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ScienceDirect
Clinical Psychology Review 28 (2008) 307–337
CLINICAL PSYCHOLOGY REVIEW

Selective attention to threat *versus* reward: Meta-analysis and neural-network modeling of the dot-probe task

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Received 16 February 2007; received in revised form 16 May 2007; accepted 18 May 2007

Abstract

Two decades of research conducted to date has examined selective visual attention to threat and reward stimuli as a function of individual differences in anxiety using the dot-probe task. The present study tests a connectionist neural-network model of meta-analytic and key individual-study results derived from this literature. Attentional bias for threatening and reward-related stimuli is accounted for by connectionist model implementation of the following clinical psychology and affective neuroscience principles: 1) affective learning and temperament, 2) state and trait anxiety, 3) intensity appraisal, 4) affective chronometry, 5) attentional control, and 6) selective attention training. Theoretical implications for the study of mood and anxiety disorders are discussed.

Keywords: Dot-probe task; Selective attention; Threat; Reward; Anxiety; Depression; Connectionism; Neural network; Amygdala

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doi:10.1016/j.cpr.2007.05.006

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1. Introduction

Theoretical constructs and research methodologies derived from cognitive psychology figure prominently in current emotion research, including investigations into the nature and function of anxiety. For example, cognitive researchers have been studying how individuals visually attend to threatening stimuli, and how between-subject variability in the functioning of attentional systems may correlate with individual differences in anxiety-related traits and disorders (*e.g.*, Williams, Watts, MacLeod, & Matthews, 1997).

Evolutionary models of emotion and attention hypothesize that nature may have programmed the visual-attention system to attend selectively to stimuli of biological significance, including both to cues of possible impending threat (*e.g.*, predators), on the one hand, and to cues of potential reinforcement-reward value (*e.g.*, food, mates), on the other (*e.g.*, LeDoux, 1996; Panksepp, 1998; Rolls, 1999). Attentional mechanisms procuring the rapid detection of sources of potential environmental threat are therefore presumed to afford an obvious survival-facilitating mechanism (A. Mathews & Mackintosh, 1998; Mathews, Mackintosh, & Fulcher, 1997; Mogg & Bradley, 1998). However, an equally integral attentional function to the biological fitness of organisms is to orient toward stimuli of potential reward value in their environments (Panksepp, 1998; Rolls, 1999).

It may be that reward and threat detections are performed by distinct attentional systems.[1] Specifically, threat-detection attentional mechanisms may represent secondary *interrupt* programs that continuously perform a background analysis of stimuli regarding their likelihood of representing a source of danger, attaining foreground and conscious significance only to the extent that this analysis results in the detection of relatively significant sources of danger (*e.g.*, LeDoux, 1996). Otherwise, the default and primary orientation of attention may be toward reward-relevant stimuli. Thus threat detection would seem adaptive when operative in the presence of stimuli signifying veritable danger, but maladaptive when consistently interfering with reward-directed behavioral engagement (*e.g.*, such as when reliably 'misfiring', coding objectively non-threatening stimuli as sources of threat; *e.g.*, A. Mathews & MacLeod, 2005; Williams et al., 1997). Distinguishing between reward and threat detection in this way also shows how the deficient allocation of attentional resources toward positive-reward stimuli, independent of anxious or fear-related interference, may represent a distinct form of abnormal emotional information processing, perhaps uniquely underlying

[1] Specifically, threat detection processing is conceived of as coding stimuli along a single dimension varying from "No Threat" to "High Threat", while reward detection systems perform a separate analysis for "Non-reward" versus "Reward". An alternative conceptualization would be that both threat and reward detection represents a coding along a bipolar dimension ranging from, for example, "Avoid" to "Approach". One way to disambiguate the explanatory power of these differing conceptualizations is how each would compute instances of 'mixed emotion'. For example, consider a socially phobic individual's attempt to obtain the affectionate and/or sexual interest of another person. He or she is simultaneously motivated and interested in pursuing the other individual's interest, but fearful of rejection and embarrassment/shame, thus experiencing a 'mixed emotion'. Whereas this state is easily codified in the dual attentional-mechanism scheme (*i.e.*, both reward and threat attentional systems score high), it is impossible to capture along the bipolar coding scheme.