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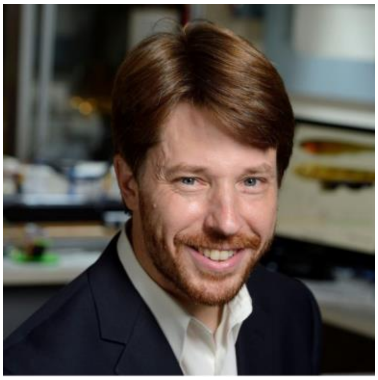

A "Cognitive Clamp" to Investigate Path Integration in the Mammalian Brain

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Path integration (aka "dead reckoning") is the neural computational process that enables an animal to estimate its location in an environment from self-motion cues (i.e., velocity and acceleration). Path integration is a state estimation process and as such requires 1) an initial estimate of position (e.g. from known landmarks), 2) sensory measurements of self-motion, and 3) a "process model" that includes a path-integration gain, namely, a multiplicative factor that relates integrated self-motion cues to movement in the physical world.

We built a virtual reality apparatus ("the Dome") to test and quantify elements of the computation of this path integration in rodents. In the dome, rats run on a circular track while visual cues are projected around them. In this talk, I will discuss two results from this VR Dome: In (Jayakumar*, Madhav*, et al., Nature, 2019), we showed that the internal gain of the path integration process is a plastic variable that can be adapted in relation to manipulations of landmarks in VR. In (Madhav*, Jayakumar* et al., In Review), we used an optic-flow based cue to control the cognitive representation, i.e. a "cognitive clamp", that turns out to be a surprisingly simple integral control law. This brain-in-the-loop closed-loop control system allowed us to make the animal "think" it was going at a speed that we so desired (i.e., the set-point of the integral feedback controller). Using this cognitive clamp, we demonstrated the strong influence of optic flow on self-motion estimation and used this to examine the complex interactions between visual and non-visual self-motion cues in forming a stable, internal representation of position.

Bio: Noah J. Cowan received a B.S. degree from the Ohio State University, Columbus, in 1995, and M.S. and Ph.D. degrees from the University of Michigan, Ann Arbor, in 1997 and 2001 – all in electrical engineering. Following his Ph.D., he was a Postdoctoral Fellow in Integrative Biology at the University of California, Berkeley for 2 years. In 2003, he joined the mechanical engineering department at Johns Hopkins University, Baltimore, MD, where he is now a Professor. Prof. Cowan's research interests include mechanics and multisensory control in animals and machines. Prof. Cowan received the NSF PECASE award in 2010, the James S. McDonnell Foundation Scholar Award in Complex Systems in 2012, and two Johns Hopkins Discovery Awards in 2015 and 2016. In addition, Prof. Cowan received the William H. Huggins Award for excellence in teaching in 2004, and the Dunn Family Award in 2014, conferred for having ". . . an extraordinarily positive impact upon the lives of one or more undergraduate students."