

Overlapping neural systems mediating extinction, reversal and regulation of fear

Daniela Schiller^{1,2}, Ifat Levy¹, Mauricio Delgado³, Annemieke Apergis-Schoute¹, Joseph E LeDoux¹ and Elizabeth A Phelps^{1,2}

¹Center for Neural Science, ²Psychology, New York University, New York, NY, ³Rutgers University, Newark, NJ

Fear learning, as established in the last few decades, is one of the most rapid and persistent emotional learning processes. These characteristics are evolutionary beneficial in preventing the need to relearn about danger, as well as in promoting ways to escape and avoid threats. However, when circumstances change, it is also advantageous to flexibly readjust behavior, and a failure to do so might be the cause of anxiety disorders.

We investigated 3 ways to modify fear learning: 1) Extinction - a process by which learned fear responses are no longer expressed after repeated exposure to the conditioned stimuli with no aversive consequences; 2) Reversal - fear responses are switched between two stimuli following a reversal of reinforcement contingencies; 3) Regulation - fear responses are diminished using a cognitive strategy of re-evaluation of the conditioned stimuli.

In these studies, our measure of fear was Galvanic Skin Response, and we used whole brain fMRI to examine the underlying neural activation. During fear acquisition, subjects were presented with two stimuli. The conditioned stimulus (CS+) co-terminated with an aversive outcome (wrist shock) in a partial reinforcement schedule, while the other stimulus was never paired with the shock (CS-). These reinforcement contingencies were then extinguished, reversed or regulated.

Fear acquisition was consistent across studies engaging the same brain regions showing greater activation to the CS+ than CS-, and this difference was then diminished or reversed following our fear modification manipulations. This fear acquisition system included the amygdala, striatum, thalamus, insula, superior frontal gyrus and midbrain. Interestingly, another system showed mirror activation, with greater decreased (below baseline) responses to CS+ than CS-, and again this difference was diminished or reversed. This mirror system included the vmPFC, dlPFC, anterior and posterior cingulate, and parietal cortex.

These two systems showed striking overlapping activation in the 3 tasks. However, some interesting differences emerged. For example, the change in vmPFC activation was greater during reversal than during extinction and regulation suggesting more resources were required for a switch in response as opposed to mere reduction. In addition, the more cognitive process of regulation elicited stronger dlPFC activation compared to reversal and extinction.

These results point to a two-system interaction in the control of fear. A system learning responses to external stimuli that are predictive of aversive consequences, while another system readjusts these learned responses when environmental circumstances change.

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