Modulation of decision-making behavior by deep brain focused ultrasound stimulation in nonhuman primates

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Noninvasive Focused Ultrasound Stimulation (FUS) has emerged as new approach for modulating brain function and behavior. Cognitive effects of FUS neuromodulation have been little explored in primates. In the current study, we applied FUS to dorsal striatum (putamen) in a series of sessions using a single element transducer and neuronavigation system during the performance of a decision making task, and evaluated the effect on decision accuracy and reaction time (RT). Two Rhesus monkeys were trained to respond using a touchpanel. A visual cue was presented on one side of the display and the monkey must reach out and touch the cue to initiate a trial. The cue was either a vertical or horizontal bar, which determined the reward size (5 or 1 drop) for the trial. After touching the cue, two patches of visual motion appeared simultaneously, one with random motion and a second with some degree of coherent motion; the monkey was rewarded for touching the coherent motion patch. The strength of motion modulated the difficulty of the decision. Data collection was done in 2 conditions, sessions without (n=31) and with sonication (n=88). Sonication was applied to one hemisphere while monkeys performed the task A pair of function generators applied 10 ms duration pulses of a 500 kHz sine wave with a duty cycle of 2 Hz for 120 s after 200 trials. The FUS pressure was 200 or 400 kPa. The analysis estimated the accuracy threshold between conditions using a generalized linear model (glm) to determine the dependency of accuracy and reaction time to side of stimulus presentation, motion strength, hemisphere sonicated, reward size, and magnitude of sonication (0, 200, 400 kPa). The accuracy threshold for all sonication levels was close to 0.4 $\pm$0.0263, showing that the FUS had a non-significant effect in accuracy; whereas the glm showed that the strength of motion, side of presentation, and reward size were significant predictors ($P<0.05$). In contrast, RT was reduced depending on the intensity of the stimulation ($P<0.05$) in both subjects. The effect was contralateral to the hemisphere that was stimulated. In conclusion, we present a clear modulation of behavior in realtime by FUS stimulation to dorsal striatum during a decision making task.

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Key words: