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 (DUS) 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
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 (1) an official or unofficial transcript of work at Yale, (2) a brief statement of purpose, which indicates academic interests and expected focus within the areas of the Cognitive Science major, and (3) 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.

Roadmap See visual roadmap of the requirements.

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 for breadth req; 6 courses in a specific topic or area, as specified for depth req; 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 Kahn (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 Quin (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 Volkman (School of Medicine), David Watts (Anthropology), Karen Wynn (Emeritus) (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), 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 Natalia Córdova Sánchez
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 175a, The Mystery of Sleep Suman Baddam and Meir Kryger
The role in which sleep and circadian rhythms affect attention, cognition, and memory through multidisciplinary consideration of neurobiology, epidemiology, and humanities. Psychological aspects of sleep; sleep disorders; sleep deprivation; and the history of sleep in philosophy, literature, and art. This course is not open to students previously enrolled in CSPC 350, CSMC 370, or CSYC 390. sc
CGSC 216b / LING 116b / PSYC 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

Advanced Courses
* CGSC 313b / PHIL 305b / PSYC 313b, Philosophy for Psychologists Joshua Knobe
Introduction to frameworks developed within philosophy that have applications in psychological research. Principal topics include the self, causation, free will, and morality. Recommended preparation: a course in philosophy or psychology. HU, SO
CGSC 352a / NSCI 352a / PSYC 352a, Arrested or Adaptive Development of 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 390b, Junior Seminar in Cognitive Science  Natalia Córdova Sánchez
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.  SC

* CGSC 410b / NSCI 410b / PSYC 410b, Topics in Brain Development, Law, and Policy  BJ Casey
Healthy development is a fundamental right of the individual, regardless of race, ethnicity, socioeconomic status, or gender. Youth require special protections of their rights due to vulnerabilities related to their physical and mental immaturity. These rights include, not only protections, but opportunities for building the cognitive, emotional, and social skills necessary for becoming a healthy adult and a contributing member of society. This seminar examines the extent to which legal policies and practices in the treatment of youths are consistent with scientific knowledge on psychological and brain development. Each class discusses one or more legal cases highlighted in the context of brain and psychological science and current laws and policies. Prerequisite: PSYC 110 and PSYC 160 preferred.  SO

* CGSC 420b / NSCI 440b / PSYC 420b, Topics in Clinical Neuroscience  Avram Holmes
An overview and examination of the neuroscience of psychiatric illness. We focus on cutting-edge research in humans and animals aimed at understanding the biological mechanisms that underlie psychiatric illness. Although these questions date back to early philosophical texts, only recently have experimental psychologists and neuroscientists begun to explore this vast and exciting domain of study. We discuss the evolutionary and developmental origins of individual differences in human personality, measurement issues, fundamental dimensions of psychopathology, stability/plasticity, heritability, and implications therapeutic interventions as well as the associated broader implications for public policy. A major focus is on the neurobiology of fear and anxiety, including brain circuits, molecular genetic pathways, and epigenetics. A secondary focus is on differences in behavior and biology that confer risk for the development of depression and addiction, including the biological systems involved in hedonic pleasure, motivated goal pursuit, and the regulation of impulses in the face of everyday temptation. Students should have some background in psychology; PSYC 110 and PSYC 160 preferred.  SO

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

Courses for Majors

* CGSC 395a, Junior Colloquium in Cognitive Science  Natalia Córdova Sánchez
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  Natalia Córdova Sánchez
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

* 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  Staff
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 or b, Mathematical Tools for Computer Science  Staff
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  Stephen Slade
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. Q8

[ 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 476, Advanced Computational Vision ]

ECON 159b, Game Theory  Benjamin Polak
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. Q8, 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 212a, Linguistic Change  Claire Bowern
How languages change, how we study change, and how language relates to other areas of society. This seminar is taught through readings chosen by instructor and students, on topics of interest. Prerequisite: LING 112 or equivalent. SO

LING 217a / EDST 237a / PSYC 317a, Language and Mind  Maria Pinango
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, by children learning language in unusual circumstances (heritage speakers, sign languages) and adults learning a second language, bilingual speakers. The processing of language in real-time. Psychological traits that impact language learning and language use. SO RP

LING 275b / CGSC 275 / PHIL 280, Pragmatics  Laurence Horn
Speakers often mean things they don’t say, but how does a hearer figure out what the speaker meant? Which sentences are designed to change the world rather than just to represent it? How are sentences used to mean different things in different contexts? Pragmatics explores the relations between what is said and what is meant, focusing on how speech acts and the principles of “street logic”—presuppositions and implicatures—help speakers and hearers shape the landscape of a conversation. No formal prerequisites, but some familiarity with linguistics or philosophy of language will help on some of the readings. SO RP

* LING 232a, Phonology I  Natalie Weber
Why do languages sound distinct from one another? Partly it is because different languages use different sets of sounds (in spoken languages) or signs (in signed languages) from one another. But it is also because those sounds and signs have different distributional patterns in each language. Phonology is the study of the systematic organization and patterning of sounds and signs. Students learn to describe the production of sounds and signs (articulatory phonetics), discuss restrictions on sound and sign distribution (morphemic alternation, phonotactics), and develop a model of the phonological grammar in terms of rules and representations. Throughout the course, we utilize datasets taken from a variety of the world’s languages. SO

* LING 233b, Phonology II  Natalie Weber
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. Secondarily, 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  Jim Wood
This course continues the development of the “principles and parameters” approach to grammatical theory in Government-Binding 
theory and the Minimalist Program. We begin with a brief review of the architecture of syntactic theory, move on to an extended 
exploration of the mechanisms of dependency formation in syntax (including displacement, agreement, control, scope and anaphora), 
and conclude with a discussion of the nature of syntactic representation (constituency in double object constructions, the mapping 
between structure and thematic relations, the role of functional categories). Throughout, a major goal of the course is to engage in 
foundational issues by reading primary literature in syntax and applying theoretical concepts to novel data. Prerequisite: LING 253.  WR, 
SO

LING 263a, Semantics I  Veneta Dayal
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  Kenneth Winkler
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 267b, 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 269b, The Philosophy of Science  Mark Maxwell
Central questions about the nature of scientific theory and practice. Factors that make a discipline a science; how and why scientific 
theories change over time; interpreting probabilistic claims in science; whether simpler theories are more likely to be true; the laws of 
nature; whether physics has a special status compared to other sciences; the legitimacy of adaptationist thinking in evolutionary biology.  HU

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 271b / LING 271b, 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 140, Developmental Psychology

PSYC 150b / EDST 160b, Social Psychology  Maria Gendron
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.  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 179a, Thinking  Woo-kyoung Ahn
A survey of psychological studies on thinking and reasoning, with discussion of ways to improve thinking skills. Topics include judgments and decision making, causal learning, logical reasoning, problem solving, creativity, intelligence, moral reasoning, and language and thought.  SO

PSYC 200b, Statistics  Staff
Measures of central tendency, variability, association, and the application of probability concepts in determining the significance of research findings.  Q8

[ PSYC 303, Social Neuroscience ]

PSYC 335b / NSCI 340b, Cognitive Neuroscience  Steve Wohn Chang
This course covers how cognition is made by the brain. Students learn brain mechanisms underlying human cognition, including making decisions, paying attention, regulating emotion, remembering events, as well as understanding others. The course discusses both established and newly emerging findings based on several landmark experiments in both humans and animals. During this process, students are also introduced to cutting-edge techniques in cognitive neuroscience for studying human cognition. Prerequisite: PSYC 160 or specific chapter readings from the instructor.  SC