Neural substrates of choking under pressure-A 7T-fMRI study

Ogasawara, Kanae

The Graduate University for Advanced Studies, SOKENDAI
School of Life Science
Department of Physiological Sciences

Introduction

Performance decrement under excessive psychological pressure is known as "choking under pressure", or simply "choking", which mechanism is little known, nor is its neural underpinning. Choking is known to increase the probability of failure by changing the behavioral pattern. Regardless of psychological pressure, changes in behavioral patterns are typically associated with changes in the internal model for motor control. In general, the success or failure of motor behavior is tied to the alteration of the internal model for fine motor control, even if a participant is an expert. The internal model is utilized in movement planning in motor preparation and control in motor execution. In addition, a previous study on choking showed that the effects of pressure differ in brain activity even during the motor preparation and execution phase. Taken together, I hypothesized that choking would be caused by the alteration of the internal model due to excessive psychological pressure even before the execution.

To test this hypothesis, I put excessive pressure on participants through the Jackpot, a low-frequency, high-reward condition, that was shown to induce choking in a previous study. To compensate for the limited statistical power due to the low frequency of the Jackpot, I used a 7T-fMRI that has a high signal-to-noise ratio. To test whether altered activation associated with failure in Jackpot is in the internal model, I tested the overlap between the internal model region and activation. The internal model region was defined by reduced/enhanced brain activity as learning progresses during the practice session. To test when the alteration of the internal model in Jackpot described above occurs, I separately analyzed two phases: the motor preparation phase and execution phase. The occurrence of choking during Jackpot was assessed by the decreased performance and physiological measures of arousal that reflect the psychological pressure: pupil diameter and grip force.

Materials and methods

Twenty-three volunteers underwent a visual reaching task. Participants used the differences in grip force between both hands to precisely control the movements of the target cursor. The experiment was divided into two sessions: a practice session and a main session, which have identical structures except for the presence/absence of the reward notification. Participants underwent a practice session followed by the main session, both of which were subject to fMRI measurements. Each trial consisted of four phases: motor preparation (2,000 ms), motor execution (5,500 ms), feedback (1,500 ms), and inter-trial resting phase (1,000 ms). At the start of the motor preparation phase of the task trial during the main session, participants were informed in advance of the reward to receive upon success. I prepared four conditions with different rewards: None (0 points), Small (2 points), Large (4 points), and Jackpot (60 points). To provide high psychological pressure, the reward under the Jackpot condition was fifteen times higher than the Large condition, and the appearance probability of a Jackpot was lower (0.05) compared to the other three conditions (0.36 for each). The only difference between conditions was the number of points obtained for success and appearance probability, and the task difficulty was identical in all conditions. Participants were instructed they could get an additional honorarium if they get many reward points in this experiment. The motor execution phase was divided into two periods: the force production period, and the visual reaching task period. In the initial force production period, a red circle appeared in the center of the screen. Participants exerted the same grip force with both hands to hold the cursor in the circle in the center of the screen. The visual reaching task period follows the force production period. The center circle disappeared, and the target rectangle appeared to the right or left of the screen. The appearance of the target rectangle was a go cue, and participants had to immediately move the cursor to the target rectangle within 1,500 ms, by differentiating the grip force between the left and right hand. One trial, including the resting phase, lasts 10 seconds. The one run includes 40 trials. Participants repeated the run six times in the practice session and the main session.

In behavioral data analysis, in the practice session, the task performance was defined as the percentage of successful trials for each run. On the other hand, in the main session, the task performance was calculated for each condition. In the main session, I analyzed the grip force during the force production period to test whether the grip force is influenced by the excessive arousal in the Jackpot condition. In addition, I calculated the average pupil diameter in the motor preparation and execution phase of each condition. In fMRI data analysis, the data from the practice session was used to define the internal model region by the decline of task-related activation. To depict the regions specific to failure in Jackpot, I applied the full factorial model with two factors: Conditions (None, Small, Large, Jackpot) and Performance (Success, Failure) in both the motor preparation and execution phase. Firstly, I searched for activation specific to failure in Jackpot by whole-brain analysis. To depict the neural basis of failure in the Jackpot, i.e. choking, I took conjunction of contrast, which shows regions of activity in failure compared to success regardless of condition, and contrast, which shows Jackpot-specific regions within failure. Second, I tested the hypothesis that choking is caused by the alteration of the internal model, by using the regions including the internal model depicted by the decline in the task-related activation during the practice session as the explicit inclusive mask.

Results

First, to confirm that learning had progressed during the practice session, the success rate was calculated for each run to see if task performance could be improved. Task performance in the practice session was shown to improve until the third run. In the main session, the success rate in Jackpot was significantly lower than in the other conditions. The grip force and pupil diameter in the Jackpot were larger than in other conditions. These results indicated that choking specifically occurred at the Jackpot.

Next, using fMRI data from the practice session, I defined the brain areas associated with the internal model in the motor execution phase. These areas were defined as internal model regions and used in the following analysis for the main session. In the main session, during the motor preparation phase of the Jackpot condition, activation in the cerebellar hemisphere, cerebellar vermis, and middle temporal visual area (hMT+) were related to the following failure. Furthermore, the cluster on the cerebellar hemisphere overlapped with internal model regions defined by the practice session. During the motor execution phase, there were regions specifically associated with a failure in Jackpot: the Brodmann area 47 (BA47) and caudate nucleus, while they did not overlap with the internal model regions.

Discussion

The behavioral results indicate that the experimental setting successfully induced choking. The results of fMRI data during the motor preparation phase suggest that the overactivation in the cerebellum preceding the failure during the Jackpot condition represents the un-optimized internal models. Several lines of previous studies reported that the cerebellum plays a key role as an internal model, that preloading an inappropriate internal model before the task leads to task failure in motor control. Given these lines of evidence, I conclude that the inappropriate modulation of the internal model in the cerebellum during the motor preparation phase may lead to the following failure in motor control. The hMT+ also showed excessive activation in the failure in Jackpot. Sensory attenuation would occur on hMT+ when I predict the outcome of my behavior even before the actual movement. Previous studies suggest that the failure of sensory attenuation cause the modification of the internal model, suggesting that the lack of attenuation is a potential cause of dysfunction of the internal model. There are some possible interpretations of the caudate nucleus and BA47 depicted as regions specifically associated with a failure in Jackpot during the motor execution phase: outcome valuation, feedback control during motor execution, and modification for the next trial. I should note that these regions are not included in the internal model regions. This suggests that changes in brain activity that lead to choking might also occur outside of the internal model. To depict the entire neural bases of choking, future research is warranted. Taken together, choking might be related to the alteration of the internal model by the psychological pressure even before the motor execution, resulting in unsatisfactory motor control.