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ATTENTION

Integrative Model of Dorsal Anterior Cingulate Cortex Supported by Reward-Based Decision-Making Task and Event-Related FMRI

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Anterior cingulate cortex (ACC) encompasses multiple subdivisions that subserve attentional, cognitive and emotional processing, but no single unifying model explains diverse results from neuroimaging and electrophysiological studies. Reviews of neuroimaging studies have shown that dorsal ACC (dACC) is vitally important to cognitive processing—but the mechanism(s) by which this region works have not been elucidated.

In a single unit recording study of the homologous area in monkeys, Shima & Tanji (1998) reported that different populations of cells responded to target detection, motor response, reward, and reward reduction during a reward-based decision-making task. Critically, the proportion of each cell type varied, with more than five times as many cells showing selective responsivity to movement selection based on reduced reward (37%) versus constant reward (7%).

The present event-related functional magnetic resonance imaging (fMRI) study in humans exploited these differential proportions to identify responses by different cell types intermixed within this region. Specifically, we predicted that during a reward-based motor decision task modeled after the Shima & Tanji task, fMRI signal within the dACC would be significantly higher following reduced reward feedback trials as compared to fixation baseline, constant reward trials and a non-specific switch command.

Methods

Seven healthy young adult volunteers (4M/3F) performed a reward-based motor decision (button-press) task while undergoing event-related fMRI per Dale et al. (2000) (Siemens 3T Allegra scanner, 8 scans, 7:30 duration each, TR=1500 ms, 300 images/slice, 16 coronal slices, 4 mm thick/skip 0). Subjects performed a total of 960 trials (80% constant reward, 10% reduced reward, 10% switch command) with 98% accuracy for all trial types. Subjects were told that the amount they would be paid would vary between $60 and $100, based on their performance (although at the end all were paid $100).

Results

In six of seven subjects, significant ($p < 10\text{-}4$) activation was observed in dACC (dorsal bank of cingulate sulcus between $y = 0$ and 16 mm) when contrasting reduced reward trials to fixation. In these individuals, activity was uniformly highest for reduced reward trials. As a group, reduced reward trials yielded greater activation than constant reward trials ($p = .0001$) and switch trials ($p<.01$).

Conclusions

The data support an integrative model of dorsal anterior cingulate cortex in which dACC is comprised of multiple cell types intermixed within the same region. Extrapolating from the current study and electophysiology work in monkeys and humans, it appears that in humans the dACC helps to direct attention and guide behavior by integrating information from cells that preferentially respond to motivation, target appearance, motor preparation, motor response, reward and reward reduction and error detection. Moreover, it is likely that such a pattern (i.e., local networks of intermixed cell types) is repeated in other areas subserving attentional, cognitive and emotional processing (e.g., lateral prefrontal cortex) so that these findings should be of general interest to those studying attention, cognition, emotion, reward, motivation, and motor control.

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