Computational Cognition Rationale

[redacted]
Colorado College

Neuroscience research today necessitates the use of computer science technologies to analyze and map the extremely dense and complex neural substrate of the brain and nervous system. These maps, while visually striking, shed no light on the living, evolving systems they depict. In fact, the more we learn about the architecture and functioning of the brain, the more difficult it is to explain how, exactly, it enables human behavior. On the other hand, computer science techniques and hardware capabilities are evolving at an exponential rate, and the gigantic energy expenditures required to employ them are inflaming issues which are already overwhelming us. This rapidly advancing computational power can provide insight into almost any topic it is applied to, neuroscience being no exception.

Many of the newest deep learning techniques are inspired by brain architectures such as neural networks and neuromorphic algorithms. The human brain, itself the most efficient computer there is, has taught, and continues to teach us much about how to make the hardware we employ more powerful, efficient, and intelligent, which in turn can be used to help us better understand how the brain functions.

Computational cognition, or computational cognitive psychology, encompasses both computer science techniques to study the brain and behavior, as well as patterns of neural functioning which inspire computer science techniques. Enhancing our understanding and knowledge of one of these topics has the potential for the same effect on the other. Researchers in this field seek to apply computer models to uncover knowledge about brain science, but also to upgrade our models to employ techniques learned from neuroscience.

Rather than being two distinct fields of study, computational cognition recognizes that the computing that takes place in the brain and on a harddrive benefits by being studied through the same perspective. By separating the study of them, or viewing each as independent, we deprive both fields of the knowledge that can be transferred. Additionally, coding ability directly translates to a much wider range of methodological techniques one can employ to study the nervous system, while decreasing the necessity for expensive equipment and funded research.

UCLA has majors for both computational cognition and cognitive psychology, as well as for cognitive neuroscience. They recognize, and encourage the study of, the connection between computation and human intelligence/cognition[1]. These disciplines are described as increasingly merging in modern day research of intelligence and the brain. The methodological approaches available to researchers in this field are suitably broad in their variety and specific targets, limited only by the skill of the programmer and the data available. Programming ability is not

[1]UCLA Computational Cognition Major:
https://www.psych.ucla.edu/graduate/areas-of-study/specialization-in-computational-cognition/

necessarily the key to all of these approaches, with empirical research being an important aspect of uncovering knowledge in this field, and of enhancing the research that does incorporate computer science.

Colorado College offers courses that review historical knowledge as well as current breakthrough science in both computer science and neuroscience. Computational Cognition is not offered as a major, nor is any comparable discipline. However, the breadth of knowledge covered in offered courses is more than enough for the study and pursuit of computational cognitive science theory and research, as well as the methods of that research.

During block two, I worked with my advisors to train a convolutional neural network on FMRI brain scan data in order to upscale, or artificially increase the resolution of that data. This process involved data management, deep learning, and research into the current state of the art. It encompassed exactly the type of knowledge sought after in my target field, that being practical coding knowledge combined with neuroscientific research methods. By utilizing data which has already been collected and made available to the public, a computer is the only tool required to attempt to produce novel understanding or techniques.

I would benefit from courses which teach how real neural systems work, providing me with more experience and a deeper level of understanding of the principles of these systems. I will endeavor to learn what they can teach us about designing efficient and powerful computer models, such that I can understand better computational principles, and how they are applied across both fields. Crucially, I will also continue to develop my skills with practical applications of our computing power for the purpose of benefiting neuroscience research and increasing the efficiency of our applications of that power.

One way I hope to do this is by building on my aforementioned project, and expanding on the techniques I have learned to conduct meaningful neuroscience research. This will likely manifest as continuing the usage of deep learning techniques in more complex ways, especially those that utilize neurofunctional patterns. With the help of my advisors, I hope to discover a novel way to analyze neuroscience or psychological data with these techniques, or build a computational model which can teach us something about intelligence and the brain. By practice and study, I can learn about these techniques, and about the shared computational principles that drive both them and the human brain.

Computational Cognition Courses

Computer Science Fundamentals:

- Computational Thinking - CP115 | None
    - Introduces Python and coding

- Computer Science 1 - CP122 | Computational Thinking
    - Introduces Java, and begins to teach the fundamentals of coding language operations/strategies

- Computer Science 2 - CP222 | Computer Science 1
    - Teaches higher level java and an understanding of how computers function

- Software Design - CP274 | Computer Science 2
    - High level overview of successful coding and coding design strategies, advanced teamwork skills in coding contexts

- Computer Organization - CP275 | Computer Science 2
    - Teaches computational principles of data representation, and more advanced teamwork skills

Neuroscience and Psychology:

- Introduction to Psychological Science - PY105 | None
    - Introduction to behavior and the brain/nervous system

- Methods I - PY205 | Introduction to Psychological Science
    - Methods of research design and statistical analysis, introduction to psychology-related experimental knowledge

- Methods II - PY305 | Methods I
    - SPSS software and advanced statistical analysis, as well as advanced research methods and design

- Neuroscience - PY299 (Double Block) | Introduction to Psychology
    - Deep analysis of modern neuroscience, emphasizing neural circuitry and patterns of neural functioning

- Behavioral Game Theory - PY435 | Methods I
    - Mathematical analysis of behavior and psychology

Computational Cognitive Science:

- Natural Language Processing - CP341 | Software Design
    - Advanced deep learning techniques, historical development of such, and

- Team Software Project - CP499 | Software Design
    - Advanced Python, data structures and storage, teamwork, and client coding

- Independent Research: FMRI Brain Scan Upscaling with Convolutional Neural Networks
    - Deep learning techniques practically applied to neuroscience data

- Senior Thesis - GS400 | GS350
    - Deep learning techniques practically applied to neuroscience data

Academic Year	Course ID	Course Title	Units
2020-2021	PY105	Introduction to Psychological Science	1
2021-2022	PY299	Neuroscience	2
2021-2022	CP115	Computational Thinking	1
2021-2022	CP122	Computer Science I	1
2021-2022	CP222	Computer Science II	1
2021-2022	CP274	Software Design	1
2021-2022	PY435	Behavioral Game Theory	1
2022-2023	CP341	Natural Language Processing	1
2022-2023	CP275	Computer Organization	1
2022-2023	CP499	Team Software Project	1
2021-2022	PY205	Methods I	1
2022-2023	PY305	Methods II	1
2022-2023	GS391	Independent Research	1
2023-2024	GS400	Thesis	1

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