Psych 5612

Introduction to Cognitive Science

Course Syllabus, Fall 2016, Undergraduate version

Course:	Psych 5612 (cross-listed as CSE 5531, Ling 5612, and Philos 5830)
Call number:	20109 (graduate) and 20110 (undergraduate)
Credits:	3
Dates:	Aug 23 – Dec 9, 2016
Times:	Tuesdays and Thursdays 09:35–10:55 a.m.
Room:	Jennings Hall, Room 140
Prerequisites:	Graduate standing, permission of instructor, or at least 12 credit hours from any of the following areas: computer science, linguistics, neuroscience, philosophy, and psychology.
Websites:	https://carmen.osu.edu and http://alexpetrov.com/teach/cogintro/
Textbook:	José Luis Bermúdez (2014). *Cognitive Science: An Introduction to the Science of the Mind* (2nd Ed.). Cambridge, UK: Cambridge UP. ISBN 978-1-107-65335-1. http://www.cambridge.org/features/bermudez/
Instructor:	Dr. Alexander Petrov petrov.11@osu.edu 200B Lazenby Hall Office hours: T, R 10:55–11:55

Course Overview

What is cognition and how does it emerge from the brain? This course introduces you to the exciting interdisciplinary field of cognitive science. Researchers in philosophy, neuroscience, psychology, artificial intelligence, and linguistics realized that they were asking many of the same questions about the nature of the human mind/brain, that they had developed complementary and synergistic methods of investigation, and that the evidence led them to compatible answers to their questions. This course introduces cognitive science through a representative sample of such questions, methods, and answers. It is not a special-topic course for students who seek detailed knowledge in a specific area of cognitive science. We will try not to lose sight of the forest for the trees but we will take a closer look at a few trees too because science is in the details. Along the way, we will introduce the constituent disciplines and their respective contributions to the study of cognition. We will discuss the foundational concepts of *computation* and *representation* from multiple points of view. Three unifying themes are emphasized throughout: 1. Information processing: The mind/brain is viewed as a complex system that receives, stores, retrieves, transforms, and transmits information. 2. Neurological grounding: Explicit effort is made to show how mental phenomena emerge from the interactions of networks of neurons in the brain. 3. Cognitive architecture: The emphasis is on functionally complete systems rather than disjoint empirical phenomena.

Intended Audience. Prerequisites

This course is cross-listed in the Departments of Computer Science and Engineering, Linguistics, Philosophy, and Psychology. It is intended for graduate and advanced undergraduate students in these departments. Interested students from related areas (notably neuroscience) are welcome too. The formal prerequisites for taking the course are: graduate standing in any of these departments **or** permission of the instructor **or** at least 12 undergraduate-level credit hours from any of the four disciplines. The informal prerequisites are: willingness to step outside the confines of one's area of specialization, willingness to read the professional literature (as opposed to textbooks) with help from the instructor and one's peers, willingness to participate in open discussions, and the ability to write clearly and concisely about topics outside one's area of specialization.

All students must be officially enrolled in the course by the end of the second full week of the semester. No requests to add the course will be approved by the Chair after that time. Enrolling officially and on time is solely the responsibility of the student.

Course Objectives

Upon successful completion of the course, the undergraduate students will:

- Appreciate the interdisciplinary nature of cognitive science, the diversity of viewpoints, the controversies and the areas of nascent consensus.
- Be exposed to the contribution of each of the five constituent disciplines and be familiar with its methods, key concepts, and focus of investigation.
- Be proficient in the *lingua franca* of cognitive science—the language of information processing.
- Have basic familiarity with brain anatomy and physiology.
- Master multiple definitions of the foundational concepts of *computation* and *representation* and be able to discuss them from multiple points of view.
- Understand the basic cognitive architecture—how perception, memory, language, motor control, and so forth come together to produce adaptive behavior.
- Know a multitude of specific concepts, theories, and experimental results covered in course. The lecture plan below lists some relevant keywords.

The graduate students will:

- Do everything in the above list with proficiency greater than that expected of undergraduate students.
- Be able to read and discuss research papers from multiple disciplines.
- Be able to write critical essays on topics outside one's area of specialization.

Course Materials

The main textbook is *Cognitive Science: An Introduction to the Science of the Mind* (Bermúdez, 2014, 2nd Ed., Cambridge UP). Various learning resources are provided on the accompanying website http://www.cambridge.org/features/bermudez/. We will supplement the textbook with additional readings listed in the bibliography below. All required readings (except the textbook itself) are posted in PDF on the Carmen (Canvas) website https://carmen.osu.edu/

Evaluation

At the undergraduate level, your grade will depend on the following components:

• Attendance (20 checks worth 2 points each)	40
• Midterm Exam #1 (Tuesday 9/27, 9:30 am, Jennings 140)	90
• Midterm Exam #2 (Tuesday 11/01, 9:30 am, Jennings 140)	90
• Final Exam (Friday 12/09, **8:00 am**, Jennings 140)	120
Total points for attendance, two midterms, and the Final:	340
• Extra credit: 3 discussions, up to 5 points per discussion	15 EC points

Grades are based on absolute cutoffs: A=280-355, B=250-279, C=220-249, D=190-219, E<=189 points, respectively.

At the graduate level, your grade will depend on the same components plus three written homework assignments (a.k.a. "reaction papers"). **Because graduate students score additional points for these homework assignments, their conversion cutoffs are different (and higher) than the undergraduate cutoffs.** See the graduate-level syllabus for details.

Exams: The two Midterm Exams (9/29 and 11/01) and the Final Exam (12/09) are closed-book and consist of multiple-choice questions. Sample questions will be given in class. The *Course Calendar* section below lists the readings required for each exam. The exams are not cumulative, except that the topics covered in later periods of the course depend on concepts and facts introduced in the earlier periods. No make-up exams will be given, except in the case of documented illness or emergency. In the event of a last-minute emergency, you **must** email Dr. Petrov (petrov.11@osu.edu) or the office associate for the cognitive area (Azuzena De Los Santos, delossantos.10@osu.edu, 614-292-1123) **on the same day as the exam**, preferably before the exam begins. Acceptable excuses for missing an exam are a death in your family, personal illness or the illness of your child or spouse, and unforeseen accidents like your car breaking down or getting stuck in an elevator. Please obtain documented proof of these events should they occur. If you are late for an exam, you will be allowed to take it but you will have to submit your answers by the closing time like everybody else.

Attendance: Attendance is required, especially on test dates. Come to class – it makes a difference. On top of that, there is a palpable incentive for attending: you earn points by just being present during a roll call. Twenty roll calls will be made during the semester without advance notice. Each time you are present during a roll call you earn 2 points.

Academic Ethics

All students enrolled in OSU courses are bound by the *Code of Student Conduct* (http://studentaffairs.osu.edu/csc/). The instructor is committed to maintaining a fair assessment of student performance in this course. Suspected violations of the *Code* will be dealt with according to the procedures detailed in the *Code*. Specifically, any alleged cases of misconduct will be referred to the Committee on Academic Misconduct. It is the responsibility of this Committee to investigate or establish procedures for the

investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the Committee (Faculty Rule 3335-5-48.7). For additional information, see the *Code of Student Conduct* at the above link.

All exams are closed book. No notes may be used during the examinations and you may not confer with your fellow students or look at their exam booklets for answers during the exam period. Prior to the examinations, you are encouraged to study in small groups. However, once you enter the examination room, you are expected to work alone.

Please silence your cell phones during the lectures. Random ringing distracts everybody in the room and shows lack of respect to your colleagues and the instructor.

Accommodations for Students with Special Needs

The University strives to make all learning experiences as accessible as possible. If you anticipate or experience academic barriers based on your disability (including mental health, chronic or temporary medical conditions), please let me know immediately so that we can privately discuss options. To contact me privately, email petrov.11@osu.edu or come to my office (200B Lazenby Hall). You are also welcome to register with Student Life Disability Services to establish reasonable accommodations. After registration, make arrangements with me as soon as possible to discuss your accommodations so that they may be implemented in a timely fashion.
SLDS contact information: slds@osu.edu; 614-292-3307; http://slds.osu.edu; 098 Baker Hall, 113 W. 12th Avenue.

Course Calendar

1. **T 8/23 – Introduction.** Course organization, exam dates, etc. Motivation: Newell's big question. Constituent disciplines. Interdisciplinary approach. Reading: Textbook Section 4.1.
2. **R 8/25 – Philosophy of Mind. Cartesian dualism.** The ship of Theseus. Unchanging essences and forms. Mind-body problem. Substance dualism. Descartes' epistemological argument. Reading: Appiah (2003).
3. **T 8/30 – Mind-body problem.** Problems with Cartesian dualism. Mental causation. Epiphenomenalism. Phineas Gage. Physicalism. Reading: Appiah (2003).
4. **R 9/01 – Behaviorism. Functionalism.** Introspection. Wittgenstein's Private language argument. The cognitive revolution in psychology. Examples of functional systems. Hardware/software distinction. Multiple realizability. Required readings: Appiah (2003), Textbook Chap. 1. Optional: Fodor (1980).
5. **T 9/06 – Linguistics. Syntax.** Components of a grammar. Chomsky. Phrases and constituents. Productivity. Reading: Whitney (1998), Jackendoff (1997, pp. 1-11).
6. **R 9/08 – Syntax and Semantics.** Generative grammars. Compositional syntax. Productivity by recursion. Surface- and deep structures. Referential theory of meaning. Compositional semantics. Reading: Whitney (1998).
7. **T 9/13 – Logic. Formal Systems. Finite State Machines.** Formal systems – examples and definitions. Interpretation. Digital circuits. Finite state automata. Readings: Haugeland (1997), Haugeland (1985), Textbook Section 1.2.
8. **R 9/15 – Universal Turing Machine.** Tribute to Alan Turing. Turing machine – structure, operation, and examples. Universal Turing Machine. Functional equivalence. Simulation. Von Neumann machines and digital computers. Readings: Haugeland (1985), Textbook Sections 1.2, 3.1, and 6.3.
9. **T 9/20 – Turing Test.** Church-Turing Thesis. Turing Test. *Deep Blue, Watson,* and *Alpha Go*. Chinese room argument.
   In-class discussion of Target Article #1: Turing (1950).
10. **R 9/22 – Artificial Intelligence. Symbols and Search.** Weak versus strong AI. Subfields, applications, and recent trends in AI. Turing Test revisited. SHRDLU. Heuristic search. General Problem Solver (GPS). Means-ends analysis. GOFAI and its limitations. Physical symbol systems (PSS). Language of Thought (LOT). Readings: Textbook Section 2.1, Haugeland (1997). [Optional: Newell (1990), Newell & Simon (1976); Textbook Sections 6.1 and 6.2.]
11. **T 9/27 – Midterm Exam #1.** Material covered in the exam: Lectures 1-10 inclusive. Readings: The union of all *required* readings listed above.
12. **R 9/29 – Neuroanatomy:** Brain anatomy. Hierarchical functional organization. Decorticate animals. Functional magnetic resonance imaging (fMRI). Readings: Baars & Gage (2010, Ch. 5), Textbook Chapters 3 and 11 and Sect. 4.5.

13. **T 10/04 – Neurophysiology.** Neuron doctrine. Neurophysiology. Ion channels. Action potentials. Synaptic transmission. Reading: Baars & Gage (2010, Ch. 3).

14. **R 10/06 – Parallel Distributed Processing.** Leaky integrate-and-fire (LIF) neurons. Brain-style computation. Computational cognitive neuroscience. Point neuron approximation. Simulated (linear) neuron. The appeal of the PDP approach. Reading: Textbook Chap. 3 & 8 and Sect. 2.3, 3.3, 5.2, & 9.5; Baars & Gage (2010, Chap. 3); McLeod, Plunkett, & Rolls (1998, excerpts from Chapters 1 & 2, pp. 9-21, 30-35).

15. **T 10/11 – Information theory. Population codes.** Problem of representation. Shannon's information theory. Population codes. Encoders, decoders. Demos and examples. Brain-computer interfaces. Readings: Textbook Sect 8.1 and 8.2.
    In-class discussion of Target Article #2: Nicolelis & Chapin (2002).
    R 10/13 – Autumn break. No classes

16. **T 10/18 – Computer memory. Hebbian learning. Pattern associator.** Computer memory arrays. Bit cells. Input/ output mapping task. Behavioral definition of learning. Hebbian learning rule. Pattern associator. Readings: McLeod, Plunkett, & Rolls (1998, Chap. 3, pp. 51-65), Textbook Section 8.2.

17. **R 10/20 –Pattern associator. Basic concepts of memory. Auto-associator.** Localist vs. distributed representations. Distributed memory traces. Principle of superposition. Basic concepts of memory. Auto-associator. Content-addressable memory. Recurrent networks. Pattern completion. Attractors in dynamical systems. Readings: McLeod, Plunkett, & Rolls (1998), Textbook Sections 8.2 & 13.1, especially Box 13.1.

18. **T 10/25 – Biological Basis of Learning.** Cajal's synaptic plasticity hypothesis. Long-term potentiation (LTP) and depotentiation (LTD). NMDA receptors and their role in LTP. Synaptic consolidation. Vertical integration.
    [Optional: Role of LTP/LTD in memory]
    Reading: Baars & Gage (2010, Chapter 3). Textbook Sections 4.2 & 4.3.

19. **R 10/27 – Error-Correcting Learning.** Limitations of Hebbian learning. Arbitrary input/ output mapping. Delta rule. XOR problem. Hidden layers. Error backpropagation learning in multi-layer nets. Networks are universal function approximators. Deep networks. Reading: Textbook Chap. 8, esp. Sect. 8.2 & 8.3.

20. **T 11/01 – Midterm Exam #2.** Material covered in the exam: Lectures 12-19 inclusive. Readings: The union of all required readings for Lectures 12-19.

21. **R 11/03 – Error backpropagation learning rule. Amnesia.** Backpropagation learning. Deep networks (continued from Lecture 19). Amnesic patients H.M. and Clive Wearing. Double dissociations. Multiple memory systems. Taxonomy of memory. Readings: Textbook Sect. 8.3 & 8.4. Baars & Gage (2010, Chapter 2).

22. **T 11/08 – Complementary Learning Systems.** Generalization. Distributed representations in neocortex. Interference. Sparse representations in hippocampus. Pattern separation and pattern completion. Hippocampal-cortical model. Consolidation. Readings: Baars & Gage (2010, Chapter 2), http://grey.colorado.edu/CompCogNeuro/index.php/CCNBook/Memory.

23. **R 11/10 – Working Memory and Executive Control.** Memory span. Dissociations of short- and long-term memory. Baddeley's working memory model. Central executive. Wisconsin card sorting task. Stroop effect. Cohen et al. (1990) model of the Stroop effect. Readings: Baars & Gage (2010, Chapter 2), Textbook Sections 5.1 & 1.4.
24. **T 11/15 – Prefrontal Cortex. Active Maintenance.** Delayed non-match-to-sample task. Active memory in prefrontal cortex (PFC). Simple localist model of active maintenance and gating. Spiking-neuron model of an integrator circuit. Molecular basis of WM. Gating in PFC and the basal ganglia. Readings: TBA
25. **R 11/17 – Cognitive Architectures I: Tripartite architecture. Integration. Modularity.** Banishing the homunculus. Cortico-striato-thalamo-cortical loops. Tripartite architecture (O'Reilly et al). Vertical integration. Marr's tri-level hypothesis revisited. Horizontal integration. The Newell Test. Modularity of mind. Encapsulation and domain specificity. Evolutionary psychology. Readings: Textbook Chapter 5 and Sections 2.3, 3.1, 4.3, 4.4, 10.2, and 10.3. Optional reading: Anderson & Lebiere (2003).
26. **T 11/22 – Cognitive Architectures II: ACT-R Architecture.** Modules and buffers in ACT-R. Declarative chunks. Production rules. Production systems and cognitive control. Serial and parallel processing in ACT-R. End-to-end behavior example. Readings: Anderson (2007). Textbook Chapter 10.
    R 11/24 – Thanksgiving – no classes
27. **T 11/29 – Cognitive Architectures III. Learning in ACT-R. Discussion of Jackendoff (1997).** Subsymbolic level and subsymbolic learning in ACT-R. Production compilation learning mechanism. ACT-R and the brain. How language helps us think? The illusion that language *is* thought. Readings: Anderson (2007), Jackendoff (1997).
    In-class discussion of Target Article #3: Jackendoff (1997).
28. **R 12/01 – Behavior-Based Robotics.** Critique of the standard representational approach. SHAKEY the robot. Perception-action cycle. Change blindness. Intelligence without representation? Subsumption architecture and behavior-based robotics. Rodney Brooks demos. BidDog demo. Decorticate animals revisited. Dynamic system approach. State spaces. Reading: Textbook Ch. 13 and Sect. 7.4.
29. **T 12/06 – The cognitive science of consciousness. Conclusions.** Leibniz's mill. The knowledge argument. Access- and phenomenal consciousness. The hard problem of consciousness. Global workspace theory. Unity and diversity of cognitive science. Course finale. Readings: Textbook Chapters 14 & 15.
30. **F 12/09, 8:00-9:45 am – Final Exam – Note the unusual day and time!!!** Material covered in the final exam: Lectures 21-29 inclusive.

The above calendar is subject to change at the discretion of the instructor, depending on the rate of progress through the material, student interest in alternative topics, and/or scheduling constraints.

Additional Readings

In addition to Bermúdez' (2014) textbook, which is the main text for this course, the following required readings supplement and amplify some topics of particular importance. All of the following items are available on Carmen (Canvas) in PDF format. The list of readings is subject to change at the discretion of the instructor.

1. Anderson, John R. (2007). Cognitive architecture. Chapter 1 in *How Can the Human Mind Occur in the Physical Universe?* (pp. 3-39). New York: Oxford Univ. Press.
2. Appiah, Kwame A. (2003). Mind. Chapter 1 in *Thinking it Through: An Introduction to Contemporary Philosophy* (pp. 1-38). Oxford University Press.
3. Baars, Bernard J. and Gage, Nicole M. (2010, Ch.2). A framework. Chapter 2 in *Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience* (2nd Ed.). New York: Academic Press.
4. Baars, Bernard J. and Gage, Nicole M. (2010, Ch.3). Neurons and their connections. Chapter 3 in *Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience* (2nd Ed.). New York: Academic Press.
5. Baars, Bernard J. and Gage, Nicole M. (2010, Ch.5). The brain. Chapter 5 in *Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience* (2nd Ed.). New York: Academic Press.
6. Haugeland, John (1985). Computer architecture. Chapter 4 in *Artificial Intelligence: The Very Idea*. MIT Press. ISBN 0-262-58095-0.
7. Haugeland, John (1997). What is mind design? In J. Haugeland (Ed.), *Mind Design II: Philosophy, Psychology, Artificial Intelligence*. Cambridge, MA: MIT Press.
8. Jackendoff, Ray (1997). [Universal Grammar:] Questions, goals, assumptions. Chapter 1 in *The Architecture of the Language Faculty* (pp. 1-11 are required, pp. 12-20 are optional). Cambridge, MA: MIT Press. ISBN 0-262-10059-2.
9. **[Target Article #3]** Jackendoff, Ray (1997). Epilogue: How language helps us think. Chapter 8 in *The Architecture of the Language Faculty* (pp. 179-208). Cambridge, MA: MIT Press. ISBN 0-262-10059-2.
10. McLeod, P., Plunkett, K., & Rolls, E. T. (1998). Excerpts from Chapters 1-4 of the textbook *Introduction to Connectionist Modeling of Cognitive Processes* (pp. 9-21, 30-35, 48-64, 72-73). Oxford University Press.
11. **[Target Article #2]** Nicolelis, Miguel A. L. and Chapin, John K. (2002). Controlling robots with the mind. *Scientific American (October 2002)*, 46-53.
12. **[Target Article #1]** Turing, Alan M. (1950). Computing machinery and intelligence. *Mind, 59*, 433-460. [Available on-line http://loebner.net/Prizef/TuringArticle.html]
13. Whitney, P. (1998). What language users must know (pp. 31-71). Chapter 2 in *The Psychology of Language*. Boston, MA: Houghton Mifflin Co.

Optional Readings

The following were used as (required) additional readings in previous installments of this course, but were dropped to save time. They still are great articles, though, and you may want to check them out. PDFs are available on Carmen (Canvas).

14. Anderson, John R. & Lebiere, Christian (2003). The Newell Test for a theory of cognition. *Behavioral and Brain Sciences, 26*, 587-640. [Read the target article, the commentary by McClelland et al, and the *Authors' Response*.]
15. Barwise, J. & Etchemendy, J. (1990). Introduction to quantification (pp. 81-87). Chapter 5 in *The Language of First-Order Logic*. Stanford, CA: CSLI.
16. Bechtel, William (1988, Ch.5). The mind-body problem: Dualism and Philosophical Behaviorism. Chapter 5 in *Philosophy of Mind: An Overview for Cognitive Science* (pp. 79-93). Hillsdale, NJ: Lawrence Erlbaum Associates.
17. Bechtel, William (1988, Ch.7). Functionalism. Chapter 7 in *Philosophy of Mind: An Overview for Cognitive Science* (pp. 112-140). Hillsdale, NJ: Lawrence Erlbaum.
18. Botterill, George & Carruthers, Peter (1999, Ch. 7). Content naturalized. Chapter 7 in *The Philosophy of Psychology*. Cambridge, UK: Cambridge University Press.
19. Cooper, L. & Bear, M. (2012). The BCM theory of synapse modification at 30: Interaction of theory with experiment. *Nature Reviews Neuroscience, 13*, 798-810.
20. Eichenbaum, Howard (2002). Amnesia: Learning about memory from memory loss. Chapter 1 in *The Cognitive Neuroscience of Memory: An Introduction*. Boston, MA: Oxford University Press. [A very readable account of the famous amnesic patient H.M. written by a prominent memory researcher who knew H.M. personally.]
21. Eliasmith, C., Stewart, T. C., Choo, X., Bekolay, T., DeWolf, T., Tang, C., & Rasmussen, D. (2012). A large-scale model of the functioning brain. *Science, 338* (30 Nov), 1202-1205. [Cutting-edge article in the most prestigious scientific journal. Announces the SPAUN model, which is discussed briefly in our last lecture. PDF of the main text and extensive supplementary material is available on Carmen (Canvas). An easy to read editorial perspective on this article is also posted on Carmen: Machens, C. K. (2012). Building the human brain. *Science, 338*, 1156-57.]
22. Feldman, Jerome (2006). The language wars. Chapter 22 in *From Molecule to Metaphor: A Neural Theory of Language* (pp. 271-282). Cambridge, MA: MIT press.
23. Fodor, Jerry A. (1980). The mind-body problem. *Scientific American, 244.1, 114-123.*
24. Jilk, D. J., Lebiere, C., O'Reilly, R. C., & Anderson, J. R. (2008). SAL: An explicitly pluralistic cognitive architecture. *Journal of Theoretical Artificial Intelligence, 20* (3), 197-218. [SAL stands for "Synthesis of ACT-R and Leabra."]
25. McClelland, J. L., Rumelhart, D. E., & Hinton, G. E. (1986). The appeal of Parallel Distributed Processing. In D. E. Rumelhart, J. L. McClelland, and the PDP Research Group (Eds.), *Parallel Distributed Processing: Explorations in the Microstructure of Cognition, Vol. I: Foundations* (pp. 3-44).

26. Miller, Ed. (2008). Mind and Matter. Chapter 5 in Miller & Jensen (2008). *Questions that Matter: An Invitation to Philosophy* (6th Ed., pp. 101-124).

27. Mitchell, T. M., Shinkareva, S. V., Carlson, A., Chang, K.-M., Malave, V. L., Mason, R. A., & Just, M. A. (2008). Predicting human brain activity associated with the meanings of nouns. *Science, 320*, 1191-1195. This used to be a discussion paper in previous installments of this course.

28. Newell, Allen (1990). Human cognitive architecture (pp. 111-131). Excerpt from Chapter 3 in *Unified Theories of Cognition*. Cambridge, MA: Harvard Univ. Press.

29. Newell, Allen & Simon, Herbert A. (1976). Computer science as empirical inquiry: Symbols and search. *Communications of the Association for Computing Machinery, 19*, 113-126. [This was the tenth Turing Award Lecture, delivered to the annual conference of the ACM in 1975. Also available from various collections, including Luger (1995, pp. 91-119) and Haugeland (1997, pp. 81-110).]

30. O'Reilly, R. C., Hazy, T. E., & Herd, S. A. (2015). The Leabra cognitive architecture: How to play 20 principles with nature and win! In. S. Chipman (Ed.), *The Oxford Handbook of Cognitive Science*, DOI: 10.1093/oxfordhb/9780199842193.013.8

31. Romo, Ranulfo & Salinas, Emilio (2003). Flutter discrimination: Neural codes, perception, memory and decision making. *Nature Reviews Neuroscience, 4*, 203-218.

32. Senghas, A., Kita, S., & Özyürek, A. (2004). Children creating core properties of language: Evidence from an emerging sign language in Nicaragua. *Science, 305*, 1779-1782.

33. Skyrms, Brian (2000). Basics of [propositional] logic. Chapter 1 in *Choice & chance: An Introduction to Inductive Logic* (4th Ed.). Belmont, CA: Wadsworth.

34. Stewart, T. C. & Eliasmith, C. (2014). Large-scale synthesis of functional spiking neural circuits. *Proceedings of the IEEE, 102* (5), 881-898.

35. Tennant, Neil (2015). What is logic? (Pages 8-11, 93-102, and 177-179.) Excerpts from Chapters 1, 7, and 13 in *Introducing Philosophy*. [See the *Recommended Books* section below for the full reference. Prof. Tennant teaches this course at OSU!]

Recommended Books

If you want to learn more, the following books are good, thoughtful starting points:

1. Abelson, Harold & Sussman, Gerald Jay (1996). *Structure and interpretation of computer programs* (2nd Ed.). MIT Press. [Arguably the best introduction to functional programming and consequently (though indirectly) to physical symbol systems (cf. Newell & Simon, 1976).]

2. Anastasio, Thomas J. (2010). *Tutorial on Neural Systems Modeling*. Sutherland, MA: Sinauer. ISBN 978-0-87893-339-6.
[Matlab software available at http://www.sinauer.com/anastasio]

3. Anderson, John R. (2004). *Cognitive Psychology and Its Implications* (6th Ed.). New York: Worth Publishers. ISBN 0716701103.

4. Anderson, John R. (2007). *How can the human mind occur in the physical universe?* New York: Oxford University Press. ISBN 978-0-19-532425-9.
5. Appiah, Kwame A. (2003). *Thinking it Through: An Introduction to Contemporary Philosophy*. Oxford University Press.
6. Baars, Bernard J. and Gage, Nicole M. (2010). *Cognition, Brain, and Consciousness: Introduction to Cognitive Neuroscience* (2nd Ed.). New York: Academic Press. ISBN 978-0-12-375070-9.
7. Ballard, Dana H. (2015). *Brain Computation as Hierarchical Abstraction*. MIT Press. ISBN 978-0-262-02861-5.
8. Bechtel, William (1988). *Philosophy of Mind: An Overview for Cognitive Science*. Hillsdale, NJ: Lawrence Erlbaum Associates.
9. Bechtel, William (2008). *Mental Mechanisms: Philosophical Perspectives on Cognitive Neuroscience*. New York: Routledge. ISBN 0-8058-6334-6.
10. Bermúdez, José Luis (2005). *Philosophy of Psychology: A Contemporary Introduction*. New York: Routledge. ISBN 978-0-415-27595-8.
11. Blackmore, Susan (2011). *Consciousness: An Introduction* (2nd Ed.). New York: Oxford University Press. ISBN 0199739099.
12. Botterill, George & Carruthers, Peter (1999). *The Philosophy of Psychology*. Cambridge, UK: Cambridge University Press. ISBN 0-521-55111-0.
13. Carnie, Andrew (2013). *Syntax: A Generative Introduction* (3rd Ed.). Wiley-Blackwell. ISBN 978-0470655313.
14. Carroll, David W. (2008). *Psychology of Language* (5th Ed.). Belmont, CA: Thompson. ISBN 0-495-09969-4.
15. Chalmers, David J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. New York: Oxford University Press. ISBN 9-780-195-117899.
16. Chalmers, David J. (Ed.) (2002). *Philosophy of Mind: Classical and Contemporary Readings*. New York: Oxford University Press. ISBN 0-19-514581.
17. Chierchia, Gennaro & McConnell-Ginet, Sally (2000). *Meaning and Grammar: An Introduction to Semantics* (2nd Ed.). Cambridge, MA: MIT Press. 978-0262531641.
18. Churchland, Patricia S. & Sejnowski, Terrence J. (1994). *The Computational Brain*. MIT Press. ISBN 0-262-53120-8.
19. Crane, Tim (2003). *The Mechanical Mind: A Philosophical Introduction to Minds, Machines, and Mental Representation* (2nd Ed.). London: Routledge. ISBN 0-415-29031-7.
20. Cummins, Robert (1989). *Meaning and Mental Representation*. Cambridge, MA: MIT Press. ISBN 0-262-53096-1.
21. Dawson, Michael (1998). *Understanding Cognitive Science*. Malden, MA: Blackwell Publishers. ISBN 0-631-20894-1.

22. Dayan, P. & Abbott, L. F. (2001). *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems.* Cambridge, MA: MIT Press. ISBN 9780262-041997.

23. Dennett, Daniel C. (1981). True believers: The intentional strategy and why it works. In A. F. Heath (Ed.), *Scientific Explanation*, Oxford: Oxford University Press. [Reprinted in Haugeland (1997) and Chalmers (2002).]

24. Eichenbaum, Howard (2002). *The Cognitive Neuroscience of Memory: An Introduction*. Boston, MA: Oxford University Press. ISBN 978-0-19-514175-7.

25. Eliasmith, Chris (2013). *How to Build a Brain: A Neural Architecture for Biological Cognition*. New York: Oxford University Press.

26. Eliasmith, Chris & Anderson, Charles H. (2003). *Neural Engineering: Computation, Representation, and Dynamics in Neurobiological Systems.* Cambridge, MA: MIT Press. ISBN 0-262-55060-1.

27. Feynman, Richard (1984/1996). *Feynman Lectures on Computation* (Edited by T. Hey and R. W. Allen). Cambridge, MA: Perseus Publishing. ISBN 0-7382-0296-7.

28. Flanagan, Owen (2007). *The really hard problem: Meaning in a material world.* Cambridge, MA: MIT Press. ISBN 987-0-262-06264-0.

29. Forbus, Kenneth (2010). AI and Cognitive Science: The past and next 30 years. *Topics in Cognitive Science, 2*, 345-356. [Special issue on the 30th Anniversary of the founding of the Cognitive Science Society. The same issue also has good commentaries on several other constituent disciplines.]

30. Ford, K. & Hayes, P. (1998). On computational wings: Rethinking the goals of AI. *Scientific American Presents, 9* (4), 78-83. [Special issue, "Exploring Intelligence"]

31. Forsyth, David A. & Ponce, Jean (2012). *Computer vision: A modern approach* (2nd Ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

32. Friedenberg, Jay & Silverman, Gordon (2012). *Cognitive Science: An Introduction to the Study of the Mind* (2nd Ed.). Thousand Oaks, CA: Sage Publications. ISBN 978-1-4129-7761-6. [Comprehensive but superficial. Basically, it's a giant glossary.]

33. Gelman, Susan A. (2005). *The Essential Child: Origins of Essentialism in Everyday Thought*. Oxford University Press. ISBN 978-0195181982.

34. Gluck, M. A., Mercado, E., & Myers, C. E. (2008). *Learning and Memory: From Brain to Behavior*. New York: Worth Publishers. ISBN 0-7167-8654-0.

35. Harris, D. M. & Harris, S. L. (2007). *Digital Design and Computer Architecture*. San Francisco, CA: Morgan Kaufmann. ISBN 0-12-370497-9.

36. Haugeland, John (1985). *Artificial Intelligence: The Very Idea*. MIT Press. ISBN 0-262-58095-0.

37. Haugeland, John (Ed.) (1997). *Mind Design II: Philosophy, Psychology, Artificial Intelligence* (2nd Ed.). Cambridge, MA: MIT Press. ISBN 0-262-58153-1.

38. Haykin, Simon (2009). *Neural Networks and Learning Machines* (3rd Ed.). New York: Prentice Hall. ISBN 978-0-13-603219-9. [The definitive textbook on NNets.]

39. Hertz, J., Krogh, A. & Palmer, R. G. (1991). *Introduction to the Theory of Neural Computation*. Redwood City, CA: Addison-Wesley.

40. Hofstadter, Douglas R. (1985). Review of *Alan Turing: The Enigma*. Chapter 12 in *Metamagical Themas: Questing for the Essence of Mind and Pattern* (pp. 483-491). Basic Books.

41. Huettel, S. A., Song, A. W., & McCarthy, G. (2008). *Functional Magnetic Resonance Imaging* (2nd Ed.). Sinauer. ISBN 0878932860.

42. Izhikevich, Eugene M. (2007). *Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting*. Cambridge, MA: MIT Press. ISBN 978-0-262-51420-0. [Chapters 1, 8, and 10 available at http://izhikevich.com, with Matlab software.]

43. Jackendoff, Ray (1997). *The Architecture of the Language Faculty*. Cambridge, MA: MIT Press. ISBN 0-262-10059-2.

44. Jackendoff, Ray (2012). *A User's Guide to Thought and Meaning*. Oxford, UK: Oxford University Press. ISBN 978-0-19-969320-7.

45. Jackendoff, Ray (2002). *Foundations of Language: Brain, Meaning, Grammar, Evolution*. Oxford, UK: Oxford University Press. ISBN 978-0-19-926437-7.

46. Kim, Jaegwon (2006). *Philosophy of Mind* (2nd Ed.). Cambridge, MA: Westview. ISBN 0-8133-4269-4.

47. Koch, C. (1999). *Biophysics of Computation: Information Processing in Single Neurons.* New York: Oxford University Press. [Warning: Very technical.]

48. Kolb, Brian & Whishaw, Ian (2008). *Fundamentals of Human Neuropsychology* (6th Ed.). New York: Worth Publishers. ISBN 0-7167-9586-8.

49. Kolb, Brian & Whishaw, Ian (2006). *An Introduction to Brain and Behavior* (2nd Ed.). New York: Worth Publishers. ISBN 0-7167-1187-7.

50. Komatsu, Lloyd K. (Ed.) (1994). *Experimenting with the Mind: Readings in Cognitive Psychology*. Pacific Grove, CA: Brooks/Cole Publishing Co. ISBN 0-534-21600-5.

51. Lakoff, George & Johnson, Mark (1980). *Metaphors We Live By*. Chicago: The University of Chicago Press. ISBN 0-226-46801-1.

52. LeDoux, Joseph (2002). *The Synaptic Self: How Our Brains Become Who We Are*. New York: Viking Penguin. ISBN 0-670-03028-7.

53. Levitin, Daniel J. (Ed.) (2011). *Foundations of Cognitive Psychology: Core Readings*. Boston, MA: Allyn & Bacon. ISBN 978-0-205-71147-5.

54. Luger, George F. (Ed.) (1995). *Computation and Intelligence: Collected Readings.* Cambridge, MA: MIT Press. ISBN 0-262-62101-0.

55. Lycan, William G. (2008). *Philosophy of Language: A Contemporary Introduction* (2nd Ed). New York: Routledge. ISBN 978-0-415-95752-6.

56. MacKay, David J. C. (2003). *Information Theory, Inference, and Learning Algorithms.* Cambridge, UK: Cambridge University Press. ISBN 978-0-521-64298-9. [Full text available at http://www.inference.phy.cam.ac.uk/mackay/itprnn/book.html]

57. Markman, Arthur B. (1999). *Knowledge Representation*. New York: Psychology Press. ISBN 978-0-8058-2441-4.

58. McClelland, James L. (2000). Connectionist models of memory. In E. Tulving & F. Craik (Eds.), *The Oxford Handbook of Memory* (pp. 583-596). Oxford Univ. Press.

59. Miller, Ed. & Jensen, Jon (2008). *Questions that Matter: An Invitation to Philosophy* (6th Ed.). New York: McGraw-Hill. ISBN 978-0073386560.

60. Newell, Allen (1990). *Unified Theories of Cognition*. Cambridge, MA: Harvard University Press. ISBN 0-674-92099-6.

61. O'Grady, W., Archibald, J., Aronoff, M., & Rees-Miller, J. (2005). *Contemporary Linguistics: An Introduction* (5th Ed.). New York: Bedford/St. Martin's. ISBN 0-312-41936-8.

62. O'Reilly, Randall C. (1998). Six principles for biologically based computational models of cortical cognition. *Trends in Cognitive Sciences, 2* (11), 455-462.

63. O'Reilly, Randall C. & Munakata, Yuko (2000). *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain.* Cambridge, MA: MIT Press. ISBN 0-262-65054-1. [2nd edition forthcoming] http://grey.colorado.edu/CompCogNeuro/index.php/CCNBook/Main

64. Palmer, Stephen E. (1999). *Vision Science: Photons to Phenomenology*. Cambridge, MA: MIT Press. ISBN 0-262-16183-4.

65. Pearl, Judea (2009). *Causality: Models, Reasoning, and Inference* (2nd Ed.). New York: Cambridge University Press. ISBN 978-0-521-89560-6.

66. Posner, Michael I. (Ed.) (1989). *Foundations of Cognitive Science*. Cambridge, MA: MIT Press. ISBN 0-262-66086-5.

67. Rieke, F., Warland, D., van Steveninck, R., & Bialek, W. (1997). *Spikes: Exploring the Neural Code*. Cambridge, MA: MIT Press. ISBN 978-0-262-18174-7.

68. Rogers, Timothy T. & McClelland, James L. (2004). *Semantic Cognition: A Parallel Distributed Processing Approach*. Cambridge, MA: MIT Press. ISBN 0-262-18239-4.

69. Rudy, Jerry W. (2008). *The Neurobiology of Learning and Memory*. Sunderland, MA: Sinauer. ISBN 978-0-87893-669-4.

70. Russell, Bertrand (1945). *History of Western Philosophy*. New York: Simon & Schuster. ISBN 978-0-671-20158-6. [Highly recommended!]

71. Russell, Stuart & Norvig, Peter (2009). *Artificial Intelligence: A Modern Approach* (3rd Ed.). Upper Saddle River, NJ: Prentice Hall. ISBN 0136042597.

72. Skyrms, Brian (2000). *Choice & chance: An Introduction to Inductive Logic* (4th Ed.). Belmont, CA: Wadsworth.

73. Smolensky, Paul & Legendre, Géraldine (2006). *The harmonic mind: From neural computation to optimality-theoretic grammar*. Cambridge, MA: MIT Press. ISBN 0-262-19526-7. [Warning: Very technical, but some chapters are more accessible.]

74. *The Stanford Encyclopedia of Philosophy*. [A great resource available freely online at http://plato.stanford.edu]

75. Stillings, N. A., Weisler, S. E., Chase, C. H., Feinstein, M. H., Garfield, J. L., & Rissland, E. L. (1995). *Cognitive Science: An introduction* (2nd Ed.). Cambridge, MA: MIT Press. ISBN 0-262-19353-1.

76. Stich, S. P. & Warfield, T. A. (Eds.) (1994). *Mental Representation: A Reader.* Cambridge, MA: Blackwell Publishing. ISBN 1-55786-477-2.

77. Stich, S. P. & Warfield, T. A. (Eds.) (2003). *The Blackwell Guide to Philosophy of Mind.* Malden, MA: Blackwell Publishing. ISBN 978-0-631-21775-6.

78. Tennant, Neil (2015). *Introducing Philosophy: God, Mind, World, and Logic*. Routledge. ISBN 978-0415537148. [Prof. Tennant teaches this course at OSU!]

79. Thagard, Paul (Ed.) (2007). *Philosophy of Psychology and Cognitive Science.* Amsterdam: Elsevier. ISBN 978-0-444-51540-7.

80. Tomasello, Michael (2014). *A Natural History of Human Thinking*. Harvard University Press. ISBN 978-0674724778.

81. *Topics in Cognitive Science*, vol. 2, no 3, July 2010. [Special journal issue on the 30th Anniversary of the first cognitive science conference in San Diego, 1979.] http://cognitivesciencesociety.org/journal_topics.html

82. Trappenberg, T. P. (2010). *Fundamentals of Computational Neuroscience* (2nd Ed.). Oxford, UK: Oxford University Press. ISBN 978-0-19-956841-3.

83. Weisberg, R. W. & Reeves, L. M. (2013). *Cognition: From Memory to Creativity*. Hoboken, NJ: Wiley. ISBN 978-0-470-22628-5. [Decent undergraduate textbook in cognitive psychology.]

84. Whitney, Paul (1998). *The Psychology of Language*. Boston, MA: Houghton Mifflin Co. ISBN 0-395-75750-9.

85. Wilson, Hugh R. (1999). *Spikes, Decisions, and Actions: The Dynamical Foundations of Neuroscience*. New York: Oxford University Press. [Warning: Very technical.]

86. Wilson, R. A. & Keil, F. C. (1999). *The MIT Encyclopedia of the Cognitive Sciences*. Cambridge, MA: MIT Press. ISBN 0-262-73144-4.

87. Woolsey, T. A., Hanaway, J. & Gado, M. H. (2003). *The brain atlas: A visual guide to the human central nervous system* (2nd Ed.). Wiley. ISBN 0-471-43058-7.

Finally, welcome to the course. I hope that you will enjoy the class and learn valuable information and skills. I look forward to seeing you on August 23.

Alex Petrov