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Attentional control theory: Anxiety, emotion, and motor planning

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ABSTRACT

The present study investigated how trait anxiety alters the balance between attentional control systems to impact performance of a discrete preplanned goal-directed motor task. Participants executed targeted force contractions (engaging the goal-directed attentional system) at the offset of emotional and non-emotional distractors (engaging the stimulus-driven attentional system). High and low anxious participants completed the protocol at two target force levels (10% and 35% of maximum voluntary contraction). Reaction time (RT), performance accuracy, and rate of change of force were calculated. Expectations were confirmed at the 10% but not the 35% target force level: (1) high anxiety was associated with slower RTs, and (2) threat cues lead to faster RTs independently of trait anxiety. These new findings suggest that motor efficiency, but not motor effectiveness is compromised in high relative to low anxious individuals. We conclude that increased stimulus-driven attentional control interferes with movements that require greater attentional resources.

Impaired attentional processes have been identified as one of the primary cognitive factors underlying the inception and maintenance of anxiety (Eysenck, Derakshan, Santos, & Calvo, 2007). Anxiety related changes in attentional processes manifest in deficits in performance noted across a broad range of tasks including spatial and verbal reasoning (Darke, 1988: Experiments 2 and 3), digit-string short-term memory (Derakshan & Eysenck, 1998) and motor learning (Calvo & Ramos, 1989). While the processing efficiency theory (PET: Eysenck & Calvo, 1992) and its early iterations were instrumental to the development of the aforementioned studies, Eysenck and colleagues (2007) have recently advanced an updated and revised approach, attentional control theory (ACT), which served as the conceptual framework for the current study. The present study tests the interactions among trait anxiety, emotional distractor cues, and motor planning within the context of two of the six hypotheses proposed in ACT.

1. Attentional control theory

ACT (Eysenck et al., 2007) contends that anxiety manifests in impaired attentional control, which leads to performance deficits in tasks involving the central executive of the working memory system. This theoretical position is founded in the assumption that attention is regulated by (1) a goal-directed attentional system, and (2) a stimulus-driven attentional system (Corbetta & Shulman, 2002). The goal-directed attentional system is governed by expectations, knowledge, and current goals and exemplifies top-down attentional control. In contrast, the stimulus-driven attentional system is sensitive to salient stimuli, and exemplifies bottom-up attentional control. ACT proposes that anxiety modulates the balance between these two attentional systems with increased anxiety leading to "... an increased influence of the stimulus-driven attentional system and a decreased influence of the goal-directed attentional system" (Eysenck et al., 2007, p. 338). Imbalances between attention control systems are reflected in performance deficits on cognitive tasks (Arnell, Killman, & Fijavz, 2007; Blair et al., 2007; Bledowski, Prvulovic, Goebel, Zanella, & Linden, 2004), but the consequences of this imbalance have yet to be investigated when performing discrete goal-directed motor tasks. ACT postulates that inhibition (in addition to shifting and updating) is a distinct function of the central executive. Inhibition refers to one's ability to minimize disruption or interference from task irrelevant stimuli. That is, an increased ability to inhibit interference from task irrelevant stimuli (which engage the stimulus-driven attentional system) allows the goal-directed attentional system to continue to function with minimal disruption.

2. Motor planning

A controlled approach to understanding how the nervous system regulates execution of goal-directed voluntary movements is to record indices of the motor parameters used when producing force against an object. Performing simple functional activities of daily living such as eating, dressing, grooming, and drinking, all

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require the application of a planned grasping force against an object. Such acts of daily living require the production of a range of sub-maximal forces with most acts necessitating low to moderate levels of force (Marshall & Armstrong, 2004; McPhee, 1987). Motor abnormalities have been associated with affective disorders (Lohr & Caligiuri, 2006; Rossi, Bartalini, Ulivelli, Mantovani, & Di Muro, 2005; Wada, Sunago, & Nagai, 2001; Yardley, Britton, & Lear, 1995), and these motor abnormalities may lead to movements that are repeatedly performed inefficiently and/or inaccurately which, in turn, may compromise quality of life. Moreover, minor variations in force output can lead to dire consequences within military, sport, and medical domains, where anxious states and unexpected distractor stimuli are routinely experienced (Janelle & Hatfield, 2008; Norman, Eva, Brooks, & Hamstra, 2006; Satava, Gallagher, & Pellegrini, 2003).

Much of the current literature that validates PET and ACT is derived from cognitive tasks (e.g., Bonnot & Croizet, 2007; Hardy, Beattie, & Woodman, 2007). Those studies that have tested PET/ACT hypotheses within the motor domain have relied on continuous tasks (Murray & Janelle, 2003, 2007; Smith, Bellamy, Collins, & Newell, 2001; Williams, Vickers, & Rodriques, 2002; Wilson, Chattington, Marple-Horvat, & Smith, 2007) or simple reaction time tasks (Elliman, Green, Rogers, & Finch, 1997). Questions therefore remain concerning how emotion and anxiety impact the parameterization of functional motor tasks. By implementing a discrete goal-directed motor task in the current study, force output will be precisely measured and movement errors will be reliably quantified in the context of ACT hypotheses for the first time.

The notion that efficient motor function is susceptible to changes in anxiety and attention has been previously demonstrated (cf., Janelle, 2002, for review). Attentional control and working memory are critical for effective motor planning given that planning voluntary motor action requires the conscious parameterization of movement, which is made possible by the working memory system (Baddeley, 1986; Beilock, Jellison, Rydell, McConnell, & Carr, 2006). Motor planning is generally accepted as a process that occurs prior to movement initiation and uses visual and cognitive information derived from the environment and actor to assist in selecting an appropriate motor response (e.g., Glover, 2004). Before movements are initiated, current information is integrated with memories of past experiences (Rosenbaum, Loukopoulos, Meulenbroek, Vaughan, & Engelbrecht, 1995). Working memory is therefore essential to motor planning. Hence, even well-learned motor behaviors which engage the goal-directed attentional system remain highly susceptible to interference from the stimulus-driven attentional system. Central to the purpose of the current study, we argue that the susceptibility of motor planning to stimulus-driven interference will be inflated among anxious individuals.

3. Anxiety, attention, and motor planning

The current study tested hypotheses three and four proposed in ACT. Hypothesis three predicts that "Anxiety impairs attentional control by increasing the influence of the stimulus-driven attentional system" (Eysenck et al., 2007, p. 342). Evidence for this hypothesis comes from protocols in which performance on a central task is negatively affected by interference from a task commanding attention from the stimulus-driven attentional system in high as compared to low anxiety individuals and situations (Fenske & Eastwood, 2003; Hopko, McNeil, Gleason, & Rabalais, 2002; Janelle, Singer, & Williams, 1999). In the current study, the task targeting the goal-directed attentional system required the production of a brief force contraction to a predetermined target force level as quickly and accurately as possible, following presentation of emotion-eliciting distractor images. Viewing the distractor images in this case served as the more salient task relative to the motor task. We anticipated that viewing the distractor image would result in a shift in attentional control from the goal-directed attentional system (planning the execution of the goal-directed motor task) to the stimulus-driven attentional system, and this stimulus-driven shift would be less inhibited in high as compared to low anxious individuals. The subsequent question, therefore, is how should increased salience of the stimulus-driven attentional system manifest in performance of the primary goal-directed motor task? ACT predicts that although the effectiveness of a task may be similar between high and low anxious groups, anxiety will lead to a reduction in performance efficiency. Accordingly, presence of distractor cues should result in high anxious individuals performing tasks more slowly, but with similar accuracy to low anxious individuals (Beilock, Kulp, Holt, & Carr, 2004; Fox, Russo, Bowles, & Dutton, 2001; Koster, Croombez, Verschuere, & De Houwer, 2006).

The fourth hypothesis of ACT predicts that "Anxiety impairs efficiency (and often effectiveness) on tasks involving the inhibition function, especially with threat-related distractors" (Eysenck et al., 2007, p. 344). This hypothesis qualifies the third hypothesis based on the characteristics of present distractors, specifically the emotional salience of the distractors. Data from the attentional bias literature demonstrate that highly anxious individuals direct their attention to threat faster than low anxious individuals, and also show deficits in being able to disengage attention from those threatening cues (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoom, 2007, for a comprehensive review and meta-analysis). Accordingly, it is reasonable to predict that threat images should engage the stimulus-driven attentional system to a greater extent than non-threatening images in anxious individuals, which would be reflected in even slower RTs. However, threat-related attentional effects in high anxious individuals only manifest at very short time windows immediately following the presentation of threatening cues (Etkin et al., 2004; Fox, 2002). Although threatening images engage the stimulus-driven attentional system at the expense of the goal-directed attentional system, such effects may only be captured at very short time intervals within a single trial. Moreover, when viewing times of emotional images are in the magnitude of seconds as compared to milliseconds, previous evidence in non-anxious individuals suggests that exposure to unpleasant (~3 s: Hajcak et al., 2007) and threat images prime the motor system for action, and lead to faster RTs (Coombes, Cauraugh, & Janelle, 2007a). Hence, because the primary task in the current study is motoric, and because the presentation window of the distractor image is 2–4 s (to replicate a previous protocol: Coombes et al., 2007a; Coombes, Cauraugh, & Janelle, 2007b), threat cues should prime the motor system in high and low anxious individuals, leading to faster RTs and more efficient performance.

The current project required high and low anxious individuals to execute brief goal-directed force contractions (to engage the goal-directed attentional system) to the offset of emotional and non-emotional distractor cues (to engage the stimulus-driven attentional system). Our primary interest was to determine the extent to which these distractor cues altered the speed, accuracy, and vigor [i.e., rate of change of force production] of a planned motor task. We tested two hypotheses: (1) high anxious, relative to low anxious individuals will display slower RTs, and (2) high and low anxious individuals will display faster RTs to threat cues as compared to non-threat cues. We expected each of these hypotheses to hold true across two target force levels (10% and 35% of MVC) and we did not expect between group differences in performance accuracy or performance vigor.