Brain structure helps guide behavior by anticipating changing demands

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(Medical Xpress) -- Every day the human brain is presented with tasks ranging from the trivial to the complex. How much mental effort and attention are devoted to each task is usually determined in a split second and without conscious awareness. Now a study from Massachusetts General Hospital (MGH) researchers finds that a structure deep within the brain, believed to play an important role in regulating conscious control of goal-directed behavior, helps to optimize behavioral responses by predicting how difficult upcoming tasks will be. The report is receiving advance online publication in *Nature*.

"The dorsal anterior cingulate cortex (dACC), which lies deep beneath the outer layer of the frontal lobes, is part of an ancient and enigmatic part of the brain," says Emad Eskandar, MD, of the MGH Department of Neurosurgery, senior author of the *Nature* paper. "Some have speculated that it plays a role in detecting errors or monitoring for conflicting demands, but exactly how it contributes to regulating behavioral responses is unclear, so we used a variety of scientific techniques to get a better picture of its function."

The study enrolled six participants who were scheduled to undergo cingulotomy – a procedure in which a small, precisely placed lesion is created within the ACC – to treat severe obsessive compulsive disorder (OCD) that has not responded to other types of treatment. A standard part of the cingulotomy procedure involves microelectrode recordings of the activity of single neurons in the area where the lesion is to be placed. To evaluate dACC function, the investigators recorded brain activity

from several neurons within the structure while participants performed a behavioral task testing their reactions to visual images.

The task presented participants with a random series of images of three numerals, which could be 0, 1, 2, or 3. In each image, two of the numerals were identical. Participants responded by pressing one of three buttons, the position of which would indicate the identity of the number that was different, with the left button indicating 1, the middle 2 and the right button 3. Each image was ranked in difficulty depending on how much the position of the target numeral or the identity of the duplicate numerals might distract participants from the correct response. For example, when presented with 3-3-2, the correct response would be to press the middle button for number 2; and that image would be ranked more difficult than 3-2-3, in which both the target number and the correct button were in the same position.

Functional magnetic resonance imaging (fMRI) of four participants performing the behavioral task prior to the cingulotomy procedure revealed that the task increased metabolic activity within the dACC, a result seen in previous fMRI studies. The fMRI images also revealed that responding to more difficult images produced greater activity levels within the dACC and in other structures known to be involved in decision making. Intraoperative microelectrode recordings of all participants demonstrated that this apparent increase in metabolic activity corresponded with an increase in neuronal activity, linking for the first time the increased activation revealed by fMRI with increased neuronal firing.

Analysis of individual neuron activity indicated that dACC neuronal activity remained elevated immediately after difficult trials. Moreover, participant reaction time revealed that the difficulty of the prior trial had an impact on the next trial: if the preceding trial was of the same level of difficulty, reaction time was shorter; if the two tests were of different

difficulty levels – even if the second test was easier – reaction time was longer. By anticipating the difficulty of upcoming tasks, the authors note, it appears that the dACC speeds up responses when difficulty levels are constant but slows response time down when faced with changing demands in order to promote accuracy.

While behavioral tests conducted after the cingulotomy procedure – which destroys tissue within the dACC – did not indicate a change in participants' ability to perform the test accurately, the impact of preceding trials on reaction time appeared to vanish. "Participants could still perform the task, but the dACC's role of priming the system based on immediate prior experience was gone," Eskandar explains. "We believe this result indicates an important role for the dACC in rapidly adjusting to different cognitive demands, possibly by recruiting other areas of the brain to solve particular problems."

An associate professor of Surgery at Harvard Medical School, Eskandar adds that, while significant cognitive changes have not been reported in patients undergoing cingulotomy, the apparent role of the dACC in adapting to changing situations implies a possible role for the structure in several psychiataric disorders. "A lack of behavior flexibility and adjustment is characteristic of OCD, for example. Whether or not our findings directly relate to these disorders remains to be determined, but we hope that continued study using complex tasks, such as the behavioral test used here, will be helpful in diagnosing or monitoring psychiatric disorders."

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