



## Q.2 - STRATEGIC PLANNING

*Task: Please describe the unit's strategic goals and aspirations, linking them to the priorities set by the chancellor and the provost.*

### MISSION

Our mission is to identify and address key questions in cognitive science. Through interdisciplinary research and education, we explore the nexus of humans and machines as we seek to understand and extend human cognition, machine intelligence, and fruitful collaborations between the two. Our research builds on artificial intelligence, cognitive neuroscience, human learning, and emotional processing to tackle some of society's most pressing challenges: understanding brain health and wellness, developing personalized therapies and interventions, enhancing and deepening human learning, and optimizing complex cognitive processes to improve human performance and collaboration.

### VISION

Our vision for the coming period is to:

- Be a campus leader in innovative, interdisciplinary research
- Be a campus leader in inclusiveness, diversity, and equity
- Reimagine our interdisciplinary educational programs
- Develop a robust resource engine to support future growth

INTERDISCIPLINARY COGNITIVE SCIENCE @ CU: OUR NEXT CHAPTER

We have identified several opportunities for building on our current expertise, computational skills, and technological trends:

**Cognition in the Wild.** Cognition in the wild refers to the complex and realistic mental activities that people engage in every day: at work, in school, at home, and when pursuing health and wellness. These activities are embedded in rich, and increasingly technologically-augmented, physical and social environments. Our cognitive processes are embodied in the sense that they are deeply situated within, and influenced by, the people, tools, and technologies available in these environments. Increasingly, people will expect learning, health, and wellness applications to be dynamically tailored to their individual needs and their social and environmental contexts.

One driver of these profound changes is the Internet of Things, whereby the majority of objects in our environment are enriched with sensors and computation, and interconnected for real-time sensing and communication. One of the objects that is increasingly enriched with sensors is the human body, through smartphones, wearable devices, smart fabrics, ingestible sensors, programmable tattoos, and functional skin. These technologies generate a constant stream of language, environmental, physiological, and behavioral data. New technologies for sensing brain signals and other mental phenomena are increasingly available.

These technologies will rapidly accelerate the shift to data-driven cognitive science, by providing unprecedented access to a rich variety of data streams capturing a broad range of human cognition, learning, and behaviors (Figure 1). Capitalizing on these data streams will require significant advances in our ability to computationally analyze, synthesize and model multimodal data streams spanning a variety of temporal and spatial scales. Neuroimaging studies will perform an important validation role by ensuring that data collected in the wild correspond in a principled and scientifically valid way to the brain regions and mental constructs identified in the laboratory. Our community has discussed various ways to increase our capacity in this area, including professional development for faculty, fostering new partnerships with other campus units and/or industry, and recruiting new faculty and fellows working in this space.

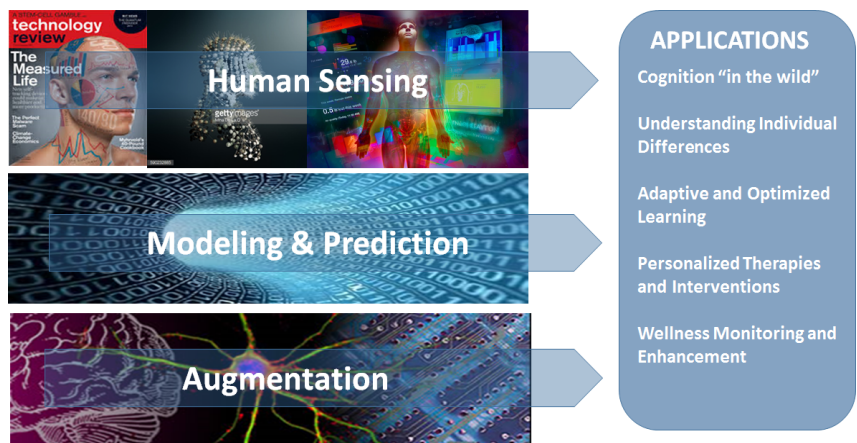


Figure 1. Studying and enhancing cognition enabled by new forms of data

**Neuroscience.** Neuroimaging is a crucial tool for brain mapping and understanding. With the recent upgrade to our neuroimaging facility, we now operate a state-of-the-art facility that is one of a handful in the country with similar capabilities. Our strength in neuroimaging - fMRI, EEG, and fNIRS - can extend and enhance our other areas of research. Avenues for building on our neuroimaging facility and expertise include bringing education and neuroscience together to expand our understanding of learning and cognition, bringing our expertise in neuroimaging and machine learning together to expand our understanding of brain functioning and brain health, and bringing together our neuroscience and computational expertise in emotions to expand understanding of affect and cognition. As we continue to push for translational impact, we will need to expand our partnerships with clinical researchers from Psychology and Integrated Physiology. One challenge we will face is the substantial learning curve associated with fMRI studies; we identified several options for mitigating this obstacle such as focusing on senior hires in this area and/or developing the capacity of our Intermountain Neuroimaging Center to offer turnkey research services.

**Interdisciplinary Partnerships.** The above two areas are not an exhaustive list of our planned research, rather, they describe two pillars of our expertise. Our community recognizes that the third pillar of our expertise is interdisciplinary breadth, and we have a stunning range of expertise and experience across our membership to draw on. We will continue to enhance our capacity to draw on our membership as we build interdisciplinary teams capable of addressing problems that require “deep integration across disciplines”, one of the two hallmarks of convergence research as defined by the National Science Foundation<sup>1</sup>. The other hallmark is solving vexing research problems, in particular, complex problems focusing on societal needs. The following questions illustrate the ‘convergence research’ challenges our interdisciplinary teams can address:

- How does the adolescent brain develop and how is development influenced by genetic and environmental factors?
- How can we combine AI with advances in our understanding of the brain, and innovations in human sensing, to provide early detection, customized treatments, and cognitive augmentation to enhance human mental health and well-being?
- How can we design more engaging, effective, and equitable learning environments? How can AI be used effectively to support and enhance human learning?

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<sup>1</sup> <https://www.nsf.gov/od/oia/convergence/index.jsp>; retrieved Oct. 9, 2018

- What are the neural processes underlying skilled reading? How can adaptive training models be used to teach advanced reading comprehension?
- What brain pathways underlie the generation and regulation of emotion and pain? How does affect and emotion influence our learning and decision-making? Can we develop machines that can reliably detect and characterize human affect and emotions?
- What cognitive factors influence high performance human-human and human-agent collaboration and teaming? How can we design learning and working environments to facilitate effective collaboration and teaming?

## SWOT ANALYSIS

### Strengths

- Built up critical expertise in key areas
- Created the necessary infrastructures

### Weaknesses

- Brittle resource engine based primarily on indirect cost returns

### Opportunities

- New campus initiatives supporting inclusiveness and diversity
- Education opportunities and partners

### Threats

- Retention and growth challenges for faculty and staff in high demand fields

**Strengths.** While the Institute is small in size, we have built up *critical expertise* in key areas and created the *necessary infrastructures*. ICS has a track record in developing and utilizing advanced computational approaches – machine learning, natural language processing, and data mining – to analyze and model structured and unstructured data in order to understand human cognition. Thus, we are already ahead of the curve in terms of preparation and skills for data-driven cognitive science. We have also recently recruited two additional faculty members (D’Mello and Hirshfield) whose expertise in affect detection, non-invasive brain-computer interfaces, adaptive user interfaces, and learning analytics will further enhance our capabilities in this area. We also host the Intermountain Neuroimaging facility which includes a state-of-the-art imaging facility as well as a strong community of researchers.

The Institute of Cognitive Science has also laid the groundwork for transformative future growth through developing significant human, technological, and capital infrastructure over the past decade. We have a suite of talented and creative interdisciplinary tenure track and research faculty, a broad range of faculty fellows from participating units, and a productive and well-functioning staff (*human*).

Our research has advanced science in learning, cognition, and brain health and wellness, with a core emphasis on developing and using innovative computational approaches and neuroimaging to study, model, and support human cognition (*technological*). This research is made possible through our ongoing operation of a state-of-the-art neuroimaging facility and the CINC laboratory facility (*capital*).

**Weaknesses.** A persistent weakness is our *brittle resource engine*. In non-profit organizations, the term ‘resource engine’ refers to a combination of money, time and energy (typically volunteered) that is needed to generate and sustain a robust organization (Collins, 2001). The Institute has relied on indirect cost returns from grant expenditures as our primary source of revenue for the past two decades. Even though the Institute offers courses, certificates, and degree programs, we receive no tuition-derived revenue for these offerings. These programs are supported through our indirect cost returns, which limits our ability to sustain them, much less scale them to meet rising student demand. While our grant expenditures are strong and growing, recent experiences highlight the potential vulnerabilities of relying on this sole income stream. One issue is our dependence on federal research awards; our financial health can be significantly and negatively impacted by a decline in federal research expenditures. A second vulnerability is our dependence on a modest number of highly productive contributors. As a small unit, our finances can be negatively impacted by the departure of a single contributor, particularly if this position goes unfilled for multiple years. Three years ago, these vulnerabilities occurred at the same time and the Institute required a small “bail-out” from the University to support continued operations. While we have since returned to profitability, underlying causes contributing to this fiscal exposure are still present and need to be addressed.

**Threats.** We will need to work closely with the University to *retain our outstanding faculty and staff* in this increasingly competitive employment environment. Our tenure track and research professors are working in cutting edge and high demand areas such as deep learning, emotion detection, brain-computer interfaces, adaptive learning, cannabis and health, neuroscience of pain, etc. Their knowledge and skills make them highly sought after in both academic and industry environments. Timely and competitive retention packages will be critical. We also need to create a productive and welcoming work environment that people are reluctant to leave. This will necessitate a remodel of our CINC research facility in the coming period.

Hiring great talent in high demand areas will also be challenging in this competitive environment. We need to partner with the University to develop a *faculty growth model* to be enacted over the next ARPAC period. Our mission - to identify and address key questions in cognitive science - is central to major, contemporary societal challenges, including navigating the human/machine cognitive nexus, helping humans to effectively learn and retrain, and developing non-addictive approaches for managing stress and mental health. Our faculty have demonstrated both the saliency of cognitive science and its enduring relevance through their ability to consistently secure peer-reviewed sponsored research funding at high levels for the past 30 years. A faculty growth model will enable us to proactively maintain and strengthen this cohort, rather than reactively responding to individual departures, which

can have strong financial consequences in a small unit. Over the next period, we will undoubtedly lose some faculty through failed retention challenges, and over half our our current faculty will be eligible for retirement.

**Opportunities.** The Institute has a strong history of supporting intellectual diversity, welcoming faculty, fellows and students that study cognition and intelligence by drawing from a wide variety of disciplines, methodologies, and theoretical approaches. While traditional cognitive science from previous decades focused on human mental representations, our Institute has grown to include brain structure and function; statistical and connectionist machine learning; knowledge representation; emotional processing; as well as situated, embodied, and socio-cultural views of human cognition and learning. As described under *Inclusiveness*, we can build on this history of supporting intellectual diversity and partner with new *campus initiatives* to make our Institute more inclusive, diverse, and equitable.

As an Institute, we have always partnered with other units to provide our educational programs. Our current courses, programs, and student support structures are described under *Interdisciplinary Education*. We will build on our *partnering skills* as we reimagine our educational programs, with the aim of developing approaches that are financially sustainable and can scale to meet student demand. For instance, the Institute has already partnered with the post-baccalaureate program in Computer Science to offer our first online course in Fall 2018: *Machines and Minds*. We have begun discussions with Continuing Education to expand access to this course and to consider how it can contribute to emerging online degree options.

## PLAN

The key actions we will undertake to achieve our vision, and their mutually reinforcing nature, are outlined in the ICS Flywheel diagram below (Figure 2). We will adapt this plan over time based on data described under Demonstrate Results. This approach to strategic planning is adapted from the monograph by Collins, entitled “*Good to Great for the Social Sector*”<sup>2</sup>. Collins advocates an approach whereby an institution connects the key components of their resource engine (time, money, and energy in social institutions) with processes necessary to support achieving the mission (center of flywheel). This approach is appropriate for ICS to use at this time as one element of our vision is strengthening our resource engine. Rather than focusing on individual programs or initiatives, the flywheel model is

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<sup>2</sup> Collins, J. (2001), *Good to Great and the Social Sectors: A Monograph to Accompany Good to Great*, Harper, New York, 38 pages.

intended to outline a set of cyclical and reinforcing activities and outcomes that gradually gather more momentum over time.

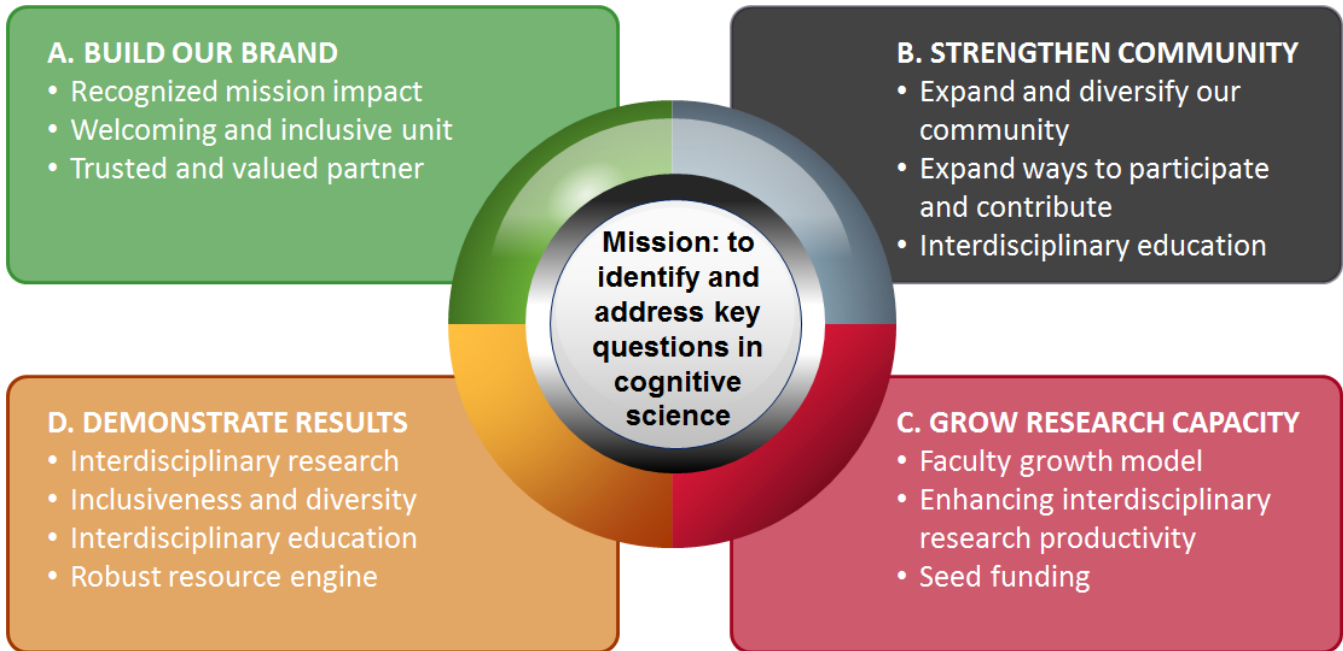


Figure 2. ICS Flywheel, adapted from "Good to Great for the Social Sector" [Collins, 2001]

**A. Build Our Brand.** This component of our flywheel focuses on understanding and improving our relationships, business practices, and communication with partners and the public. These activities will contribute to all components of our vision.

- Recognized mission impact. We will enhance our communication and marketing practices to ensure that we are consistently communicating our mission, vision, and research and education outcomes and impacts to a wide range of audiences, including our community, our affiliated units and partners, the larger CU community, and the general public.
- Welcoming and inclusive unit. As discussed under *Inclusiveness*, we will engage in regular internal assessment, planning, education, and professional development opportunities to continuously enhance diversity, inclusiveness, and equity practices and to ensure that our community is accessible and welcoming to all.
- Trusted and valued partner. As a small unit, it is essential that we work productively with other units on campus and a wide range of partner institutions to achieve our mission and vision. We will refine our communication processes to ensure that our affiliated units and other partners understand the research and education opportunities available to their faculty and students through participating in or partnering with the Institute. We will continue to develop and share

innovative, transparent, and objective business process tools, such as the ICR calculator we jointly developed with Psychology & Neuroscience, to streamline cross-unit transactions and ensure consistent outcomes.

**Resources Needed.** These additional activities are beyond the capacity of our current staffing and budget to pursue. Yet, we believe that they are essential for meeting our vision, particularly the *inclusiveness and diversity* component. Therefore, we are asking the University to partner with us to bootstrap this process by providing three years of support for an additional 0.5 FTE staff. We anticipate half of this being applied towards a marketing and outreach specialist and half being applied towards a ‘diversity officer’ charged with leading our inclusivity, diversity, and equity assessments, education, and other activities.

**B. Strengthen Community.** This component of our flywheel emphasizes building our community and providing a range of ways for members to participate in the Institute and to develop their interdisciplinary research and education capacity. New participants will strengthen and diversify our community; new forms of participation will strengthen and diversify our research and educational programs, and ultimately, our resource engine.

- Expand and diversify our community. Building on our better understandings and practices for creating and maintaining an inclusive and welcoming unit, the Institute will seek out new faculty, fellows, students and partners that contribute to the intellectual vitality and diversity of our community.
- Expand ways to participate and contribute. We will continue to expand options for non-traditional faculty to contribute to the Institute’s research, education and service activities. The Institute is home to many non-traditional faculty - including research professors, research associates, and affiliated faculty fellows - who outnumber traditional tenure track faculty. Participation in our research programs and weekly colloquium are the primary avenues for participating. Recently, we developed a stipend program to support research faculty to contribute to ongoing and occasional service activities. Several of our research faculty made outstanding contributions to this self-study report. As we reimagine our educational offerings, we will develop new ways for our non-traditional faculty, community members and partners to contribute to these offerings.
- Interdisciplinary education. The Institute has begun the process of reimagining our educational programs, after first introducing them 20 years ago. As a first step, we identified several core values that will guide our re-imagining effort: build interdisciplinary capacity, support pedagogical innovation, provide new kinds of teaching opportunities, generate revenue, further our reach, and support translational research. We anticipate two main thrusts for our



‘reimaging’ activities: online learning and advanced interdisciplinary research training. In terms of online learning, we are studying the range of online options and partners emerging as a result of new campus initiatives, and we are conducting pilot implementations with select partners. Each campus initiative has a very different business model and they reach different audiences. As discussed under Interdisciplinary Education, graduate students at the Fall 2018 Townhall generated a range of interesting ideas for enhancing their interdisciplinary research training. We will build on these ideas to enhance our current practices and we will develop an interdisciplinary training grant application to investigate new models and approaches.

**Resources Needed.** In order to grow our educational offerings, both on campus and online, we will need staff support and a viable financial model that allows us to sustain the effort and not be dependent on ICR. Seed funding is needed to support online course development and enhancements. We will need RIO support and advice to navigate the institutional processes and limits for submitting federal training grant applications through CU.

**C. Grow Research Capacity.** This component of our flywheel outlines how we will make progress toward our vision of being a campus leader in innovative, interdisciplinary research.

- **Faculty growth model.** Earlier in this plan, we discussed the rationale for investing in cognitive science, outlining the intellectual merits and broader impacts that can be realized through our innovative, interdisciplinary research. We also discussed the pitfalls of the current ‘reactive’ approach to faculty growth, which typically results in a zero sum game and can leave a faculty position unfilled for a prolonged period. Establishing a proactive faculty growth model is essential to the long-term vitality of our Institute.

Our tenure track faculty is small in number (8.5, including Director Sumner); yet these individuals function as keystone species within our broader research ecosystem, supporting critical interactions across units, mentoring research associates and graduate students, and leading new research programs and grant initiatives. We anticipate each new tenure track position will increase our research expenditures by \$800,000 annually, allowing for a period during which they build up their lab and their local research network. As detailed in Q3 (Interdisciplinary Research and Scholarship), our track record and evidence suggests that each faculty line would yield robust research expenditures: our per capita FTE productivity by active grant dollars over the last seven years was \$807,942. In addition to being a great investment, we need to start investing in our future to ensure continuity: our current tenure track faculty is top heavy (5 Full Professors, 2 Associates, and 1 Assistant) and maturing, with a potential “retirement cliff” approaching over this next period.

- Enhancing interdisciplinary research productivity. The Institute will continue to refine and implement recommended research-based strategies for creating and sustaining research-productive departments. We are drawing on the excellent work of Bland et al (2005)<sup>3</sup> which integrates an extensive literature review with their own in-depth and longitudinal research on a wide range of departments. As noted in this work, there is no single strategy for guaranteed effectiveness, rather a broad set of strategies needs to be consistently implemented to support cultural change and build research capacity:
  - Research is a clearly-communicated priority
  - Systematically foster rich scientific conversations
  - Identify strategic areas
  - Align rewards and recognition
  - Mentoring and professional development (grant development, technical skills, research methods)
  - Identify leaders and coalesce around them
  - The Institute has focused on making changes to align with these strategies that do not require additional resources.

Towards this end, we have: (1) adopted clear communication of our research priority, (2) worked with our Executive Committee to revamp our merit review criteria and processes, (3) engaged in strategic planning, and (4) held a number of meetups and workshops to foster scientific conversations. Over the coming period, depending upon available financing, the Institute will develop ways to incentivize interdisciplinary research collaborations that lead to successful grant submissions. We also need to update our CINC research facility to accommodate growth and to make the existing space more useful and usable to our faculty, staff, and students (see Space section for rationale).

- Seed funding for pilot studies. Our faculty have identified the lack of seed funding for pilot studies as a serious impediment to interdisciplinary research. An internal source of funding is particularly critical for high risk/high reward interdisciplinary research, which may not cleanly fall into current programs and funding sources. While the CU Seed Grant program is well-regarded, it provides only a small number of annual awards and may be focused on a topic that is not aligned with cognitive science.

**Resources Needed.** We will need university financial commitment to develop and implement a faculty growth model. The Institute will investigate models for financing and implementing seed

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<sup>3</sup> Bland, Weber-Main, Lund and Finstad (2005), *The Research-Productive Department: Strategies from Departments that Excel*, Wiley.

funding. The small program recently implemented by CU REACH provides a promising model. It was started through a philanthropic donation; grantees are expected to repay twice the original grant in order to grow the seed funding pool.

**D. Demonstrate Results.** This component of our flywheel outlines the *measures* we will use to assess and communicate our progress towards realizing our mission. Collins believes that clearly and consistently communicating progress is essential for providing momentum to the social sector flywheel. We will focus on results aligned to the four components of our vision:

- Be a campus leader in innovative, interdisciplinary research. Our measures here will target our ability to grow our research programs, the degree to which we are promoting interdisciplinary collaborations, and the impact of our research. To understand growth, we will track annual research expenditures (total, average), research publications (total, average), as well as change over time. To understand how we are promoting interdisciplinary collaboration, we will disaggregate grant and publication data to characterize the breadth and depth of non-traditional faculty and graduate students participation as well as interdisciplinary collaborations. To understand the impact of our research, we will track: (1) K12 teachers and students impacted; (2) general public impacted through events such as Brain Awareness Week; (3) products produced (e.g., new curriculum, learning environments, tools); (4) research-practice partnerships (schools, districts, industry); and (5) technology/research transfer arrangements. We will also track media coverage of ICS-related research and educational programs, as well as coverage of our faculty, fellows, students and other community members.
- Be a campus leader in inclusiveness and diversity. We will work with our Executive Committee to establish processes for administering a ‘climate and inclusiveness’ survey at regular intervals. These data will be used to monitor changes in our climate and inclusiveness and they will inform periodic updates to our Inclusiveness Policy.
- Reimagine our interdisciplinary educational programs. We will use quantitative and qualitative measures of student success and learning outcomes, similar to those described elsewhere in this self-study. These measures include: (1) students matriculating from our certificate and degree programs; (2) students participating in online courses; (3) graduate research assistants (number supported annually, change over time, post-graduation placements); (4) research assistants and post-docs (number supported annually, change over time, promotions and placements). We will need to refine our measures as we reimagine our educational programs.
- Develop a robust resource engine to support future growth. ICS will continue to improve the robustness of our resource engine through growth and revenue diversification. Revenue diversification aligns with the Chancellor’s goals for the entire campus. We will measure

research expenditures, ICR percent returned to the Institute, and revenue diversification on an annual basis. The flywheel outlines our theory of how to grow our research capacity and portfolio, which should directly impact our research expenditures and ICR return percentage. We are working to diversify our revenue sources by including direct cost returns in low overhead grants, tuition return from online courses, and contributions from faculty, alumni, and the community. We are also expanding our research funding portfolio to include non-federal sources.

- *Prepared by Prof. Tamara Sumner on behalf of the Institute of Cognitive Science.*