Lucy Lai

Statement of Scholarly Activities

...teachers possess the power to create conditions that can help students learn a great deal, or keep them from learning much at all. Teaching is the intentional act of creating those conditions, and good teaching requires that we understand the inner sources of both the intent and the act. —*Parker J. Palmer, The Courage to Teach*

Teaching is my first love, and becoming a teaching faculty has always been my long-term career goal. I began teaching in my sophomore year of college, and since then, have taught a total of 5 semesters as an instructor of record and 12 semesters as a teaching assistant and fellow (TA / TF). My teaching experience spans neuroscience, psychology, AI, and mathematics courses ranging from 12 to 101 students, and includes both virtual and in-person instruction. My teaching has been recognized through 3 awards and an average teaching evaluation score of **4.86 / 5** across all courses.

Additionally, my research interests in learning and decision-making have led to a productive thesis on the cognitive costs of behavior in health and disease. I have published 2 first-authored and 3 co-authored papers in reputable journals, built several collaborations, and successfully funded my own Ph.D. with 3 grants. I have also involved undergraduate and high school students in my research projects as an extension of my teaching endeavors. This statement describes the principles and practices by which I teach, as well as my research on the trade-off between cognitive effort and reward.

Teaching Principles and Practice

My overarching goals as an educator are to (1) foster agency, rigor, and critical-thinking skills that can be used to tackle real-world problems and (2) create a classroom environment that celebrates diversity, promotes belonging, and supports the intellectual growth of *all* students. I achieve these goals by intentionally designing a course's **structure** (the foundation on which it is built) as well as its **function** (the real-time implementation). Below, I recount 8 years of experience in putting these principles of structure and function into practice.

Structure

Course policies and organization

Course policies set the tone of a course and profoundly impact student learning. What a student can expect from the instructor and vice versa must be made clear at the beginning of the course. These expectations can take the form of grading rubrics and learner-centered syllabi with clearly specified deadlines, late policies, and feedback mechanisms (O'Brien et al., 2009). Each policy should also be backed by a rationale and communicated to the student. For example, as Head TF for GenEd1125: *Artificial and Natural Intelligence*, I let students know that while they were allowed one free late pass on a problem set, the maximum number of days late could not exceed 5. I explained that this was so that we could release the answer key for all other students to receive prompt feedback on their problem set, learn from their misunderstandings, and ask for clarification.

Course organization can greatly reduce students' extraneous cognitive load (Paas et al., 2003) and allow them to devote the majority of their cognitive resources to learning (instead of figuring out when the due dates for assignments are, for example). In *Artificial and Natural Intelligence*, I enforced weekly rhythms that persisted throughout the semester: problem sets were always due every 2 weeks on Friday at midnight, and were always graded and handed back the following Tuesday (thanks to my incredible teaching staff!). Students were then able to clarify any misunderstandings at their discussion sections later in the week. Informal feedback revealed that **100%** of students thought the problem sets were graded in a timely manner. Students quickly caught onto this course rhythm and knew exactly when to expect what, as well as what was expected of them.

Another way I utilize organization to reduce extraneous load is in designing easily accessible websites for students to navigate course content. While course management systems such as Canvas are useful for hosting course content in one place, they can at times be hard to navigate if the course site itself has not been organized in a straightforward way. To remedy this, I have created several course websites that link to all the relevant files and assignments organized in chronological order, offering students a one-stop shop for class preparation. In one course, **82%** of students reported using my website over Canvas to access course materials.

Aligning learning goals, objectives, assessments, and activities

Utilizing the principles of backward design (Wiggins et al., 2005), I always consider the learning goals and objectives of my course before preparing the assessments and in-class activities *in alignment* with the specified goals. Additionally, I strive to incorporate all levels of Bloom's Taxonomy (Krathwohl, 2002) into my course to promote a range of critical-thinking skills. In *How Music Plays the Brain,* the learning goals range from "**understand** the biological mechanisms underlying auditory perception" to "**formulate** scientific questions related to music cognition and processing." Assessments and activities such as labeling a diagram of the inner ear and reading scientific research articles on music cognition build a knowledge foundation that serves analytic and creative thinking in alignment with the learning goals.

Interdisciplinarity

The interdisciplinary nature of cognitive science is what drew me to the field in college and still captures my fascination today. Teaching across disciplinary lines allows for interesting dialogue and perspectives, and also provides a forum for students to combine their strengths and knowledge domains. Many of the courses I have developed and been involved in reflect my desire to encourage interdisciplinary thinking, including *How Music Plays the Brain, Math Tools for Neuroscience, Artificial and Natural Intelligence,* and *From Bench to Bedtime: Entraining Policy to Science.* I also put much effort into curating readings and materials from multiple disciplinary perspectives and modalities. For example, in *Math Tools for Neuroscience*, I used a YouTube video from 3blue1brown to explain the concept of a "null space" using visual geometry (a null space is the set of all vectors that become zero when a transformation is applied). I then related this concept to a finding published in Nature Neuroscience which proposed that motor cortex uses a null space-like mechanism to prepare a motor movement without prematurely causing it. This kind of interdisciplinary crosstalk is not only useful for teaching but also for innovation in research. Thinking across disciplines is therefore a crucial skill for the next generation of (cognitive) scientists.

Rigor and agency

Another guiding principle involves what students take away from my courses after the term has ended. I always tell students that my pedagogical goal in every course I teach is not simply rote memorization of the material. Rather, it is to equip them with critical and transferable skills that enable them to acquire, evaluate, and synthesize knowledge in new domains. One crucial skill for students to develop is an intuition for scientific rigor. For example, by teaching students how to identify pseudoscience (in *How Music Plays the Brain*) or by asking them to consider the weaknesses of research studies on circadian biology (in *From Bench to Bedtime*), they learn to assess the validity of scientific claims and scrutinize the methods used to reach those claims. This skill is not only important within the course context, but is also useful in many other domains: from evaluating statistics in the news to deciding whether or not to get vaccinated.

It is also important for students to develop a sense of agency in order to become independent thinkers and lifelong learners. To encourage learner agency, I provide freedom of choice in several course components, such as allowing students to write their final paper on a topic of their choosing or to demonstrate understanding of the material in a creative way (e.g., recording a podcast, writing a poem, drawing a zine). I also always provide students with extra resources in all kinds of modalities (research papers, blog posts, videos, podcasts, and even Twitter posts) in case they are interested in delving further into any given topic. By encouraging both rigor and agency, students are able to become drivers of their own lifelong education. My intentionality in promoting independent thinking has been noticed and appreciated by students:

> *[...] For the amount of instruction time available and all the info available about how music affects the brain, Lucy does a very nice job of* ***both teaching this subject to her students and fostering independent thinking from her students*** *about this topic.*

Feedback

Finally, it is important to give students adequate feedback to learn from, and to provide mechanisms for gathering student feedback about the course. In *Artificial and Natural Intelligence*, I trained my TF team to prioritize giving written feedback on student problem sets and addressing commonly made mistakes in their discussion sections. At the end of term, **94%** of students indicated that the feedback on their work was adequate. In fact, 81.3% of students only looked at the TF-provided comments compared to 18.8% who looked at both answer keys and TF comments, proving the importance of individualized feedback.

Student feedback is also crucial for improving a course. I provide anonymous avenues for course feedback at multiple timepoints throughout the term. I also strive to incorporate feedback to improve a course. As mentioned in my cover letter, the course ratings for *Artificial and Natural Intelligence* increased from 3.81 to 4.24 (out of 5) after using student feedback from the previous year to inform curriculum improvement. One common complaint from the first rendition of the course was that the problem sets often seemed irrelevant and detached from the lectures. Another complaint was that there was too much variety between each individual TF's discussion section content. To remedy this, I revisited each lecture's learning objectives and rewrote all the problem sets to align with the objectives. I also standardized the discussion section content, creating lesson plans and template slides so that all TFs were all teaching the same material. At the end of the term, **98%** of students said the problem sets were helpful in solidifying the course material, and **86%** said the same about their discussion section.

Teaching, like any truly human activity, emerges from one's inwardness, for better or worse. As I teach I project the condition of my soul onto my students, my subject, and our way of being together. —The Courage to Teach

Function

Inspiring the subject

I will always remember my high school physics teacher, who made me love physics even though I hated it. That is when I realized that the first secret of effective teaching is a genuine, effusive enthusiasm for the subject. Enthusiasm inspires the subject and brings it to life. It is also usually contagious, and goes a long way when engaging students. While this may seem like a "soft" skill to write about in a teaching philosophy, it does not go unnoticed, as evidenced in several of my teaching evaluations:

> *Very* ***enthusiastic, genuine, personable,*** *and* ***makes learning enjoyable and less stressful*** *for everyone. One of the best TAs!*
>
> *Lucy was always* ***energetic and enthusiastic*** *which made section a lot more* ***fun and rewarding.***
>
> *[...] The* ***enthusiasm*** *she brought to class was* ***inspiring****. She is also very approachable and likable.*

Additionally, I believe an enthusiastic demeanor invites curiosity. I want students to wonder: *why is she so excited about this subject?* The human brain and mind is so incredibly fascinating; I can't help but invite students to wonder with me. Speaking of curiosity leads me to my next principle:

Starting with a puzzle, leaving with a question(s)

Science can be dry if not motivated through a lens of storytelling and curiosity. Motivating students with curiosity can also emphasize an attitude of learning and growth over a fixation on grades. That is why in any given class, I try to start with a puzzle. For example, when lecturing about the computational role of dopamine in learning, I introduce a series of scientific findings that led to a significant puzzle: *does dopamine simply* *signal reward, or does it encode something more complex?* I then use this opening question to motivate the experiments that led to the discovery that dopamine encodes a *reward prediction error*.

Equally important is ending well. In another class, I asked students to write down "one thing they learned today, and one question they still have." This continues the cycle of curiosity by encouraging students to think about what they still want to learn. As a way to bridge class periods, I often begin the next class session by first addressing some student questions from the previous session. This continues the cycle of starting with puzzles and ending with questions.

Student-teacher synchrony

In my experience as both student and teacher, I have come to understand good teaching as a delicate, closed-loop dance between two parties: a skilled teacher is responsive to students' body language and facial expressions as signals of comprehension. Student-teacher synchrony is particularly vital when teaching mathematics, since many complex topics build upon simpler concepts that must first be solidly grasped. When teaching *Math Tools for Neuroscience*, I learned the importance of slowing down when I noticed that students were getting lost during the lecture, instead of rushing to finish teaching all the material I had prepared for that day. I often turned away from the chalkboard to face my students and check for expressions of comprehension or confusion. I also used language that invited questions, asking *"What questions do we have?"* instead of *"Does anyone have any questions?"*

My attention to students' understanding meant that we would often spend longer on a mathematical example than I had planned for. But because I prioritized learner comprehension, many students indicated that they were able to grasp the mathematical concept better than all the previous times they had learned it in high school or college. This understanding was further evidenced in an end-of-course assessment.

Active and collaborative

Research shows that active learning activities increase student performance over traditional lecturing (Freeman et al., 2014). I intentionally incorporate many active learning activities into my class sessions, offering students opportunities to engage with the material and with each other. I have used a variety of verbal and non-verbal techniques, from think-pair-share to PollEverywhere quizzes, in courses of all sizes. In *From Bench to Bedtime,* we grouped students into discussion pods and had them consider the effects of permanent Daylight Savings Time on health. We first gave students some time to reflect on the question by themselves. Then they discussed in their small discussion pods before reconvening with the entire class to distill key take-aways. By asking each group to designate one person to share out for each question, there were never awkward silences in class. Students' feedback reflected my efforts in promoting an active and collaborative class environment:

> *Lucy was excellent in teaching the material and did a fantastic job in* ***facilitating thoughtful discussions.*** *This section was definitely the best aspect of the course.*
>
> *I really enjoyed coming to section since she made it* ***quite interactive and fun.***

There are ways to engage students even in virtual instruction. In fact, on Zoom, every student technically sits at the front of the "classroom." When teaching during the pandemic, I made extra effort to engage students by utilizing the Zoom chat function for side conversations and allowing ample time in Zoom breakout rooms for group debates. In one teaching evaluation, one student remarked:

> *Lucy really goes above and beyond as a TF and really clearly cares about students and pedagogy. Sections are well thought out and* ***incredibly engaging especially given the Zoom context****…*

Community and belonging

Last, but certainly not least, I am committed to fostering a collaborative intellectual environment that prioritizes community and belonging. I know I've succeeded when every student feels empowered to contribute and that their ideas fundamentally matter. This is especially important for underrepresented students, who may be less likely to speak up during class. To set this expectation of community and belonging early on, I ask students to introduce themselves on the first day of class by sharing their names along with the meaning of their names. This simple activity sets up the tone of the class such that students themselves are more likely to interact with me and each other (and pronounce names correctly!) throughout the term. I also make an effort to ask students about their non-academic lives, and convey the importance of bringing one's “whole self” to the classroom. These small gestures help foster a sense of intellectual community and have been noticed and appreciated by my students:

> *[Lucy] easily* ***encouraged participation through icebreakers*** *or questions about* ***how our lives were going*** *in general [...]*
>
> *[...] I also love how she* ***fostered a sense of community*** *within the course and* ***supported lively in-class discussion.***

Notably, I have been able to cultivate community and belonging even during virtual instruction. The first year that we offered *Artificial and Natural Intelligence* was during the COVID-19 pandemic. I taught a discussion section of 12 students, many of whom were first-years. In a time of social isolation, I took advantage of Zoom to promote dialogue and a feeling of community, especially since it was many of these students' first exposure to intellectual discourse in a college setting. To contrast their 3x/week lectures, I kept students engaged by encouraging everyone to share their thoughts and allowing for ample interaction in breakout rooms. I affirmed my students' unique academic perspectives, by highlighting, for example, how the computer science majors could learn about AI policy and ethics from the social studies majors. At the end of the term, one student specifically noted that:

> *[...] section in general was a joy, such a nice discussion environment fostered there that* ***EVERYONE had their cameras on and mics on all the time and were always talking and laughing.*** *This class was absolutely fantastic but a significant part of that is because of Lucy and everything she meant for us.*

In summary, my teaching philosophy is entirely driven by intentional principles of structure and function that promote the intellectual growth and belonging of all students. I am excited to continue teaching effectively as an Assistant Professor of Cognitive Science at UCSD, and am confident that I am well-positioned to do so.

Research and Scholarship

Policy Compression in Action Selection

The human brain has limited cognitive resources for use in everyday behaviors such as learning and decision-making. Behaviors can be cognitively costly because of the amount of mental effort that is required to perform a task. Cognitive cost impacts performance in many domains, from low-level functions like visual memory all the way up to high-level cognitive tasks, such as studying for an exam. **How do humans weigh the cognitive costs of behavior against its potential benefits or rewards? And how does this trade-off between cognitive effort and reward impact behavior in health and disease?**

To address these questions, my research utilizes behavioral experiments and computational modeling. One challenge in studying this cost-benefit trade-off is that mental effort can be characterized in a variety of ways: computational models have formalized effort as the amount of thinking time that is required for a task, as well as the inherent difficulty of learning a task (Dayan & Daw, 2008; Filipowicz et al., 2020). But less studied is the **amount of *memory* required for executing a task**. My research aims to fill this gap by examining how humans weigh rewards against the memory demands imposed by behavior.

First, I developed a computational model describing how people should act if they seek to maximize rewards under a fixed memory capacity. This model uses information theory to quantify memory load as the amount of environmental “state” information that is taken into account when selecting actions. Under this framework, optimal behavior achieves a balance between the complexity of the behavioral policy, or how specific one’s actions are to the states, and the amount of reward that can be obtained (Parush et al., 2011; Still, 2009; Tishby & Polani, 2011). When behavior is simplified by reducing demand on memory, it is called **policy compression**.

Next, I explored the consequences of policy compression in a variety of tasks. I showed that a range of behavioral phenomena including habit formation, action chunking, and navigational planning could be described in terms of reward optimization under limited memory capacity . Additionally, our model predicts that maladaptive behaviors such as perseveration, which is implicated in various psychiatric diseases, are a consequence of reduced memory capacity. We validated these model predictions in a previously published dataset, showing that patients with schizophrenia are biased towards less complex policies compared to healthy controls (Gershman & Lai, 2021).

In novel behavioral tasks, I test further predictions of our model to reveal how people adapt to varying incentives and demands on memory. I showed that action chunking, or the act of grouping individual actions together to enable faster execution, is modulated by cognitive load and can be understood as policy compression (Lai et al., 2022). In collaboration with the Janak Lab at Johns Hopkins, I am applying our policy compression framework towards understanding habit formation under different reward schedules.

The outcome of my thesis research has important applications to the field and to society: knowing how humans specifically trade-off memory load and reward is important for developing a more holistic model of resource-rationality in human behavior. My work could inform the development of interventions for psychiatric conditions associated with memory deficits, and could also inspire the design of human-centered technologies that alleviate memory load for easier decision-making.

A Computational Account of Egodystonia

During my PhD, I developed an interest in computational psychiatry and started a collaboration with Quentin Huys and Tobias Hauser at the Max Planck Institute for Computational Psychiatry and Ageing in London. Our project focused on a curious behavioral phenomenon called egodystonia: a metacognitive problem where one’s actions and their subjective accounts are detached from one another (Robbins et al., 2019). Egodystonia has been documented in psychiatric conditions such as obsessive compulsive disorder (OCD), bulimia nervosa, and drug addiction.

What drives this mismatch between beliefs and behavior? Neuroscientists have shown that people with OCD are able to develop accurate beliefs about the environment but fail to use their beliefs to guide their actions (Vaghi et al., 2017, 2019). While these studies have shown a dissociation between cognitive knowledge and subsequent behavior, none have (1) provided an explanation for how this mismatch arises or (2) measured one’s subjective sense of their actions being “bothersome,” which is a key signature of egodystonia. We wondered if we could elicit egodystonic feelings in a healthy population as a key to understanding why and how it emerges.

In a novel experiment combining behavior and subjective report, we successfully elicited egodystonic feelings in a healthy population with a range of obsessive compulsive traits. We found that egodystonicity does not change with reward availability or action rate, and is driven by a fear of consequences or “missing out.” Guided by our results, we develop a computational account of egodystonia that can capture our behavioral and subjective report data. Our results provide the first evidence for experimentally-induced egodystonia and paves the way for a better understanding of this curious phenomenon.

Future Research Agenda

Going forward, I hope to expand the scope of my research towards understanding how cognitive limitations can lead to severe behavioral consequences such as belief rigidity and polarization. This is an important and relevant subject given the recent polarization of political ideologies in the United States, as well as the effects of individual beliefs on climate (in)action. It is also pertinent for understanding the mechanisms underlying disordered beliefs and actions in psychiatric disease. Understanding the influence of cognitive resource limitations on belief formation and maintenance is therefore crucial for developing interventions to change beliefs.

I believe that the UCSD is a great place to carry out these research interests. In collaboration with talented undergraduates and research faculty with similar interests (such as Marcelo Mattar, Ed Vul, Adam Aron, and Craig McKenzie), I will continue to pursue my curiosities about brain and behavior as both a researcher and an educator. I also hope to help train and inspire the next generation of scientists by bringing star undergraduates to conferences and sitting on graduate student thesis committees. Finally, I will continue to share my research and scholarship with the broader community by volunteering to give talks at local high schools (as I have in the past) and writing popular science articles.

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