Eran Mukamel, Harvard
Ernst LA, CMU
Eskin Eleazar (University of California, Los Angeles)
Evans, Jonathan, University of Plymouth, UK
Fabian A, Rowan University
Fernbach, Philip, University of Colorado
Fisher Brian, Simon Fraser University (Collaborator)
Flanigan T, Brown University
Fletcher, A., Dana-Farber Cancer Institute 450 Brookline Avenue Boston, MA
Flight, Patrick, Brown University
Forsberg AS, self-employed
Fox, Craig, University of California, Los Angeles
Frank Michael, Brown
Fraser SE, Caltech
Friedland RP, University of Louisville
Fry, Adam, University of Connecticut
Garrison, B., Immune Disease Institute, Inc. 200 Longwood Avenue Boston, MA
Gautier, E.L., Washington University Department of Pathology & Immunology 660 South Euclid Avenue St. Louis, MO

Gazit, R., Immune Disease Institute, Inc. 200 Longwood Avenue Boston, MA
Gennari, Silvia, University of York, UK
Ghoniem Mohammad, French University of Egypt (Co-author)
Gilchrist, George, College of William and Mary and NSF
Gold, Joshua I., University of Pennsylvania
Goldin, Gideon, Brown U
Goldrath, A., University of California San Diego, Division of Biological Sciences 9500 Gilman Dr. La Jolla, CA
Gomez S., Brown University
Goolkasian Paula, UNC Charlotte (Dissertation committee)
Gordon E, Brain Resource Company
Grant JE, Brown University
Green Tera, Simon Fraser University (Collaborator)
Greter, M., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Grieve SM, Brain Resource Company
Grimm CM, Washington University
Gronchi, Giorgio, University of Florence, Italy
Gunstad J, Brown University
Hadjichristidis, Constantinos, University of Leeds, UK
Hageveld Weiss AP, Brown University
Hagmayer, York, University of GÃ¶ttingen, Germany
Halilaj E, Brown University
Hall M, University College London,
Hamilton, Matthew, Georgetown University
Haney, Robert, Harvard University
Hardy, R.R, Fox Chase Cancer CenterÊ333 Cottman AvenueÊPhiladelphia, PA
Harrison, Richard, Cornell University
Hashimoto, D., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Hedrick TL, UNC Chapel Hill
Hege HC, Zuse Institute Berlin
Helft, J., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Heng, T., Harvard Medical School Division of Microbiology & Immunobiology 77 Avenue Louis Pasteur Boston, MA
Hester R, University of Mississippi
Hill, J., Harvard Medical School Division of Microbiology & Immunobiology 77 Avenue Louis Pasteur Boston, MA
Holmbeck, Marissa, Brown University
Hoth KF, Brown University
Huang J, Brown University
Hubel T, University of London
Huey, Raymond, University of Washington
Hughes JF, Brown University
Hung N, Brown University
Hyun Dong Jeong, University of the District of Columbia (Co-author)
Iriarte-Diaz J, Brown University
Jackson CD, Aptima Inc.
Jakubzick, C., Washington University Department of Pathology & Immunology 660 South Euclid Avenue St. Louis, MO
Jakun-Kelly TJ, James Bagley College of Engineering
Janjic JM, CMU
Jianu R, Brown University

Jianu, R., Brown University Computer Science Department 115 Waterman Street Providence, RI
Jojic, V., Stanford University Computer Science Department 353 Serra Mall Stanford, CA
Ju-Park, Hwa, unaffiliated
Kahn Crystal, (Ab Initio)
Kang, J., University of Massachusetts Medical School 55 Lake Avenue North Worcester, MA
Kann, Lisa, Personal Genome Diagnostics
Karelitz DB, Sandia
Keefe DF, University of Minnesota
Kilpatrick, Steve, University of Pittsburgh
Kim, C.C., University of California, San Francisco Department of Microbiology & Immunology 513 Parnassus Avenue, San Francisco
Kim, F., Joslin Diabetes Center 1 Joslin Place, Boston, MA
Knell, J., University of California San Diego, Division of Biological Sciences 9500 Gilman Dr. La Jolla, CA
Koller, D., Stanford University Computer Science Department 353 Serra Mall Stanford, CA
Kosara Robert, UNC Charlotte (PhD advisor)
Kostandov M, Eureka Aerospace Corporation
Kreslavsky, T., Harvard Medical School Division of Microbiology & Immunobiology 77 Avenue Louis Pasteur Boston, MA
Lagnado, David, University College London
Lagnado, David, University College, London
Laidlaw David, Brown
Laidlaw, D., Brown University Computer Science Department 115 Waterman Street Providence, RI
Lanier, L.L., University of California, San Francisco Department of Microbiology & Immunology 513 Parnassus Avenue, San Francisco
Lawrence Charles (Brown University)
Lawrence J, Butler Hospital and Brown University
Lebrecht Sophie, Brown
Lee SY, Dartmouth Medical School
Lewontin, Richard, Harvard University
Lin JT, Brown University
Liu H, Brown University
Lombrozo, Tania, UC Berkeley
Loriot GB, retired
Lu Aidong, UNC Charlotte (Dissertation committee)
Lucas, Chris, UC Berkeley
Malhotra, D., Dana-Farber Cancer Institute 450 Brookline Avenue Boston, MA
Malloy PF, Butler Hospital and Brown University
Malt, Barbara, Lehigh University
Marai GE, University of Pittsburgh
Mathis, D., Harvard Medical School Division of Microbiology & Immunobiology 77 Avenue Louis Pasteur Boston, MA
Meiklejohn, Colin, University of Rochester
Merad, M., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Miles J, Brown University
Miller DE, UCHSC

Millier, J., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Monach, P., Boston University Department of Medicine 72 East Concord Street, Boston MA
Montooth, Kristi, Indiana University
Moore DC, Brown University
Morel PA, University of Pittsurgh
Mossman, Jim, Brown University
Narayan, K., University of Massachusetts Medical School 55 Lake Avenue North Worcester, MA
Navia B, Brown University
Nguyen V, Brown University
Niaura R, Brown University
O'Brien T, Google
O'Brien Trevor (Google)
Ochsner Kevin, Columbia University
Ombao Hernando, Brown
Over, David, Durham University
Oztekin Ilke, Brown
Palmer, Michael R., Biotech Industry
Paul RH, University of Missouri St Louis
Paxinos, Ellen, Virologix Inc.
Pelcovits RA, Brown University
Pevzner Pavel, (University of California, San Diego)
Pogun S, Ege University (Raphael)
Pollard Nancy, Carnegie Mellon University (Co-author)
Price, J., Mount Sinai Hospital Icahn Medical Institute 1425 Madison Avenue, New York, NY
Rao, T.N., Joslin Diabetes Center 1 Joslin Place, Boston, MA
Raphael B, Brown University
Regev, A., Broad Institute 7 Cambridge Center Cambridge, MA
Ribarsky William, UNC Charlotte (Employer)
Rips, Lance (Northwestern University)
Riskin DK, Brown University
Ritz A, Brown University
Robert Barretto, Columbia Univ
Robinson, Emanuel, Westat Corporation
Rogers, Todd, Harvard University
Rossi, D.J., Immune Disease Institute, Inc. 200 Longwood Avenue Boston, MA
Rumelhart, David (deceased)
Rusu A, Rowan University
Salloway SP, Brown University
Salomon AR, Brown University
Santini, John, Alion Science and Technology
Schmidt, Paul, University of Pennsylvania
Schmidt, Paul, University of Pennsylvania
Schulz SC, University of Minnesota
Shakhnarovich G, Toyota Technological Institute at Chicago
Shakhnarovich Gregory (Toyota Technical Institute)
Sharan Roded (Tel Aviv University)
Shay, T., Broad Institute 7 Cambridge Center Cambridge, MA
Sheridan Margaret, Harvard University

Shinton, S.A., Fox Chase Cancer CenterÊ333 Cottman AvenueÊPhiladelphia, PA
Simon JH, Portland VA Hospital
Sindi Suzanne (University of California, Merced)
Slavin VA, Lockheed Martin
Solomon Marjorie, UC Davis
Srinivas M, CMU
Stebbins G, Brown University
Suma Evan, University of Southern California (Co-author)
Sun, J.C., University of California, San Francisco Department of Microbiology & Immunology 513 Parnassus Avenue, San Francisco
Swartz SM, Brown University
Sweet L, Brown University
Sylvia, K., University of Massachusetts Medical School 55 Lake Avenue North Worcester, MA
Tai, Joanna, unknown
Tashima K, Kochi Medical School
Tate DF, Brigham and Women's Hospital
Taylor G, University of Missouri St. Louis
Taylor LE Miriam Hospital and Brown University
Turkey BJ, Brown University
Turley, S., Dana-Farber Cancer Institute 450 Brookline Avenue Boston, MA
Turner MS, University of Pittsburgh
Tversky, Amos (deceased)
Ulin SP, Brown University
Upfal Eli (Brown University)
Verstynen Tim, Pitt
Villa-Cuesta, Eugenia, Brown University
Voorn T, Hageveld
Wagaman, Rebecca, Brown University
Wagers, A., Joslin Diabetes Center 1 Joslin Place, Boston, MA
Wagner Anthony, Stanford University.
Walsh, Clare, University of Plymouth, UK
Wartell Zachary, UNC Charlotte(Co-author)
Weinreich, Daniel, Brown University
Weiss AP, Brown University
Willis DJ, University of Massachusetts Lowell
Wilson Richard (Washington University, St. Louis)
Wolfe SW, Hospital for Special Surgery
Woodruff, Ron, Bowling Green State University
Yang Jing, UNC Charlotte(Co-author)
Yang, E., University of California San Diego, Division of Biological Sciences 9500 Gilman Dr. La Jolla, CA
Yooseph Shibu (JCVI), Charles Lawrence (Brown University)
Yu K, Brown University
Zhang S, Mississippi State University
Zhou W, Brown University
Zhou, Y., Fox Chase Cancer CenterÊ333 Cottman AvenueÊPhiladelphia, PA
Zhu, Lei, Brown University
Zouros, Eleftherios, University of Crete
van't Wout, Mascha, Brown University

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 11-1

NSF 10-564 **03/10/12**

FOR NSF USE ONLY

NSF PROPOSAL NUMBER

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

CCF - EXPERIMENTAL EXPEDITIONS

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
				001785542	

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

AWARDEE ORGANIZATION CODE (IF KNOWN)

0034017000

ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE

Brown University
BOX 1929
Providence, RI. 029121929

NAME OF PRIMARY PLACE OF PERF

Brown University

ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE

Brown University
115 Waterman Street
Providence ,RI ,029121910 ,US.

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 **Collaborative Research: Cognitive Optimization of Brain-Science Visual-Analysis Tools**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **7,155,897**	**60** months	**07/01/13**	

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 **Benjamin J Raphael**	**DPhil**	**2002**	**401-863-7643**	**Benjamin_Raphael@brown.edu**
CO-PI/PD **Steven A Sloman**	**PhD**	**1990**	**401-863-7595**	**Steven_Sloman@brown.edu**
CO-PI/PD				
CO-PI/PD				

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 11-1). 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 Eva J Faling		03/12/12

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
401-863-1291	Eva_Faling@Brown.edu	

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

Cognitive Optimization of Brain-Science and Genomics Visual-Analysis Tools

David H. Laidlaw (PI), Benjamin Raphael (Co-PI), Caroline Ziemkiewicz, Brown Computer Science;
Steven Sloman (Co-PI), David Badre, Brown Cognitive, Linguistic, and Psychological Sciences;
David Rand, Brown Ecology and Evolutionary Bio.; Christophe Benoist (Co-PI), Harvard Med. School;
Mark Schnitzer (Co-PI), Stanford Bio. Sciences and Appl. Physics and Howard Hughes Medical Institute;
Jeff Chi-Tat Law, Stanford Bio. Sciences; Fritz Drury, Rhode Island School of Design

We propose a research agenda blending cognitive science, neuroscience, genomics, and human-computer interaction to study and improve interactive tools for facilitating scientific analysis. We believe knowledge of human cognition is now at a level where it can inform the design of interactive computer tools. We will develop a set of driving software applications for brain scientists to reason about connections within the brain and for genomics researchers to reason about relationships among gene sequence and expression across cell types, across individuals, and across environments. These applications will use advanced visual analysis techniques to support reasoning and help users manage complex data.

The primary computational research goal of our work is to use the set of tools as a testbed for new human-computer interaction techniques, new visualization techniques, and analysis of these techniques. In particular, we will instrument the testbed to capture usage information and analyze and predict the underlying cognitive state of users according to different hypothesized models of cognition. Some models will capture principles of cognition and perception, others will explicitly relate user actions and computer events. One of our targeted contributions is a mechanism for uniformly incorporating models of user action and thought at these different levels of abstraction into our testbed. We hypothesize that the cognitive modeling will ultimately allow us to evaluate interaction techniques in simulation, partially automating the development of effective techniques.

An additional computational research goal is to disseminate results via expanded mechanisms based on the Immunological Genome (ImmGen) website. This site, developed for for public browsing of genomics data, already has substantial impact in the immunology and genomics community. It will provide us with an excellent platform with which to test the paradigms proposed here. New elements will include social and collaborative aspects that we anticipate will increase the use and impact of the data as well as capturing knowledge that can help the analytic process.

Cognitive modeling, software research and development, some genomics work, and human brain science will be done at Brown. Rodent brain science will be done at Stanford. Immunological genomics work will be done at Harvard.

Intellectual Merit The intellectual merit of this project is fourfold. First, computer scientists will advance their understanding of how humans interact with computers at the cognitive and perceptual level and how such interactions can be improved. Some automation of the development of effective techniques is expected and would be transformative. Second, we anticipate advances in the understanding and modeling of human cognition from our cognitive modeling evaluation and experimentation. Third, social and collaborative web tools will help to both disseminate and gather new analytic data. Fourth, the proposed infrastructure will enable brain scientists and genomicists to advance their research agendas more efficiently and more quickly by incorporating information from a broader set of sources into their scientific reasoning, and into the knowledge-gennerating tools tools for data display aimed for use by the scientific community.

Broader Impact. This project will provide practical experience with interdisciplinary research to graduate students, postdoctoral scholars, and undergraduates. Because the tools will be made widely available, they will potentially benefit the entire brain science and genomics research communities. The impact of this availability could be substantial. Many other disciplines study linked networks of data, e.g., protein signaling and even crime and terrorism analysis; All have the potential to benefit. In fact, almost any human-computer interface that involves reasoning has the potential to be improved by results from this research.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

	Total No. of Pages	Page No.* (Optional)*
Cover Sheet for Proposal to the National Science Foundation		
Project Summary (not to exceed 1 page)	1	
Table of Contents	1	
Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) **(Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**	10	
References Cited	2	
Biographical Sketches (Not to exceed 2 pages each)	14	
Budget (Plus up to 3 pages of budget justification)	6	
Current and Pending Support	0	
Facilities, Equipment and Other Resources	0	
Special Information/Supplementary Documents (Data Management Plan, Mentoring Plan and Other Supplementary Documents)	6	
Appendix (List below.) **(Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)**		
Appendix Items:		

*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.

Cognitive Optimization of Brain-Science and Genomics Visual-Analysis Tools

David H. Laidlaw (PI), Benjamin Raphael (Co-PI), Caroline Ziemkiewicz, Brown Computer Science;
Steven Sloman (Co-PI), David Badre, Brown Cognitive, Linguistic, and Psychological Sciences;
David Rand, Brown Ecology and Evolutionary Bio.; Christophe Benoist (Co-PI), Harvard Med. School;
Mark Schnitzer (Co-PI), Stanford Bio. Sciences and Appl. Physics and Howard Hughes Medical Institute;
Jeff Chi-Tat Law, Stanford Bio. Sciences; Fritz Drury, Rhode Island School of Design

a Research Vision and Plan

In recent years, advances in computing and experimental methods have resulted in the rapid growth of large-scale high-dimensional data in almost every area of scientific research. The growth of such complicated data holds enormous potential for scientific progress. At the same time, analyzing all this new information is a serious challenge. Humans are adept at finding patterns, and existing scientific visualization methods leverage that, but as the size and complexity of data increase, visualization alone is not enough. In this proposal, we aim to generate data analysis tools that enable human interaction with high-dimensional data at multiple levels of abstraction, allowing scientists to reason and make discoveries well beyond what is possible today.

We propose to apply concepts from cognition and perception to the development, evaluation, and optimization of visual analysis interfaces for scientific inquiry. We will include not only scientific models of cognition and perception, but also those developed over centuries by artists and visual designers. Artists' phenomenological understanding of the response of viewers to stimuli captures behavior that some scientific models miss, and we propose to codify this understanding to influence interface designs for big data applications in the sciences.

The work will be guided by driving scientific applications in brain science and genomics. Understanding the human brain is a daunting enterprise. Brain researchers must interpret interpret their voluminous data in the context of everyone else's voluminous data. Genomics researchers face an analogous challenge. These pressing needs, including specific examples from our labs, are further described in Secs. a.1 and a.1. The software tools we propose will make these enterprises less daunting and more productive.

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 guiding the aims of the proposed work. 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 can bring to bear.

Analogously, visual designers draw on centuries of knowledge about how to create artifacts for humans to use. At Brown our visualization research has considered deeply the design and evaluation process of such tools. We will utilize visual design knowledge into the software design process as we have in the past [3, 24].

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

To achieve our vision, we propose a number of specific activities and deliverables, many with clear expected outcomes:

1. Develop an interactive analysis and reasoning software tool for brain scientists to explore and analyze connectivity in the brain via imaging data, published literature, and other experimental data.
2. Develop an analogous software tool for genomics researchers.
3. Support the linkage of analysis to external data by leveraging existing curated knowledge on the web, by providing web access to our own curated brain and genomics data, and by utilizing social and collaborative web interfaces to grow these resources.
4. Support the tools across a range of visualization hardware platforms, from laptops and desktops to display walls and a new "retina cave" at Brown.
5. Instrument the tools to create a testbed for new interaction and visualization techniques.
6. Capture data of scientists using the tools, including interaction hardware events, video of body motion and body language, and tracking of what users are looking at.
7. Manually analyze captured data as training and evaluation data for subsequent automated model fitting.
8. Create a software framework for comparing captured data with models and principles from cognition, perception, and art.
9. Evaluate a series of cognition and perception models and principles for their ability to predict user performance measured in Item 6.
10. Using feedback from brain scientists and genomics researchers, define improved visualization, interaction, and analysis techniques.
11. Iteratively optimize these new techniques using predictions from the cognition and perception models and principles.
12. Validate the approach by confirming predictions empirically.
13. Integrate our research efforts with several Brown classes.
14. Make publicly available throughout the process our captured user-interaction data, our modeling testbed, the brain-connectivity and genomics visual-analysis software tools, and the interaction and visualization techniques developed.

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 and genomics.

a.1 Need for Visual Analysis Software in Scientific Applications

We describe these needs in terms of our two driving application areas.

Brain Connectivity The first target scientist community for our analysis software is brain scientists studying the architecture and function of the rodent and human brains. Three of the seven labs involved in this project are a part of this community.

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 and cognition to learning and memory. However, our understanding of the neural basis underlying these brain functions are limited because the networks of connections are so complex and because recent advances in molecular and imaging techniques have expanded the data about those networks to an overwhelming level.

We illustrate the needs with an example from the Schnitzer laboratory at Stanford. A research direction there is the study of neural circuits that underlie sensorimotor learning in rodents. They study the prefrontal cortex of the rat, 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.

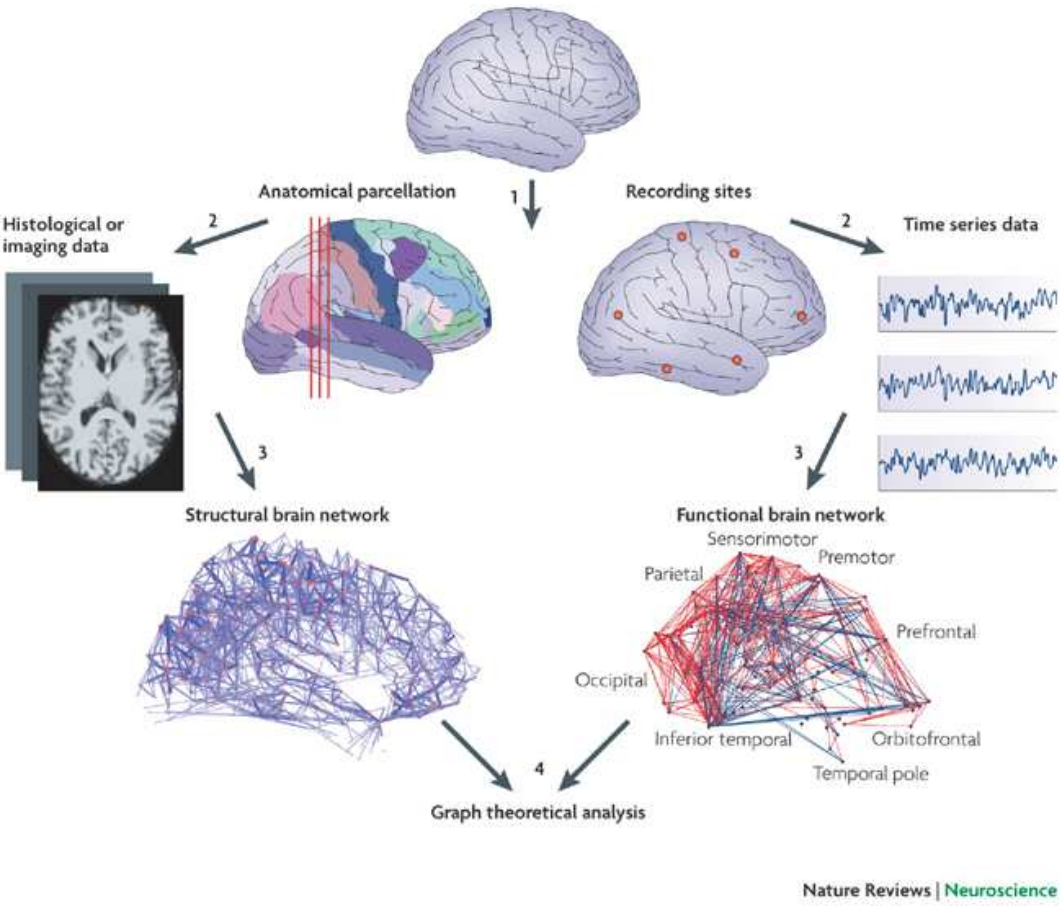

Figure 1: An example of the multi-level workflow of brain network analysis (from [8]).

To form hypotheses 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 [8] and is shown in Fig. 1. In preliminary work, Schnitzer's group developed a prototype "MindMap" to begin addressing these issues. In this diagram of brain regions and connections, which must be reproduced impractically large to be legible, the challenges of displaying and understanding the data are clear.

Badre's laboratory studies problems analogous to Schnitzer's, but deals with cognitive control in the human brain. Cognitive control is our ability to plan and guide our behavior based on internally maintained goals. Understanding cognitive control function requires studying how the prefrontal cortex (PFC) operates dynamically within systems-level networks. We expect to find new challenges in this second area because the human brain is so much more complex than the rat brain and the data about it is far less available.

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,

and 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.

Connectivity Analysis in Genomics Interactions, relationships, networks, and hierarchies are ubiquitous in models that explain gene sequence and expression data. Such networks are studied by three of the seven research labs involved in the proposed work.

Understanding genomic activity and variation is critical to a broad array of high-impact scientific applications. High-throughput genomic approaches and rapid declines in the cost of DNA sequencing are producing great advances in the amount of data available to researchers in these areas. It is more important than ever to be able to analyze the complex interactions of these genes and protein signaling pathways.

As an example, the immune system has been compared to the brain in terms of its ability to process information from the environment, adapt quickly in response to challenges, and store information in long-term memory. Perhaps because the immune system is more accessible to experimental dissection that the brain, there is a good knowledge of the bewildering complexity of cell-types it includes ($>$250 different cell types can be distinguished). A full description of the variation in the genome's activity in these cell-types, during their differentiation or their responses to pathogens or antigens, are fundamental to understanding how the immune system works. The Immunological Genome Project [17] (ImmGen), a consortium of laboratories led by Benoist, has created a microarray compendium of all immunological cell types. Computational biologists that were part of ImmGen have started using this vast collection of data to create regulation models, grouping genes into discrete functional modules and determining likely regulators for each module, thus deriving network structure of regulation in immune cells.

IGERT students working with Rand and Raphael study genomic variation across individuals and how genomic variation in a population is impacted by changes in the environment (metagenomics). While there are algorithms to automate the assembly and alignment of sequencing data, these algorithms do not resolve the data unambiguously. In particular, the automated algorithms perform poorly in the repetitive sequences that are common in the genomes of many species, including human, where approximately 50% of the DNA sequence is repetitive. Thus, automated analysis is typically combined with manual analysis by biologists. In addition to these challenges, metagenomics studies also have the problem of performing robust comparisons of genetic variation in different environmental samples.

As tens of thousands of human and cancer genomes are presently being sequenced (e.g. through NIH projects like the 1000 Genomes Project and The Cancer Genome Atlas) there is increasing demand for tools to interpret this data. Interactive environments that combine automated interpretation from algorithms with human expertise will leverage the strengths of both types of analysis. While ImmGen is a powerful resource for the immunology community, the expression data and the derived module/network structures are currently distributed using simple web based querying tools with minimal visualization components. For example, regulatory modules are simply listed in the order they were identified by an algorithm along with a few precomputed heatmaps indicating the microarray expression patterns of genes and regulators contained in each module. While useful for browsing the modules and understanding their potential function, more advanced visualization tools are now needed to allow genomicists to think in terms of "multiple hop" regulation mechanisms.

Improved tools for analyzing these networks and combining multiple sources of data will make it possible for researchers to form new hypothesis and improve the speed and accuracy of their experimental workflow. As these are vital applications in biology and medical science, aiding these users has the potential to not only advance science, but save lives.

a.2 Related Work in Brain and Genomics Circuitry and Network Visualization

Network visualization in biological domains remains an unsolved problem. Some online databases hosting connectivity

information have developed their own visualization modules [38]. Others have developed personalized visualizations for specialized brain regions or organisms [1]. Still other systems include visualization features that link to online gene or protein interaction databases [7, 37]. We may be able to layer genomic data atop such systems.

However, these approaches each have one or more drawbacks: they fail to adequately merge findings from network visualization with scientists' intuition; they are limited in scope to singular organisms, atlases, or databases; they don't allow users to integrate their own experimental data into the analysis; or they don't offer analysis features such as load/save capabilities, or hypothesis-formation support [32]. We propose to address all of these limitations.

The work that comes closest to our proposed system, Cytoscape [36], provides a graph visualization platform targeted at systems biology, but unlike the proposed work, it does not provide support for building visualizations that are optimized for improved cognition, perception, and analysis by end users.

a.3 Preliminary Results in Developing Visual Analysis Tools for Science at Brown Over the last decade, we have developed numerous scientific visualization tools that have taught us a number of lessons about science and about developing tools to support it. While some of these tools have been directed at our two driving application areas of brain science and genomics, our experience with other application domains is also relevant to the proposed work. Our experience provides us a solid foundation of knowledge, laboratory culture, and infrastructure 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.

Our experiences with network visualization will help in developing the multi-scale circuit and network 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 [22]. 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. Linked views of the signaling network and experimental data, and quick access to the literature and to database information about the proteins and signaling should apply to brain circuit analysis tools.

Our experience developing dissemination tools for ImmGen's genomic data will help us generalize the network analysis principles to all three genomic applications. In the context of the ImmGen project, a vast effort aimed at documenting the immunological genome of the mouse, we developed methods of distributing the projects data in readily analyzable forms using the familiar Google Maps interface. Visualizations included a genome viewer, planar multidimensional data maps, heatmaps, and a network representation. In the context of cancer research we have developed a novel, interactive visualization model for comparative analysis of structural variants and rearrangements in human genomes, with emphasis on data integration and uncertainty visualization [31].

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 [13], diffusion MRI visualization and analysis [40, 19], carpal kinematics analysis [28, 29], and even archeology visual analysis [4]. Two publications in particular capture the brain science visualization work we intend to build on. In the first [20], 2D schematic diagrams of complex fiber tracts are displayed in a readily accessible stylized manner; in the second [19], multiple visualization approaches for viewing human brain connectivity are linked to facilitate interoperation and understanding.

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, Drury, is an investigator on this proposal. Laidlaw and Drury have collaboratively 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. Some of what we have learned is documented in examples cited here [25, 39, 3, 24]; space limitations preclude a more complete list.

a.4 Preliminary Results in Capturing and Cognitively Analyzing User-Interaction Data Laidlaw's lab has been one of the leading visualization labs in experimental evaluation of visualization

methods [26, 12, 10]. Some of these evaluations were done in collaboration with perceptual psychologists from Sloman and Badre's department. They involved 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 visual design 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.

Working with researchers from Benoist's lab, Ziemkiewicz recently performed a task analysis of visual exploration of gene expression data in the course of an immunobiology research project. This analysis uncovered patterns of interaction and important differences in behavior across users [9]. In a related project, researchers in Laidlaw's lab are working on designing a model to capture visualization user tasks based on user interaction history. Such a model will help bridge the gap between observable user interactions and higher level cognitive tasks, and this will potentially ease the application of cognitive principles concerning higher level user cognition. These findings and ongoing work in this area will inform our understanding of these types of cognitive scientific research tasks.

Additional recent work has focused on simplifying quantitative evaluation methods for visualization tools. Laidlaw's lab created a semi-automated system, Tome, that analyzes discrete user interactions with visualization GUIs and predicts task completion times [15]. These predictions are useful in evaluating task performance for a crowd of end users and can be modified to evaluate how unimplemented GUI features affect task speed. To do this, Tome interacts with the modeling tool CogTool [23] that simulates these tasks inside a cognitive modeling architecture; as explained in the next section, this coupling of models with software interfaces is a specific aim of the proposed work.

a.5 Overview of Models and Principles of Cognition and Perception One 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, especially cognitive principles concerning 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 temporal orders of magnitude.

In [5], 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 [16], 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 [14]. 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 our approach, we will use three types of principles in developing our models. First, principles of perception and attention will determine the physical parameters of the display. For example, recent work in the study of attention has examined the number of objects that can be tracked at any given time [33] and the physical parameters that determine the identity of an object [35].

Second, principles of goal selection will determine the number of tasks made available to the user and their accessibility at any point in time. Research has studied the process of multitasking using a variety of paradigms including prospective memory [30], task switching [34] and goal priming [2, 6].

Third, principles of problem-solving and reasoning will determine the design of the tool, the information that is on display at any given time, the actions that are given priority status, and the guidance and feedback

that it provides. This principle will guide the design in ways that avoid common cognitive errors such as "confirmation bias," the tendency to seek out evidence to support a conclusion and ignore evidence that disconfirms it. The most simple and effective way that psychologists have found to reduce this bias is to ask people to "consider the opposite" [27]. A second remediation method is to ask people to think diagnostically rather than causally [11].

a.6 A Software Framework At the heart of our research is a software framework that will use particular models or principles to predict user performance. This framework will provide to software modules a description of the model or principle, a description of the user interface, and a description of user goals; the software modules will produce probabilistic estimates of the state of a user over time predicted by the model.

Modules that implement cognitive or perceptual performance can be coupled and compared within the framework. Because each such module has a common interface, the system can be extended to include new modules. A supervisor module can access predictions from all relevant modules and assemble the results into an overall prediction. It can also compare the results to acquired user performance data to establish contexts in which various models might be more or less appropriate.

a.7 Knowledge Transfer Public access has been from the outset an important aspect of this project. ImmGen data are already made publicly available prior to publication, following NIH guidelines for large community resource projects. Modeled on this, a new community oriented web portal will offer access to all scientific data we have curated: HCI, software, brain science, and genomics. Extended community features will be designed to make both sites into platforms for collaborative discovery so that users can not only consume information but also produce it in the form of annotations, feedback, discussion threads, and wiki entries. Versions of the software 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, VRG3D, that we are developing with other NSF support (OCI-0923393). Releases will be advertised through blog postings, publications, direct contact, and during conference presentations. We will also propose to teach tutorials and classes at conferences if there is interest. Additionally, our brain science and genomics participants 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. We expect this data sharing plan to strike a balance between broad dissemination and the building of a lasting, long-term research community. Finally, as with any scientific endeavor, publication of results will be an important mechanism to transfer knowledge.

a.8 Timeline While our overall plan is enumerated at the beginning of the project description, some additional information about staging is included here. Note that this preproposal is primarily intended to motivate the problem and provide the vision for a solution. There is insufficient space for a complete research plan.

Our plan is divided into three phases to take place over five years. Each phase will be driven by multiple evaluatable milestones, e.g., requirements documents, design sketches, design reviews, releases at various scopes, and experiments. The timing is approximate; we expect the stages to overlap.

Years 1-2: Knowledge sharing, data gathering, modeling, setup, and prototyping. In the first year 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. We will also evaluate and gather the external data that will be available for analysts. As a part of that data gathering, community web tools will be put in place. 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 [24]. 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 [18]. This will provide preliminary data to help ground our cognitive modeling efforts and provide feedback for software development. We will also set up the SourceForge repository, including its bug tracker and forums for developers and users. The initial design will incorporate the highest priority requirements and will be prototyped to demonstrate to the brain

scientists and genomics researchers 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. Once a first prototype in place we will instrument the tool to gather usage data and anecdotal feedback from neuroscientists.

Years 2-4: 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 labs. This phase will include an iterative series of increasingly complete prototype systems, each of which will be deployed to the brain science and genomics 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. 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. During the second year, feedback will be gathered and analyzed more broadly, and we will employ community-building efforts utilizing SourceForge mechanisms and our web sites. User data capture will continue, as will internal improvements.

Years 4-5: Validation and dissemination. The final systems will first be deployed to the brain science and genomics labs, with the goal of incorporating its use into ongoing research. Researchers in these labs will empirically evaluate 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 final versions of the systems to the public in accordance with our data sharing plan.

a.9 Contributions to Expedition Program Goals The proposed research contributes to the goals of the Expedition Program as follows.

Goal: To catalyze research into deep scientific questions, hard problems, and compelling applications in CS-related areas. Our work reaches far into three different research areas: human-computer interaction, cognitive modeling, the study of connectivity in the brain, and the study of genomics. In human-computer interaction, a framework for predictive modeling of human interactions with computers has the potential to catalyze significant follow-on research in such models. The models we experiment with ourselves have the potential to accelerate others' research in user interface design not only in two scientific domains, but across many and likely outside of science as well. Beyond computing, our proposed research addresses fundamental questions about how the brain works, from the level of cellular connections up to analytical reasoning. It also addresses fundamental questions of genomic variation across individuals and environments.

Goal: To inspire pursuit of careers in CS and engineering. The students and postdocs in this unusually interdisciplinary research will likely continue on in research careers that reflect some of the novel aspects of the work. The PI's experience with earlier interdisciplinary research projects is that they tend to attract students who are not attracted by more traditional computer science. Students interested in biology or visual design tend to be more diverse than those interested in computer science and engineering. Brown University also devotes considerable attention to creating an environment of diversity in its student population. The proposed work will be able to draw on that diversity.

The proposed work will also add significantly to two computer science courses at Brown that link education and research. One, "Interdisciplinary Scientific Visualization" centers around designing and executing research projects by emulating the US model of research design and funding. Students identify a research problem with a collaborator from another discipline, explore potential solutions, write a "funding" proposal, peer review the set of proposals, do the research, write it up, and present it all during one 13 week semester. They get a taste of the excitement, challenge, and risk inherent to interdisciplinary research in a context where the real risk is minimal. This class will serve as a first line of outreach for our proposed work,

broadening exposure from the handful of students directly involved to a dozen or so each time it is taught. From past experience, we expect that some of these students will go on to participate actively in the proposed work or other research projects.

A second course that will benefit from this research is "Virtual Reality Design for Science." This course, jointly listed and taught at Brown and the Rhode Island School of Design, teaches design students enough science so that they can author new interactive tools for scientists. We plan to automate the process of evaluating these interfaces without going through the months-to-years implementation process, providing a demonstration of the acceleration our research will make possible

Goal: To stimulate research, education, and knowledge transfer that promise scientific, economic and other societal benefits. Our plan to make the modeling testbed, the captured interaction data, the interactive brain connectivity analysis software, and the genomic analysis software all widely available should effectively transfer knowledge into several scientific communities. Both binary and source distributions will be provided. The research and development that ultimately result using these resources should provide broad scientific benefits, as already described. Broader societal benefits that may result are difficult to predict specifically, but more effective ways for people to use computers has great potential.

a.10 Demonstration of Expedition Characteristics In addition to matching the Expedition program goals well, the project we propose has characteristics expected of expedition projects.

Characteristic: Foster creativity, informed risk-taking, and synergy. Our project is creative in bringing together several disciplines and in advancing all of them. These coordinated advances, each dependent on elements from other disciplines, are indicative of an Expedition that is greater than the sum of its parts. Our research will continue a tradition of research creativity within and across the investigators' research groups. Our groups have already demonstrated that they value complementary and collaborative research, and Brown has a long tradition of blending education and research as effectively as any institution we know. If anything, we expect that the risk inherent to the work we propose and the environment we may build is beyond what reviewers will view enthusiastically. But we feel the risk is worth the potential rewards.

Characteristic: Draw upon well-integrated, diverse teams. Our proposed work is structured around a vision that integrates all of the investigators – each is essential to the success of the project. The investigators' work is diverse; six different departments are represented by our group. Each member brings unique abilities. Although only two of us are formally in a computer science department, our vision is centered around a core computer science problem: understanding human computer interaction and applying that understanding for scientist users.

Characteristic: Stimulate effective knowledge transfer. We propose to spend significant effort to transfer knowledge across disciplines and outside of the immediate research group, as outlined in Section a.7.

Characteristic: Demonstrate elements that enable discovery. Our experimental data capture, cognitive modeling testbed, and brain connectivity analysis tools are directly targeted at enabling discovery.

a.11 Summary of Synergy 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. The synergy of the group is outstanding. Though relatively small, it covers a surprisingly large range of disciplines. Although the group includes computer scientists, artists, psychologists, and neuroscientists, the shared goal of understanding the brain brings us all together. Research in each of the disciplines is advanced by the proposed work, so motivation to succeed is shared by all. No discipline can be removed without fundamentally changing the nature and reducing the scope of the overall research – the sum is greater than what any subset could accomplish. The group and the project seem ideal to take on an Expedition in Computing, and we look forward to providing additional detail in a full proposal.

b Leadership and Collaboration

We have assembled an excellent team of recognized experts in cognitive science, neuroscience, computer science, genomics, computational biology, and visual design. Their complementary expertise covers a breadth unusual in such a small group. The scientific problem areas of genomics and brain science and the research thrust of cognitive optimization of 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 years. Laidlaw has collaborated and published with all of the other participants save Rand and Badre. 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 and have published together in this area [21]. Laidlaw and Sloman have taught each other's students and co-advised as well. Schnitzer provided the inspiration for attacking the brain-connectivity problem by contacting Laidlaw two years ago, and their groups have been interacting since on what the neuroscience needs are and on a prototype "MindMap" that Schnitzer and his group developed. 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. Drury has also participated in a number of perception oriented studies of visualization and interaction tools. Laidlaw and Benoist have worked together closely on the ImmGen project over the last 5 years and are co-authors on the major publications from that project. And Raphael and Laidlaw have collaborated on a genome-rearrangement visualization tool applied to cancer genomes [31]. Raphael and Rand work together in the Center for Computational Molecular Biology, where an IGERT they both participate on will leverage the tools we propose.

Brown provides a supportive environment for multidisciplinary work such as we propose. The diverse student body is 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. This institute also provides numerous brain scientists who may be interested in using and testing the tools that we will develop.

Because of the relatively small size of the group, the existing relationships among the members, and the natural incentives of the project, the management structure will be relatively simple. The PI, Laidlaw, will be responsible for monitoring the program and interacting with the other research lab leaders to track progress. Because the work is so interdependent, shared deliverables and dependencies will help to keep the research labs synchronized. A full-time postdoctoral scholar will help Dr. Laidlaw with this coordination. While this leadership structure is simple, Laidlaw has had excellent results with similar organizational structures in past collaborations of similar scope. One of the reasons this works well is that almost all of the elements are naturally advantageous for the the participants doing them. None of the research groups is acting as a service to the others. The research goals are linked so that the overall project is a win for all of the participants, providing natural incentives that will lead to success.

c Experimental Systems and Shared Experimental Facilities

Much of the proposed work requires facilities typical to each individual investigator, e.g., computers and laboratory space. We propose to acquire a few resources specific to this project including a pupil tracking system. We will also leverage a number of interaction and display devices already in place in Brown's Computer Science Department and its Center for Computation and Visualization (CCV). These include tiled display walls, stereo-enabled desktop displays, an ultra-high-resolution Wheatstone stereoscope, haptic devices, and a virtual-reality cave expected to produce first light in late 2012. This NSF-funded cave will feature a 360 degree field of view, resolution at the limit of human perception, and head tracked stereo imagery. It will be able to emulate displays of many different form factors because of its display properties.

1. Wormweb. http://wormweb.org/.
2. H. Aarts and A. Dijksterhuis. Habits as knowledge structures: Automaticity in goal-directed behavior. *Journal of Personality and Social Psychology*, 78(1):53–63, 2000.
3. D. Acevedo, C. Jackson, D. H. Laidlaw, and F. Drury. Using visual design experts in critique-based evaluation of 2D vector visualization methods. *IEEE Trans. on Visualization and Computer Graphics*, 14(4):877–884, July 2008.
4. D. Acevedo, E. Vote, D. H. Laidlaw, and M. Joukowsky. Archave: A virtual environment for archaeological research. In *Work in Progress Proc. of IEEE Visualization'00*, 2000.
5. J. R. Anderson. Spanning seven orders of magnitude: A challenge for cognitive modeling. *Cognitive Science*, 26(1):85–112, 2002.
6. J. Bargh and T. Chartrand. The unbearable automaticity of being. *American Psychologist*, 54(7):462–479, 1999.
7. B. J. Breitkreutz, C. Stark, and M. Tyers. Osprey: a network visualization system. *Genome Biol.*, 4:R22, 2003.
8. E. Bullmore and O. Sporns. Complex brain networks: graph theoretical analysis of structural and functional systems. *Nature Reviews Neuroscience*, 10(3):186–198, 2009.
9. cziemki, S. R. Gomez, and D. H. Laidlaw. Analysis within and between graphs: Observed user strategies in immunobiology visualization. In *ACM CHI*, 2012. In Press.
10. C. Demiralp, C. Jackson, D. Karelitz, S. Zhang, and D. H. Laidlaw. Cave and fishtank virtual-reality displays: A qualitative and quantitative comparison. *IEEE Trans. on Visualization and Computer Graphics*, 12(3):323–330, May 2006.
11. P. Fernbach, A. Darlow, and S. Sloman. Neglect of alternative causes in predictive but not diagnostic reasoning. *Psychological Science*, 21(3):329, 2010.
12. A. Forsberg, J. Chen, and D. H. Laidlaw. Comparing 3D vector field visualization methods: A user study. volume 15, pages 1219–1226, 2009.
13. A. Forsberg, P. Richardson, J. Sobel, D. H. Laidlaw, D. Keefe, I. Pivkin, and G. Karniadakis. Arterial motions and flows seen in virtual reality. In *Proc. World Congress on Medical Physics and Biomedical Engineering*, Sydney Australia, 2003.
14. K. A. Gluck. *Eye movements and algebra tutoring*. PhD thesis, Pittsburgh, PA, USA, 1999. Chair-Anderson, John R.
15. S. R. Gomez and D. H. Laidlaw. Modeling task performance for a crowd of users from interaction histories. In *Proc. of the ACM Conf. on Human Factors in Computing Systems (CHI)*, 2012. In Press.
16. W. D. Gray, B. E. John, and M. E. Atwood. Project ernestine: validating a goms analysis for predicting and explaining real-world task performance. *Hum.-Comput. Interact.*, 8(3):237–309, 1993.
17. T. S. P. Heng and many others. The Immunological Genome Project: networks of gene expression in immune cells. *Nature Immunology*, 9:1091–1094, 2008.
18. R. Jianu, C. Demiralp, and D. Laidlaw. Exploring 3D DTI Fiber Tracts with Linked 2D Representations. *IEEE Trans. on Visualization and Computer Graphics*, 15(6), 2009.
19. R. Jianu, C. Demiralp, and D. H. Laidlaw. Exploring 3D DTI fiber-tracts with linked 2D representations. *IEEE Trans. on Visualization and Computer Graphics (Proc. Visualization '09)*, 15(6):1449–1456, 2009.
20. R. Jianu, C. Demiralp, and D. H. Laidlaw. Exploring brain connectivity with two-dimensional neural maps. In *IEEE Visualization 2010 Poster Compendium (Best Poster Award)*, 2010.
21. R. Jianu and D. H. Laidlaw. An evaluation of how small user interface changes can improve scientists analytic strategies. In *Proc. of the SIGCHI conf. on human factors in computing systems*, 2012. In Press.
22. R. Jianu, K. Yu, V. Nguyen, L. Cao, A. Salomon, and D. H. Laidlaw. Visual integration of quantitative proteomic data, pathways and protein interactions. *IEEE Trans. on Visualization and Computer*

Graphics, September 2009.

23. B. E. John, K. Prevas, D. D. Salvucci, and K. Koedinger. Predictive human performance modeling made easy. In *Proc. of the SIGCHI conf. on Human factors in computing systems*, CHI '04, pages 455–462, 2004.
24. D. Keefe, D. Acevedo, J. Miles, F. Drury, S. Swartz, and D. H. Laidlaw. Scientific sketching for collaborative VR visualization design. *IEEE Trans. on Visualization and Computer Graphics*, 14(4):835–847, July-2008.
25. D. Keefe, D. Karelitz, E. Vote, and D. H. Laidlaw. Artistic collaboration in designing VR visualizations. *IEEE Computer Graphics and Applications*, 25(2):18–23, March/April 2005.
26. D. Laidlaw, R. Kirby, C. Jackson, J. Davidson, T. Miller, M. Da Silva, W. Warren, and M. Tarr. Comparing 2D vector field visualization methods: A user study. *IEEE Trans. on Visualization and Computer Graphics*, pages 59–70, 2005.
27. C. Lord, M. Lepper, and E. Preston. Considering the opposite: A corrective strategy for social judgment. *Journal of Personality and Social Psychology*, 47(6):1231–1243, 1984.
28. G. E. Marai, J. J. Crisco, and D. H. Laidlaw. Development of a kinematic 3D carpal model to analyze in vivo soft-tissue interaction across multiple static postures. *Proc. Engineering in Medicine and Biology Society*, pages 7176–7179, 2009.
29. G. E. Marai, C. Demiralp, S. Andrews, and D. H. Laidlaw. Jointviewer an interactive system for exploring orthopedic data. IEEE Visualization 2004 Poster Compendium, 2004.
30. M. McD. and G. Einstein. Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, 14(7):S127–S144, 2000.
31. T. M. O'Brien, A. M. Ritz, B. J. Raphael, and D. H. Laidlaw. Gremlin: An interactive visualization model for analyzing genomic rearrangements. *IEEE Trans. on Visualization and Computer Graphics (Proc. Information Visualization '10)*, 2010.
32. S. Peri and . others. Human protein reference database as a discovery resource for proteomics. *Nucleic Acids Res.*, 32:497–501, Jan 2004.
33. Z. Pylyshyn and R. Storm. Tracking multiple independent targets: Evidence for a parallel tracking mechanism*. *Spatial Vision*, 3(3):179–197, 1988.
34. R. Rogers and S. Monsell. Costs of a predictible switch between simple cognitive tasks. *Journal of experimental psychology: General*, 124(2):207–231, 1995.
35. B. Scholl and Z. Pylyshyn. Tracking multiple items through occlusion: Clues to visual objecthood. *Cognitive Psychology*, 38(2):259–290, 1999.
36. P. Shannon, A. Markiel, O. Ozier, N. S. Baliga, J. T. Wang, D. Ramage, N. Amin, B. Schwikowski, and T. Ideker. Cytoscape: a software environment for integrated models of biomolecular interaction networks. *Genome Res.*, 13:2498–2504, Nov 2003.
37. M. E. Smoot, K. Ono, J. Ruscheinski, P. L. Wang, and T. Ideker. Cytoscape 2.8: new features for data integration and network visualization. *Bioinformatics*, 27:431–432, Feb 2011.
38. D. Szklarczyk and . others. The STRING database in 2011: functional interaction networks of proteins, globally integrated and scored. *Nucleic Acids Res.*, 39:D561–568, Jan 2011.
39. E. Vote, D. Acevedo, C. Jackson, J. Sobel, and D. H. Laidlaw. Design-by-example: A schema for designing visualizations using examples from art. In *SIGGRAPH 2003 Sketches and Applications*. ACM SIGGRAPH, 2003.
40. S. Zhang, C. Demiralp, D. Keefe, M. DaSilva, B. D. Greenberg, P. J. Basser, C. Pierpaoli, E. A. Chiocca, T. S. Deisboeck, and D. H. Laidlaw. An immersive virtual environment for DT-MRI volume visualization applications: a case study. In *Proc. of IEEE Visualization 2001*, pages 437–440, 2001.

David H. Laidlaw

Professor
Computer Science
Brown University, Providence, RI 02912

Phone: (401) 354-2819
Fax: (401) 863-7657
Email:dhl@cs.brown.edu

Professional Preparation

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.*

Appointments

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

Selected Publications Most Relevant to the Proposed Project

- 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.
- 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.
- Caroline Ziemkiewicz, Steven Gomez, and David H. Laidlaw. Analysis Within and Between Graphs: Observed User Strategies in Immunobiology Visualization." In ACM CHI Notes (2012). To Appear.
- Radu Jianu and David H. Laidlaw. An Evaluation of How Small User Interface Changes Can Improve Scientists Analytic Strategies. In Proceedings of the SIGCHI conference on human factors in computing systems, 2012.

Other Significant 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
In 2009 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. For more info: http://www.cs.brown.edu/courses/cs237.

Co-taught one-day course at premiere computer graphics conference, SIGGRAPH, about using art-based methods for scientific visualization. I led a 2-hour session where approx. 80 computer graphics professionals used traditional art media (paint, charcoal, 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, Indiana University, 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

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

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

BENJAMIN J. RAPHAEL
Associate Professor
Department of Computer Science & Center for Computational Molecular Biology
Brown University, Providence, RI 02912
Phone: (401) 863-7643 FAX: (401) 863-7657
Email: braphael@brown.edu Web: cs.brown.edu/people/braphael

Professional Preparation

Massachusetts Institute of Technology	**S.B.** in Mathematics, **S.B. Minor** in Biology	1996
University of California, San Diego	**Ph.D.** in Mathematics	2002
University of California, San Diego	**Postdoctoral Fellowship** in Computer Science (Bioinformatics)	2002-2006

Appointments

2011-present	**Associate Professor**, Department of Computer Science & Center for Computational Molecular Biology, Brown University
2006-2011	**Assistant Professor**, Department of Computer Science & Center for Computational Molecular Biology, Brown University
2005-2006	**Burroughs Wellcome Postdoctoral Fellowship** in Computer Science (Bioinformatics), University of California, San Diego. Sponsor: Professor Pavel Pevzner.
2002-2004	**Alfred P. Sloan Postdoctoral Fellowship** in Computer Science (Bioinformatics), University of California, San Diego. Sponsor: Professor Pavel Pevzner.

Publications

Most closely related to the proposed project (with graduate* and undergraduate co-authors):**

Vandin F., Upfal E., **Raphael, B.J.**. (2012) De novo Discovery of Mutated Driver Pathways in Cancer. *Genome Research.* 22(2):375-85. [Preliminary version appeared at RECOMB 2011]

The Cancer Genome Atlas Research Network. (2011). Integrated Genomic Analyses of Ovarian Carcinoma. *Nature*. 474(7353):609-15.

*O'Brien T., *Ritz A., **Raphael B.J.**, and Laidlaw D.H. (2010) Gremlin: An Interactive Visualization Model for Analyzing Genomic Rearrangements. *IEEE Trans. on Visualization and Computer Graphics* (Proc. IEEE Information Visualization Conference 2010) 16(6):918-26.

*Vandin F., Upfal E., **Raphael BJ**. Algorithms for Detecting Significantly Mutated Pathways in Cancer. (2010) *Journal of Computational Biology.* 18(3):507-22.*Proceedings of the 14th Annual International Conference on Research in Computational Molecular Biology (RECOMB* 2010).

Sindi S., **Helman E., *Bashir A., **Raphael BJ**. (2009) A Geometric Approach for Classification and Comparison of Structural Variants. *Bioinformatics* 25: i222-i230. [*Proceedings of the Joint 17th Annual International Conference on Intelligent Systems in Molecular Biology (ISMB/ECCB 09)]*

Five other significant publications:

*Ritz, A., Bashir, A. & **Raphael, B.J.** (2010) Structural Variation Analysis with Strobe Reads. *Bioinformatics*. 26(10):1291-8.

*Kahn, C.L., **Hristov, B.H. and **Raphael, B.J.** (2010) Parsimony and Likelihood Reconstruction of Human Segmental Duplications. *Bioinformatics* (In Press). [*Proceedings of the 9th European Conference on Computational Biology*].

Sindi S. & **Raphael, B.J**. (2010). Identification and Frequency Estimation of Inversion Polymorphisms from Haplotype Data. *Journal of Computational Biology*, 17(3):517-31. [Journal version of RECOMB 2009 paper].

*Bashir A, Volik S, Collins CC, Bafna V, and **Raphael BJ**. (2008) Evaluation of Paired-end Sequencing Strategies for Detection of Genome Rearrangements in Cancer. *PLOS Computational Biology*. 4(4):e1000051.

Chaisson M, **Raphael BJ,** and Pevzner P. (2006) Micro-inversions in Mammalian Evolution. *Proceedings of the National Academy of Sciences.* 103: 19824-19829.

Synergistic Activities

1. Broadening participation of underrepresented groups in science and engineering. Currently advise female computer science Ph.D. students Anna Ritz, Layla Oesper (Both NSF Graduate Research Fellowship recipients), and Alexandra Papoutsaki. Mentoring undergraduate research of female students Elena Helman (Brown class of 2009, now graduate student at MIT), Jihan Chao (Brown class of 2010, now at Cisco), Sarah Aerni (UCSD class of 2006, now Stanford graduate student) and minority student Eric Corona (UCSD class of 2007, now Stanford graduate student). Lectured at the Artemis Program, a computing summer camp for 9th grade girls (2007-11). Hosted underrepresented minority high school student in summer research (2011).

2. Integrated teaching and research. Developed an undergraduate course and a graduate course on algorithmic foundations on computational biology. Member of the Computational Molecular Biology Curriculum Committee (undergraduate and Ph.D.) at Brown University. Graduate adviser in the Computer Science, Computational Biology, and Molecular Biology graduate programs at Brown University.

3. Development of software for the biomedical community. Develop and distribute software tools including Geometric Analysis of Structural Variants (GASV), Motif Description Length (MoDL), HotNet (used by The Cancer Genome Atlas project), and Dendrix. All available at: http://compbio.cs.brown.edu/software.

4. Service to the Scientific Community. Co-Leader of the Genome Aberrations Group for the *International Cancer Genome Consortium*. Member of *The Cancer Genome Atlas* Analysis Group. Founder and Steering Committee member RECOMB Satellite Workshop on Computational Cancer Biology. Program Committee member for several computational biology conferences including RECOMB, ISMB, ECCB, and WABI. Scientific Advisory Committee, NSF-EPSCoR Rhode Island Genomics and Sequencing Center

Collaborators & Other Affiliations

(i) Collaborators

Vineet Bafna (University of California, San Diego), Ali Bashir (Pacific Biosciences), Eli Upfal (Brown University), Eleazar Eskin (University of California, Los Angeles), Li Ding (Washington University, St. Louis), Richard Wilson (Washington University, St. Louis), Shibu Yooseph (JCVI), Charles Lawrence (Brown University), Colin Collins (Vancouver Prostate Center)

(ii) Ph.D. Advisor: Jim Agler, University of California, San Diego

(iii) Postdoctoral Sponsor: Pavel Pevzner, University of California, San Diego

(iv) Thesis Advisor: Crystal Kahn. [And 6 current students] Selim Onal, Anna Ritz; Brown University.

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:

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

Sloman, S. A., Fernbach, P. M. & Ewing, S. (in press). A causal model of intentionality judgment. Mind and Language.

Sloman, S. A., & Fernbach, P. M. (in press). Human representation and reasoning about complex Causal Systems. In W.B. Rouse, K. R. Boff & P. Sanderson (Eds.). Information • Knowledge • Systems *Management*, 10 (1-4).

Hagmayer, Y. & Sloman, S. A. (2009). Decision makers conceive of themselves as interveners, not observers. Journal of Experimental Psychology: General, 138, 22-38.

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

(2) Five additional publications:

Darlow, A. & Sloman, S. A. (2010). Two systems of reasoning: Architecture and relation to emotion. Wiley Interdisciplinary Reviews Cognitive Science, 1, 382-392.

Fernbach, P. M., Darlow, A. & Sloman, S. A. (2010). Neglect of alternative causes in predictive but not diagnostic reasoning. Psychological Science, 21(3), 329-336..

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. & 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

- Senior Associate Editor, Cognition, 2011-
- Working with Program in Public Health at Brown University to improve system for aiding choice among nursing homes.
- Worked with physicians at Rhode Island Hospital to develop a procedure for medical hand-offs.
- Associate Editor, various journals, since 1998.
- Robert J. Glushko Distinguished Visiting Scholar in Cognitive Science, University of California, Berkeley, 2009.

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
Fernbach, Philip, University of Colorado
Fox, Craig, University of California, Los Angeles
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
Rogers, Todd, Harvard University
Walsh, Clare, University of Plymouth, UK

(2) Graduate and Post-Doctoral Advisors

Gordon Bower (Stanford University)
Lance Rips (Northwestern University)
David Rumelhart (deceased)
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: 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
2012 Visiting Scholar, Department of Psychology, Harvard 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:

Verstynen, T., Badre, D., Jarbo, K., and Schneider, W. Microstructural organizational patterns in the human corticostriatal system. *Journal of Neurophysiology*. In Press.

Badre, D., Doll, B. B., Long, N. M., and Frank, M. J. (2012). Rostrolateral prefrontal cortex and individual differences in uncertainty-driven exploration. *Neuron*, 73, 595-607.

Badre, D. and Frank, M. J. (2012). Mechanisms of hierarchical reinforcement learning in cortico-striatal circuits 2: Evidence from fMRI. *Cerebral Cortex*, 22(3), 527-536.

Frank, M. J., and Badre, D. (2012). Mechanisms of hierarchical reinforcement learning in corticostriatal circuits 1: Computational analysis. *Cerebral Cortex*, 22(3), 509-526.

Öztekin, I. and Badre, D. (2011). Distributed patterns of brain activity that lead to forgetting. *Frontiers in Human Neuroscience*, 5, 1-8.

Other Publications:

Long, N. M., Öztekin, I., and Badre, D. (2010). Separable prefrontal contributions to free recall. *Journal of Neuroscience*, 30(33), 10967-10976.

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.

Synergistic Activities

1) I organized a workshop of diffusion spectrum imaging this year that was attended by members of several departments, including CLPS, Neuroscience, Computer Science, Statistics, and Psychiatry. This type of tool may be important for the software applications being proposed.

2) 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 journals *Psychological Science* and *Cognitive Neuroscience*. As a member of the founding board of the latter journal, I've had a role in shaping the direction of that journal.

3) I am an ad hoc reviewer for *Biology Letters; Biological Psychiatry; Brain and Language; Brain Research; Brain Sciences; Cerebral Cortex; Cognition; Cognitive, Affective, and Behavioral Neuroscience; Cognitive Neuropsychology; Cognitive Neuroscience; Cognitive Psychology; Developmental Neuropsychology; Experimental Brain Research; European Journal of Neuroscience; Hippocampus; Human Brain Mapping; Journal of Cognitive Neuroscience; Journal of Experimental Psychology: Human Perception and Performance; Journal of Experimental Psychology: Learning, Memory, and Cognition; 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; Quarterly Journal of Experimental Psychology; Social, Cognitive, and Affective Neuroscience; Science; Scientific Reports; Topics in Cognitive Science; Trends in Neurosciences*; in addition to the NSF Perception, Action, and Cognition and Cognitive Neuroscience panels, Neurosciences and Mental Health Board, MRC (UK), Neuroscience and Mental Health, Wellcome Trust (UK), Biotechnology and Biological Sciences Research Council (UK), Leaders Opportunity Fund, CFI (Canada), Natural Sciences and Engineering Research Council (Canada)

5) I am in the middle of a two-year term on the slide session committee of the Cognitive Neuroscience Society Annual Meeting. I helped organize the session of working memory, executive function, and attention this year.

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), *Tim* Verstynen (Pitt), 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

Past: *Ilke Öztekin* (Assistant Professor, Koc University, Istanbul, Turkey)

Current: *Christopher Chatham*, *Theresa Desrochers, Erika Nyhus*

Students

Current: *Jennifer Barredo, Jason Scimeca, Patti Shih*

Current Committee Member: *Elizabeth Chrastil, Adam Darlow, Jessica Feldman (Neuro), Heida Sigurdardottir (Neuro), Kaivon Paroo (Neuro).*

Fritz Drury
Department of Illustration Rhode Island School of Design
2 College St., Providence RI 02903
401-454-6243
fdrury@risd.edu

i.) Education

BA 1977 Stanford University
MFA 1981 Yale University School of Art

ii) Appointments

Rhode Island School of Design, Providence RI
Professor of Illustration, June 2003-present
Chief Critic, European Honors Program, Rome, January-June 2011.
Department Head, Illustration 2000-2003, 2008-2009.
Associate Professor of Illustration and Foundation Studies, 1997-2003.
Adjunct Professor of Illustration and Painting 1981-1997.

iii) Publications & Exhibitions

Drawing Structure and Vision, textbook on drawing technique and tradition, Fritz Drury and Joanne Stryker, September 2007, Prentice Hall, Upper Saddle River NJ.

Visualization Criticism, with Kosara et al., Computer Graphics and Applications, IEEE, May-June 2008.

Using Visual Design Expertise to Characterize the Effectiveness of 2D Scientific Visualization Methods, with Acevedo et al, Poster at IEEE Visualization 2005. Minneapolis, Minnesota, October 2005.

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.

Interactive Exercises in Visual Design for A World of Art, by Henry Sayre, Prentice Hall, Upper Saddle River NJ, 2002

177th Annual Invitational Exhibition, National Academy of Design, NYC May 2002

Solo Exhibition, AAA Gallery, NYC, November 1998.
Review in *Art in America* July 1999, by Nancy Grimes.

Solo Exhibition, "Bedtime Stories", Nancy Moore Gallery, NYC, May, 1997.

Solo Exhibition, Black and Greenberg Gallery, NYC, April 1995.

Solo Exhibition, "Nature", 55 Mercer Gallery, NYC, October 1993.
Review in *Art in America*, June 1994, by Eleanor Heartney.

iv) Synergistic Activities

September-December 2004, co-taught Virtual Reality Design for Science at Brown University with Professor David Laidlaw, studying collaboration between artists and scientists in the design of immersive, interactive scientific visualizations of the aerodynamics of bat flight.

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 Cullen Jackson on the design of 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 of arterial blood flow.

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.

v) Collaborators & Other Affiliations

Professor David Laidlaw, Department of Computer Science, Brown University
Professor Sharon Swartz, Department of Biology, 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
Colin Jackson, Department of Computer Science, Brown University

b) Graduate Advisors

Professor William Bailey (emeritus) Yale School of Art
Professor Bernard Chaet (emeritus) Yale School of Art

BIOGRAPHICAL SKETCH – David M. Rand

A. Expertise as related to the proposed research

Dr. Rand is an empirical population geneticist with over 25 years experience in Drosophila research related to mtDNA effects on fitness and performance traits.

B. Professional Preparation:

Harvard College, Cambridge, MA	Biology	B.A. *cum laude*, 1980
Yale University, New Haven, CT	Biology	Ph. D. 1987
Harvard University	Postdoc in Population Genetics	1988-1991

C. Professional Appointments:

7/03–present	Professor of Biology, Brown University, Providence, RI
7/97–6/03	Associate Professor of Biology, Brown University, Providence, RI
7/91-7/97	Assistant Professor of Biology, Brown University, Providence, RI
9/87-12/87	Postdoctoral Fellow, Institute of Marine Biology, Department of Biology, University of Crete, Greece
9/83-6/86	Teaching Assistant, Yale University
9/81-6/83	Biology and Mathematics Teacher, St. Albans School, Washington, DC
9/80 - 6/81	Biology Teaching Fellow, Phillips Andover Academy, Andover, MA

D. (i) Five Publications Relevant to this Research (undergraduate coauthors underlined)

Flight, P. A., D. Nacci, D. Champlin, A. Whitehead, **D. M. Rand**. 2011. The effects of mitochondrial genotype on hypoxic survival and gene expression in a hybrid population of the killifish, *Fundulus heteroclitus.* Molecular Ecology 20:4503–4520.

Folk, D. A., P. Zwollo, **D. M. Rand**, G. W. Gilchrist. 2006. Selection for knockdown performance in *Drosophila melanogaster* impacts thermotolerance and heatshock response differentially in males and females. Journal of Experimental Biology 209(Pt 20):3964-73.

Montooth, K. L., Abt, D., Hofmann, J, and **D. M. Rand**. 2009. Comparative genomics of Drosophila mtDNA: variation in evolutionary rates across regulatory elements, oxidative phosphorylation complexes and lineages. Journal of Molecular Evolution 69(1):94-114.

Montooth, K. L., Meiklejohn, C. D., Abt, D. N., and **D. M. Rand**. 2010. Mitochondrial-nuclear epistasis affects fitness within species but does not contribute to incompatibilities between species in *Drosophila*. Evolution 64(12):3364-79.

Rand, D.M., D. M. Weinreich, Lerman, D., Folk, D. A., G. W. Gilchrist. 2010. Three selections are better than one: Clinal variation of thermal QTL from independent selection experiments in Drosophila. Evolution 64(10):2921-34.

(ii) Five additional relevant publications

Flight, P. A., Schoepfer, S., and **D. M. Rand**. 2010. Physiological stress and the fitness effects of *Mpi* genotypes in the acorn barnacle *Semibalanus balanoides*. Marine Ecology Progress Series 404: 139-149.

Meiklejohn, C. D., Montooth, K, L. and **D. M. Rand. 2007.** Positive and negative selection on the mitochondrial genome. Trends in Genetics 23(6):259-63.

Rand, D. M. 1994. Thermal habit, metabolic rate and the evolution of mitochondrial DNA. Trends in Ecology and Evolution 9: 125-131 (cover article)

Rand, D. M., A. J. Fry, and L. A. Sheldahl. 2006. Nuclear-mitochondrial epistasis and Drosophila aging: Introgression of *D. simulans* mtDNA alters longevity in *D. melanogaster* nuclear backgrounds. Genetics 172: (1):329-41

Rand, D. M. 2011. Mitochondrial genome size, population genetics of the germline cytoplasm and the units of selection on Drosophila mtDNA. Genetica 139(5):685-97.

E. Synergistic Activities

Elected positions	President, American Genetic Association, 2009 Fellow, American Association for the Advancement of Science, 2011
Director	NSF IGERT Program in Reverse Ecology, Brown / Marine Biological Laboratory Joint Graduate Program, 2010-2015 Center for Computational Molecular Biology, Brown University, 2011
Associate Editor	MBE, 1997-2003; *Genetics,* 2004-2009; BioScience, 2005-present
Panel Member	NSF Population Biology 10/95, 10/97, 4/98, 4/05 NIH Study Section 7/99, 4/05, GVE Panel Regular member 10/08-10/12
Memberships/Reviewer:	Genetics Society of America, Society for the Study of Evolution, Society for Molecular Biology and Evolution; *American Naturalist, Evolution, Genetics, Journal of Molecular Evolution, Molecular Biology and Evolution, PloS, PNAS, Science, Nature*

Biographical Sketch

Caroline Ziemkiewicz
Postdoctoral Research Associate
Brown University Department of Computer Science
Box 1910
Providence, RI 02912
cziemki@cs.brown.edu
http://cs.brown.edu/people/cziemki

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

Postdoctoral Research Associate, Brown University, Department of Computer Science (September 2010 – present)
Researcher, UNC Charlotte, Department of Computer Science (May 2010 – August 2010)
National Visual Analytics Center Intern, Pacific Northwest National Laboratory, (June-August 2009)

C. PUBLICATIONS

Publications Most Closely Related to Proposal

Caroline Ziemkiewicz, R. Jordan Crouser, Ashley Rye Yauilla, Sara L. Su, William Ribarsky, and Remco Chang. "How Locus of Control Influences Compatibility with Visualization Style," Proceedings of IEEE Visual Analytics Science and Technology, 2011, http://cs.brown.edu/people/cziemki/documents/ziemkiewicz11_locus-of-control.pdf. To Appear.

Caroline Ziemkiewicz and Robert Kosara. "Laws of Attraction: From Perceived Forces to Conceptual Similarity," IEEE Transactions on Visualization and Computer Graphics, 16, 1009-1016, 2010, http://cs.brown.edu/people/cziemki/documents/ziemkiewicz10_laws-of-attraction.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.

Other Significant 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. "Beyond Bertin: Seeing the Forest Despite the Trees," IEEE Computer Graphics and Applications, 30, 7-11, 2010, http://cs.brown.edu/people/cziemki/documents/ziemkiewicz10_beyond-bertin.pdf.

Wenwen Dou, **Caroline Ziemkiewicz**, Lane Harrison, Dong Hyun Jeong, Roxanne Ryan, William Ribarsky, Xiaoyu Wang, and Remco Chang. "Comparing Different Levels of Interaction Constraints for Deriving Visual Problem Isomorphs." Proceedings of IEEE Visual Analytics Science and Technology, 2010, http://www.cs.tufts.edu/~remco/publications/2010/VAST2010-MathScrabble.pdf

Dong Hyun Jeong, **Caroline Ziemkiewicz**, Brian Fisher, William Ribarsky, and Remco Chang. "iPCA: An Interactive System for PCA-based Visual Analytics." Computer Graphics Forum, 28, 767-774, 2009, http://www.knowledgeviz.com/portfolio/pdf/iPCA-fin.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 served as a student volunteer at IEEE VisWeek for one year and at IEEE Virtual Reality for four years.

COLLABORATORS AND OTHER AFFILIATIONS

Collaborators Over The Last 48 Months:

David Badre (Brown University)
Christophe Benoist (Harvard Medical School)
Remco Chang (Tufts University)
R. Jordan Crouser (Tufts University)
Wenwen Dou (UNC Charlotte)
Fritz Drury (Rhode Island School of Design)
Eric Fields (Tufts University)
Brian Fisher (Simon Fraser University)
Tera M. Green (Simon Fraser University)
Lane Harrison (UNC Charlotte)
Dong Hyun Jeong (University of the District of Columbia)
Robert Kosara (UNC Charlotte)
David Laidlaw (Brown University)
Jeff Chi-Tat Law (Stanford University)
William Ribarsky (UNC Charlotte)
Roxanne Ryan (UNC Charlotte)
Mark Schnitzer (Stanford University)
Steven Sloman (Brown University)
Sara Su (Tufts University)
Xiaoyu Wang (UNC Charlotte)
Ashley Rye Yauilla (UNC Charlotte)

Graduate and Postdoctoral Advisors

Robert Kosara (UNC Charlotte)
David Laidlaw (Brown University)

Budget Justification

A. Senior Personnel

Dr. David Laidlaw (PI) 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. Benjamin Raphael (Co-PI) is requesting support for one summer month per year of the project. As a Co-PI, he will be responsible for coordinating with biology collaborators, leading the cancer genome and environmental genome thrusts, and researching quantitative tools for automating the analysis process.

Dr. Steven Sloman (Co-PI) 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 Rand is requesting support for one summer month per year of the project to facilitate IGERT student participation.

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 and ongoing 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.

Postdoctoral Research Associate: 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 HCI and CLPS groups and sites.

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 visualization 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 Research Associate: Dr. Laidlaw is requesting full time support for Postdoctoral Research Associate yet-to-be-named for each year of the project. That person will assist Dr. Raphael in coordination among the faculty and student groups focusing on genomics.

Senior Software Engineer. Dr. Laidlaw is requesting 50% time support for an expert software engineer yet to be named, who will be responsible for creating and running regular tests to ensure that the software is

reliable, for providing installation and infrastructure support for external users, and also to ensure that the software works across platforms and across operating system versions.

Research staff. Dr. Laidlaw is requesting 25% time support for a research staff person to coordinate efforts with the collaborators at the Harvard Medical School and the ImmGen website and data.

Research Staff: PI Laidlaw requests support for 20% of software engineer John Huffman's time related to the project's visualization software research with the Center for Computation and Visualization (CCV). Mr. Huffman is Manager of the CCV User Services and Applications at Brown University. He will help, in particular, with the virtual reality Cave facility that CCV manages.

Graduate Students: support is requested for 5.5 to-be-named graduate students for each year of the project. Two graduate students will work 100% time in Computer Science with Dr. Laidlaw on brain applications. One graduate student will work 100% time in Computer Science with Dr. Laidlaw on ImmGen data research. One graduate student will work 100% in Computer Science or in Biology with Drs. Raphael and Rand on genomics and cancer applications.

In Cognitive, Linguistic & Psychological Sciences; one graduate RA will work 100% for Dr. Sloman on cognition issues and the second will work 50% for Dr. Badre on brain analysis using tools.

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. One will be primarily responsible for Cave-related experimentation and evaluation. 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 & Psychological 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. 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 31.7% for faculty, post-doctoral, and staff salaries, and 8% 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 requested for visiting research collaborators at Stanford and Harvard and for the PI, Co-PIs, Senior Personnel and Graduate RAs attending scientific conferences and meetings.

F. Other Direct Costs

Materials and Supplies: $5,000 is requested in the first year for 2-3 computers to run experiments specific to this project.

Experimental subjects: Support is requested annually for funding of costs associated with experimental subjects in research related to cognitions issues in the Cognitive, Linguistic & Psychological Sciences.

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, Post-docs and research staff, 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 6.54% of costs projected for the project excluding graduate tuition and equipment.

Other: Included on the G.6. Other Direct Costs - Other line is Graduate Tuition.

G. Indirect Costs

Brown's approved indirect cost rate is used here: 62.5% MTDC. This rate was approved for Brown University by the U.S. Department of Health and Human Services on June 26, 2011.

Post-Doc Mentoring Plan

NSF does not request a mentoring plan for the Expeditions Pre-proposal – Not applicable.

PROJECTED COMMITMENTS

No institutional commitments have been made.

PARTNER INSTITUTIONS

Academic Institutions:
- Brown University
- Stanford University
- Harvard Medical School

PROJECT SENIOR PERSONNEL

Laidlaw, David, Brown University
Badre, David, Brown University
Sloman, Steven, Brown University
Raphael, Benjamin, Brown University
Rand, David, Brown University
Ziemkiewicz, Caroline, Brown University
Drury, Fritz, Rhode Island School of Design
Benoist, Christophe, Harvard Medical School
Schnitzer, Mark, Stanford University
Law, Jeff, Stanford University

Results of Prior Support

a David H. Laidlaw

Over the last five years David Laidlaw's research group has been funded by several NIH awards or subcontracts to NIH awards, continuation funding from several NSF awards and a Keck Foundation grant, and one recent NSF instrumentation grant. Most of the NIH awards and subcontracts related to developing and applying computational tools for the analysis of diffusion MRI imaging data. Laidlaw's group has published extensively in this area with collaborators from around the world. Another NIH award was for developing computational bioengineering tools to study the human carpus in collaboration with PI Joseph Crisco in the Department of orthopedics. A final NIH subcontract involves creating interactive tools for studying gene expression in the immune system. This is in collaboration with Christophe Benoist at Harvard Medical School. Laidlaw's most recent NSF funding was an MRI award to develop a new virtual reality display instrument at Brown. That project is in year three of four. Finally, he has been a co-PI on Keck and NSF awards to study animal kinematics and dynamics. In the last five years his research has led to about 25 refereed journal articles, approximately 10 refereed conference papers, two patent applications, and about 40 conference abstracts or posters. Laidlaw has been recognized via a number of best poster and best panel awards at conferences and received in 2008 the prestigious IEEE VGTC Visualization Technical Achievement Award.

b Steven Sloman

Steven Sloman's primary sources of funding over the past 5 years have been an NSF award entitled "Causal Models of Decision Making: Choice as Intervention" and a research contract with Unilever Corporation entitled "Designing Products to Cue Causal Reasoning." The NSF project was designed to test the hypothesis that decision makers are actively trying to understand their environments in order to construct and use causal models that predict the effects of their choices on themselves, on others, and on the world around them. The project has yielded 10 publications. The Unilever award examined the causal knowledge that people have about consumer products and how they make inferences about the benefits those products provide. The work has led to 2 publications and several that are currently under submission or in preparation.

c Mark Schnitzer

Schnitzer had an NSF grant (Award 0352456) from 2004-2007 that involved the development of fiber-optic microscopy for use in freely moving rodents. This work led to 5 patent filings and 10 publications – including more papers to date on Ca2+ imaging in awake behaving animals than from any other lab – and sparked the ideas proposed here. For this body of NSF-supported papers, Schnitzer was recently named the 2010 recipient of the Michael and Kate Barany Young Investigator Award from the Biophysical Society.

d Christophe Benoist

Naive T cell homeostasis: Treg selection and survival (PI) This project analyzes the cellular mechanisms that control the homeostasis of FoxP3+ Treg cells and how genetic variability affects these mechanisms. An NIH diversity research supplement was granted under this award for the sole use of a post doc's salary and fringe.

Imaging autoimmune disease (PD: D. Mathis) Proj 3: Visualizing lymphocyte attack on pancreas β cells (PI) In the context of a collaborative P01 on the application of imaging techniques to study autoimmune diseases, this project aims to use cutting-edge imaging techniques to visualize the infiltration and interplay of pancreas Treg and Teff cells in autoimmune diabetes.

T cell costimulatory pathways: functions and interactions (PD: A. Sharpe) Proj 2: Costimulatory cues and T cell phenotypes (co-PI) This project, shared with the Kuchroo laboratory, investigates the effects the costimulatory molecules of the CD28 family in phenotypic differentiation of T lymphocytes, in relation to pathenogenic vs protective roles in autoimmune disease.

Genetics of arthritis susceptibility in outbred HS mice (PI) This projects aims to analyze the genetic basis of susceptibility to arthritis in genetically complex mice.

ImmGen: a gene expression compendium for immune cells (PI) The goal of this consortium project is to generate, under carefully standardized conditions, a complete microarray dissection of gene expression

in the mouse immune system, focused on primary cells ex vivo. This in basal conditions or in response to genetic or environmental perturbations, to support the reverse-engineering of gene regulatory networks.

JDRF Center on Immunological Tolerance in Type-1 Diabetes at HMS (PD: Diane Mathis) Project 4: Genomics of FoxP3+ Treg cells in mice and humans (PI) This project explores the genomic roots of partially defective Treg cells in diabetes susceptible mice and human patients

JDRF Center on Immunological Tolerance in Type-1 Diabetes (PD: Diane Mathis) Manipulated NOD Mouse Core (PI) This core provides Center members with access to a panel of genetically engineered NOD mouse strains, as well as to diverse means of manipulating the NOD mouse genome.

GlaxoSmithKline *Studies on Tregs anti-CD3 and kinase inhibitors (Co-PI)* This program analyzes the cellular and molecular determinants if Treg cell differentiation in the thymus, and their involvement in animal models of type-1 diabetes and arthritis.

Gene Expression and Regulatory Networks in Human Leukocytes (PI) This study represents a broad exploration of gene expression in human blood cells across groups of African-American, Asian and European ancestry, addressing how these profiles are affected by genetic variation or by age. This award includes all of the funds for the proposed project period.

The molecular mechanism of Aire: partnering with DNA-PK (co-PI) The goal of this proposed project is to determine the role of DNA-PK in partnering with Aire to control immunological tolerance.

Microbiota derived novel therapeutic to prevent Type 1 diabetes (co-PI) The goal of these studies is to establish whether and how B. fragilis or its product PSA influences type-1 diabetes development in mice.

Aire, a zinc finger protein that controls autoimmunity (co-PI) The goal of this project is to understand why Aire must be expressed in perinatal mice to guard against autoimmunity but is dispensable in adults.

Adipose-tissue Tregs: Important players in the immunological control of metabolism (co-PI) The goal of this proposed project is to elucidate the generation, dynamics and function of visceral-fat Tregs.