Movement selection and initiation in the rat superior colliculus

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We are interested in how the nervous system uses sensory stimuli to select and initiate appropriate motor actions. To this end, we have been studying how rats use olfactory cues to guide choices about, and to initiate, directional movements. We hypothesized that the superior colliculus (SC) could play an important role in these processes, since it is known to produce directional orienting movements, via descending projections to several motor nuclei. In rats, it is not known how activity in the SC underlies movement initiation, and whether the SC is also involved in selecting among potential movements.

In order to address these questions, we used tetrodes to record from intermediate and deep layer SC neurons in well-trained rats performing a two-alternative choice olfactory discrimination task. In each trial of the task, the rat first entered a centrally located odor port, triggering the delivery of an odor, and then moved to either the left or right reward port to obtain a water reward. The odor was either a pure compound or a mixture of two compounds. One pure odor was rewarded following a left choice and the other following a right choice, and mixtures were rewarded according to their dominant component.

We analyzed the activity during the pre-movement epoch, defined as the 100 ms preceding the exit from the odor port. The activity of many neurons during this epoch depended on whether the upcoming movement was leftward or rightward, independent of whether the choice was correct or incorrect. Across the population, higher firing rates preceded movement contralateral to the recording site (i.e., left SC neurons preferred rightward movement). In some cells, this direction selectivity disappeared at the onset of movement, while in other cells it persisted during the movement.

These data suggest that prospective direction selectivity in the SC is involved in the initiation of directionally orienting movements. In order to determine whether the observed selectivity causes, or is simply correlated with, movement initiation, we used the GABA_A agonist muscimol to unilaterally inactivate the SC in rats performing the behavioral task. If SC output is necessary for initiating contralateral movements, we would expect inactivation to bias the rat towards ipsilateral movements. Indeed, we found that muscimol, but not saline, delivered to the left SC biased the rat towards leftward choices, and this bias was dosage-dependent. Thus, normal SC activity is necessary for initiating appropriate directional movements.

We next asked whether the SC is also involved in the selection of movements, in addition to their initiation. We reasoned that if the SC is only involved in initiating movements, its activity on trials in which the same direction was selected should be independent of the stimulus presented. We found that this is not the case: The strength of predictive left/right selectivity of several neurons exhibited a clear dependence on the mixture ratio of the odor stimulus.

Together, these results suggest that, in rats, the SC is necessary for the initiation of appropriate orienting movements and may be involved in their selection as well. Future studies will attempt to determine how the SC interacts with other brain regions to make and act upon decisions based on sensory stimuli.

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