Rapid amygdala responses during trace fear conditioning without awareness.

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Understanding the nature of human consciousness is one of the fundamental goals of psychological research. Recent studies of consciousness and learning suggest that learning the relationship between two temporally separated events requires the individual to hold one event in working memory, and that this maintenance requires conscious awareness. In trace fear conditioning a neutral stimulus (CS) predicts the occurrence of an aversive outcome (UCS) after a brief stimulus free period (trace interval). This type of learning requires the amygdala. Given that this structure is also sensitive to face stimuli, we hypothesized that amygdala activity may be capable of maintaining a representation of a face CS during a brief trace interval.

Subjects underwent 60 trials of differential trace conditioning, while we recorded their brain activity using magnetoencephalography (MEG). We used faces as CSs and (backward) masked them so that subjects were unable to identify the faces on any given trial. One face was paired with a shock (CS+), while one face was presented alone (CS-). We asked subjects to continuously report whether or not they expected to get a shock, and subjects showed similar patterns of expectancy across the trials for the CS+ and CS-, during the 900 ms trace interval. One group of subjects saw broad spectrum face CSs, while another group saw highpass filtered faces, which have been shown not to drive amygdala activity. The goal of this experiment was to show that the amygdala is capable of maintaining a representation of a face CS during a brief trace interval.

We used source imaging to model the MEG signal. First, we collected structural MRI scans for each individual and generated 3d surface models of each individual's cortex, amygdala, and hippocampus. We then modeled the MEG signal by uniformly distributing current dipoles across the surfaces of these 3d models. Finally, we sampled the timecourse of amygdala activity during the 900ms trace interval and averaged the signal across subjects.

Subjects were unaware of the experimental contingencies during training. Even so, during the trace interval, those shown the broad spectrum faces had larger responses and bursts of gamma activity in the amygdala than those shown the filtered faces. These results suggest that the amygdala may be capable of maintaining a representation of a face CS during a brief trace interval, which may be sufficient to support trace conditioning in the absence of awareness. These results also suggest that source imaging can be used to localize MEG signals that originate from within subcortical structures.

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