How to build a mind: Lessons from babies, animals, and AI

Department of Psychological & Brain Sciences
Course AS.200.324
Syllabus

Meeting Time & Place: **Wednesday & Friday 3:00 pm - 4:15 pm, Ames 217**

Instructor: Qiong Cao
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Office hours: by appointment
Email: qcao14@jhu.edu
Calendly: https://calendly.com/qiongcao/45min

Course Description and Objectives:

Have you ever wondered how babies, who appear to have little knowledge and limited abilities, manage to grow into adults capable of riding a bike, reading a novel, or mastering algebra? Are humans the only creatures capable of complex thought, or do other animals think like we do? And what about non-biological "minds" like Google Assistant and Siri; will they ever become as smart as or smarter than humans?

In this course, we will tackle questions about the mind and intelligence in different cognitive systems. To explore the origins of human intelligence, we will examine early cognitive abilities in human infants. To better understand what makes human thinking similar to and different from that of other complex systems, we will dive into research on non-human animals and artificial intelligence. We will start with discussions of topics such as "What counts as intelligence?" and "How does learning occur?" Then we will consider how different cognitive systems might work by exploring five cognitive abilities known to be important for human cognition: intuitive physics, intuitive psychology, numerical cognition, causal reasoning, and language.

This course is an in-person seminar-style course. It is offered for upper-level undergraduate students with prior coursework in psychology, cognitive science, or cognitive neuroscience. Prior coursework in research methods is strongly recommended.

By the end of this course, you should be able to:

- articulate major findings in infant cognitive development
- analyze major differences in cognition among humans, non-human animals, and AI

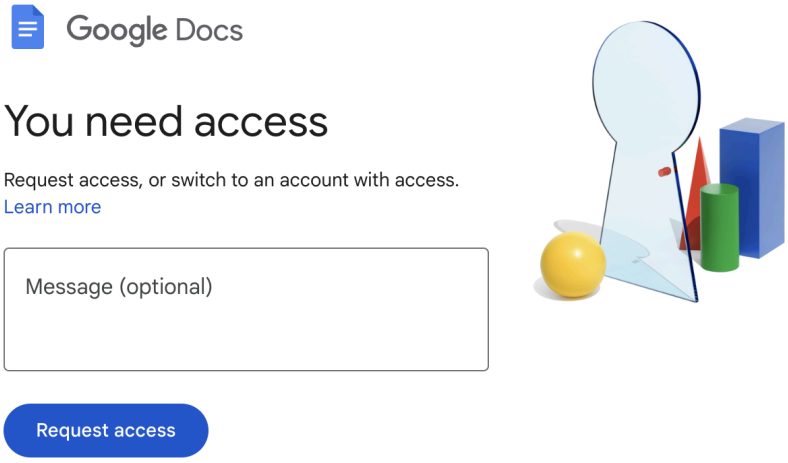
- identify contributions and limitations of existing empirical research
- synthesize evidence from multiple sources to make interpretive claims
- effectively convey ideas and navigate discussions in scientific communication

Course Materials:

There is no textbook in this course. We will focus on original journal articles. Occasionally, we will read book chapters and watch videos. All course materials are stored in this Google Drive Folder.

Please download local copies of the papers if you plan to make notes on them. If you intend to make a public note on a file in the shared folder, select the relevant part and make a comment.

Note: The first time you try to access the Google Drive, you'll see the following message:



Type in your first and last name in the message box, and click "Request access". If you are a student on the waitlist, please add "(waitlist)" in your message after your name. I'll grant you access asap after I receive the notification from Google.

Assignments and Grading:

- Discussion questions – 10%
- In-class participation – 10%
- Paper summaries – 20% (4 papers in total, each 5%)
- Paper presentation – 20% (Draft: 5%. Final version: 15%, including 5% peer evaluation)
- Research Proposal – 40% (Draft: 15%. Final version: 25%)

TLDR:

Assignment	Grade	Due	Note

Discussion questions	10%	15h before each class	- At least one question per class. - You can skip 4 classes' questions. No discussion questions needed for the first class.
In-class discussions	10%	NA	- You are expected to actively engage in discussions in class. - Share your thoughts with the whole class about once per class.
Paper summary 1	5%	09/13	- Submit your summary as a PDf file 1h before class. Revised version (optional) should be emailed to the instructor by 11:59 pm on the same day. - Use QDAFI method for Summary 1 to 3. You can develop your own method for Summary 4. - Summary 3 & 4 should include a critique part besides the paper summary part. - See more details in the Paper Summary Guideline.
Paper summary 2	5%	09/27	
Paper summary 3	5%	10/11	
Paper summary 4	5%	11/01	
Paper presentation: sign up for a paper	NA	09/07	- Sign up here. - Skim the paper to see if you feel ok presenting it before you sign up.
Paper presentation: draft	5%	At least 5 days before your presentation day	- Use the Calendly link at least 7 days before your presentation day to ensure a meeting spot. - Presentation should be about 15 min. - Follow requirements in the Presentation Guideline.
Paper presentation: final version	10% + 5%	Your presentation day	- Upload your slides to Canvas before class. - The presentation should be about 15 min. Afterwards you will lead the Q&A session (time varies). - Follow requirements in the Presentation Guideline.

Peer evaluation of other people's presentations	In note	11:59 pm of the presentation day	- A survey link will be provided here under the column "Peer evaluation link " for you to provide feedback. - Failure to provide peer evaluation by the due time for more than twice will result in a 20% deduction of your in-class participation grade.
Research Proposal: topic selection & foundation paper(s)	0%	10/24/23 at 11:59 pm	- Choose a research topic, and list one or two foundation papers. (Ideally, list research questions, hypotheses, and a tentative design as well.) - Not graded, but you should submit it for your own sake.
Research Proposal: draft	15%	11/26/23 at 11:59 pm	- 6-8 pages (not including the title page, reference page, figures, or tables), double-spaced. - Have at least 3 scientific papers as references. - Written in APA style. - See other requirements in the Research Proposal Guideline.
Research Proposal: final version	25%	12/14/23 at 11:59 pm	- 8-12 pages (not including the title page, reference page, figures, or tables), double-spaced. - Have at least 5 scientific papers as references. - Written in APA style. - See other requirements in the Research Proposal Guideline.
(optional) Extra credit: assignment proposal	0%	10/01/23 at 11:59 pm	- Propose an assignment for yourself and submit it to Canvas. - Design your assignment as a SMART assignment.
(optional) Extra credit: completed assignment	5%	12/14/23 at 11:59 pm	- Complete the assignment you proposed and submit it to Canvas.

Notes:

- All assignments should be submitted to Canvas, except for the optional revised paper summary (email it to the instructor).
- Paper Summaries and the Research Proposal should be submitted as PDFs.

Discussion questions:

The goal of the discussion questions is to practice critical thinking skills and prepare you for class discussion. Discussion questions should raise issues that occur to you as you read the papers, and should be pertinent to the content of the specific papers. Discussion questions can be related to (this is a non exhaustive list): alternative interpretations of the findings, better experimental designs that you come up with, alternative operationalization for the mental construct of interest, the connections between this paper and related papers you read in the past, potential applications for the findings, how does this paper connected to the big questions such as "what is mind" and "what is intelligence", how do cognitive systems operate to achieve the same cognitive capacity, what is missing from the current literature, what are some interesting questions that you want to address inspired by the paper. Note, simply "look-up" (i.e., factual, definitional) questions are not accepted for this purpose, but do ask them during class or make a comment on the paper in the Google Drive if you cannot find the answers on your own.

Before each class, you should read the required readings, and submit at last one discussion question for a given class. You can skip discussion questions for 4 classes, and no discussion question is needed for the first class. Discussion questions should be submitted here at least 15 hours before the next class. One point will be deducted for each missing discussion question. Late submissions follow the late policy specified below.

In-class participation:

This course is fueled by discussions from you. There will be different forms of discussions: small discussions with your neighbor, group discussion with several people, whole-class discussion, or debates between different teams. A good discussion is not simply speaking out what you want to say, it also involves actively listening to what other people are saying, analyzing the quality of arguments you or other people made, drawing connections between different perspectives, and making high-level conclusions. Also remember that discussions should be goal-oriented conversations rather than casual chats where topics flow randomly.

I understand that some people are more introverted than others, and that's totally ok. Every type of personality has its strengths and weaknesses; plus, everyone is constantly changing, so don't limit yourself by any label that yourself or others put on you. The expectation for the class is that you should share your thoughts with the class at least once per class. For some people, it may be challenging to reach this expectation at the beginning of the semester, and that's ok. What matters is you try and make improvements: maybe you can write out your questions beforehand and read them to the class, or just share your agreement with another person's idea and explain why you liked it, also you can challenge yourself with the goal of speaking up at least once for each week and increase that number

when you feel more comfortable. For people who are already very good at sharing your thoughts, try to improve your speaking skills: think about how to better frame your arguments before you speak, modify the words you use based on the specific audience you are speaking to, be better at active listening, try to think deeper and broader while incorporating different perspectives.

Paper summaries:

Understanding scientific articles is the butter and bread for learning and researching. We all hope that we can easily remember what we read. Yet as humans, forgetting is inevitable. Chances are, despite you paying close attention to the paper when you read it, you will only remember the gist and some special details later on. That's why we are practicing how to distill a paper to make reading papers more efficient in the long run.

We will practice a method called QDAFI — a structured way to analyze and summarize a paper. This method can help you have a better understanding and memory of the paper in the long run. To use the QDAFI method, you need to write a few sentences to answer the following five questions of the paper: (1) **Q**: What was the research **q**uestion that the authors tried to answer? (2) **D**: What did the authors **d**o to answer the question? (3) **A**: What was the **a**uthors' r**a**tionale? (4) **F**: What did the authors **f**ind?, and (5) **I**: What is the authors' **i**nterpretation of these findings with regard to the initial question? Here is a great tutorial for the QDAFI method, and you can find other relevant tutorials in the folder QDAFI Method.

You will be writing summaries on four papers (specifies by ** in the weekly schedule below). We will focus on developmental studies using behavioral methods for this assignment. The four summaries are designed to help you practice the QDAFI method, and to develop your own paper summarizing method eventually. For the first two paper summaries, you will write the summary using the QDAFI method. For the third summary, you'll need to add a short paragraph of evaluation of the paper beside the QDAFI parts. The fourth summary is similar to the third one, but you are encouraged to adjust the QDAFI method to create a new method that's more helpful to you.

Each paper summary is due 1 hour before the class, and you should submit a pdf file to Canvas by the due time. You will have the chance to discuss the paper summary with your peers during class, and feel free to make edits and take notes during the discussion. Depending on your preference, you can either print out your summary and bring it to class, or you can share the summary on your computer screen, or through a sharable link to your peers. If you want, you can submit a revised version of your summary by 11:59 pm that day. Grading will be primarily based on your first version, but you can get an extra 0.5 point if your revised version is all correct.

See more details in the Paper Summary Guideline.

Paper presentation:

One of the best ways of learning is through teaching. To practice your scientific communication skills and to deeply understand a paper that you are interested in, each one of you will give an in-class presentation during the semester. You will prepare slides and present the content of the paper (about 15 minutes), and then lead a Q&A (time varies). See other requirements in the Presentation Guideline.

You can sign up for one paper here before 09/07/23. Eligible papers are also marked by * in the weekly schedule below.

1, The draft presentation to the instructor:

You will present a draft of your presentation to the instructor, who will help you improve your presentation prior to your in-class presentation. Present the draft presentation as a real presentation. The draft counts 5% towards your final grades, and it will be graded using the same criterion of the in-class presentation but on a more lenient end. It is recommended to upload your slides (or the link to your Google Slides) to Canvas before your meeting.

You need to meet with the instructor at least 5 days before your presentation day. To make sure you can locate a meeting spot in time, use the instructor's Calendly link at least 7 days before your presentation day to book a meeting (the instructor's Calendly doesn't accept meeting appointments 48h into the future). Failure to schedule a meeting with the instructor to go over your draft will result in the loss of your grades for this portion. Meetings scheduled later than the required time will follow the late policy specified below.

2, The final presentation to the class:

Your final version of the in-class presentation will count 15% towards your final grades, of which 10% comes from the instructor and 5% from your peers. Please upload your slides (or link to your Google Slides) to Canvas before the class.

(You may wonder why we are including peer evaluation in this course: The goal of any presentation is to help your audience understand the information that you are trying to convey. The real audience for your in-class presentation is your classmates rather than the instructor, therefore your real audience's opinions should count. To ensure your peer evaluation grade won't be influenced by extreme values, the highest and lowest scores from the peer evaluation will be dropped, and the average score of the remaining scores will be your final score for the peer evaluation portion.

Having peer evaluation also means that, when you are not presenting, you are still a vital part of the presentation. You should respect the presenter's effort by paying attention to the presentation and engaging in the discussion. In addition, giving peer evaluations is an important practice on how to evaluate other people's work and how to give constructive feedback.

Peer review should be submitted using the Google Form link specified here under the column "Peer evaluation forms" for the corresponding paper. Make sure you are on the correct form by checking the paper title and the presenter's name on the top of the Google Form. Peer evaluation

should be submitted by 11:59 pm of the presentation day. Failure to provide timely feedback to your peers for more than 2 times will result in 20% of deduction of your in-class participation grades.)

If for some reason you are unable to present on the day for which you signed up, please arrange to switch presentation days with a classmate at least a week before. Please email the instructor about any schedule changes.

Research Proposal:

The research proposal assignment is an opportunity to (1) dive into a topic that interests you, (2) hone your research skills, and (3) practice scientific writing. You can choose a topic that is relevant to the case studies covered in class (intuitive physical, intuitive psychology, numerical cognition,), or some other topics related to the big theme of the course (e.g., geometric cognition, emotion, social cognition, decision making, categorization, visual perception, etc.) Talk to the instructor if you are not sure if your selection of topic is appropriate or not. You may focus on only one of the cognitive systems (human infants, non-human animals, AI) in your proposal.

1, topic selection and foundation paper(s)

By 10/24/2023 at 11:59 pm, you should submit a tentative research topic, and one or two empirical articles that you intend to use as the key readings for your research proposal. If you can have a tentative experimental design that is even better.

This part is not graded, but you will receive written feedback on your topic selection and foundational paper(s). This serves as a safety net for you to avoid big deviations of the requirements when you submit your first draft.

2, first draft

By 11/26/2023 at 11:59 pm, you should submit the first draft as a pdf file to Canvas. The first draft should be 6 to 10 pages (not including the title page, reference page, figures, or tables), double-spaced. You should have at least 3 scientific papers referenced in your proposal. These papers should be closely related to your research questions and can support the importance of your research questions.

You should have all required components of a research proposal in your first draft. The focus of the first draft though is to make sure you have a clear and solid foundation about the reasons for exploring your research questions (introduction), and how you want to test your hypotheses (methods and results).

The instructor will give you written feedback on your first draft. You are encouraged to schedule a meeting with the instructor to go over the feedback you received.

3, final version

By 12/14/2023 at 11:59 pm, you should submit the final version of your proposal as a pdf file to Canvas. The final draft should be 8 to 12 pages long (not including the title page, reference page, figures, or tables), double-spaced. Include at least 5 references of scientific papers.

Style: Both the draft and the final version should be written in APA style (7th edition). APA is the standard formatting style for most academic papers in psychology. As a psychology or related major, it's helpful to be comfortable with using APA style in scientific writing.

See more details in the Research Proposal Guideline.

Extra credit – 5% (choose your own adventure)

The reason for having assignments is not sorely evaluative; assignments are designed to help you learn better. You are the master of your education, you came into the class with your own purposes, and you have your own way of learning. So, take a wild ride, if you want, and design your own assignment to help YOU learn.

There is no requirement except that the assignment should be helpful to better achieve your learning goals for this course. Be creative and have fun!

If you want to do this extra credit assignment, propose an assignment (submit to Canvas) before 10/01/23. It is highly recommended that the assignment should be SMART: *specific* ("make a list questions about how AI learning algorithms can be improved by infant cognition" is specific, whereas "list some questions about AI" is not), *measurable* ("a list of at least 20 questions" is measurable, whereas "a list of questions" is not), *achievable* ("conduct a comprehensive literature review of the history of AI development" is too huge a task), *relevant* (if you are interested in learning about AI learning algorithms, then don't make an assignment about animal cognition), and *time-bound* (you need to submit it by the due date specified below. Also, you may want to break your assignment down into smaller pieces and give yourself specific deadlines for the small pieces).

Extra credit assignment is due 12/14/23 at 11:59 pm. The extra credit assignment includes 50% of your self-grading (you made the assignment yourself after all), and 50% of instructor's grading (based on how good your assignment is compared to the overall quality of other students' extra credit assignments). Write down your self grading at the end of your assignment. Submit your assignment to Canvas.

Late policy:

All assignments are due on the dates and times specified above. We use ET for all the time specified. Should you run into an instance that will cause your work to be late, contact the instructor as soon as possible to determine whether late work will be accepted. For all late work, with the exception of illness or emergency, 20% will be deducted for each 24h late.

Course Ethics:

Everyone in the class offers you important companionship during this learning journey, so be kind to other people and to yourself. Specifically for in-class time, you should: (1) pay attention to their classmates and the instructor, be kind and supportive, be willing and able to give constructive feedback, and (2) respect yourself and use your time in class wisely (multitasking is harmful rather than beneficial for most people!).

Two important reminders:

1. Your physical health and mental health comes first, not your grades. If you don't have a healthy body and a healthy mind, hard-working causes you pain rather than fulfillment. Check out these tips for stress managing and self-care guidance.

2. Value the learning experience, rather than the content of the course or the score you get. When you look back many years later, no one (including your parents, your teachers, your employers, and yourself) will remember what scores you got for each of the courses you took. There are more important and memorable moments in your learning journey: a eureka moment when you understand a new concept, a genius idea you come up with for a problem, the critical moment where you decided to work rather than procrastinate, the hard yet rewarding process where you tackled a difficult quest, the growth-mindset that you developed little by little, etc. Value these more precious experiences — they will help you get better grades, and more importantly, lead you to a happy and rewarding career and life in the long run.

Academic Integrity:

You may discuss readings with your peers or search for information online to better understand the readings. However, all written work must be entirely your own. Copying others (including other people or AI programs such as ChatGPT) in whole or in part without appropriate citation constitutes plagiarism. Language taken directly from a source should be included in quotation marks and cited appropriately.

Undergraduate students enrolled in the Krieger School of Arts and Sciences or the Whiting School of Engineering at the Johns Hopkins University assume a duty to conduct themselves in a manner appropriate to the University's mission as an institution of higher learning. Students are obliged to refrain from acts which they know, or under circumstances have reason to know, violate the academic integrity of the University. Violations of academic ethics include, but are not limited to: cheating; plagiarism of another student's or another scholar's work; submitting the same or substantially similar work to satisfy the requirements of more than one course without permission; failure to cite sources adequately. See the guide on "Academic Ethics for Undergraduates" and the Ethics Board Website for more information: http://e-catalog.jhu.edu/undergrad-students/student-life-policies/#UAEB.

Accessibility/Accommodations

If you are a student with a registered accommodation for a disability, please let your instructor know. If you believe you might require accommodations, please contact Student Disability Services (studentdisabilityservices@jhu.edu, 410-516-4720) or visit their office at 385 Garland Hall.

Johns Hopkins University values diversity and inclusion. We are committed to providing welcoming, equitable, and accessible educational experiences for all students. Students with disabilities (including those with psychological conditions, medical conditions, and temporary disabilities) can request accommodations for this course by providing an Accommodation Letter issued by Student Disability Services (SDS). Please request accommodations for this course as early as possible to provide time for effective communication and arrangements.

Weekly Schedule

Note: 1. All readings listed for a given class should be completed prior to class.
*2. Readings marked with * are readings for in-class presentations.*
*3. Readings marked with ** are readings for short paper summaries*

Foundational issues

Week 1 & 2 – Foundations

Class 1 (08/30)

No required readings. Watch "What Kind of Computation Is Cognition" by Joshua Tenenbaum: https://www.youtube.com/watch?v=NsID1iM8gRw

Class 2 (09/01)

Turing, A. M. (1950). Computing machinery and intelligence. *Mind, 59*(236), 433-460.

Griffiths, T. L. (2020). Understanding human intelligence through human limitations. *Trends in Cognitive Sciences, 24*(11), 873-883.

Class 3 (09/06)

Gallistel, C.R., Brown, A., Carey, S., Gelman, R., & Keil, F. (1991). Lessons from animal learning for the study of cognitive development. In S. Carey & R. Gelman (Eds.), *The epigenesis of mind: Essays on biology and cognition*, pp. 3-36. Hillsdale: Erlbaum.

Watch "Rethinking Thinking: How intelligent are other animals?" by World Science Festival: https://www.youtube.com/watch?v=tdsVRh9oKiE

Class 4 (09/08)

Gopnik, A. (2003). The theory theory as an alternative to the innateness hypothesis. *Chomsky and his critics*, 238-254.

Spelke, E. S., & Kinzler, K. D. (2007). Core knowledge. *Developmental Science, 10*(1), 89–96.

Optional: Watch "What infants know (and don't know)" by Elizabeth Spelke: https://www.youtube.com/watch?v=r-F8Dlp-POk

Case Studies

~ Objects & Intuitive Physics ~

Class 5 (09/13)

Baillargeon, R. (1994). Physical reasoning in young infants: Seeking explanations for impossible events. *British Journal of Developmental Psychology, 12*(1), 9-33.

** Baillargeon, R., Spelke, E. S., & Wasserman, S. (1985). Object permanence in five-month-old infants. *Cognition*, *20*(3), 191-208.

Class 6 (09/16)

* Huntley-Fenner, G., Carey, S., & Solimando, A. (2002). Objects are individuals but stuff doesn't count: Perceived rigidity and cohesiveness influence infants' representations of small groups of discrete entities. *Cognition, 85*(3), 203–221.

* Stahl, A. E., & Feigenson, L. (2015). Observing the unexpected enhances infants' learning and exploration. *Science, 348*(6230), 91-94.

Class 7 (09/20)

* Regolin, L., & Vallortigara, G. (1995). Perception of partly occluded objects by young chicks. *Perception & Psychophysics, 57*(7), 971–976.

* Cacchione, T., & Call, J. (2010). Intuitions about gravity and solidity in great apes: The tubes task. *Developmental Science*, *13*(2), 320-330.

Class 8 (09/22)

* Battaglia, P. W., Hamrick, J. B., & Tenenbaum, J. B. (2013). Simulation as an engine of physical scene understanding. *Proceedings of the National Academy of Sciences*, *110*(45), 18327-18332.

Piloto, L. S., Weinstein, A., Battaglia, P., & Botvinick, M. (2022). Intuitive physics learning in a deep-learning model inspired by developmental psychology. *Nature human behaviour*, 1-11.

~ Agents & Intuitive Psychology ~

Class 9 (09/27)

Baillargeon, R., Scott, R. M., & Bian, L. (2016). Psychological Reasoning in Infancy. *Annual Review of Psychology, 67*(1), 159–186.

** Onishi, K. H., & Baillargeon, R. (2005). Do 15-Month-Old Infants Understand False Beliefs? *Science, 308*(5719), 255–258.

Class 10 (09/29)

* Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*(1), 1–34.

* Liu, S., Ullman, T. D., Tenenbaum, J. B., & Spelke, E. S. (2017). Ten-month-old infants infer the value of goals from the costs of actions. *Science, 358*(6366), 1038–1041.

Class 11 (10/04)

Bonini, L., Rotunno, C., Arcuri, E., & Gallese, V. (2022). Mirror neurons 30 years later: Implications and applications. *Trends in Cognitive Sciences, 26*(9), 767–781.

* Krupenye, C., Kano, F., Hirata, S., Call, J., & Tomasello, M. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science, 354:6308,* 110-114.

Class 12 (10/06)

* Shu, T., Bhandwaldar, A., Gan, C., Smith, K., Liu, S., Gutfreund, D., Spelke, E., Tenenbaum, J. & Ullman, T. (2021). AGENT: A Benchmark for Core Psychological Reasoning. *Proceedings of the 38th International Conference on Machine Learning*, in *Proceedings of Machine Learning Research* 139:9614-9625.

Brożek, B., & Janik, B. (2019). Can artificial intelligences be moral agents?. *New ideas in psychology*, *54*, 101-106.

~ Numerical Cognition ~

Class 13 (10/11)

Feigenson, L., Dehaene, S., & Spelke, E. (2004). Core systems of number. *Trends in cognitive sciences*, *8*(7), 307-314.

* Feigenson, L., & Carey, S. (2005). On the limits of infants' quantification of small object arrays. *Cognition, 97*(3), 295–313.

** Wynn, K. (1992) Addition and subtraction by human infants. *Nature, 358,* 749–750.

Class 14 (10/13)

Nieder, A., & Dehaene, S. (2009). Representation of Number in the Brain. *Annual Review of Neuroscience, 32*(1), 185–208.

* Gennari, G., Dehaene, S., Valera, C., & Dehaene-Lambertz, G. (2023). Spontaneous supra-modal encoding of number in the infant brain. *Current Biology, 33*(10), 1906-1915.e6.

Class 15 (10/18)

* Ditz, H. M., & Nieder, A. (2015). Neurons selective to the number of visual items in the corvid songbird endbrain. *Proceedings of the National Academy of Sciences, 112*(25), 7827–7832.

* Cantlon, J. F., Merritt, D. J., & Brannon, E. M. (2016). Monkeys display classic signatures of human symbolic arithmetic. *Animal Cognition, 19*(2), 405–415.

10/20: Fall break, no class

Class 16 (10/25)

Nasr, K., Viswanathan, P., & Nieder, A. (2019). Number detectors spontaneously emerge in a deep neural network designed for visual object recognition. *Science Advances, 5*(5), eaav7903.

* Testolin, A., Dolfi, S., Rochus, M., & Zorzi, M. (2020). Visual sense of number vs. Sense of magnitude in humans and machines. *Scientific Reports, 10*(1), 10045.

~ Causal Reasoning ~

Class 17 (10/27)

Meltzoff, A. N. (2007). Infants' causal learning: Intervention, observation, imitation. In Causal Learning, In A. Gopnik & L. Schulz (Eds.), *Causal Learning: Psychology, Philosophy, and Computation* (pp. 37-47), Oxford University Press.

* Oakes, L. M., & Cohen, L. B. (1990). Infant perception of a causal event. *Cognitive Development*, *5*(2), 193-207.

Class 18 (11/01)

** Gweon, H., & Schulz, L. (2011). 16-month-olds rationally infer causes of failed actions. *Science*, *332*(6037), 1524-1524.

* Saxe, R., Tenenbaum, J. B., & Carey, S. (2005). Secret agents: Inferences about hidden causes by 10-and 12-month-old infants. *Psychological science*, *16*(12), 995-1001.

Class 19 (11/03)

* Blaisdell, A. P., Sawa, K., Leising, K. J., & Waldmann, M. R. (2006). Causal reasoning in rats. *Science*, *311*(5763), 1020-1022.

* Taylor, A. H., Miller, R., & Gray, R. D. (2012). New Caledonian crows reason about hidden causal agents. *Proceedings of the National Academy of Sciences*, *109*(40), 16389-16391.

Optional: Penn, D. C., & Povinelli, D. J. (2007). Causal Cognition in Human and Nonhuman Animals: A Comparative, Critical Review. Annual Review of Psychology, 58(1), 97–118.

Class 20 (11/08)

Pearl, J. (2019). The seven tools of causal inference, with reflections on machine learning. *Communications of the ACM, 62*(3), 54–60.

Optional: Pearl, J., & Mackenzie, D. (2018). Big data, artificial intelligence, and the big questions. In J. Pearl & D. Mackenzie, *The book of why: the new science of cause and effect* (pp. 367-390). Basic Books.

Bishop, J. M. (2021). Artificial Intelligence Is Stupid and Causal Reasoning Will Not Fix It. *Frontiers in Psychology, 11*, 513474.

~ Language ~

Class 21 (11/10)

Perszyk, D. R., & Waxman, S. R. (2018). Linking language and cognition in infancy. *Annual review of psychology, 69*, 231-250.

Optional: Dehaene-Lambertz, G., Hertz-Pannier, L., & Dubois, J. (2006). Nature and nurture in language acquisition: anatomical and functional brain-imaging studies in infants. *Trends in Neurosciences, 29*(7), 367-373.

* Saffran, J., Aslin, R. N., & Newport, E. L. (1996). Statistical Learning by 8-Month-Old Infants. *Science, 274*(5294), 1926–1928.

Class 22 (11/15)

* Fulkerson, A. L., & Waxman, S. R. (2007). Words (but not tones) facilitate object categorization: Evidence from 6-and 12-month-olds. *Cognition, 105*(1), 218-228.

* Choi, D., Dehaene-Lambertz, G., Peña, M., & Werker, J. F. (2021). Neural indicators of articulator-specific sensorimotor influences on infant speech perception. *Proceedings of the National Academy of Sciences, 118*(20), e2025043118.

Class 23 (11/17)

(choose your own adventure: pick two papers among the following three papers to read, and be ready to explain what you read to your classmates)

Cartmill, E. A., & Byrne, R. W. (2007). Orangutans Modify Their Gestural Signaling According to Their Audience's Comprehension. *Current Biology, 17*(15), 1345–1348.

Kaminski, J., Call, J., & Fischer, J. (2004). Word learning in a domestic dog: evidence for" fast mapping". *Science*, *304*(5677), 1682-1683.

Suzuki, T. N., Wheatcroft, D., & Griesser, M. (2016). Experimental evidence for compositional syntax in bird calls. Nature Communications, 7(1), 10986.

11/22 & 11/24: Thanksgiving Break, no class

Class 24 (11/29)

Joshi, A. K. (1991). Natural language processing. *Science, 253*(5025), 1242-1249.

Hirschberg, J., & Manning, C. D. (2015). Advances in natural language processing. *Science*, *349*(6245), 261-266.

* Adolfi, F., Bowers, J. S., & Poeppel, D. (2023). Successes and critical failures of neural networks in capturing human-like speech recognition. *Neural Networks, 162*, 199–211.

Conclusion

Class 25 (12/1)

Lake, B. M., Ullman, T. D., Tenenbaum, J. B., & Gershman, S. J. (2017). Building machines that learn and think like people. *Behavioral and Brain Sciences*, *40*, e253. (Skim the main paper)

Shanahan, M., Crosby, M., Beyret, B., & Cheke, L. (2020). Artificial intelligence and the common sense of animals. *Trends in cognitive sciences*, *24*(11), 862-872.