Program#/Poster#: 818.18/EE4

Title: Single-trial representation of uncertainty about reach goals in macaque PMd

Location: San Diego Convention Center: Halls B-H

Presentation Start/End Time: Wednesday, Nov 07, 2007, 9:00 AM -10:00 AM

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Animals are often faced with uncertainty about which actions will be the most beneficial. When presented with two possible movements the nervous system could withhold planning; however, previous studies have suggested that monkeys represent plans to both options simultaneously (Cisek & Kalaska, Neuron, 2005) or alternate plans between locations (Horwitz & Newsome, J. Neurophys., 2001). Presumably, these strategies allow for faster movements than not planning at all, though the behavioral benefit of these strategies has not been explored. Here, we recorded from ensembles of neurons to directly observe which strategy is adopted when a monkey must make fast and accurate reaches, given uncertainty about target location. We trained monkeys to perform a delayed reach task where 2 possible targets (same color) were presented during a delay period after which the correct target was identified (by a change of color). Simultaneous responses of 82-102 neurons were recorded using a multielectrode array implanted in PMd, and we used linear methods to reduce the dimensionality of the neural responses. Using the first few dimensions of the low-D projections of these responses, we examined single-trial trajectories representing the evolution of delay-period activity. These plan trajectories suggested that on some trials monkeys alternated planning to the two possible reach goals, planned reaches to only one of the targets, or formed plans not directly corresponding to any of the targets. To increase confidence that these results were due to coordinated neural activity, rather than spurious spiking noise, we computed the fraction of each trajectory's path that lay closer to the target zones than to the baseline (no plan) zone. Bootstrap analysis revealed far greater amounts of plan trajectory residing close to the single-target planning zones than expected by chance ($p<0.001$, comparison with trial-shuffled data, 3 datasets). To our knowledge this is the first evidence that in a task with 2 target options, a variety of strategies are used on different trials. Future experiments will be necessary to determine how the degree of uncertainty in a task influences which strategies are employed, ultimately allowing us to understand the dynamics of planning in ethologically-relevant contexts.

Disclosures: **Z. Rivera Alvidrez**, None; **R.S. Kalmar**, None; **A. Afshar**, None; **G. Santhanam**, None; **B.M. Yu**, None; **S.I. Ryu**, None; **K.V. Shenoy**, None.

Support: BioX, BWF, CIS, CRF, MSTP, NDSEG, NSF, ONR, SGF, Sloan, Whitaker

[Authors]. [Abstract Title]. Program No. XXX.XX. 2007 Neuroscience Meeting Planner. San Diego, CA: Society for Neuroscience, 2007. Online.