Neural Coding of Reward Value in Richly Modulated Spike Patterns in Monkey Ventrolateral Prefrontal Cortex

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Abstract Monkeys with lesions of the lateral prefrontal cortex lose the ability to integrate the reward value information across multiple domains. We recorded neuronal responses from the area 9/46 of ventrolateral prefrontal cortex (vlPFC) of two monkeys while they were performing a task in which in each trial was offered a reward. The reward value, signaled through its association with a visual cue, was constructed by combining one of 3 reward sizes (2, 4 or 6 drops of water) with one of 3 discounting delays (1, 5 or 10 s after the choice). The monkeys accepted or refused the offer by releasing the bar after the appearance of the go signal. They were increasingly likely to accept offers as the reward became larger and the delay became shorter. We observed that the reward values were well described by a simple reinforcement learning model for the discounted value of the rewards. In the period soon after the visual cue was presented to the animal, 69% (117/170) of the neurons modulated their firing rate according to the reward size and/or delay. We asked whether vlPFC neurons modulated their activity according to the value that the animal assigned to each offer. The estimated discounted values from the reinforcement model from the behavior were used to correlate with the mean firing rate for each offer, for each neuron. We found that 35% (41/117) of the neurons increased or reduced their firing rate linearly in relation to the discounted value measured from the behavior. The other neurons clearly showed modulation according to both reward size and delay, very few neurons were sensitive to only one factor. Some vlPFC neurons had a strong pulse after value cue appeared, others showed a strong pause, and still others showed three phase responses (small pulse followed by a pause followed by a strong pulse). Despite these striking patterns of responses, principal component analysis showed that the value-related information was encoded in the spike count. This analysis showed, however, that the period with the strong value related coding

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A. Lintas et al. (eds.), *Advances in Cognitive Neurodynamics (VII)*, Advances in Cognitive Neurodynamics,
https://doi.org/10.1007/978-981-16-0317-4_33

was restricted to a window that began and ended during cue's presence before the imperative target (a small yellow or purple spot) appeared.