Proseminar in Developmental Psychology, Fall 2021

October 8: Spatial cognition, navigation, and the modularity hypothesis

1. **Readings on object representation that are still to be discussed, with one new one:**
   a. Stahl, A. E. & Feigenson, L. (2015). Observing the unexpected enhances infants' learning and exploration. *Science, 348(6230),* 91-94.
   b. Smith, L. B. (2003). Learning to recognize objects. *Psychological Science, 14(3),* 244-250.
   c. Ullman, T., et al. (2017). Mind games: Game engines as an architecture for intuitive physics. *Trends in Cognitive Sciences, 21(9),* 649-655.
   d. Marr, D. (1982). *Vision,* chapter 5, sections 5.1-5.3 (pp. 295-309). This chapter deals with object recognition and presents Marr's ideas about how to represent object shapes. It's all worth reading but if you're short on time, just look at the figures.

2. **For fun: Old and new readings on vision that are great and totally optional:**
   a. Helmholtz, H. von. (trans. 1925) *Treatise of Physiological Optics, Vol 3* chap. 26. Especially pp 1-9 and 24 (bottom)-end.
   b. Ge, X., Xhang, K., Gribizis, A., Hamodi, A. S., Sabino, A. M., & Crair, M. C. (2021). Retinal waves prime visual motion detection by simulating future optic flow. *Science, 373,* eabd0830.

3. **Readings on modularity, navigation and spatial cognition, for all:**
   a. Fodor, J. A. (1983). *The modularity of mind.* Skim all the sections of Part III, pp. 47-100, and read section 5, pp. 64-84. You may want to compare this to Helmholtz's discussion of visual space perception as unconscious inference, a century before.
   b. Muller, M. & Wehner, W. (1988). Path integration in desert ants. *PNAS*, 85, 5287-5290.
   c. Landau, B. & Lakusta, L. (2009). Spatial representation across species: geometry, language and maps. *Current Opinion in Neurobiology, 19,* 12-14. This article begins with a useful review of the work on reorientation in animals and children; the rest is optional.
   d. Bonner, M. F. & Epstein, R. A. (2017). Coding of navigational affordances in the human visual system. *Proceedings of the National Academy of Sciences, 114,* 4793-4798.
   e. O'Keefe, J. & Burgess, N. (1996). Geometric determinants of the place fields of hippocampal neurons. *Nature*, 381(6581):425–428.
   f. Gupta, A. S., van der Meer, M. A., Touretzky, D. S., & Redish, A. D. (2010). Hippocampal replay is not a simple function of experience. *Neuron, 65(5),* 695-705.
4. **Behavioral studies of children and animals:** Read at least one.
   a. Lee, S. A., Spelke, E. S. & Vallortigara, G. (2014). Chicks, like children, spontaneously reorient by three-dimensional environmental geometry, not by image matching. *Biology Letters, 8,* 492-494.
   b. Julian, J. B., Keinath, A. T., Muzzio, I. A., & Epstein, R. A. (2015). Place recognition and heading retrieval are mediated by dissociable cognitive systems in mice. *Proceedings of the National Academy of Sciences, 112(20),* 6503-6508.
   c. Chiandetti, C. & Vallortigara, G. (2008). Is there an innate geometric module? Effects of experience with angular geometric cues on spatial reorientation based on the shape of the environment. *Animal Cognition, 11,* 139-146.
5. **Studies in cognitive neuroscience:** Here's a feast of papers: Read at least one.

   a. Doeller, C. F., King, J. A., & Burgess, N. (2008). Parallel striatal and hippocampal systems for landmarks and boundaries in spatial memory. *Proceedings of the National Academy of Sciences, 105* (15), 5915-5920.
   b. Wills, T. J., Cacucci, F., Burgess, N., & O'Keefe, J. (2010). Development of the hippocampal cognitive map in preweanling rats. *Science, 328*(5985), 1573-1576.
   c. Keinath, A. T., Julian, J. B., Epstein, R. A. & Muzzio, I. A. (2017). Environmental geometry aligns the hippocampal map during spatial reorientation. *Current Biology, 27,* 309-317.
   d. Julian, J. B., Ryan, J., Hamilton, R. H. & Epstein, R. (2016). The occipital place area is causally involved in representing environmental boundaries during navigation. *Current Biology, 26,* 1104-1109.
   e. Farooq, U. & Dragoi, G. (2019). Emergence of preconfigured and plastic time-compressed sequences in early post-natal development. *Science, 363(6423),* 168-173.
6. **Beyond modularity:** Read either the rest of the Landau & Lakusta article, or at least one of these.
   a. Pyers, J.E., Shusterman, A., Senghas, A., Spelke, E.S., & Emmorey, K. (2010). Evidence from an emerging sign language reveals that language supports spatial cognition. *Proceedings of the National Academy of Sciences, 107*(27), 12116-12120.
   b. Javadi, A.-H., et al. (2017). Hippocampal and prefrontal processing of network topology to simulate the future. *Nature Communications.* DOI: 10.1038/ncomms14652.
   c. Schuck, N. W. & Niv, Y. (2019). Sequential replay of nonspatial task states in the human hippocampus. *Science, 364,* eaaw5181.

Questions to think about and maybe write on:

1. Marr outlines a number of problems faced by any attempt to come up with a single scheme for representing object shapes, but he also presents one such scheme. What are the pros and cons of the scheme that he proposes? If children started with this scheme, how might they deal with the problem of representing the shapes of their toys and other artifact objects? The optional Smith paper is relevant to this question as well.
2. Fodor divides cognitive systems into two broad classes: "input systems" and "central systems." How do these differ and relate to each other? Now consider the literature on the "geometric module." Is this an input system? Is it modular in Fodor's various senses?
3. The hippocampus is typically viewed as a quintessentially central system--a seat of our conscious, explicit memories of our past experiences—yet it is a major player in research on the "geometric module." Does this say anything about the modularity or non-modularity of navigation systems? About the relation between central systems and modular systems?
4. Research on animals and humans suggests that navigation depends first and foremost on representations of the ground on (or over) which animals navigate, and its borders. Why might this be? How might this representation relate to Marr's 2.5D sketch?
5. Experiments reveal very similar findings in ants to Cheng's findings in rats and to findings with children (as described in Landau). Such similarities could be explained either by shared inheritance from a common ancestor or by convergent evolution in the face of common environmental or computational constraints. What evidence would favor one of these accounts over the other?
6. Marr argued that interpreting the activity of neurons requires a multi-leveled computational understanding of the task performed by the neurons whose activity is being recorded. For

today's class, I've assigned a bunch of papers in systems and cognitive neuroscience, and no computational papers on navigation. Do the neural readings contribute to our understanding of how animals and people represent and navigate their surroundings? If so, in what ways?

7. In one of the oldest works of experimental psychology, Socrates (via Plato, *Meno*) asked whether the abstract concepts of Euclidean geometry are innate, and he did a (pretty bad) experiment to address the question. Do you think this is a meaningful question? If not, say why, and what a meaningful question about the development of knowledge of geometry would be. If so, how would you answer it in light of these readings? If you think the question is meaningful but unanswered, then what further evidence is needed?