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New perspectives in attentional control theory

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ABSTRACT

There have been several theoretical attempts to explain the effects of anxiety on cognitive performance. According to attentional control theory, anxiety impairs the efficiency of two executive functions (the inhibition and shifting functions). Another major theoretical assumption is that anxiety impairs performance effectiveness (the quality of performance) to a lesser extent than processing efficiency (the relationship between performance effectiveness and effort or use of processing resources). However, there may be conditions (e.g., prior presentation of threat-related stimuli) in which that assumption is not applicable. The extensive recent research (including several cognitive neuroscience studies) of direct relevance to the theory is discussed, and suggestions are made for maximizing the value of future cognitive neuroscience research. Finally, attentional control theory is developed to explicate the relationship between anxiety and motivation. Implications for theoretical predictions and alternative theoretical accounts are discussed.

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1. Introduction

This article is concerned with the effects of individual differences in anxiety on cognitive performance. The emphasis is mainly on anxiety as a personality dimension (i.e., trait anxiety or test anxiety), but the effects of transient anxiety (i.e., state anxiety) are also considered. There is plentiful evidence that anxiety (whether regarded as a personality dimension or as an emotional state) is associated with performance impairments on numerous tasks. A meta-analysis based on hundreds of studies revealed an overall correlation of −0.29 between test anxiety and academic aptitude or achievement (Hembree, 1988).

There have been numerous attempts to provide a theoretical explanation for the adverse effects of anxiety on performance. However, we will focus on one particular theoretical approach that has evolved over time. The original statement of the theory was by Eysenck (1979). This was followed by processing efficiency theory (Eysenck & Calvo, 1992), and more recently by attentional control theory (Derakshan & Eysenck, 2009; Eysenck, Derakshan, Santos, & Calvo, 2007). It would be superfluous to describe in detail the development of the theory. Instead, we will consider only the major theoretical hypotheses incorporated within processing efficiency theory and attentional control theory (the additional hypotheses associated with attentional control theory are discussed at length in Eysenck et al.).

The first major hypothesis forms an important part of processing efficiency theory (Eysenck & Calvo, 1992): anxiety impairs the efficiency of the central executive, which is an attention-like, limited capacity component of the working memory model put forward by Baddeley (1986). In contrast, it was assumed that there are only modest effects of anxiety on the other two components of the original model: (1) the phonological loop (used to rehearse verbal material and to store it briefly) and (2) the visuo-spatial sketchpad (used to process and store transiently visual and spatial information).

Much evidence provides support for the first hypothesis in terms of the effects of anxiety on the central executive (see Derakshan & Eysenck, 2009, for a review). However, there are very few studies in which the effects of anxiety on all three components of the working memory model have been compared directly in a single experiment. One such study was carried out by Eysenck, Payne, and Derakshan (2005). Individuals high and low in trait anxiety performed the Corsi Blocks Test concurrently with a secondary task involving the central executive, the phonological loop, or the visuo-spatial sketchpad. Performance on the Corsi Blocks Test was impaired by high trait anxiety when the secondary task involved use of the central executive but not when it involved use of the phonological loop or the visuo-spatial sketchpad. These findings suggested that high anxiety only impaired the functioning of the central executive.

Christopher and MacDonald (2005) used a different approach to the same issue. Their participants performed a series of tasks designed to assess different components of the working memory system. The findings closely resembled those of Eysenck et al. (2005):

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high trait anxiety only impaired performance on those tasks involving the central executive. Walkenhorst and Crowe (2010) used the same general approach as Christopher and MacDonald. They also failed to find any significant effects of trait anxiety on tasks involving the phonological loop or the visuo-spatial sketchpad. However, in contrast to the findings of Christopher and MacDonald, they also reported non-significant effects of anxiety on tasks involving the central executive.

The second and third major hypotheses are novel to attentional control theory but developed out of the assumption that anxiety impairs the functioning of the central executive. In short, there is accumulating evidence that various executive functions are associated with the central executive. For example, Miyake et al. (2000) asked their participants to perform numerous executive tasks, and then performed latent-variable analysis to identify the main underlying executive functions. They identified partially independent inhibition, shifting, and updating functions. The inhibition function (subsequently clarified by Friedman and Miyake (2004)) prevents task-irrelevant stimuli and responses from disrupting performance. The shifting function is used to allocate attention in a flexible and optimal way to the task stimulus or stimuli that are currently most relevant. The updating function is used to update and monitor the information currently within working memory. This function is important for various short-term memory tasks.

The second hypothesis is that anxiety impairs the functioning of the inhibition function, and the third hypothesis is that anxiety impairs the functioning of the shifting function. The overarching assumption is that anxiety impairs attentional control whether that control is negative (inhibition function) or positive (shifting function).

The fourth major hypothesis is based on the distinction between processing efficiency and performance effectiveness, and is incorporated in all versions of the theory from Eysenck (1979) onwards. Performance effectiveness can be defined as the quality of performance (e.g., the percentage of correct task responses). Processing efficiency is defined by the relationship between performance effectiveness and the use of resources or effort. More specifically, processing efficiency is high when performance effectiveness is high and use of resources is low and it is low when performance effectiveness is low but use of resources is high. The crucial hypothesis is that anxiety will typically impair processing efficiency to a greater extent than performance effectiveness.

Bishop (2009) agreed with the assumption that anxiety is associated with a broad impairment of attentional control. However, she offered an alternative explanation of the underlying processes. According to her account, individuals high in trait anxiety often exhibit an *impoverished* recruitment of attentional control mechanisms centered on the dorsolateral prefrontal cortex. This differs from the prediction stemming from attentional control theory, namely, that high anxiety will often be associated with *increased* activation of brain areas (e.g., dorsolateral prefrontal cortex) associated with attentional control.

We have already discussed Hypothesis 1. As a result, we will focus in what follows on the remaining hypotheses.

Hypothesis 2. Anxiety impairs the inhibition function.

The inhibition function is used to resist interference from task-irrelevant stimuli and responses. There is considerable evidence that anxiety impairs the functioning of the inhibition function (see Derakshan & Eysenck, 2009, for a review). Most of the research included in that review involved paradigms in which the conditions varied in terms of the presence and/or nature of distracting stimuli. The typical finding was that high-anxious individuals were more susceptible to distraction than were low-anxious individuals, a finding that has been replicated in more recent research (e.g., Pacheco-Ungietti, Acosta, Callejas, & Lupianez, 2010; Pacheco-Ungietti, Lupianez, & Acosta, 2009).

It is important for research in this area to use conceptually simple tasks that are as 'process pure' as possible so that the findings obtained are interpretable. The antisaccade task was identified by Miyake et al. (2000) as such a task. On this task, a visual cue is presented to the left or the right of the fixation point, and the instructions are to make an eye movement to the opposite side of the visual cue as rapidly as possible. The latency of the first saccade to the correct side is one of the main dependent variables of interest. There is also a control task (the pro-saccade task), in which the instructions are to fixate the cue when it appears.

According to attentional control theory, adverse effects of anxiety in terms of latency of the first correct saccade should be present with the antisaccade task but not the pro-saccade task. Derakshan, Ansari, Hansard, Shoker, and Eysenck (2009) obtained the predicted pattern of findings in their first experiment in which the cue consisted of a neutral oval shape. In their second experiment, Derakshan et al. used angry, happy, and neutral faces as cues. They obtained similar findings to their first experiment, with the adverse effects of anxiety on the antisaccade task being greatest with angry cues.

Two other recent studies have investigated the effects of anxiety on the antisaccade task using emotional cues. Garner, Ainsworth, Gould, Gardner, and Baldwin (2009) used negative and neutral picture cues. The high-anxious group made significantly more eye-movement errors than the low-anxious group on antisaccade trials regardless of cue type. Wieser, Pauli, and Muhlberger (2009) used happy, fearful, sad, and neutral facial expressions as cues in their study. Individuals high in social anxiety made more eye-movement errors than controls on antisaccade trials for all facial expressions.

Ansari and Derakshan (in press) successfully replicated the previous findings of Derakshan et al. (2009) using neutral cues. They also used additional conditions to explain more fully why the latency of the first correct eye saccade is greater for high-anxious than for low-anxious individuals. They discovered that this effect is due predominantly to the negative effects of anxiety on inhibitory control rather than on volitional action generation. This strengthens the argument that performance on the antisaccade task is relevant to attentional control theory.

We have discussed convincing evidence that anxiety is often associated with increased susceptibility to distraction and thus impaired efficiency of the inhibition function. As mentioned earlier, there are two contrasting theoretical accounts of this inefficiency when the inhibition function is required. According to attentional control theory, the inefficiency of high-anxious individuals often manifests itself in *greater* activation in brain areas associated with attentional control in distraction conditions. In contrast, Bishop (2009) argued that the inefficiency of high-anxious individuals in distraction conditions is often due to a partial failure to engage attentional control mechanisms (revealed by *reduced* activation in brain regions associated with attentional control).

The evidence obtained by Bishop (2009) using functional magnetic resonance imaging (fMRI) suggests that each approach is correct under certain conditions. A horizontal string of six letters was presented on each trial with the target letter being presented six times in the string (low perceptual load) or once (high perceptual load). The task was to decide which target letter (N or X) was presented. In addition, a task-irrelevant letter congruent or incongruent with the target letter was presented slightly above or below the letter string. In the high perceptual load-condition, there was no difference in performance (target detection time) between the congruent and incongruent distractor conditions for groups low or high in trait anxiety. However, only individuals high in trait

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