Study unveils a neural mechanism involved in terminating decisions

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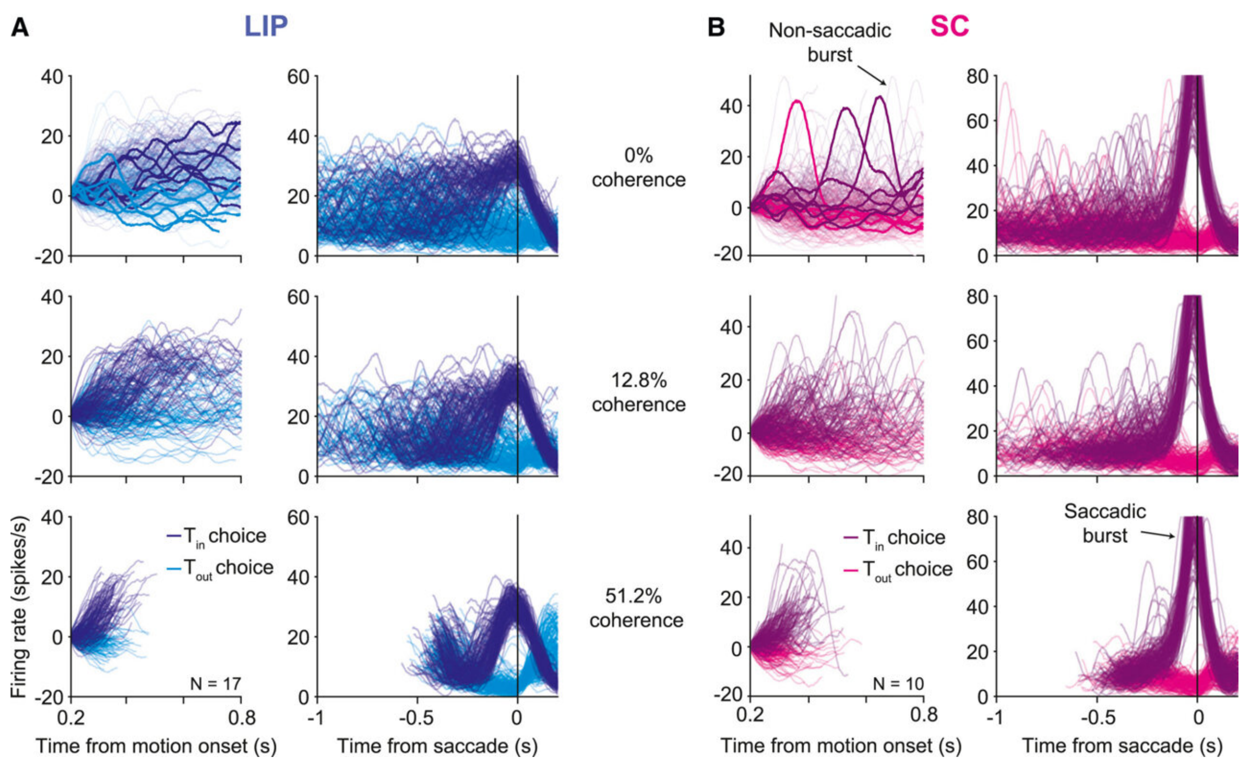

Single-trial dynamics in LIP and SC are different. (Neuron, 2023).

During decision-making, the human brain essentially accumulates useful information and weighs options until it has enough evidence to choose. Past studies showed that choice-relevant evidence is accumulated in specific parts of the brain's outer layer, known as the cortex, yet the neural mechanisms underlying the final 'selection' of a decision remain poorly understood.

Researchers at Columbia University carried out a study aimed at better understanding these neural mechanisms. Their paper, published in *Neuron*, highlights the role of the superior colliculus (SC), a structure in the midbrain, in terminating decisions.

"This work is the culmination of decades of research on the neurobiology of decision making," Michael N. Shadlen, one of the researchers who carried out the study, told Medical Xpress.

"The phrase is a little deceptive, because the focus is not on making good vs. bad decisions but on how the brain gives rise to a thought, or at least that's how I think about it. Decision making carves thought—or cognition—at its joints because it involves contingency, indeterminacy, and flexibility in the use of information and the use of time. I refer to the latter as freedom from immediacy, and that is the relevant concept for the study at hand."

Studies consistently showed that while they are trying to decide something, both humans and nonhuman primates ponder on it for some time, considering available evidence sequentially until they are ready to choose.

Shadlen's work specifically focuses on perceptual decision making, or in other words decisions that are guided by sensory information. These can include, for example, deciding what to do if an obstacle suddenly appears while driving in adverse weather conditions.

During this type of decision making, the brain is known to accumulate sensory evidence relevant to the choice one is trying to make. Once this accumulated, evidence passes a threshold level (i.e., when the brain gathered enough information to choose a specific course of action), the accumulation stops and the brain 'commits' to a given choice.

"We have known for a while that in the tasks we study, the accumulation of noisy information is represented by neurons in the lateral intraparietal cortex (area LIP) in the parietal lobe—, a part of the brain responsible for knowing," Shadlen explained.

"When the strength of the neural signal in LIP reaches a threshold level, the decision ends about a tenth of a second later. Up to now, we did not know how that threshold was implemented to terminate the decision."

The overall objective of the study by Shadlen and his colleagues was to characterize the broad set of interconnected brain areas that interact with LIP during decision making. The researchers first started looking at the SC, one of the key areas onto which the LIP directly projects information.

To do this, they conducted a series of experiments during which two monkeys completed a simple perceptual decision-making task. During this experiment, the monkeys decided the direction in which they thought a small patch of dots on the screen would move in by moving their eyes in their chosen direction.

"Our strategy was to record simultaneously from neurons in both areas that represent the same choice-target, that is, the target the monkey would look at to tell us that the direction of motion is leftward," Shadlen said. "This effort was rendered practical by the recent development of Macaque neuropixels probes, a new technology that allows us record from over 100 neurons in both areas, all but guaranteeing we would have populations in both areas that represent the same answer."

The recording technology used by the researchers allowed them to measure the neural signal that accompanied an individual decision. This means that they did not need to calculate single signals by averaging the signals observed during repetitions of decisions, as other techniques would have required them to do.

"Averaging removes the variability in the signals—what gives rise to the variability in the choice and the time taken to make the choice," Shadlen said. "By recording from many neurons at once we could see the variable signals in LIP that give rise to each choice and the discovery of burst-like activity in SC. Those bursts occur at random times, so averaging, in a word, averages them away."

Interestingly, Shadlen and his colleagues observed bursts of activity in the monkeys' SC, which were associated with features of the signal they recorded in the LIP during the accumulation of decision-relevant information.

Based on these observations, they hypothesized that the SC is ultimately responsible for 'terminating' decisions once collected evidence passes the threshold point. In their paper, they suggest that this brain area also has a 'threshold' of sorts, which once passed ignites the final burst of activity, prompting the monkey to communicate its final decision by moving its eyes in the chosen direction.

"Our simultaneous recordings suggested that the SC implements the threshold that terminates the decision," Gabriel Stine, another researcher who carried out the study, explained. "If so, we reasoned that inactivating SC while the monkeys made their decisions would impair this threshold mechanism. Remarkably, this is exactly what we found: with SC inactivated, the monkeys became more deliberative."

Essentially, the researchers observed that when their SC was inactivated, monkeys took longer to reach a decision during the perceptual decision-making task. Their brain appeared to accumulate more choice-related evidence than it would have under normal circumstances (i.e., if the SC remained active).

"We don't know how the nodes in a macro-circuit (a circuit comprising several brain regions) interact," Shadlen said.

"A popular idea is that they distribute the computation, and that view had support from experiments that looked only at averages across repetitions. We provide a clear example of distinct operations."

"In addition, the signal in LIP is the elusive drift-diffusion signal long believed to explain the variation in choice and response times as well as the trade-off between speed and accuracy of decisions. This seemed controversial a few years ago, but it is presumably settled now."

The recent findings gathered by this team of researchers emphasize the key role of the SC in terminating perceptual decision-making processes. Specifically, their observations suggest that the accumulation of "noisy" (i.e., randomly fluctuating) sensory information in the LIP does not depend on the SC. In contrast, the SC appears to be responsible for terminating this accumulation process.

"We would like to know if the SC plays a role in terminating decisions that terminate surreptitiously (i.e., silently or secretly) without an action, and are testing this now as part of our next studies," Shadlen added. "In addition, we soon plan to record simultaneously from more nodes in the macro-circuit."

More information: Gabriel M. Stine et al, A neural mechanism for terminating decisions, *Neuron* (2023). DOI: 10.1016/j.neuron.2023.05.028