Orbitofrontal cortex as a cognitive map of task space

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Objective: Orbitofrontal cortex (OFC) has long been known to play an important role in decision making yet the exact nature of this role has remained elusive. Here we propose a new unifying theory of OFC function: that OFC encodes the state-space for reinforcement learning, and specifically, that it is critical for representing partially observable states. The state-space captures the underlying structure of the task—the states of the world, the available actions, and the links between them. The states themselves can be either *observable*, that is, signaled by external stimuli, or *partially observable*. The latter are states that are a critical part of the task's generative structure, but are not uniquely identified by external stimuli. Thus, these partially observable states must be inferred from information that is not externally available, such as the memory of previous stimuli or actions. We hypothesize that without a functional OFC, animals and humans are limited to only using observable states, with the consequential impairment of performance on tasks with more a complex state space.

Methods and Results: We use our framework to explain the role of OFC in a variety of decision making tasks and account for the behavioral deficits that occur when OFC is damaged. Specifically, we model delayed alternation, devaluation, extinction and reversal learning. In all cases, normal subjects are assumed to learn with an intact state space that makes use of relevant unobservable information such as past actions and outcomes or predictions about the future. On the other hand, OFC-lesioned subjects are assumed to use a state space that is bound to observable stimuli.

For example, in delayed alternation subjects choose between two options. To maximize reward, they must alternate their choices, that is, choose the option they did not choose on the previous trial. In our model, normal subjects use a state space that includes a memory of the previous choice, and hence learn quickly. OFC-lesioned subjects, however, do not have access to this hidden information about the past and thus never increase their performance above chance. Strikingly, this exact pattern of behavior was seen in monkey experiments in which the OFC was lesioned (Mishkin et al., 1969), but only if a delay was introduced between trials. If trials followed one another such that body position could signal the previous action (thus making the two states observable), monkeys were not impaired.

Conclusions: Our model provides a parsimonious account for the role of OFC in decision making and accounts for OFC-lesion induced deficits in a variety of tasks.

Acknowledgements: This research was funded in part by NIMH grant 1R01MH098861