Medial prefrontal cortex and the temporal control of action

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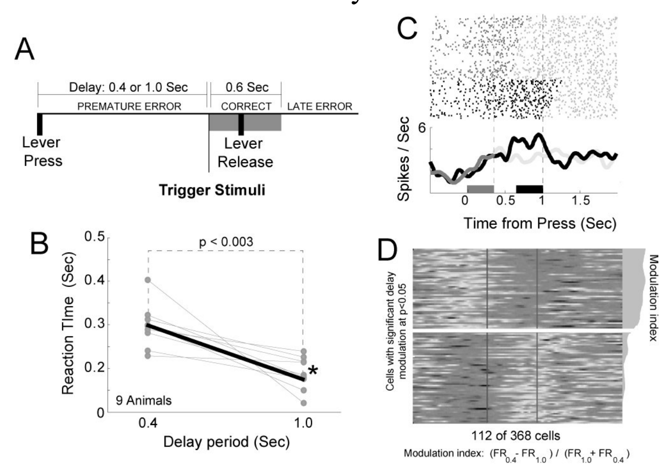
Neuroimaging studies in human beings and unit recording studies in primates suggest that medial areas of prefrontal cortex (mPFC) are involved in decision making and action selection[1,2,3]. A major aspect of mPFC function that has not been widely studied is its role in controlling the timing of action, i.e., deciding *when* to act. Our laboratory has addressed this issue in three recent studies. First, we used reversible inactivation methods to "knock out" mPFC activity during a simple delayed response task[4]. This manipulation resulted in excessive premature responding and a lack of temporal control over response initiation. Second, we combined reversible inactivations in mPFC with ensemble recordings in motor cortex during a delayed response task[5]. We found that inactivation of mPFC reduced delay activity in motor cortex. Third, we recorded in mPFC during a delayed response task[5]. We found that about one-third of neurons fired persistently during the delay period. Most recently, we tested the hypothesis that activity in mPFC is sensitive to stimulus timing. In a baseline task with a 1s delay, the firing rates of 15% of 170 neurons were modulated by the trigger stimulus. When animals learned to respond at an earlier delay (0.5 s), the percentage of stimulus-related neurons increased to 24% (of 157). After learning, one-third of 368 neurons were active during the delay period and all of these neurons fired more at either the short or long delays. At the population level, strong temporal correlations between delay-related neurons were observed early, but not late, in the delay period. These effects were not observed in the motor cortex. Our results suggest that medial prefrontal cortex is critical for the temporal control of action because it accounts for the expected timing of trigger stimuli. We interpret our results in the context of previous anatomical studies of mPFC, especially its massive descending projections to limbic, autonomic, and monoaminergic centers[6,7]. These studies suggest that mPFC might influence motivational and emotional brain systems to achieve temporal control over behavior.



Medial PFC is sensitive to stimulus timing.
A – Design of simple delayed response task. B – RTs are shorter following long delays. C – Neurons fire in anticipation of specific delay durations (red = short, blue = long). D – Delay-specific tuning: 112 of 368 cells fire maximally until the short or long delay.

References

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