Anxiety, Processing Efficiency, and Cognitive Performance

New Developments from Attentional Control Theory

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Abstract. There have been many attempts to account theoretically for the effects of anxiety on cognitive performance. This article focuses on two theories based on insights from cognitive psychology. The more recent is the attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which developed from the earlier processing efficiency theory (Eysenck & Calvo, 1992). Both theories assume there is a fundamental distinction between performance effectiveness (quality of performance) and processing efficiency (the relationship between performance effectiveness and use of processing resources), and that anxiety impairs processing efficiency more than performance effectiveness. Both theories also assume that anxiety impairs the efficiency of the central executive component of the working memory system. In addition, attentional control theory assumes that anxiety impairs the efficiency of two types of attentional control: (1) negative attentional control (involved in inhibiting attention to task-irrelevant stimuli); and (2) positive attentional control (involved in flexibly switching attention between and within tasks to maximize performance). Recent (including unpublished) research relevant to theoretical predictions from attentional control theory is discussed. In addition, future directions for theory and research in the area of anxiety and performance are presented.

Keywords: anxiety, performance, attention, efficiency, central executive

Introduction

It is a matter of practical and theoretical importance to develop an understanding of the effects of anxiety on cognitive performance. Here, we focus on trait anxiety: (1) individual differences in anxiety as a personality dimension, generally assessed by measures of trait anxiety, e.g., the State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983); and (2) on state anxiety (a mood state): where anxiety is manipulated experimentally (e.g., via evaluative instructions, competing situations).

Anxiety is an aversive motivational state that occurs in situations in which level of perceived threat to the individual is high. State anxiety is interactively determined by trait anxiety and by situational stress (Eysenck, 1992). According to Power and Dalgleish (1997; pp. 206–207) anxiety can be conceptualized as "a state in which an individual is unable to instigate a clear pattern of behavior to remove or alter the event/object/interpretation that is threatening and existing goal." Anxious individuals worry about threat to a current goal and try and try to use strategies to reduce the effects of anxiety to achieve the goal. It is therefore not surprising that anxiety is associated with adverse effects on cognitive performance. Our focus in this paper is to discuss the effects of anxiety on cognitive tasks performed under laboratory conditions, in particular those that place significant demands on attentional resources. Such tasks permit the investigation of the underlying cognitive processes involved in performance under controlled conditions.

There is a considerable body of research devoted to the relationship between anxiety and cognitive performance (see Eysenck, 1992, for a review). It has often been found that anxiety impairs performance, especially when the task being performed is complex and attentionally demanding. Evidence supporting this generalization has been obtained both when anxiety is regarded as a personality dimension (i.e., trait anxiety) and when anxiety is regarded as a transient mood state (i.e., state anxiety).

Our emphasis in this article is on attentional control theory, which is our recent theory of anxiety and cognitive performance (Eysenck, Derakshan, Santos, & Calvo, 2007). In the article by Eysenck et al. (2007), there are many lacunae in the experimental evidence, as one would expect with a new theory containing what were then a number of somewhat speculative theoretical assumptions. Since then, however, we and other researchers have conducted much further research of direct relevance to attentional control theory. This research (some of which is as yet unpublished) is discussed in detail in this article, and there is also consideration of future directions of research building on these recent findings.

Before proceeding, however, it is important to provide a context by discussing briefly some previous theoretical ap-

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proaches in this area. We focus especially on processing efficiency theory (Eysenck & Calvo, 1992), which was the precursor to attentional control theory. Before doing that, however, we consider the important approach developed by Sarason (1988). The central assumptions of his cognitive interference theory are that the experience of anxiety involves having various task-irrelevant thoughts (e.g., self-preoccupation; worry), and that these task-irrelevant thoughts affect performance by reducing the amount of attention available to be allocated to a central ongoing task. In the words of Sarason (1988, p. 5), "proneness to self-preoccupation and, most specifically, to worry over evaluation is a powerful component of what is referred to as test anxiety."

There is much that is valuable in cognitive interference theory. In general terms, most of the research designed to test the theory has provided at least some support for its major assumptions. There is evidence that test anxiety consists of two major components (worry and emotionality; see Morris, Davis, & Hutchings, 1981, for a review), and that adverse effects of anxiety on task performance are predominantly due to the worry component (Morris et al., 1981). Borkovec (1994) defined worry as a concern over evaluation and failure characterized by expectations of aversive consequences that becomes activated, especially in high trait anxious individuals, in stressful situations that involve evaluative and/or competitive components. However, there are two major limitations with cognitive interference theory as an explanation of the adverse effects of anxiety on performance. First, the main prediction of the theory is that task-irrelevant processing in the form of worry causes anxious individuals to perform tasks worse than nonanxious individuals who are believed to experience fewer task-irrelevant thoughts. However, there are several studies in which the predicted difference between low-anxious and high-anxious groups in worry levels was not associated with any group difference in performance. For example, Blankstein, Toner, and Flett (1989) and Blankstein, Flett, Boase, and Toner (1990) carried out studies in which low and high test-anxious groups had very similar levels of performance on an anagram task, but the latter group reported many more negative thoughts about themselves. Such findings indicate that it is an oversimplification to assume that the effects of anxiety on performance are mediated directly by worry.

Second, cognitive interference theory fails to provide a detailed account of how task-irrelevant processing relates to the functioning of the cognitive system. More specifically, it is important to specify those components of the cognitive system directly affected by worry.

Processing Efficiency Theory

Eysenck and Calvo (1992) put forward processing efficiency theory in part to address the two major lacunae in cognitive interference theory. The first problem with that theory was addressed by drawing a distinction between performance effectiveness and processing efficiency. Performance effectiveness is easily defined, because it refers to the quality of performance (e.g., as assessed by outcome measures such as accuracy of performance). Processing efficiency is based on the relationship between performance effectiveness on the one hand and the amount of effort or resources used to attain that level of performance on the other hand. Task-irrelevant thoughts such as worry and self-preoccupation are assumed to impair processing efficiency. Worrisome thoughts use up attentional resources necessary for task demands and leave less resources available for concurrent task processing. However, a crucial assumption is that task-irrelevant processing does not necessarily have adverse effects on performance effectiveness. The argument is that worrisome thoughts enhance motivation in anxious individuals to minimize the adverse effects of anxiety. This is usually accomplished by an enhanced effort such that anxious individuals generally try to compensate for the adverse effects of anxiety on processing efficiency by utilizing additional processing resources. It follows from these assumptions that anxiety typically impairs processing efficiency to a greater extent than performance effectiveness. Since this part of processing efficiency theory is incorporated into attentional control theory, we discuss recent relevant research findings in conjunction with that theory. The findings are predominantly supportive of the theory (see Eysenck et al., 2007, for a review).

Processing efficiency theory addressed the second problem with cognitive interference theory by relating the effects of anxiety to the working memory system proposed by Baddeley (1986). This system consists of three components (recently increased to four) arranged in a hierarchical fashion. At the apex of the hierarchy is the central executive, an attention-like, domain-free system involved in various complex functions such as planning, strategy selection, and attentional control. There are also two "slave" systems: the phonological loop involved in the rehearsal of verbal material and the visuo-spatial sketchpad involved in processing and storing visual and spatial information. The assumption is that task-irrelevant processing affects the functioning of the working memory system. More specifically, it primarily affects the central executive but it also has a small adverse effect on the functioning of the phonological loop. As a consequence, anxious individuals should show impaired performance in dual-task situations in which the concurrent demands of the two tasks on the central executive are high.

Much research supports these assumptions (see Eysenck et al., 2007, for a review). Relatively direct evidence was reported by Eysenck, Payne, and Derakshan (2005). In their study, individuals low and high in trait anxiety performed a primary complex visuo-spatial task while concurrently performing a secondary task that involved the central executive, the phonological loop, or the visuo-spatial sketchpad. The high-anxious group only performed the primary visuo-spatial task significantly worse than the low-anxious group when it was accompanied by a secondary task requiring use of the central executive. With respect to the secondary task, there were significant adverse effects of anxiety on performance only with the task requiring the central executive. Thus, anxiety impaired performance on both the primary and secondary tasks in this condition. That means that the adverse effect of anxiety on performance of the primary task when combined with the secondary task involving the central executive cannot be attributed to anxiety producing a strategic change in which the priority given to the primary task was reduced. Instead, the overall pattern of the findings suggests that anxiety reduces the available capacity of the central executive but has minimal effects on the phonological loop and visuo-spatial sketchpad.

Other relevant evidence was reported by Rapee (1993) who studied the effects of several tasks varying in their demands on the central executive on worry-related thoughts. Random letter generation (a task known to require central executive resources) reduced worry-related thoughts. This is consistent with the theory, because it suggests that worry-related thoughts and the random letter generation task competed for use of the limited-capacity central executive resources. Also consistent with the theory were the additional findings that tasks requiring minimal central executive involvement (word repetition; fixed-order key presses) failed to reduce worry-related thoughts.

Attentional Control Theory

In view of the predominantly positive findings when processing efficiency theory has been put to the test, why was it deemed necessary to develop and extend that theory to produce attentional control theory? There are several reasons, but here we discuss only the most important ones. The assumption within processing efficiency theory that anxiety impairs the efficiency of the central executive is relatively imprecise. The central executive fulfills a number of functions, for example, switching attention between tasks, selective attention and inhibition, updating working memory contents, and coding representations of time and place in working memory (see Smith & Jonides, 1999), although there is no consensus concerning either the number or nature of those functions. Accordingly, it is important to specify which functions are more or less affected by anxiety, an issue addressed directly within attentional control theory. This issue was not addressed directly by Eysenck and Calvo (1992), in part because relatively little was known about the detailed functioning of the central executive at that time. In the current paper we focus on these functions, but for a wider coverage of attentional control theory and its predictions see Eysenck et al. (2007).

At the heart of attentional control theory, it is predicted that anxiety affects performance via its adverse effects on attentional control, a key function of the central executive. The term "attentional control" has been given various definitions in the literature. Here we adopt the one preferred by Yantis (1998), where we distinguish between top-down goal driven or controlled processes and bottom-up stimulus driven processes. According to Corbetta and Shulman (2002), there are two attentional systems: one influenced by the individual's current goals, expectations, and knowledge, i.e., top-down goal driven system; and the other system, the stimulus-driven system, influenced by salient stimuli. The goal-directed system resembles the cognitive system proposed by Miller and Cohen (2001), which is centered in the prefrontal cortex and is involved in the top-down regulation of attention. The stimulus-driven system includes the temporo-parietal and ventral frontal cortex and resembles the posterior attentional system of Petersen (1990). According to Corbetta and Shulman (2002) the stimulus driven system "is recruited during the detection of behaviorally relevant sensory events, particularly when they are salient and unattended." The goal driven and stimulus driven systems are believed to interact with one another frequently (see Pashler, Johnston, & Ruthruff, 2001, for a review).

According to attentional control theory, anxiety disrupts the balance between these two systems by enhancing the influence of stimulus driven bottom-up processes over the efficient top-down goal driven processes. The development of this theory has been influenced by the ideas put forward by Derryberry and Reed (2002) and others, e.g., Fox, Russo, and Dutton (2002) and Mathews and Mackintosh (1998). Accordingly, there is much evidence to show that anxiety is associated with an attentional bias for threat-related material and an enhanced distractibility in the presence of task-irrelevant, especially threatening material, and with a failure to disengage from the processing of threat related material (see Bar-Haim et al., 2007, for a review). There is accumulating evidence (see Bishop, 2007; for a review) to show that anxiety is associated with enhanced amygdala activation and reduced recruitment of prefrontal cortical areas (especially the dorsal lateral prefrontal cortex, DLPFC, and ventral lateral prefrontal cortex, VLPFC) that are heavily involved in top-down regulation of attention especially when attentional focus is required for efficient task performance. Thus, both behavioral and neuroimaging work has shown that anxiety is associated with adverse effects on cognitive performance, especially on tasks that require attentional focus. The assumption that anxiety increases attention to task irrelevant stimuli (especially threat related) indicates that anxiety typically reduces attentional focus on concurrent task demands. In other words, anxiety affects attentional control: a key function of the central executive component of the working memory.

Attentional Control, the Central Executive, and Anxiety

As mentioned already, there is no consensus concerning the number and nature of functions of the central executive. However, the approach adopted by Miyake et al. (2000) and by Friedman and Miyake (2004) has the advantage over many others being based squarely on extensive empirical evidence. They used many tasks generally regarded as involving the central executive, and then used latent variable analysis to work out its functions. They identified three functions, all corresponding closely to functions identified by other researchers using different approaches. First, there is the inhibition function, which involves using attentional control to resist disruption of interference from task-irrelevant stimuli or responses. This is negative attentional control. Second, there is the shifting function, which involves using attentional control to shift attention flexibly to ensure that it remains focused on task-relevant stimuli of current importance. Thus, it involves using attentional control in a positive way to enhance task performance. Third, there is the updating function, which involves "updating and monitoring of working memory representations" (Miyake et al., 2000, p. 56). This function is primarily concerned with the transient storage of information and so involves short-term memory rather than attentional control per se. It can be regarded as a measure of basic attentional or short-term capacity.

In attentional control theory, Eysenck et al. (2007) assumed that the inhibition, shifting, and updating functions are the main functions of the central executive. According to this theory anxiety impairs attentional control, and so its main adverse effects are on functions involving attentional control. The updating function involves memory rather than attention, and so is not directly affected by anxiety. In contrast, the inhibition function involves using attentional control to restrain attention being directed to task-irrelevant stimuli and responses, and the shifting function involves using attentional control in a positive way to respond optimally to changing task requirements. Thus, the most important novel assumption of attentional control theory is that anxiety impairs the efficiency of the inhibition and shifting functions.

Published research of relevance to attentional control theory is reviewed at length by Eysenck et al. (2007). Accordingly, we focus on very recent, including unpublished research of direct relevance to the major assumptions of the theory.

Inhibition Function

Recent Research

There have been approximately 30 studies concerned with the effects of anxiety on the inhibition function (see Eysenck et al., 2007), most of which have compared task performance under low and high distraction conditions. Two points need to be made about the detailed assumptions of attentional control theory before discussing the relevant evidence. First, anxiety should impair processing efficiency whether the distracting stimuli are external (i.e., task-irrelevant stimuli presented by the experimenter) or internal (i.e., worrying thoughts; self-preoccupation). Thus, some of the assumptions of cognitive interference theory (i.e., those to do with the effects of worry on attentional processes) are incorporated within the new theory, but attentional control theory offers a more comprehensive theoretical account.

Second, the adverse effects of anxiety under distraction conditions are greater when the task-irrelevant stimuli are threat-related rather than neutral. This assumption is based on much research showing that anxious individuals have an attentional bias for threat-related stimuli and find it harder than nonanxious ones to disengage from such stimuli (Bar-Haim et al., 2007).

In most of the published studies, the key finding was that the adverse effect of high distraction on performance compared to low distraction was greater for high-anxious than for low-anxious individuals. The most-used paradigm was the emotional Stroop task in which participants name as rapidly as possible the colors in which threat-related and neutral words are presented. High-anxious individuals are generally slower than low-anxious ones to name the colors when the words are threat-related. This is consistent with the notion that anxiety impairs attentional control. However, the findings are not definitive, because findings on the emotional Stroop task can be interpreted in various ways and an unequivocal interpretation is not possible (Bar-Haim et al., 2007). For example, interference effects with threat-related words may be due to preattentive processes, attentional processes, postattentional processes, or cognitive avoidance.

The findings are also not definitive from other studies in which it was found that distraction impaired the performance of high-anxious individuals more than that of low-anxious ones. For example, Calvo and Eysenck (1996) found that text comprehension was impaired by the concurrent presentation of meaningful speech for high-anxious but not for low-anxious individuals. This is consistent with the assumption that anxiety impairs the inhibition function. However, there was no direct evidence in this study that the greater susceptibility of high-anxious than of low-anxious individuals to distraction was due to the effect of anxiety on attentional processes rather than on other processes.

The prediction that anxiety impairs the efficiency of attentional control involving the inhibition function can be tested more directly by using the antisaccade task that involves the measurement of eye movements (Hallet, 1978). In this task, saccadic eye movements provide a more direct measure of attentional processes. In the antisaccade task, participants are presented with an abrupt peripheral stimulus to one side of a central fixation point and are instructed not to look at the stimulus, but to direct their gaze as quickly as possible to the other side of the fixation point. Correct performance in this task requires top down attentional processes to suppress a reflexive saccade toward the abrupt peripheral stimulus (i.e., inhibit) and simultaneously generate a saccade to its mirror position as fast as possible (see Hutton & Ettinger, 2006; for a review). In a neuroimaging study, Ettinger et al. (2007) identified specific brain regions involved in attentional control to predict correct antisaccade performance. It was found that activation in the dorsolateral prefrontal cortex (DLPFC) and the ventrolateral prefrontal cortex (VLPFC) predicted correct antisaccade performance. The authors argued that these areas were directly involved in the inhibition of reflexive saccades as well as the volitional generation of saccades.

Impaired antisaccade performance is indicated by erroneous saccades toward the abrupt stimulus. The implication is that the inhibition function is needed for successful performance on the antisaccade task. This is consistent with the findings of Miyake et al. (2000), who found that the antisaccade task loaded more than any other task on the inhibition function. Theoretical models of the antisaccade task (e.g., Massen, 2004; Hunt, Olk, von Muhlenen, & Kingstone, 2004; Reuter, Jäger, Bottlender, & Kathmann, 2007) suggest that the reflexive saccades and the volitional saccades compete for execution. As a result, errors can occur if the generation of the volitional response is done too slowly or is too weak to successfully compete with the reflexive response. The task includes a control condition (prosaccade) where participants are simply instructed to look at the cue (stimulus) when it appears. Here, the reflexive and volitional responses are not in conflict and so inhibition is not necessary. There are two main dependent variables of interest in the antisaccade task: Accuracy and latency of first eye movement in the correct direction.

Using the antisaccade task, Derakshan, Ansari, Hansard, Shoker, and Eysenck (2009) examined inhibition of neutral and emotional material in two separate experiments. In their first experiment, an oval-shaped object was used as the cue. The main dependent variable was the latency of the first correct saccade (correct antisaccade latencies), which was used as a measure of processing efficiency. The percentage of incorrect saccades (error rates) was used as a measure of performance effectiveness. Analyses on latencies showed a significant interaction between group (low-versus high-anxious) and task (antisaccade versus prosaccade). As predicted, the high-anxious group took significantly longer than the low-anxious group to make a correct saccade in the antisaccade task, but there was no effect of anxiety on latency in the prosaccade task. In addition, there was no effect of anxiety on error rates (performance effectiveness). Thus, the findings indicated that anxiety impaired processing efficiency to a greater extent than performance effectiveness, which is in line with theoretical predictions from attentional control theory.

In their second experiment, Derakshan et al. (2009) used angry, happy, and neutral facial expressions of emotion as cues in the antisaccade and prosaccade tasks. There was a highly significant three-way interaction on latency of the first correct saccade involving task (antisaccade versus prosaccade), valence (happy, angry, or neutral), and group (low-anxious versus high-anxious). There were effects of anxiety on latency of the first correct saccade only on the antisaccade task, and on that task the slowing effect of anxiety on latency of the first correct saccade was greatest when the cue was threatening (angry emotional expression). This finding is consistent with the assumption of Eysenck et al. (2007) that high-anxious individuals process threatening stimuli more than do low-anxious individuals, and also take longer to disengage from them (see also Bar-Haim et al. 2007). However, there were no effects of anxiety on percentage incorrect saccades (error rates). Thus, as in the first experiment, anxiety impaired processing efficiency rather than performance effectiveness.

The above findings show that anxiety impairs attentional control and processing efficiency on the antisaccade task. These novel findings are of considerable theoretical relevance and are precisely as predicted by attentional control theory. Of particular importance is that these two experiments provide the strongest evidence to date that anxiety impairs the efficiency of the inhibition function and of attentional processes associated with its use. We are currently carrying out additional studies using the antisaccade task to clarify the precise processes affected by anxiety.

Research in Preparation

According to attentional control theory anxiety is associated with reduced inhibition of task-irrelevant distracting stimuli. However, most evidence from the emotional Stroop task is difficult to interpret and the characteristics of the distracting stimuli have not been systematically manipulated. We discuss two of our studies that measured eye movements to obtain a direct index of attentional control. The first looked at the effects of anxiety on distractibility in a reading task, and the second examined the effects of anxiety on inhibition using visual search tasks.

Derakshan, Shoker, Hansard, and Eysenck (in preparation) used a modified version of the paradigm used by Hopko, Ashcraft, Gute, Ruggiero, and Lewis (1998) which involved self-paced reading texts. In their experiment, participants read “neutral” stories that included neutral and threat-related distractor words unrelated to the story. The distractors could either be static or flashing. Participants completed a comprehension task when they had finished reading the story. State anxiety was manipulated in a between-participant design such that one group of participants were told that their comprehension ability would be evaluated by others. This manipulation was designed to enhance the effects of anxiety on the efficient task performance in the presence of distracters. Eye movements were recorded online. Results on reading time (response times as indicated by button press when participant finished reading the story) showed that high-anxious individuals took longest to read the stories in the presence of both neutral and threat-related static distractors. Importantly, high-anxious individuals compared with low-anxious individuals made more fixations when reading the story in the presence of static distracters and spent more time looking at distractors under evaluative conditions. Thus, anxiety impaired the ability to inhibit the effects of distracters efficiently and so impaired processing efficiency when it was needed for successful task completion. These findings provide additional support for the theoretical assumption that anxiety impairs the efficiency of the inhibition function.

A suitable task for assessing the effects of anxiety on inhibition of distracting stimuli is the visual search task in which participants are asked to find a target in a matrix of several distracters. Hansen and Hansen (1988) were the first to show that angry facial expressions of emotion were detected faster in a crowd of happy expressions whereas happy face targets were the slowest to be detected in a crowd of angry faces (the face in the crowd effect) (e.g., Öhman, Lundqvist, & Esteves, 2001; Juth, Lundqvist, Karlsson, & Öhman, 2005). These findings indicated that angry faces slowed down the detection of happy target faces. Of special relevance here, is evidence that anxiety enhanced this slowing effect as high-anxious individuals were slower than low anxious ones to find a happy target face in a crowd of angry faces (Byrne & Eysenck, 1995), indicating that they were less efficient at inhibiting the impact of angry faces (i.e., threat). A major limitation with previous research is that eye movements were not recorded and so it is unclear what processes occurred during the visual search process.

Derakshan et al. (in preparation) asked participants to find the “odd face out” using the “face-in-the-crowd paradigm” that manipulated the facial expressions of target and crowd. Eye movements were recorded. Behavioral data (response button press) replicated the previous findings that participants were slower to indicate a happy target was present when the crowd distracters were angry faces and this effect was enhanced in the high-anxious group. However, what was of central importance were the eye-movement data showing that this effect was due mainly to the high-anxious individuals checking other distractor faces after fixating the target and before indicating (via button press) that the target had been found. Thus anxiety reduced “target processing efficiency” to a greater extent when the distractor faces were threat-related. This replicated effect (Derakshan et al., in preparation) was enhanced when participants had to perform the task under attentional load, which imposes extra demands on central executive resources. This effect is predicted by attentional control theory. According to the theory, the effect of anxiety on the efficiency of the inhibition function should be greater as overall demands on the attentional system increase.

Shifting Function

Recent Research and Work in Preparation

There has been practically no previous research on the effects of anxiety on the shifting function. What is needed to test the prediction that anxiety impairs the functioning of the shifting function? The optimal approach is one based on task-switching paradigms (see Monsell, 2003, for a review). In essence, there are two conditions and all participants perform the same two tasks in both conditions. The crucial difference between the conditions is that participants either alternate rapidly between tasks (switching condition) or they are presented with an entire block of trials involving one task followed by another block of trials involving the other task (nonswitching condition). The main prediction is that task-switching should have a significantly greater adverse effect on high-anxious than on low-anxious individuals, because the task-switching condition imposes greater demands on the shifting function.

The above prediction was tested by Derakshan, Smyth, and Eysenck (submitted). Participants performed addition and subtraction problems in one condition and multiplication and division problems in the other condition. The two tasks in each condition were either performed on alternate trials or in blocks. On each trial, two numbers were presented and a cue indicating the arithmetical process to be performed was either present or absent.

The crucial finding in the experiment by Derakshan et al. (submitted) was that there was a highly significant interaction between anxiety and task-switching. In this interaction, high-anxious participants performed substantially worse with task-switching than with no task-switching, whereas low-anxious participants were not affected by task-switching. This is as predicted theoretically. It means that anxiety impairs attentional control in terms of using the shifting function to switch attention between tasks.

The effect of anxiety on task-switching was investigated using the mixed antisaccade task (Ansari, Derakshan, & Richards, 2008), a well-known variant of the standard antisaccade task (mentioned above). In this version, antisaccade and prosaccade trials are randomly presented within blocks and a cue signals the execution of an antisaccade or a prosaccade trial before the start of each trial. When participants are required to switch between trials, antisaccade performance typically improves (i.e., faster correct latencies) compared to when antisaccade and prosaccade trials are performed inseparably blocks (Cherkasova, Manoach, Intriligator, & Barton, 2002). This is known as “switch benefit.” This paradoxical improvement is interpreted within a goal-driven controlled processing approach (see Nieuwenhuis, Broerse, Nielen, & Jong, 2004) such that “performance variability in tasks assessing executive functions may arise from failures to fully or consistently focus attention on task requirements . . . although task requirements may be understood and remembered, they are not turned into active goals or adequately maintained as such” (p. 199), also known as *goal-neglect* (De Jong, Berendsen, & Cools, 1999).

When switching between antisaccade and prosaccade trials, more attentional resources need to be invested in a flexible way to accommodate the changing nature of the task demands in an efficient fashion. It is predicted that anxiety interferes with efficient allocation of attentional resources to task demands and so the high-anxious individuals do not show an improvement in "switch" compared to "repeat" conditions. Using a mixed antisaccade task, Ansari, Derakshan, and Richards (2008) obtained the predicted pattern: Low-anxious participants showed the typical improvement in terms of "switch benefit," i.e., they had faster correct antisaccade latencies on "switch" trials compared to "repeat" trials, the high-anxious individuals showed no improvement. These findings indicate that anxiety affected the efficiency of the shifting function as predicted by attentional control theory. However, the two groups did not differ in performance effectiveness as they had comparable error rates in both versions of the task. The analysis also showed that improvement in the switched antisaccade task was not a result of speed/accuracy trade-off.

Further evidence that anxiety impairs processing efficiency more than performance effectiveness was obtained by Santos, Wall, and Eysenck in an unpublished study. Their study was concerned with task-switching and so involved the shifting function. Participants low or high in anxiety were presented with single digits, and performed one of three simple tasks depending on the location of the digit on the screen. There were blocks of trials which differed in the extent of task-switching within the block: no task-switching, low task-switching, or high task-switching. The demands on attentional control (i.e., the shifting function) were greatest in the high task-switching condition and least in the no task-switching condition. The prediction from attentional control theory is that high-anxious individuals should become progressively less efficient than low-anxious ones as the demands on attentional control via the shifting function increased (i.e., with increasing task-switching).

A novel feature of the experiment by Santos et al. (unpublished) was that functional magnetic resonance imaging (fMRI) was used to assess patterns of brain activation in all three conditions. What specific predictions follow from attentional control theory? First, it was predicted that the high-anxious participants would show greater increases than the low-anxious ones in brain activation in the high task-switching condition compared to the low task-switching and no task-switching conditions. This prediction is based on the assumption that increases in brain activation (when combined with information about performance effectiveness) providing a measure of processing efficiency. Second, it was predicted that the greater increase in brain activation among high-anxious than among low-anxious individuals would focus mostly on those areas of the brain involved in attentional control and task-switching. A review by Wager, Jonides, and Reading (2004) indicated that areas within the prefrontal cortex are directly involved in shifting of attention, and so this was the part of the brain that was predicted to show the clearest group differences.

The findings provided support for the predictions of attentional control theory. There were no effects of anxiety on performance effectiveness, probably because of the undemanding nature of the tasks used. However, there was the expected group difference in terms of increased brain activation. The finding that high-anxious individuals required a greater increase in brain activation than low-anxious ones when dealing with task-switching to obtain a comparable level of performance indicates they had reduced efficiency compared to the low-anxious individuals.

Conclusions

Most of the relevant research (including recent unpublished research from our laboratories) provides empirical support for the main predictions of attentional control theory. More specifically, there is strong evidence that anxiety impairs processing efficiency more than performance effectiveness; that anxiety impairs the inhibition function; and that anxiety impairs the shifting function. That is very encouraging and provides a solid foundation on which to build. Overall, the empirical support for attentional control theory is significantly greater than it was at the time of Eysenck et al.'s (2007) article. This is the case with respect to all three predictions discussed in detail in this article. However, it is especially the case with respect to the prediction that anxiety impairs the shifting function, a prediction for which there is practically no relevant research in the published literature.

It is always speculative to anticipate future developments in any area of research. However, we are convinced that four features should characterize future research on anxiety and performance. First, it is important to assess attentional processes as precisely and directly as possible. Too much research has relied exclusively on indirect behavioral measures to assess the effects of anxiety on attentional processes relevant to performance, and it is very desirable to measure eye movements as well as continuing to obtain behavioral measures. This is important regardless of whether there is an apparent correspondence or lack of correspondence between behavioral and eye-movement data. If there is correspondence, then the eye-movement data serve to strengthen conclusions about the involvement of attentional processes drawn on the basis of the behavioral data. If there is a lack of correspondence, then the eye-movement data may suggest that processes additional to attentional ones are influencing behavior.

Second, there needs to be a continuing search for "process-pure" tasks that reflect primarily a single underlying process rather than several. We have endeavored to move in that direction with our emphasis on the antisaccade task and the task-switching paradigm. However, in neither case can it realistically be claimed that we have used "process-pure" tasks (Monsell, 2003; Hutton & Ettinger, 2006). At the very least, it is important to utilize tasks that are relatively simple conceptually. The performance of conceptually complex tasks typically involves several different forms of processing, making it exceptionally difficult to identify which process or processes are most affected by anxiety.

Third, there is genuine promise in combining neuroimaging and behavioral data to assess processing efficiency. As yet, there is only a single study (Santos et al., unpublished) that has done this. However, the findings were sufficiently promising to warrant further research of this type. In most previous research, processing efficiency was assessed by means of behavioral measures. This reliance on behavioral measures makes it hard to disentangle the assessment of processing efficiency from that of performance effectiveness, which is necessarily assessed by behavioral measures.

Fourth, there are unresolved issues concerning the number and nature of executive functions associated with the central executive component of working memory. More specifically, it remains unclear whether dual-task coordination should be identified as an executive function. Miyake et al. (2000) found that dual-task performance did not relate clearly to any of the three executive functions they postulated. Collette and van der Linden (2002) reviewed brain-imaging findings, and concluded that dual-task coordination should be added to Miyake et al.'s (2000) list of executive functions. If further research substantiates Collette and van der Linden's position, it will be important to identify the precise psychological processes underlying dual-task coordination and assessing the effects of anxiety on that executive function.

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