

# COGNITIVE SCIENCE

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Cognitive science explores the nature of cognitive processes such as perception, reasoning, memory, attention, language, decision making, imagery, motor control, and problem solving. The goal of cognitive science, stated simply, is to understand how the mind works. Cognitive science is an inherently interdisciplinary endeavor, drawing on tools and ideas from fields such as psychology, computer science, linguistics, philosophy, economics, and neuroscience. Approaches include empirical studies of the ontogenetic and phylogenetic development of cognitive abilities, experimental work on cognitive processing in adults, attempts to understand perception and cognition based on patterns of breakdown in pathology, computational and robotic research that strives to simulate aspects of cognition and behavior, neuroscientific investigations of the neural bases of cognition using neural recording and brain scanning, and the development of philosophical theories of the nature of mind.

## PREREQUISITE

An introductory survey course, CGSC 110, is normally taken by the end of the fall term of the sophomore year and prior to admission to the major.

## REQUIREMENTS OF THE MAJOR

The requirements of the major for the B.S. and B.A. degrees are the same, except for the skills requirement and the senior requirement. Fourteen term courses, for a total of thirteen and one half course credits, are required for the major, including the introductory course and the senior requirement. Each major program must include the elements described below. The particular selection of courses must be approved by the director of undergraduate studies in order to assure overall coherence. No course may be used to fulfill more than one requirement for the major.

**Breadth requirement** A breadth requirement introduces students to the subfields of cognitive science. Each major is required to take a course from four of the following six areas:

1. Computer science: CPSC 201
2. Economics and decision making: ECON 159
3. Linguistics: LING 110, 116, 217, 130, 232, 253
4. Neuroscience: CGSC 201, MCDB 320, PSYC 160, 270
5. Philosophy: PHIL 126, 182, 269, 270, 271
6. Psychology: PSYC 110, 140, 139

**Depth requirement** Students fulfill a depth requirement by completing six courses that focus on a specific topic or area in cognitive science. The depth courses must be chosen from at least two disciplines, and are typically drawn from the six cognitive science subfields. It may be possible to draw depth courses from other fields when necessary to explore the student's focal topic, in consultation with the DUS. All six depth courses must be at the intermediate or advanced level; for most disciplines, courses numbered 300 or above fulfill the requirement. With permission of the DUS, up to two directed reading or research courses may count toward the depth requirement.

**Skills requirement** Because formal techniques are fundamental to cognitive science, one skills course is required, preferably prior to the senior year. Courses that fulfill the skills requirement for the B.A. include CPSC 112, 202, LING 224, PSYC 200, and 270. Other courses may fulfill this requirement with permission of the DUS. The skills requirement for the B.S. is fulfilled by PSYC 200 or another course with permission of the DUS.

**Junior colloquium** In the junior year, students are required to take CGSC 395, a half-credit colloquium in which majors discuss current issues and research in cognitive science and select a senior essay topic.

**Credit/D/Fail** Courses taken Credit/D/Fail may not be counted toward the requirements of the major, except with permission of the DUS.

## SENIOR REQUIREMENT

In the senior year, students take CGSC 491, a full-credit capstone course in which the senior essay is written. Students in the course meet regularly with one another and with the faculty to discuss current work in cognitive science and their own developing research projects. Students must take this course during their last spring term at Yale. If spring is not the student's final term, (e.g., a planned December graduation date), then it is possible to attend the class and complete some of the assignments, but not turn in the finished thesis until November. In this case, a grade of INC will be given for the Spring term. (Unlike other incomplete grades at Yale, an incomplete for a thesis does not expire.)

**B.S. degree program** The B.S. degree is typically awarded to students who conduct empirical research as part of their senior requirement. This normally includes designing an experiment and collecting and analyzing data.

**B.A. degree program** The B.A. degree is typically awarded to students who conduct a nonempirical senior essay. There are no restrictions on the research format for the B.A.

#### ADVISING AND APPLICATION TO THE MAJOR

Students may apply to enter the major at any point after the first year. Applications must be made in writing to the DUS. Applications must include (a) an official or unofficial transcript of work at Yale, (b) a brief statement of purpose, which indicates academic interests and expected focus within the areas of the Cognitive Science major, and (c) a list of the six upper-level courses that the student plans to take as part of the research focus. Application forms and answers to frequently asked questions are available on the program's website.

#### REQUIREMENTS OF THE MAJOR

**Prerequisite** CGSC 110

**Number of courses** 14 term courses, for a total of 13.5 course credits (incl prereq and senior req)

**Specific course required** CGSC 395

**Distribution of courses** 1 course each in 4 of 6 subfields, as specified; 6 courses in a specific topic or area, as specified; 1 skills course, as specified

**Senior requirement** B.S. – Empirical research and senior essay in CGSC 491; B.A. – Nonempirical senior essay in CGSC 491

#### FACULTY ASSOCIATED WITH THE PROGRAM IN COGNITIVE SCIENCE

**Professors** Woo-kyoung Ahn (*Psychology*), Stephen Anderson (*Emeritus*), Amy Arnsten (*School of Medicine*), John Bargh (*Psychology*), Paul Bloom (*Psychology*), Hal Blumenfeld (*School of Medicine*), Marvin Chun (*Psychology*), Michael Della Rocca (*Philosophy*), Ravi Dhar (*School of Management*), Julie Dorsey (*Computer Science*), Robert Frank (*Linguistics*), Shane Frederick (*School of Management*), David Gelernter (*Computer Science*), Tamar Gendler (*Philosophy*), Laurence Horn (*Emeritus*) (*Linguistics*), Marcia Johnson (*Emeritus*), Dan Kahan (*Law School*), Frank Keil (*Psychology, Linguistics*), Joshua Knobe (*Philosophy*), Daeyeol Lee (*School of Medicine*), Gregory McCarthy (*Psychology*), Drew McDermott (*Computer Science*), Nathan Novemsky (*School of Management, Psychology*), Kenneth Pugh (*School of Medicine*), Ian Quinn (*Music*), Holly Rushmeier (*Computer Science*), Laurie Santos (*Psychology*), Brian Scassellati (*Computer Science, Mechanical Engineering*), Brian Scholl (*Chair*) (*Psychology*), Sun-Joo Shin (*Philosophy*), Jason Stanley (*Philosophy*), Zoltán Szabó (*Philosophy*), Nick Turk-Browne (*Psychology*), Tom Tyler (*Law School*), Fred Volkmar (*School of Medicine*), David Watts (*Anthropology*), Karen Wynn (*Psychology*), Gideon Yaffe (*Law School*), Raffaella Zanuttini (*Linguistics*), Steven Zucker (*Computer Science, Biomedical Engineering*)

**Associate Professors** Daylian Cain (*School of Management*), James McPartland (*Child Study Center*), Maria Piñango (*Linguistics*)

**Assistant Professors** Ryan Bennett (*Linguistics*), Steve Chang (*Psychology*), Philip Corlett (*Psychiatry*), Henry Cowles (*History*), Molly Crockett (*Psychology*), Yarrow Dunham (*Psychology*), Julian Jara-Ettinger (*Psychology*), Hedy Kober (*School of Medicine*), George Newman (*School of Management*)

#### Introductory Courses

**CGSC 110a / PSYC 130a, Introduction to Cognitive Science** Brian Scholl

An introduction to the interdisciplinary study of how the mind works. Discussion of tools, theories, and assumptions from psychology, computer science, neuroscience, linguistics, and philosophy. SO

**CGSC 139a / EDST 139a / PSYC 139a, The Mental Lives of Babies and Animals** Karen Wynn

Interdisciplinary exploration of the cognitive, social, and emotional capacities of creatures lacking language and culture. The extent to which our complex psychology is unique to mature humans; the relative richness of a mental life without language or culture. Some attention to particular human populations such as children with autism and adults with language disorders. SO

**CGSC 216b / LING 116b, Cognitive Science of Language** Robert Frank

The study of language from the perspective of cognitive science. Exploration of mental structures that underlie the human ability to learn and process language, drawing on studies of normal and atypical language development and processing, brain imaging, neuropsychology, and computational modeling. Innate linguistic structure vs. determination by experience and culture; the relation between linguistic and nonlinguistic cognition in the domains of decision making, social cognition, and musical cognition; the degree to which language shapes perceptions of color, number, space, and gender. SO

**CGSC 277b / AFAM 198b / EDST 177b / EP&E 494b / PHIL 177b, Propaganda, Ideology, and Democracy** Jason Stanley

Historical, philosophical, psychological, and linguistic introduction to the issues and challenges that propaganda raises for liberal democracy. How propaganda can work to undermine democracy; ways in which schools and the press are implicated; the use of propaganda by social movements to address democracy's deficiencies; the legitimacy of propaganda in cases of political crisis. HU

**CGSC 282a / PHIL 182a / PSYC 182a, Perspectives on Human Nature** Joshua Knobe

Comparison of philosophical and psychological perspectives on human nature. Nietzsche on morality, paired with contemporary work on the psychology of moral judgment; Marx on religion, paired with systematic research on the science of religious belief; Schopenhauer paired with social psychology on happiness. HU

## Advanced Courses

### **CGSC 315a / PSYC 315a, The Modern Unconscious** John Bargh

The notion of the unconscious mind traced from the early 1800s through Freud to present-day cognitive science, with a focus on the past thirty years. The power and function of the unconscious as a pervasive part of normal everyday human functioning. Readings from philosophy of mind and evolutionary biology. so

### **CGSC 352a / NSCI 352a / PSYC 352a, Arrested or Adaptive Development in the Adolescent Brain** BJ Casey

Study of empirical and theoretical accounts of adolescent-specific changes in the brain and in behavior that relate to the development of self control. Discussions will focus on adaptive and arrested adolescent brain development in the context of relevant legal, social, and health policy issues. sc

### \* **CGSC 390a, Junior Seminar in Cognitive Science** Mark Sheskin

Discussion of historically important papers in cognitive science. Topics are varied and reflect student interests. Some attention to planning for the senior project. Intended for juniors in the Cognitive Science major.

### \* **CGSC 421a / PSYC 421a, Cognitive Science of Pleasure** Paul Bloom

Exploration of the mysterious pleasures of the imagination, including daydreams, novels, movies, pretend play in children, and video games. Approach is eclectic, drawing on fields such as psychology, philosophy, neuroscience, evolutionary theory, and literary criticism. so

### \* **CGSC 425b / PSYC 425b, Social Perception** Brian Scholl

Connections between visual perception, among the earliest and most basic of human cognitive processes, and social cognition, among the most advanced forms of higher-level cognition. The perception of animacy, agency, and goal-directedness; biological motion; face perception (including the perception of facial attractiveness); gaze processing and social attention; "thin-slicing" and "perceptual stereotypes"; and social and cultural influences on perception. so

### \* **CGSC 426b / EP&E 490b / PHIL 426b / PSYC 422b, The Cognitive Science of Morality** Joshua Knobe

Introduction to the emerging field of moral cognition. Focus on questions about the philosophical significance of psychological findings. Topics include the role of emotion in moral judgment; the significance of character traits in virtue ethics and personality psychology; the reliability of intuitions and the psychological processes that underlie them. HU

### \* **CGSC 437b / PSYC 437b, Minds, Brains, and Machines** Julian Jara-Ettinger

Exploration of the implications that the brain is a kind of computer that gives rise to the mind. Readings combine classical and cutting-edge research in psychology, philosophy, and artificial intelligence. so RP

## Courses for Majors

### \* **CGSC 395b, Junior Colloquium in Cognitive Science** Mark Sheskin

Survey of contemporary issues and current research in cognitive science. By the end of the term, students select a research topic for the senior essay. Enrollment limited to Cognitive Science majors. ½ Course cr

### \* **CGSC 471a and CGSC 472b, Directed Research in Cognitive Science** Joshua Knobe

Research projects for qualified students. The student must be supervised by a member of the Cognitive Science faculty, who sets the requirements and directs the research. To register, a student must submit a written plan of study to the director of undergraduate studies and the faculty supervisor. The normal minimum requirement is a written report of the completed research, but individual faculty members may set alternative equivalent requirements. Only one term may be offered toward the major, with permission of the director of undergraduate studies; two terms may be offered toward the bachelor's degree.

### \* **CGSC 473a and CGSC 474b, Directed Reading in Cognitive Science** Joshua Knobe

Individual study for qualified students who wish to investigate an area of cognitive science not covered in regular courses. The student must be supervised by a member of the Cognitive Science faculty, who sets the requirements and meets regularly with the student. To register, a student must submit a written plan of study to the director of undergraduate studies and the faculty supervisor. The normal minimum requirement is a term paper, but individual faculty members may set alternative equivalent requirements. Only one term may be offered toward the major, with permission of the director of undergraduate studies; two terms may be offered toward the bachelor's degree.

### \* **CGSC 491b, Senior Project** Mark Sheskin

A research colloquium leading to the completion of the senior essay. Students attend regular colloquium presentations. Enrollment limited to Cognitive Science majors.

## Related Courses That May Count toward the Major

### **ANTH 267b / ARCG 267b, Human Evolution** David Watts

Examination of the fossil record of human evolution, including both paleontological and archaeological evidence for changes in hominid behavior during the Pleistocene. Prerequisite: Introductory course in biological anthropology or biology. so

\* **CHLD 350b / EDST 350b / PSYC 350b, Autism and Related Disorders** Fred Volkmar and James McPartland

Weekly seminar focusing on autism and related disorders of socialization. A series of lectures on topics in etiology, diagnosis and assessment, treatment and advocacy, and social neuroscience methods; topics cover infancy through adulthood. Supervised experience in the form of placement in a school, residence, or treatment setting for individuals with autism spectrum disorders. Details about admission to the course are explained at the first course meeting. Prerequisite: an introductory psychology course. SO

**CPSC 112b, Introduction to Programming** Benedict Brown

Development on the computer of programming skills, problem-solving methods, and selected applications. No previous experience with computers necessary. QR

**CPSC 201a or b, Introduction to Computer Science** Stephen Slade

Introduction to the concepts, techniques, and applications of computer science. Topics include computer systems (the design of computers and their languages); theoretical foundations of computing (computability, complexity, algorithm design); and artificial intelligence (the organization of knowledge and its representation for efficient search). Examples stress the importance of different problem-solving methods. After CPSC 112 or equivalent. QR

**CPSC 202a, Mathematical Tools for Computer Science** Dana Angluin

Introduction to formal methods for reasoning and to mathematical techniques basic to computer science. Topics include propositional logic, discrete mathematics, and linear algebra. Emphasis on applications to computer science: recurrences, sorting, graph traversal, Gaussian elimination. QR

**CPSC 470b, Artificial Intelligence** Brian Scassellati

Introduction to artificial intelligence research, focusing on reasoning and perception. Topics include knowledge representation, predicate calculus, temporal reasoning, vision, robotics, planning, and learning. After CPSC 201 and 202. QR

[ **CPSC 471, Advanced Topics in Artificial Intelligence** ]

**CPSC 475a / BENG 475a / EENG 475a, Computational Vision and Biological Perception** Steven Zucker

An overview of computational vision with a biological emphasis. Suitable as an introduction to biological perception for computer science and engineering students, as well as an introduction to computational vision for mathematics, psychology, and physiology students. Prerequisite: CPSC 112 and MATH 120, or with permission of instructor. QR, SC RP

**CPSC 476b / BENG 476b, Advanced Computational Vision** Steven Zucker

Advanced view of vision from a mathematical, computational, and neurophysiological perspective. Emphasis on differential geometry, machine learning, visual psychophysics, and advanced neurophysiology. Topics include perceptual organization, shading, color and texture analysis, and shape description and representation. After CPSC 475. QR, SC

**ECON 159a or b, Game Theory** Staff

An introduction to game theory and strategic thinking. Ideas such as dominance, backward induction, Nash equilibrium, evolutionary stability, commitment, credibility, asymmetric information, adverse selection, and signaling are applied to games played in class and to examples drawn from economics, politics, the movies, and elsewhere. After introductory microeconomics. No prior knowledge of game theory assumed. QR, SO

**LING 110a, Language: Introduction to Linguistics** Jason Shaw

The goals and methods of linguistics. Basic concepts in phonology, morphology, syntax, and semantics. Techniques of linguistic analysis and construction of linguistic models. Trends in modern linguistics. The relation of linguistics to psychology, logic, and other disciplines. SO

**LING 217a / EDST 237a / PSYC 317a, Language and Mind** Maria Piñango

The structure of linguistic knowledge and how it is used during communication. The principles that guide the acquisition of this system by children learning their first language and adults learning a second language. The processing of language in real-time. Language breakdown as a result of brain damage. SO

**LING 220b / PSYC 318b, General Phonetics** Jason Shaw

Investigation of possible ways to describe the speech sounds of human languages. Acoustics and physiology of speech; computer synthesis of speech; practical exercises in producing and transcribing sounds. SO

**LING 224a, Mathematics of Language** Robert Frank

Study of formal systems that play an important role in the scientific study of language. Exploration of a range of mathematical structures and techniques; demonstrations of their application in theories of grammatical competence and performance including set theory, graphs and discrete structures, algebras, formal language, and automata theory. Evaluation of strengths and weaknesses of existing formal theories of linguistic knowledge. QR, SO

**LING 227a / PSYC 327a, Language and Computation I** Robert Frank

Design and analysis of computational models of language. Topics include finite state tools, computational morphology and phonology, grammar and parsing, lexical semantics, and the use of linguistic models in applied problems. Prerequisite: prior programming experience or permission of instructor. QR, SO

**LING 231b / PSYC 331b, Neurolinguistics** Maria Piñango

The study of language as a cognitive neuroscience. The interaction between linguistic theory and neurological evidence from brain damage, degenerative diseases (e.g., Alzheimer's disease), mental illness (e.g., schizophrenia), neuroimaging, and neurophysiology. The connection of language as a neurocognitive system to other systems such as memory and music. SO

**\* LING 232a, Introduction to Phonological Analysis** Staff

The structure of sound systems in particular languages. Phonemic and morphophonemic analysis, distinctive-feature theory, formulation of rules, and problems of rule interpretation. Emphasis on problem solving. Prerequisite: LING 220, or a grade of B or above in LING 110. SO

**\* LING 235b, Phonological Theory** Staff

Topics in the architecture of a theory of sound structure. Motivations for replacing a system of ordered rules with a system of ranked constraints. Optimality theory: universals, violability, constraint types and their interactions. Interaction of phonology and morphology, as well as the relationship of phonological theory to language acquisition and learnability. Opacity, lexical phonology, and serial versions of optimality theory. Prerequisite: LING 232 or permission of instructor. SO RP

**LING 253a, Syntax I** Raffaella Zanuttini

If you knew all the words of a language, would you be able to speak that language? No, because you'd still need to know how to put the words together to form all and only the grammatical sentences of that language. This course focuses on the principles of our mental grammar that determine how words are put together to form sentences. Some of these principles are shared by all languages, some differ from language to language. The interplay of the principles that are shared and those that are distinct allows us to understand how languages can be very similar and yet also very different at the same time. This course is mainly an introduction to syntactic theory: it introduces the questions that the field asks, the methodology it employs, some of the main generalizations that have been drawn and results that have been achieved. Secondly, this course is also an introduction to scientific theorizing: what it means to construct a scientific theory, how to test it, and how to choose among competing theories. SO

**LING 254b, Syntax II** Hadas Kotek

Recent developments in the principles and parameters approach to syntactic theory. In-depth exploration of theoretical and empirical issues in long-distance dependencies (island effects, dependency types, movement vs. binding), the character of syntactic structure (constituency, thematic mapping, functional categories), and the architecture of grammatical derivations (logical form, operations for structure building, anaphora). Prerequisite: LING 253. SO

**LING 263a, Semantics I** Hadas Kotek

Introduction to truth-conditional compositional semantics. Set theory, first- and higher-order logic, and the lambda calculus as they relate to the study of natural language meaning. Some attention to analyzing the meanings of tense/aspect markers, adverbs, and modals. QR, SO

**MCDB 320a / NSCI 320a, Neurobiology** Haig Keshishian and Paul Forscher

The excitability of the nerve cell membrane as a starting point for the study of molecular, cellular, and systems-level mechanisms underlying the generation and control of behavior. Prerequisites: year of college-level chemistry; a course in physics is strongly recommended. SC

**PHIL 126b, Introduction to Modern Philosophy from Descartes to Kant** Michael Della Rocca

An introduction to major figures in the history of modern philosophy, with critical reading of works by Descartes, Malabranche, Spinoza, Leibniz, Locke, Berkeley, Hume, and Kant. Intended to be taken in conjunction with PHIL 125, although PHIL 125 is not a prerequisite. HU

**PHIL 267a, Mathematical Logic** Sun-Joo Shin

An introduction to the metatheory of first-order logic, up to and including the completeness theorem for the first-order calculus. Introduction to the basic concepts of set theory. Prerequisite: PHIL 115 or permission of instructor. QR

**PHIL 270b, Epistemology** Keith DeRose

Introduction to current topics in the theory of knowledge. The analysis of knowledge, justified belief, rationality, certainty, and evidence. HU

**PHIL 271a / LING 271a, Philosophy of Language** Jason Stanley

An introduction to contemporary philosophy of language, organized around four broad topics: meaning, reference, context, and communication. Introduction to the use of logical notation. HU

**PSYC 110a or b, Introduction to Psychology** Staff

A survey of major psychological approaches to the biological, cognitive, and social bases of behavior. SO

**PSYC 131a, Human Emotion** Matthias Siemer

Introduction to major discoveries in human emotion. Evolutionary theories of anger, love, and disgust; emotion and morality; cultural and gender differences; emotion and the brain; relation between emotion and thinking; development of emotion; and abnormal emotions in mental illness. SO RP

**PSYC 140b / EDST 140b, Developmental Psychology** Frank Keil

An introduction to research and theory on the development of perception, action, emotion, personality, language, and cognition from a cognitive science perspective. Focus on birth to adolescence in humans and other species. Prerequisite: PSYC 110. SO

**PSYC 150b / EDST 160b, Social Psychology** Staff

Theories, methodology, and applications of social psychology. Core topics include the self, social cognition/social perception, attitudes and persuasion, group processes, conformity, human conflict and aggression, prejudice, prosocial behavior, and emotion. Prerequisite: PSYC 110. SO

**PSYC 160a / NSCI 160a, The Human Brain** Gregory McCarthy

Introduction to the neural bases of human psychological function, including social, cognitive, and affective processing. Preparation for more advanced courses in cognitive and social neuroscience. Topics include memory, reward processing, neuroeconomics, individual differences, emotion, social inferences, and clinical disorders. Neuroanatomy, neurophysiology, and neuropharmacology are also introduced. SC

**[ PSYC 179, Thinking ]****PSYC 200b, Statistics** Angela Johnston

Measures of central tendency, variability, association, and the application of probability concepts in determining the significance of research findings. QR

**PSYC 270a or b / NSCI 235a or b, Research Methods in Behavioral Neuroscience** Nelson Donegan

Students design and conduct research to study brain function and behavior. Emphasis on hands-on participation in behavioral and neuroscience techniques. Prerequisites: PSYC 160 or 170, and a course in statistics, or with permission of instructor. SC

**PSYC 303b / NSCI 355b, Social Neuroscience** Molly Crockett

Exploration of the psychological and neural mechanisms that enable the formation, maintenance, and dissolution of social relationships. Topics include the neuroscience of how we form impressions and decide whether to instigate relationships with others; how we build relationships through trust, cooperation, attachment, conflict, and reconciliation; and group-level processes including intergroup bias, moral judgment, and decision making. Prerequisite: PSYC 110 or permission of instructor. SC

**PSYC 335b / NSCI 340b, Cognitive Neuroscience** Steve Wahn Chang

Examination of the fundamental and advanced principles underlying several cognitive functions from the perspectives of modern cognitive, systems, and computational neuroscience. Discussion of cognition in both humans and animal models through research of general neurobiological principles followed by several key examples from research studies that have influentially shaped the field. Prerequisite: PSYC 160 or specific chapter readings from the instructor. SC