PSYCHOLOGY 1654: What Infants Know, How Children Learn

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office hours: by appointment (contact Cristina Sarmiento, csarmiento@g.harvard.edu)

class time: Tuesdays 9-11:45 am (normally, 9-11 am, but with time for overflow)

Scope and goals

Despite recent advances in computer science and machine learning, human infants and children remain the most prodigious learners known to science. This seminar considers the origins and nature of human cognitive development in four broad domains: knowledge of objects and their physical relationships, knowledge of geometry and the larger spatial layout, knowledge of number and mathematics, and knowledge of people, our actions, our social relationships, and our mental states. We will consider the foundational cognitive building blocks that emerge in infancy and support children's learning, as well as the development of cognitive skills that are critical for successfully navigating the physical world, the abstract world of mathematics, and the social world. Finally, we will consider how children's cognitive development sheds light on our minds as adults. Understanding these core psychological competencies has become central to progress in many areas of society, including efforts to improve education, to create digital cognitive assistants that help us navigate, plan, and remember things, and to develop human-like artificial intelligence. Building on findings from basic research, we will consider how each of these efforts can be advanced.

Each class is organized around a specific research topic, a set of broader questions, and a variety of approaches to addressing those questions. (See syllabus, below.) The class is a seminar: an opportunity for students to engage with a set of hard questions in developmental psychology and cognitive science, with important implications for society. The class also will give students opportunities to present their own ideas and design an original experiment or other project. Don't take the class unless you're prepared to do the readings in advance, and you want to think hard about the open and difficult questions on which we will focus. Estimated class duration: 2 hours most weeks, but please allow for an extra 45 minutes so that discussions aren't cut off in midstream.

Readings: A small number of core readings will be assigned to everyone in class each week. **Note that the first core readings should be read before the first class meeting**. Beginning with the second class, supplementary readings focused on specific experiments will accompany the required readings. Each student will sign up to read two of the supplementary papers for that week: one for which they will be the primary presenter, and one for which they will be the back-up presenter (see presentations, below).

Response Papers: Each week, before class, each student should write a brief response (1/2-1 page) to the week's required readings. The response should not summarize the readings; instead it should raise a question or venture an idea that the readings sparked, and that you'd like to see discussed in class. If you like, you may focus your response paper in part on the supplementary papers that you read that week, but if you do this, be sure to engage one or more questions raised by the required readings as well. Response papers should be submitted by noon on Monday.

Presentations: To encourage discussion and engagement by all, each student will present one paper from the supplementary readings to the class each week, and they will lead the discussion that follows. Each student also will serve as a back-up presenter and discussion leader for the other supplementary paper that they have read that week.

Individual meetings with the instructor: Each student should plan to meet at least twice with the instructor during the term. The first meeting should occur in the first half of the semester and focus on connections between the concepts, methods and ideas discussed in this class and the student's other academic interests. The second meeting can occur any time during the semester and following the first meeting; it will focus on a discussion of the student's plan for their final paper. Additional meetings can be scheduled at any time, as questions about the class arise.

Final paper: A paper (10-15 pages) is due at the start of exam period. The paper may address any of the topics discussed in class or in the readings. Your paper may take various forms, including: (i) presenting, comparing, and evaluating two theories of infants' knowledge or children's learning in some domain, (ii) proposing a new experiment to address a question raised in class, (iii) applying an idea discussed in class to another academic field, or (iv) discussing the potential applications of some experimental findings discussed in class to an issue of scientific or societal importance.

Grading: Response papers: 40% of grade; Class presentations and contributions to the discussion: 20% of grade; Final paper: 40% of grade.

Schedule of classes

Jan. 24: Developmental cognitive science: An introduction (NB: This class will end at 11 am).

Jan. 31: The development of visual perception: Approaches from psychology, neuroscience, and computer science to the understanding of the origins and development of abilities to perceive a stable, 3D world.

Feb. 7: Objects 1: Infants' knowledge of bodies and their motions

Feb. 14: Objects 2: Children's learning about object forms, functions, and kinds

Feb. 21: Places 1: Developing knowledge of the navigable spatial layout

Feb. 28: Places 2: Developing knowledge of spatial symbols: pictures, maps, and reading

Mar. 7: Number 1: What infants know about number

Mar. 14: SPRING BREAK

Mar. 21: Number 2: How children learn about natural number and arithmetic

Mar. 28: Number 3: Educational interventions to enhance children's math learning: Can cognitive science be leveraged to enhance education?

Apr. 4: Social cognition 1: What do infants and young children know about people as agents who act efficiently to achieve their goals?

Apr. 11: Social cognition 2: What do infants and young children know about people as social beings who engage with one another to share experiences and build a social network?

Apr. 18: Social cognition 3: Children's changing conceptions of their own and others' minds.

Apr. 25: Wrap-Up: project presentations and general discussion.

Readings

Jan. 24: Read at least one of these classic papers in cognitive science to help you think about the assignment below.

a. Fodor, J. A. (1975). *The language of thought.* Chapter 1, "First approximations," pp. 27-53.
b. Gallistel, C. R. (1990). *The organization of learning:* Chapter 2, "Representations," pp. 15-33.
c. Marr, D. (1982). *Vision (1st edition):* General introduction and chapter 1, "The philosophy and the approach," pp. 3-38.

The assignment: Words like *concept, representation, computation, innate,* and *learning* are used, both in ordinary language and in developmental cognitive science, with multiple meanings. Are these useful notions? Can we do without any of them? If so, what should the study of the origins and development of knowledge be about? If not, how should we use these terms? Pick one or a few of these terms and write down how you think each should be used or what you think it should mean. Although the standard response paper should be about a page long, here you can limit yourself to one or a few sentences.

Jan. 31: Required readings

a. Descartes, R. *Optics*, Discourse VI (it's short!)
b. Berkeley, G. *Essay toward a new theory of vision,* paragraphs 1-28 (ditto).
c. Helmholtz, H. von *Treatise on physiological optics*, vol 3, chap. 26. Read pp. 1-9 and 24 (bottom)-end.
d. Walk, R., Gibson, E., & Tighe, T. (1957). Behavior of light and dark-reared rats on the visual cliff. *Science,* 126, 80-81.
e. Gibson, E. J. (1988). The concept of affordances in development: The renascence of functionalism. Excerpts reprinted with a new introduction in Gibson, E. J. (1991). *An Odyssey in Perception and Learning* (pp. 557-570). Cambridge, MA: MIT Press.
f. Held, R., Birch, E. & Gwiazda, J. (1980). Stereoacuity of human infants. *Proceedings of the National Academy of Sciences USA, 77,* 5572-74.
g. Optional: D. Marr (1982). *Vision: A computational investigation into the human representation and processing of visual information.* Cambridge: MIT Press (either this edition or the 2010 reissue). Read chapter 4, sections 4.1 – 4.5 (pp. 268-279) and try to get a feel for his theory of the 2.5D sketch. This is the representation that is most relevant to the remaining papers for this week.

Jan. 31: presentations:

a. E. J. Gibson (1962). The visual cliff. *Scientific American.* Gibson collaborated with the Gibson discussed in Marr's chapter. Though Marr doesn't cite this work, it gives an example of how psychophysical research on animals can serve as a basis for the computational project that Marr describes. Present the main findings not covered in the Walk et al. paper.
b. Held, R. & Hein, A. (1963). Movement-produced stimulation in the development of visually guided behavior. *Journal of Comparative and Physiological Psychology, 56(5),* 872-876.
c. Slater, A., Mattock, A. & Brown, E. (1990). Size constancy at birth: newborn infants' responses to retinal and real size. *Journal of*

Experimental Child Psychology, *49,* 314-322. Skim the first experiment and read and present the second.

d. Wood, J. N. (2013). Newborn chickens generate invariant object representations at the onset of visual object experience. *Proceedings of the National Academy of Sciences*, *110,* 14000-14005.

e. Ostrovsky, Y., Meyers, E., Ganesh, S., Mathur, U. & Sinha, P. (2009). Visual parsing after recovery from blindness. *Psychol. Sci.* **20,** 1484–1491 (2009).

f. Ge., X. et al. (2021). Retinal waves prime visual motion detection by simulating future optic flow. *Science, 373,* 412-422. This paper leverages heavy artillery from developmental, cellular and molecular neuroscience to suggest a mechanism that may account for the perceptual abilities discovered by Gibson, Slater and others.

Feb. 7: all read:

a. Piaget, J. (1954). *The construction of reality in the child, chapter* 1, *section* 2, pp. 13-44. NY: Basic Books. Read the introduction to section 2 (on pp 13-14), observations 13 & 14 (pp 21-22), and observation 29 (pp. 37-38) to get a feel for the phenomena that Piaget discovered.

b. Spelke, E. S. (1990). Principles of object perception. *Cognitive Science, 14,* 29-56. NB: read the intro and the studies of occluded objects (pp. 29-36 and 41-48.)

c. Keen, R. (2003). Representations of objects and events: Why do infants look so smart and toddlers look so dumb? *Current Directions in Psychological Science, 12*(3), 79-83.

d. Ullman, T., Spelke, E., Battaglia, P., & Tenenbaum, J. (2017). Mind games: Game engines as an architecture for intuitive physics. *Trends in Cognitive Sciences, 21(9),* 649-665. Focus on Ullman’s explanation for the developmental phenomena that the other readings describe.

Feb. 7: presentations:

a. Clifton, R. K., Litovsky, R., & Perris, E. (1991). Object representation guides infants’ reaching in the dark. *Journal of Experimental Psychology: Human Perception & Performance, 17,* 323-329.

b. Baillargeon, R. (2004). Infants’ physical world. *Current Directions in Psychological Science, 13(3),* 89-94.

c. Stahl, A. & Feigenson, L. (2015). Observing the unexpected enhances infants’ learning and exploration. *Science, 348,* 91-94.

d. Diamond, A., & Lee, E. (2000). Inability of 5-month-old infants to retrieve a contiguous object: A failure of conceptual understanding or of control of action? *Child Development, 71,* 1477-1494.

e. Valenza, E., Leo, I., Gava, L. & Simion, F. (2006). Perceptual completion in newborn human infants. *Child Development, 77,* 1810-1821.

f. Chiandetti, C. & Vallortigara, G. (2011). Intuitive physical reasoning about occluded objects by inexperienced chicks. *Proc. Roy. Soc. B., 278,* 2621-2627.