



Value Representation of Delayed and Probabilistic Rewards in the Supplementary Eye Field of Monkeys

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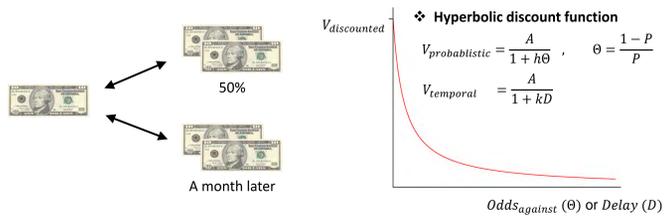
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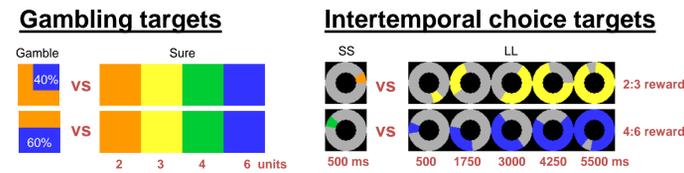
Introduction

The effects of uncertain and delayed rewards have been studied with gambling and intertemporal choice tasks in laboratory situations, and typically both humans and animals show less preference to the options with a smaller probability of winning or the ones delayed longer over time, which is known as discounting. From recent studies performed with gambling tasks, it has been shown that neurons in the supplementary eye field (SEF) encode the value of the chosen option during saccades, which indicates that SEF has a role in making decisions with probabilistic rewards. To test whether SEF plays a similar role across multiple tasks in which the subjective values of reward options are influenced by different task factors, we trained monkey subjects with both gambling and intertemporal choice tasks and recorded neural activity from SEF.

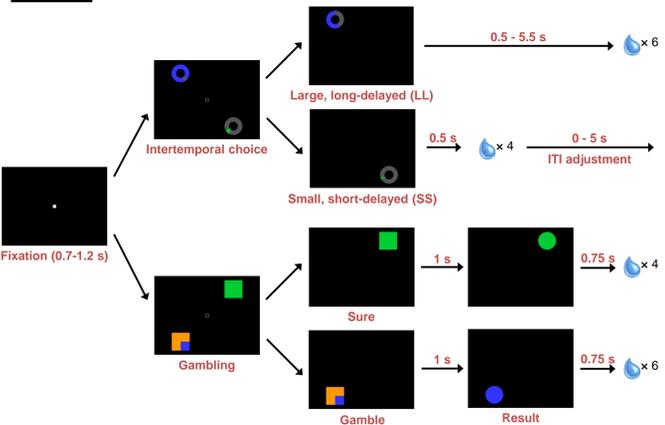


Methods

The subjects performed an intertemporal choice task and a gambling task that were repeatedly block-wise alternated in each recording session. In the intertemporal choice, the length and the color of the bar on an annulus-shaped target indicated the delivery delay and the amount of reward, respectively. The bar decreased gradually at a constant angular speed upon the target being chosen and the reward was delivered when it was extinguished. In the gambling task, a sure option consisted of only one color and a gamble option, two colors. The portion of a color within the gamble target corresponded to the probability of receiving that reward amount.

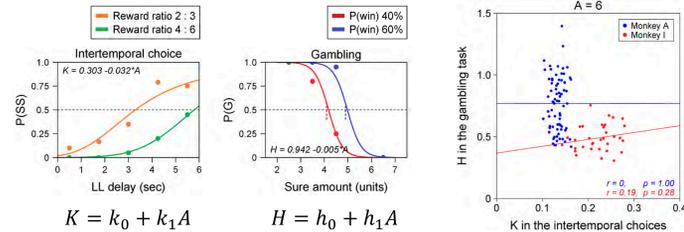


Task



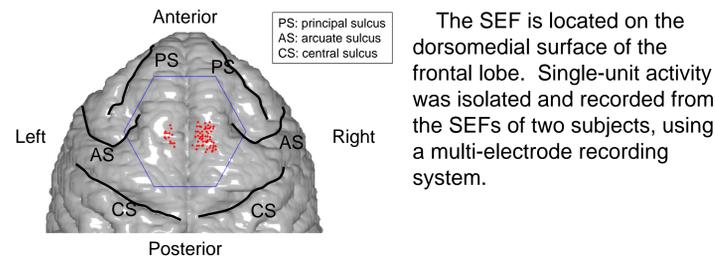
Results

Behavioral performance



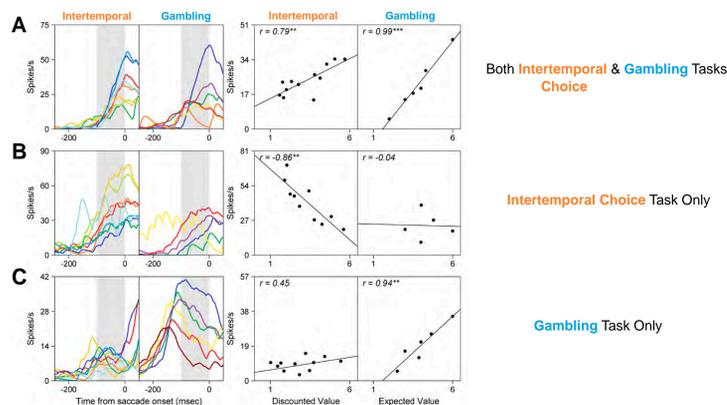
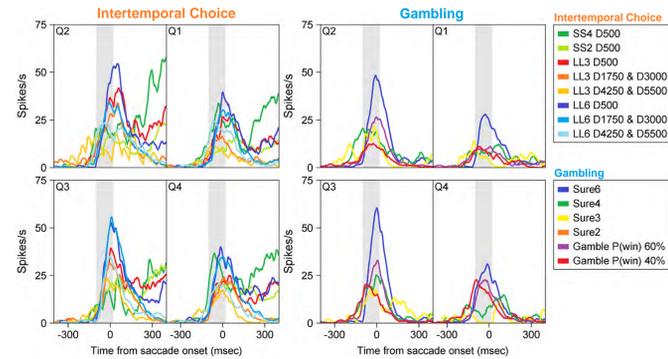
Due to the amount-dependent nature of value discounting, we modeled the discount rate parameter (K and H) as a linear function of the reward amount (A). We compared the discount rates between the tasks on a daily basis, but there was no significant correlation.

Recording of neural activity

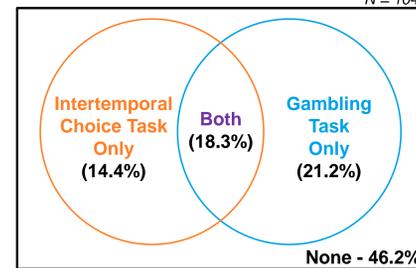


The SEF is located on the dorsomedial surface of the frontal lobe. Single-unit activity was isolated and recorded from the SEFs of two subjects, using a multi-electrode recording system.

Neurons that encode action value during saccade preparation



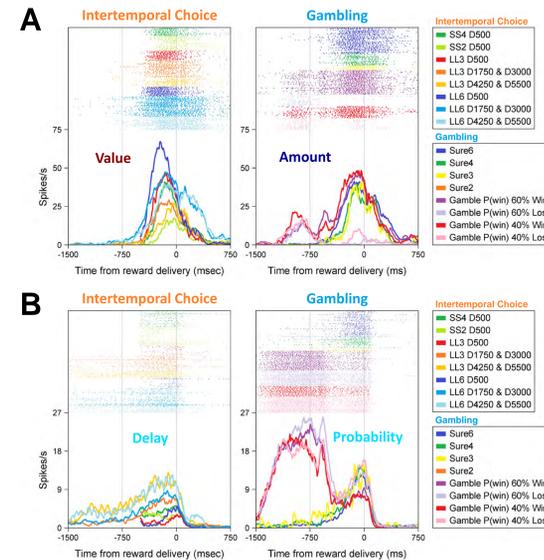
Action value encoding in SEF



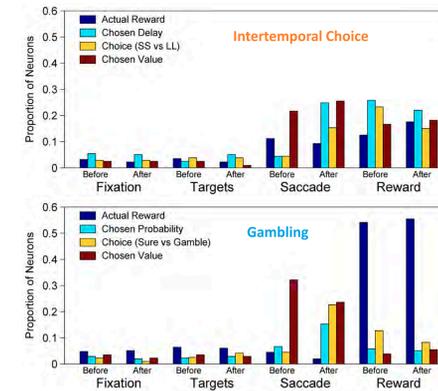
Out of 314 neurons, 104 neurons exhibited directionally tuned saccadic activity.

The action value signals are carried by overlapping but different subgroups of SEF neurons during each task.

Neurons that encode different variables between the tasks during the waiting period

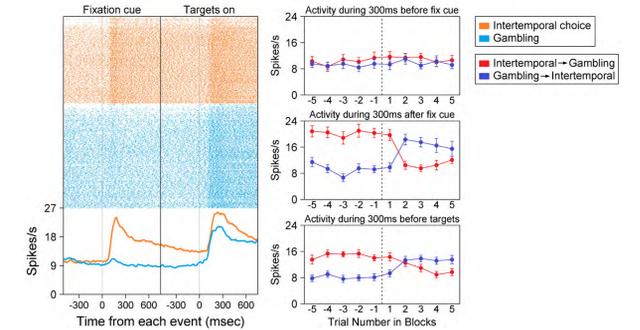


Effects of task variables

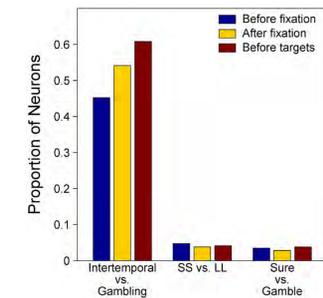


Around the time of reward delivery, the actual amount of rewards is dominantly represented by SEF neurons during the gambling, whereas chosen delays and chosen values still have strong effects during the intertemporal choices. This indicates that SEF neurons switch the variables that they are monitoring, depending on the task that the subject is currently performing.

Task-dependent activity during the fixation period



Context-related signals in SEF



The majority of the SEF neurons responded differently between the tasks during the fixation period, although an identical fixation cue was presented in both tasks. It seems that the task-dependent aspects of SEF activity are modulated by this context signal.

Conclusions

- The action values of the saccades are represented in SEF during both probabilistic and intertemporal decision making, but with different mappings.
- SEF itself does not appear to be involved in the value computation.
- During the reward wait period, SEF neurons contextually encode task-relevant variables necessary for evaluating reward outcomes.
- Task-dependent action value mapping and reward monitoring seem to be controlled by a context signal which is also carried by SEF neurons.

References

Green L, Myerson J (2004) A discounting framework for choice with delayed and probabilistic rewards. Psychol Bull 130:769-792.
So N, Stuphorn V (2010) Supplementary eye field encodes option and action value for saccades with variable reward. J Neurophysiol 104:2634-2653.
So N, Stuphorn V (2012) Supplementary eye field encodes reward prediction error. J Neurosci 32:2950-2963.

Acknowledgement

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