The mission of the Cognitive Science Program is to advance the study of minds and brains, real or artificial, in all their aspects, through research and teaching. This interdisciplinary field, encompassing the fields of psychology, linguistics, computer science, philosophy, anthropology, and neuroscience, provides excellent preparation for life in the age of information. The program aims to instill in students a solid grasp of the intellectual problems, frameworks, and methodologies currently available; to provide experience exploring these through guided research; and to foster the desire to create and disseminate new knowledge. With this foundation, students are well prepared for a wide variety of careers at the interfaces of technology, minds, brains, and behavior, and for graduate study in Cognitive Science or any of the contributing disciplines.

We offer undergraduate B.A. and B.S. degrees in Cognitive Science, an undergraduate minor, and a graduate certificate. A Cognitive Science major is easy to combine with a second major in the humanities, natural sciences, social sciences, or computer science.

Professors. Kiri Lee, PHD (Harvard University); Barbara C. Malt, PHD (Stanford University); Hector Munoz-Avila, PHD (Technische Universität Kaiserslautern); Pádraig O’Séaghdha, PHD (University of Toronto); Dominic J. Packer, PHD (University of Toronto)

Associate Professors. Catherine M. Arrington, PHD (Michigan State University); Amanda C. Brandone, PHD (University of Michigan); Jeffrey D. Hefflin, PHD (University of Maryland, College Park); Almut Hupbach, PHD (Universitat Trier)

Assistant Professor. Nancy B. Carlisle, PHD (Vanderbilt University, Peabody College)

B.A. IN COGNITIVE SCIENCE

The B.A. in Cognitive Science requires a minimum of 14 courses. All majors take COGS 007, an introduction to cognitive science, plus core courses in cognitive psychology, philosophy, artificial intelligence, and cognitive neuroscience, and collaterals in computer science. They also complete a course in research methods or tools. Students then pursue their individual interests by completing at least five electives from across three tracks. A capstone integration occurs in the required two-semester senior project (COGS 301 and COGS 302, or, for Honors, COGS 391 and COGS 392), in which students focus on a topic of their choice spanning at least two cognitive science sub-disciplines.

Additional coursework in affiliated disciplines is recommended, to be selected in consultation with the major adviser and dependent upon anticipated career path. These courses may fulfill college distribution requirements. Note: A number of major courses have pre-requisites.

Collateral Requirements

<table>
<thead>
<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>CSE 001</td>
<td>Breadth of Computing</td>
</tr>
<tr>
<td>or CSE 012</td>
<td>Survey of Computer Science</td>
</tr>
<tr>
<td>CSE 002</td>
<td>Fundamentals of Programming</td>
</tr>
</tbody>
</table>

B.S. IN COGNITIVE SCIENCE

The B.S.in Cognitive Science entails additional courses beyond those in the B.A. to provide both additional breadth and depth. It requires a minimum of 20 courses. All majors take COGS 007, an introduction to cognitive science, plus core courses in cognitive psychology, philosophy, artificial intelligence, and cognitive neuroscience, and collaterals in computer science, math, and social science. They also complete two courses in research methods or tools and at least one semester of supervised research. Students then pursue their individual interests by choosing a concentration area from among three tracks and completing at least six electives with a minimum of four in the concentration area. A capstone integration occurs in the required two-semester senior project (COGS 301 and COGS 302, or, for Honors, COGS 391 and COGS 392), in which students focus on a topic of their choice spanning at least two cognitive science sub-disciplines.

Additional coursework in affiliated disciplines is recommended, to be selected in consultation with the major adviser and dependent upon anticipated career path. These courses may fulfill college distribution requirements. Note: A number of major courses have pre-requisites.

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<td>CSE 002</td>
<td>Fundamentals of Programming</td>
</tr>
<tr>
<td>MATH 021</td>
<td>Calculus I</td>
</tr>
<tr>
<td>or MATH 051</td>
<td>Survey of Calculus I</td>
</tr>
<tr>
<td>or MATH 075</td>
<td>Calculus I, Part A</td>
</tr>
<tr>
<td>&amp; MATH 076</td>
<td>and Calculus I, Part B</td>
</tr>
<tr>
<td>CSE 140</td>
<td>Foundations of Discrete Structures and Algorithms</td>
</tr>
<tr>
<td>PSYC 001</td>
<td>Introduction to Psychology</td>
</tr>
</tbody>
</table>
Two courses in research methods and tools.

For Artificial Intelligence and Formal Models Concentration:

CSE 160 Introduction to Data Science
& MATH 231 Probability and Statistics
or ECO 045 Statistical Methods

For all other concentrations:

PSYC 201 Research Methods and Data Analysis I
& PSYC 202 and Research Methods and Data Analysis II

Introduction Course

COGS 007 Introduction to Cognitive Science 4

Disciplinary Core Course

COGS/PSYC 117 Cognitive Psychology 16
COGS/PSYC 176 Cognitive Neuroscience
COGS/PHIL 250 Philosophy of Mind
COGS/CSE 327 Artificial Intelligence Theory and Practice

COGS 183
or COGS 184 Cognitive Neuroscience Recitation

18-24

Choose six electives from the concentration lists, at least four of them from within the same concentration. The lists are the same for the B.A. and the B.S. Requirements specific to each concentration for the B.S. are as follows:

Artificial Intelligence and Formal Models

CSE 017 Programming and Data Structures

Cognition, Culture, and Meaning

COGS 140 Introduction to Linguistics

Cognitive Neuroscience

BIOS 121 Biology Core III: Integrative & Comparative Biology 2

Research Experience 3

COGS 161 Supervised Research 4 2-4

Senior Project

COGS 301 & COGS 302 Senior Project in Cognitive Science: Proposal and Senior Project in Cognitive Science: Execution 6-8


Total Credits 46-56

1 Collateral courses may count toward CAS distribution requirements where applicable.

2 BIOS 121 Biology Core III: Integrative & Comparative Biology pre-reqs: any CHM course that fulfills the pre-requisite for BIOS 041, plus BIOS 041 Biology Core I: Cellular and Molecular and BIOS 042 Biology Core I: Cellular and Molecular Lab. These are not part of the major but can count toward CAS Natural Science distribution.

3 Students are encouraged to take the required research credits beginning in the second year or even earlier. At least two semesters of relevant research experience (minimum 4 credits) and supervisor (pre-requisite for Honors Thesis in Cognitive Science: Proposal) and Honors Thesis in Cognitive Science: Project Execution and Thesis for their senior project.

4 May be repeated for credit.

MAJOR ELECTIVES

Artificial Intelligence and Formal Models

CSE 017 Programming and Data Structures
CSE 042 Game Design
CSE 140 Foundations of Discrete Structures and Algorithms

CSE 262 Programming Languages
CSE 318 Introduction to the Theory of Computation
CSE 326 Fundamentals of Machine Learning
CSE 331 User Interface Systems and Techniques
CSE 335 Topics on Intelligent Decision Support Systems
CSE 337 Reinforcement Learning
CSE 347 Data Mining
CSE 348 AI Game Programming
CSE 360 Introduction to Mobile Robotics
CSE 428 Semantic Web Topics
CSE 431 Intelligent Agents

PHIL/MATH 114 Symbolic Logic
PHIL/MATH 214 Topics in Philosophical Logic
PHIL 265 Philosophy of Mathematics
PHIL/MATH 303 Mathematical Logic
MATH 261 Discrete Structures
MATH 304 Axiomatic Set Theory
MATH 329 Computability Theory

Cognition, Culture, and Meaning

ANTH 376 Culture and the Individual
COGS/ANTH/MLL 140 Introduction to Linguistics
COMM 385 Seminar in Communication Issues
CSE 252 Computers, the Internet, and Society
PHIL 128 Philosophy Of Science
PHIL 135 Modern Philosophy
PHIL 139 Contemporary Philosophy
PHIL 220 Ways of Knowing
PHIL 228 Topics in the Philosophy of Science
PHIL 260 Making Sense of Words
PSYC 307 Higher Order Cognition
PSYC 313 Person Perception
PSYC 314 Social Cognition
PSYC 320 Psychology of Language
PSYC/HMS 344 Health Care Reasoning and Decision Making
PSYC 351 Children's Thinking
PSYC/ES 357 Psychology of Environmental Issues
PSYC 358 Inside the Infant Mind
PSYC 362 Cognition in Practice & Policy
PSYC/GS 365 Human Development in Cross-Cultural Perspective
PSYC 384 Self and Identity
SOC/JOUR 135 Human Communication

Cognitive Neuroscience

ANTH 012 Human Evolution and Prehistory
ANTH 145 Human Evolution
BIOS 121 Biology Core III: Integrative & Comparative Biology
BIOS 276 Central Nervous System and Behavior
BIOS 277 Experimental Neuroscience Laboratory
BIOS 365 Neurobiology of Sensory Systems
BIOS 366 Diseases of the Nervous System
BIOS 382 Endocrinology of Behavior
BIOS 385 Synapses, Plasticity and Learning
BIOS 386 Genes and the Brain
PSYC 012 Introduction to Human Neuroscience
The undergraduate minor in Cognitive Science requires five courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>COGS 007</td>
<td>Introduction to Cognitive Science</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Four additional courses selected from among the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>major's core courses and major electives, with</td>
<td></td>
</tr>
<tr>
<td></td>
<td>at least two of these being Disciplinary Core</td>
<td>12-16</td>
</tr>
<tr>
<td></td>
<td>Courses</td>
<td></td>
</tr>
</tbody>
</table>

**Total Credits** 16-20

**PROGRAM HONORS**

Majors seeking to graduate with honors in cognitive science must have a 3.30 GPA in the major, a 3.30 GPA overall, and complete a high quality senior thesis with enrollment in COGS 391 Honors Thesis in Cognitive Science: Proposal and COGS 392 Honors Thesis in Cognitive Science: Project Execution and Thesis. Theses submitted for honors will be evaluated by a committee of at least three cognitive science faculty.

**GRADUATE CERTIFICATE IN COGNITIVE SCIENCE**

The graduate certificate provides the opportunity to develop an interdisciplinary perspective on human and machine intelligence. It is available to both enrolled and external students.

Students in Lehigh University graduate degree programs such as computer science, psychology, and instructional technology are encouraged to participate with the approval of an adviser in their major program. Non-degree, post-baccalaureate individuals with sufficient background to complete the coursework are also welcome to undertake the certificate. The certificate may be especially relevant to those working in technology-related fields. Interested individuals should contact the Director of the Cognitive Science Program. External candidates will also need to apply to the College of Arts and Sciences for non-degree graduate status.

The certificate will appear on the student’s transcript after submission of a signed completion form by the program director.

The Graduate Certificate requires four courses from the list below.

At least two of the courses must be at the 400-level, and the four courses must be spread over at least two departments. For Lehigh degree candidates, at least three of the four courses must be outside the home department. The certificate will entail 12-16 credits.

**ELECTIVES**

<table>
<thead>
<tr>
<th>Course Code</th>
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</tr>
</thead>
<tbody>
<tr>
<td>CSE 327</td>
<td>Artificial Intelligence Theory and Practice</td>
</tr>
<tr>
<td>CSE 331</td>
<td>User Interface Systems and Techniques</td>
</tr>
<tr>
<td>CSE 332</td>
<td>Multimedia Design and Development</td>
</tr>
<tr>
<td>CSE 335</td>
<td>Topics on Intelligent Decision Support Systems</td>
</tr>
<tr>
<td>CSE 348</td>
<td>AI Game Programming</td>
</tr>
<tr>
<td>CSE 409</td>
<td>Theory of Computation</td>
</tr>
<tr>
<td>CSE 426</td>
<td>Fundamentals of Machine Learning</td>
</tr>
<tr>
<td>CSE 428</td>
<td>Semantic Web Topics</td>
</tr>
<tr>
<td>CSE 431</td>
<td>Intelligent Agents</td>
</tr>
<tr>
<td>CSE 435</td>
<td>Topics on Intelligent Decision Support Systems</td>
</tr>
<tr>
<td>CSE 437</td>
<td>Reinforcement Learning and Markov Decision Processes</td>
</tr>
<tr>
<td>CSE 447</td>
<td>Data Mining</td>
</tr>
<tr>
<td>CSE 460</td>
<td>Mobile Robotics</td>
</tr>
<tr>
<td>PSYC 316</td>
<td>The Talking World: Psychology and Neuroscience of Speaking</td>
</tr>
<tr>
<td>PSYC 347</td>
<td>Cognitive Neuroscience of Memory</td>
</tr>
<tr>
<td>PSYC 355</td>
<td>Seminar in Cognitive Neuroscience</td>
</tr>
<tr>
<td>PSYC 369</td>
<td>Memory Under Construction</td>
</tr>
<tr>
<td>PSYC 377</td>
<td>Attention and Attentional Failures</td>
</tr>
<tr>
<td>PSYC 433</td>
<td>Cognitive Neuroscience Techniques</td>
</tr>
</tbody>
</table>

**MINOR IN COGNITIVE SCIENCE**

The undergraduate minor in Cognitive Science requires five courses:

<table>
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<tr>
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<tbody>
<tr>
<td>COGS 007</td>
<td>Introduction to Cognitive Science</td>
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<td>Courses</td>
</tr>
</tbody>
</table>

**Total Credits** 16-20

**Psychology**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSYC 307</td>
<td>Higher Order Cognition</td>
</tr>
<tr>
<td>PSYC 313</td>
<td>Person Perception</td>
</tr>
<tr>
<td>PSYC 314</td>
<td>Social Cognition</td>
</tr>
<tr>
<td>PSYC 316</td>
<td>The Talking World: Psychology and Neuroscience of Speaking</td>
</tr>
<tr>
<td>PSYC 320</td>
<td>Psychology of Language</td>
</tr>
<tr>
<td>PSYC/HMS 344</td>
<td>Health Care Reasoning and Decision Making</td>
</tr>
<tr>
<td>PSYC 347</td>
<td>Cognitive Neuroscience of Memory</td>
</tr>
<tr>
<td>PSYC 351</td>
<td>Children’s Thinking</td>
</tr>
<tr>
<td>PSYC 355</td>
<td>Seminar in Cognitive Neuroscience</td>
</tr>
<tr>
<td>PSYC 358</td>
<td>Inside the Infant Mind</td>
</tr>
<tr>
<td>PSYC 362</td>
<td>Cognition in Practice &amp; Policy</td>
</tr>
<tr>
<td>PSYC 377</td>
<td>Attention and Attentional Failures</td>
</tr>
<tr>
<td>PSYC 402</td>
<td>Developmental Psychology</td>
</tr>
<tr>
<td>PSYC 403</td>
<td>Cognitive Psychology</td>
</tr>
<tr>
<td>PSYC 406</td>
<td>Social Cognition</td>
</tr>
<tr>
<td>PSYC 433</td>
<td>Cognitive Neuroscience Techniques</td>
</tr>
<tr>
<td>PSYC 448</td>
<td>Seminar in Psychology of Language</td>
</tr>
<tr>
<td>PSYC 464</td>
<td>Naive Realism in Social Judgement</td>
</tr>
<tr>
<td>PSYC 476</td>
<td>Seminar In Cognition</td>
</tr>
<tr>
<td>PSYC/COGS 478</td>
<td>Ontological Psychology</td>
</tr>
<tr>
<td>PSYC 480</td>
<td>Seminar in Cognitive Development</td>
</tr>
<tr>
<td>PHIL/COGS 250</td>
<td>Philosophy of Mind</td>
</tr>
<tr>
<td>PHIL 260</td>
<td>Making Sense of Words</td>
</tr>
<tr>
<td>ANTH 376</td>
<td>Culture and the Individual</td>
</tr>
</tbody>
</table>

**Total Credits** 0

1 Note: These particular 200-level courses may be taken by graduate students.

**Courses**

**COGS 007 Introduction to Cognitive Science 4 Credits**

What is a mind? How is the mind related to the brain? Could we make an artificial mind? Issues concerning knowledge representation and intelligence in minds and computers as investigated by psychologists, philosophers, linguists, neuroscientists, and researchers in artificial intelligence.

**COGS 117 (PSYC 117) Cognitive Psychology 4 Credits**

The architecture and dynamics of the human mind: How we acquire knowledge through perception, represent and activate it in memory, and use it to communicate, make decisions, solve problems, and reason creatively. May not be taken pass/fail.

**Prerequisites:** PSYC 001 or COGS 007

**Attribute/Distribution:** SS

**COGS 127 (CSE 127) Survey of Artificial Intelligence 3 Credits**

An introduction to artificial intelligence (AI) intended for non-majors. AI concepts, systems, and history. Credit will not be given for both CSE/COGS 127 and CSE/COGS 327.

**Prerequisites:** CSE 002 or CSE 004 or CSE 007

**COGS 140 (ANTH 140, MLL 140) Introduction to Linguistics 4 Credits**

Relationship between language and mind; formal properties of language; language and society; how languages change over time. May not be taken pass/fail.

**Attribute/Distribution:** SS

**COGS 161 Supervised Research 1-3 Credits**

Research under the direct supervision of a faculty member in the cognitive science program. Students must arrange the particular project with a faculty member before enrolling. Consent of program director required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** ND
COGS 176 (PSYC 176) Cognitive Neuroscience 4 Credits
Perception and cognitive neuroscience as the link between mental processes and their biological bases. Visual and auditory perception; the control of action; neuropsychological syndromes of perception, language, memory, and thought; neural network (connectionist) models of mental processes. May not be taken pass/fail.
Prerequisites: CSE 017 and CSE 140
Repeat Status: Course may be repeated.
Attribute/Distribution: NS

COGS 183 (PSYC 183) Cognitive Psychology Recitation 1 Credit
Research, discussion, and analysis of topics in cognitive psychology.
Prerequisites: PSYC 117 or COGS 117
Can be taken Concurrently: PSYC 117, COGS 117

COGS 184 (PSYC 184) Cognitive Neuroscience Recitation 1 Credit
Research, discussion, and analysis of topics in cognitive neuroscience.
Prerequisites: PSYC 176 or COGS 176
Can be taken Concurrently: PSYC 176, COGS 176

COGS 194 Special Topics in Cognitive Science 2-4 Credits
Topics vary from semester to semester. Topics are addressed at an intermediate level. Previous course work in cognitive science and consent of faculty sponsor is required.
Repeat Status: Course may be repeated.

COGS 250 (PHIL 250) Philosophy of Mind 4 Credits
An exploration of the mind-body problem. Are the body and mind distinct substances (dualism); or is there only body (materialism); or only mind (idealism)? Other views to be considered include behaviorism (the view that behavior can be explained without recourse to mental states), and the view that the mind is a complex computer.
Attribute/Distribution: HU

COGS 300 Apprentice Teaching 1-4 Credits

COGS 301 Senior Project in Cognitive Science: Proposal 1-3 Credits
For students not intending to apply for program Honors. Background reading and preparation of a short written proposal are conducted in the first semester in consultation with a faculty advisor. Students must enroll for a total of three credits which may be split between the sections of a primary and secondary advisor. Consent of program director and project advisor required.

COGS 302 Senior Project in Cognitive Science: Execution 1-3 Credits
For students not intending to apply for program Honors. Execution of the project is conducted in the second semester in consultation with a faculty advisor. A presentation will be given at the end of the semester. Students must enroll for a total of three credits which may be split between the sections of a primary and secondary advisor. Consent of program director and project advisor required.
Prerequisites: COGS 301

COGS 327 (CSE 327) Artificial Intelligence Theory and Practice 3 Credits
Detailed analysis of a broad range of artificial intelligence (AI) algorithms and systems. Problem solving, knowledge representation, reasoning, planning, uncertainty and machine learning. Applications of AI to areas such as natural language processing, vision, and robotics. Credit will not be given for both CSE/COGS 127 and CSE/COGS 327.
Prerequisites: CSE 017 and CSE 140

COGS 361 Independent Research 2-4 Credits
Independent research in cognitive science with a faculty advisor. Students must arrange the particular project with a faculty advisor before enrolling. Consent of program director required.
Repeat Status: Course may be repeated.
Attribute/Distribution: ND

COGS 391 Honors Thesis in Cognitive Science: Proposal 1-4 Credits
For students with 3.3 or higher major and overall GPA by the spring of the junior year, who want to undertake a project with the potential for program Honors. Literature review and preparation of a written proposal are conducted in the first semester in consultation with a faculty advisor. An oral presentation will be given at end of the semester. Students must enroll for four credits which may be split between co-advisers. Consent of program director and project advisor required.

COGS 392 Honors Thesis in Cognitive Science: Project Execution and Thesis 1-4 Credits
For students with 3.3 or higher major and overall GPA by the spring of the junior year. Project execution and preparation of the written report is conducted in the second semester. An oral presentation will be given at end of the semester. Theses will be evaluated for Honors by three cognitive science faculty. Students must enroll for a total of four credits which may be split between co-advisers. Consent of program director and project advisor required.
Prerequisites: COGS 391

COGS 394 Special Topics in Cognitive Science 3-4 Credits
Topics vary from semester to semester. Topics are presented at an advanced level.
Repeat Status: Course may be repeated.

COGS 399 Senior Project in Cognitive Science: Thesis 1-3 Credits
Research during senior year culminating in senior thesis advised by a member of the Cognitive Science faculty. Execution and written report of project proposed and approved in COGS 301. Students must enroll for a total of three credits which may be split between the sections of a primary and secondary advisor. Theses submitted for honors will be evaluated by a committee of at least three cognitive science faculty. Prerequisite: COGS 301 and consent of the program director.
Repeat Status: Course may be repeated.
Prerequisites: COGS 301

COGS 405 Individual Study in Cognitive Science 1-6 Credits
Study of a topic not covered in regular course offerings. By arrangement with a consulting faculty member. Consent of program director required.
Repeat Status: Course may be repeated.

COGS 423 (PSYC 423) Foundations of Cognitive Science 3 Credits
Survey of fundamental theory and methodologies from artificial intelligence, linguistics, cognitive psychology, philosophy, and neuroscience, as well as salient research problems such as knowledge acquisition and representation, natural language processing, skill acquisition, perception and action, and the philosophical question of intentionality.

COGS 478 (PSYC 478) Ontological Psychology 3 Credits
Principles and constraints for modeling psychological phenomena. Representation; perception; memory; knowing; learning; emotions; consciousness; language; rationality.