From processing efficiency to attentional control: a mechanistic account of the anxiety–performance relationship

Mark Wilson*

School of Sport and Health Sciences, University of Exeter, UK

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The aim of this paper is to outline the development of Eysenck and Calvo’s (1992) processing efficiency theory (PET) and to summarise research testing its predictions in the sporting domain. PET provides a mechanistic explanation for how anxiety may influence performance through its impact on attentional resources. The central tenet of PET is that as well as pre-empting resources in working memory, increased anxiety provides a motivational function, leading to the allocation of additional effort to attempt to maintain task performance. Research in sport settings has been supportive of the predictions of PET, adopting a range of measures of processing efficiency; including self-reported effort, secondary task performance and psychophysiological indices. Furthermore, cognitive sport psychologists have recently examined direct influences of anxiety on the efficiency of information processing via gaze behaviour analyses. These findings are particularly relevant in the light of a recent update and development of PET; attentional control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007). ACT purports that anxiety reduces attentional control by increasing the influence of the stimulus-driven attentional system at the cost of goal directed control. It is evident that ACT may provide a useful framework for examining the relationship between anxiety, attention and performance in sport skills.

Keywords: anxiety; attention; gaze behaviour

Anxiety and performance

The influence that anxiety exerts on performance continues to be a major area of interest for researchers and practitioners within sport psychology (e.g., Woodman & Hardy, 2001, 2003). While a number of advances have been made by sport psychologists over the last 20 years, these developments have tended to be rather descriptive and focused on the measurement and categorisation of constructs related to anxiety. Indeed as Janelle (2002) highlighted, ‘Despite extensive research devoted to determining the nature of the relationship between stress and performance, there has been little systematic examination of the mechanisms underlying this relationship’ (p. 237).

From a cognitive psychology perspective anxiety is viewed as an emotion characterised by negative affect that impairs performance (Eysenck, 1996; Neiss, 1988). Several theorists have argued that the negative performance effects of anxiety are largely due to the manner in which worry and other forms of cognitive interference such as self-preoccupation occupy attention (e.g., Liebert & Morris, 1967; Sarason, 1988). These so-called distraction or attentional theories are based on the assumption that a key aspect of successful task
performance is the ability to attend to task-relevant cues, processes and behaviours while ignoring task-irrelevant or task-disruptive information (Kahneman, 1973; Wine, 1971). Interference with these attentional processes is assumed to result in poorer performance and, in extreme cases, can lead to what has been termed ‘choking’; acute performance decrements under circumstances of heightened incentive for good performance (Baumeister, 1984).

**Distraction theories and working memory**

Distraction theories (e.g., cognitive interference theory (CIT); Sarason, 1988) propose that cognitive anxiety, in the form of worry, is resource intensive and causes a diversion of attention from task-relevant cues. This diversion of resources effectively changes single-task performance into a dual-task situation in which controlling the task at hand and attending to worrisome thoughts compete for attention (Beilock & Carr, 2001). These thoughts therefore interfere with the mental processes that support performance as adequate attention cannot be directed to task-relevant information (Kahneman, 1973; Sarason, 1984). Breakdowns in performance under pressure are more likely to occur during complex, attentionally demanding tasks that rely on working memory for the storage and manipulation of decision and action-relevant information (Rapee, 1993).

Working memory acts as a temporary storage and manipulation system for information and is assumed to comprise three distinct sub-systems; the articulatory loop, the visuo-spatial sketchpad and the central executive (Baddeley, 1986). The articulatory loop is responsible for the brief storage and manipulation of verbal information while the visuo-spatial sketchpad is an equivalent sub-system concerned with storage of visual and spatial information. ‘Overseeing’ these two sub-systems is the central executive, essentially a type of capacity limited attentional system which functions to control the other two systems (Baddeley, 1986). This conceptualisation of the working memory system has recently been expanded into a four component model, with the inclusion of an episodic buffer function (Baddeley, 2001). The episodic buffer fulfils some of the functions implicitly assigned to the central executive in the earlier model; integrating information from the subsidiary systems and from long-term memory. The updated model allows the central executive to be defined in less vague terms as a purely attentional system (Baddeley, 2001); so the update has little impact on the predictions of PET.

Research implicating the effects of anxiety on the working memory system was initially carried out on digit span and reading span tasks (see Eysenck, 1992, for a review). Findings suggested that worry mainly pre-empts the resources of the central executive, but also typically makes use of the articulatory loop (Eysenck, 1985). Tasks which place substantial demands on the central executive and articulatory loop components of the working memory system are, therefore, more likely to be adversely affected by worry (Eysenck & Calvo, 1992). For this reason it is not surprising that support for distraction theories comes mainly from research involving academic tests (e.g., Eysenck, 1979; Wine, 1971). However, recent competitive anxiety research in sport has also supported such an interpretation for performance decrements caused by anxiety (e.g., Mullen & Hardy, 2000; Williams, Vickers, & Rodrigues, 2002; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006).

Notwithstanding the arguments made for an attentional explanation of choking, it is important to note that, in general, the support for the predicted negative influence of cognitive anxiety on performance is less than would be expected (e.g., Carver & Scheier,
1988; Clark III, 2002; Collins & Smith, 1997). As well as equivocal findings from test-based studies (e.g., Calvo & Ramos, 1989; Eysenck, 1985), recent sport-based research would suggest that increased cognitive anxiety is not always detrimental to performance (see Hanton, Neil, & Mellalieu’s, 2008 review of the literature examining a facilitative as well as debilitative interpretation of pre-competitive anxiety). It is indeed unlikely that anxiety will have generally predictable effects on performance given that suitably motivated performers can play an active role in the interpretation and mediation of anxiety. A theoretical perspective that helps to provide an explanatory account of these equivocal findings is Eysenck and Calvo’s (1992) processing efficiency theory (PET).

### Processing efficiency theory

PET was developed to attempt to provide an explanation for some of the divergence between performance-anxiety theories and actual research findings. According to PET, state anxiety, which in turn is determined by the interaction of trait anxiety and the level of perceived threat in any performance setting, plays an important role in influencing performance (Eysenck, 1996). The theory is intended to have general performance applicability but arguably is most relevant to tasks with high cognitive demands in settings in which evaluation and social comparison are common (Eysenck & Calvo, 1992).

PET was developed through the incorporation of existing theories with new insights into the mechanisms by which anxiety could affect performance. The initial version of PET (Eysenck, 1979, 1985) was influenced primarily by Sarason’s (1972, 1984, 1988) developments of cognitive interference theory (CIT). Whilst PET shares the assumption that worry pre-empts resources of working memory with CIT, the authors argue that Sarason’s theory exaggerates the role worry plays in impairing performance. The more recent version of the theory therefore drew more on the model of behaviour economy, proposed by Schönpfug (1983).

Schönpfug’s (1983) model of behaviour economy emphasises the role played by effort in determining the level of performance, and is concerned with the relationship between levels of effort, current performance levels and the costs associated with increasing effort levels (e.g., fatigue). Schönpfug and colleagues conducted a series of experiments which showed that, when anxious, participants often applied additional effort to tasks in order to maintain performance (e.g., Schulz & Schönpfug, 1982). This process of increasing effort was assumed to involve increased resource expenditure to balance demand and supply, but with a subsequent psychological cost.

### Predictions

PET postulates that cognitive anxiety in the form of worry influences performance in two ways. First, worry is assumed to pre-empt storage and processing resources from working memory, producing performance decrements in tasks that impose high levels of mental demand (Eysenck, 1992). Second, worry is also proposed to serve a motivational function. Concern over sub-optimal performance leads to the allocation of additional processing resources (i.e., effort) to tasks, or the initiation of alternative processing strategies designed to maintain performance. Compensatory effort is aimed at maintaining performance at a desired level and serves to reduce, or eliminate, apprehension associated with worrisome thoughts related to the aversive consequences of poor performance (Eysenck & Calvo, 1992).
According to PET, there is an important distinction between performance effectiveness and processing efficiency. Performance effectiveness refers to the quality of task performance and processing efficiency refers to the relationship between the effectiveness of performance and the effort or processing resources invested (Eysenck, 1992). One of the central predictions of PET is that the adverse effects of anxiety on performance effectiveness are often less than those on processing efficiency. This is because the reduction in available attentional resources caused by worry may be partially or completely compensated for by increased effort (Calvo, 1985).

A central tenet of PET is that there is a control or self-regulatory system (Hockey, 1986), which is involved in mediating the effects of anxiety on processing and performance (Eysenck & Calvo, 1992). This system performs the task of co-ordinating resource allocation based on outcome probabilities and relies on negative feedback resulting from the detrimental effects of anxiety on performance as a trigger for its activation. There are two major types of reactions to poor performance, which are initiated by the control system. First, it may be possible to cope directly with the current level of threat through palliation or denial, thereby reducing worry and increasing the available capacity of working memory. Second, it is possible to reduce or eliminate the negative effects of worry on performance by applying additional resources (e.g., effort or time) or activities (e.g., more efficacious strategies, seeking external assistance) to the task (Eysenck & Calvo, 1992).

Eysenck and Calvo (1992) argue that either of these reactions will be more likely in high-trait anxious (HTA) as opposed to low-trait anxious (LTA) individuals. Research evidence supports this prediction and indicates that there are fundamental differences between such individuals. First, HTA individuals tend to devote more of their processing resources to worry, therefore increasing the probability of detecting a mismatch between expected and actual performance (Eysenck & Calvo, 1992). Research in test situations (e.g., Jerusalem, 1990), has demonstrated that compared to LTA individuals, HTA individuals are also more sensitive to failure feedback. Within the framework of PET this means that HTA individuals are therefore more likely to be motivated to allocate additional effort to task performance than LTA individuals.

The previous discussion serves to introduce the predictions of PET, which can be summarised as follows. Anxiety typically impairs processing efficiency more than performance effectiveness and high-anxious participants should report higher levels of subjective effort than low-anxious participants on tasks in which their performance is comparable. This greater impairment of anxiety on efficiency than on effectiveness can potentially be detected by psychophysiological measures, secondary task performance or by lengthened processing time. Increased effort will not always be able to compensate for the pre-emption of processing resources by anxiety. Any adverse effects of anxiety on task performance are therefore predicted to become stronger as task demands on working memory capacity increase.

An impressive body of research evidence within the mainstream cognitive psychology literature has been accumulated over the last 25 years that provides support for the predictions of PET (see Eysenck, 1992, 1996; Eysenck, Payne, & Derakshan, 2005; Eysenck, Derakshan, Santos, & Calvo, 2007, for reviews). However, until recently there have been very few studies in sport that have adopted PET as a theoretical framework for examining the effect of anxiety on performance (Janelle, 2002). This situation has changed over the last five years as researchers have begun to test the predictions of PET using a variety of measures of processing efficiency in a number of sport settings. These settings
include golf putting (Wilson, Smith, & Holmes, 2007a); table-tennis (Williams et al., 2002); simulated archery (Behan & Wilson, 2008); karate defence techniques (Williams & Elliott, 1999); field hockey (Wilson & Smith, 2007); volleyball (Smith, Bellamy, Collins, & Newell, 2001); climbing (Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008); and simulated racing driving (Murray & Janelle, 2003, 2007; Wilson et al., 2006; Wilson, Chattington, Marple-Horvat, & Smith, 2007b).

Measuring processing efficiency

As highlighted earlier, comparability of performance effectiveness alone may camouflage reduced processing efficiency, as such outcome measures may not be sensitive enough to reveal if and how anxiety exerts an influence on performance. However, while performance effectiveness can be relatively straightforward to measure, this is not the case for processing efficiency (Eysenck, 1992). A number of methods for assessing processing efficiency, including assessment of subjective effort, psychophysiological measures, secondary task paradigms and assessment of processing time have been adopted in the sport anxiety domain.

Subjective mental effort

The most used self-report measure in the sport psychology literature is Zijlstra’s (1993) rating scale for mental effort (RSME) (see Smith et al., 2001; Williams et al., 2002; Wilson et al., 2006; Wilson et al., 2007a, b). The RSME is a unidimensional, single report measure of effort which has robust psychometric properties and has undergone extensive validation in a range of settings (see Zijlstra, 1993). Zijlstra claimed that the RSME score may be regarded as an adequate estimation of the mental costs associated with task execution and ‘used as an operationalisation of processing efficiency’ (1993, p. 137). It consists of a vertical axis scale with a range of 0 to 150 with nine descriptive indicators along the axis ranging from 3 (not effortful) to 114 (awfully effortful). Participants are asked to mark a point on the scale that reflects the amount of mental effort invested in task performance.

The findings from studies adopting the RSME have generally supported the predictions of PET, in that participants report exerting significantly more effort in more threatening situations. This finding is robust whether the task is carried out in laboratory settings (Williams et al., 2002; Wilson et al., 2007a); using simulated tasks (Wilson et al., 2006, 2007b); or during actual game play (Smith et al., 2001). The RSME has also been sensitive enough to support PET’s predictions relating to trait anxiety differences in exerting effort. While not all studies testing PET in sport settings have considered the effects of dispositional anxiety sensitivity, those that have, have found that high trait anxious participants reported exerting more effort when their performance was similar to that of low trait anxious participants (e.g., Smith et al., 2001; Wilson et al., 2007a).

Secondary task measures

Secondary tasks are a further way in which the effects of anxiety on mental effort can be assessed (Murray & Janelle 2003, 2007; Williams et al., 2002; Wilson et al., 2007b). The secondary task is carried out concurrently, and in addition to, the primary task being examined. As both the primary and secondary tasks are assumed to utilise the same limited
resources, more than full capacity might be needed to maintain performance on the primary task (Kahneman, 1973). The degree of disruption to either primary or secondary task performance reflects the mental effort required to perform the primary task (Meshkati, Hancock, Rahimi, & Dawes, 1995).

For example, in Murray and Janelle’s (2003) simulated driving study, performance in a primary driving task was maintained under pressure, although performance of a concurrent visual search task was negatively affected. A similar result was found in Wilson et al.’s (2007b) simulated driving study, which used auditory rather than visual secondary tasks. Again, driving performance was maintained when participants were anxious at the expense of secondary task performance. These results therefore reflect increased effort being applied to the primary task in high-pressure situations, leaving less attention available to perform the secondary task. In these cases, performance effectiveness (driving speed) was maintained though at the expense of reduced processing efficiency (reduced secondary task performance).

**Psychophysiological measures**

Psychophysiology as a discipline has been driven by paradigms derived from psychology, focusing on physiological parameters that relate to psychological and behavioural states (Bernston et al., 1997). Individuals provide indirect indices of their level of mental effort through changes in the status of a number of physiological systems (Mulder, 1986). The advantages of using psychophysiological measures are that they do not require an overt response by the participant and most measures can be collected relatively continuously and unobtrusively (Veltman & Gaillard, 1996). Three psychophysiological measures of effort have recently been adopted in the sport anxiety literature in order to test the predictions of PET; heart rate variability (HRV; Wilson et al., 2007a), cognitive pupillary response (CPR; Wilson et al., 2006), and event related potentials (ERP; Murray & Janelle, 2007). HRV and CPR are so-called peripheral measures of mental effort as they reflect variations in the regulation of the autonomic nervous system, whereas ERP is a central measure of neuronal activity.

**Heart rate variability (HRV)**

The beat-to-beat fluctuation of the heart rhythm (the inter-beat interval) decreases under conditions that require increased mental effort, primarily due to changes in the baroreflex blood pressure control subsystem (Bernston et al., 1997; Mulder, 1986). Wilson et al. (2007a) used HRV as a psychophysiological index of mental effort in a study examining the effects of anxiety on golf-putting. While the authors found significant increases in reported effort, processing time and changes to pre-putt strategies, there were no significant changes in HRV for participants in low threat as opposed to high threat conditions. These results were similar to those of Mullen, Hardy, and Tattersall (2005) who also found that HRV was not able to distinguish between the attentional demands of two types of secondary task or the effect of an anxiety condition. It is possible that changes in respiratory frequency or volume (potentially as a result of a relaxation strategy), which were not controlled for in either study, may have confounded the HRV analyses (Wilson et al., 2007a).
Cognitive pupillary response (CPR)

Pupillary diameter is controlled by the combined activity of the sympathetic and parasympathetic branches of the autonomic nervous system that reflect dynamic interactions between the frontal lobes and the midbrain (Karatekin, Couperus, & Marcus, 2004). The dilation muscle, the dilator pupillae, is controlled by sympathetic pathways and as the sympathetic nervous system is associated with activation, task evoked dilation of the pupil is viewed as an attenuated correlate of mental activity (van Gerven, Paas, van Merrienboer, & Schmidt, 2004).

CPR was adopted by Wilson et al. (2006) to examine the effort exerted by participants in a simulated driving task. An Applied Science Laboratories (ASL) 501 pan-tilt gaze registration system was used to assess pupil diameter for the duration of each drive. Participants had increased pupil dilation in the high threat condition, possibly reflecting compensatory effort being applied to the task, in order to try and maintain performance effectiveness. CPR is not as frequently adopted in applied environments as HRV, as the largest changes in pupil diameter occur as a result of other factors (e.g., changes in ambient illumination and the near reflex). For this reason, it has been suggested that CPR is only suitable for laboratory tasks where such conditions can be controlled (Kramer, 1991). However, the results from Wilson et al.’s (2006) study suggest that CPR might be a useful index of mental effort in tasks where the effect of other confounding variables can be controlled.

Event related potentials (ERP)

ERP is a central measure derived from the summation of neuronal activity originating within the brain via electroencephalogram (EEG) recordings from the scalp. ERPs represent cortical activation that is time-locked to a specific stimulus, so are a useful measure of attention in dual-task environments (Murray & Janelle, 2007). Most research has utilised the amplitude and latency of positive potentials that occur minimally 300ms after stimulus presentation (P3). The amplitude of the P3 is reduced in line with an increase in the perceptual demands of the secondary task (Nash & Fernandez, 1996). Murray and Janelle (2007) examined the impact of anxiety on the amplitude of P3 for participants who were required to drive as quickly as possible in a simulator while responding to secondary visual targets (see also, Murray & Janelle, 2003). A reduction in P3 amplitude to cue onset in the visual detection task occurred during the high threat condition, suggesting a reduction in processing efficiency as participants became more state anxious. As average lap speed did not decrease in the high threat condition, the results supported PET’s central prediction that anxiety impairs processing efficiency to a greater extent than performance effectiveness (Murray & Janelle, 2007).

Processing time

Eysenck and Calvo (1992) suggested that the time taken to process information can be regarded as a measure of processing efficiency. Much of the research examining temporal efficiency in the cognitive psychology domain has used reading tasks, with both the time taken to read a section of text and the performance in questions designed to test understanding of the material being measured (e.g., Calvo, Eysenck, Ramos, & Jimenez, 1994). Calvo et al. found that although performance in a subsequent comprehension test
was similar, anxious readers required additional processing time to acquire an amount of
information equivalent to that acquired by less anxious readers.

In the sport domain Wilson et al. (2007a) adopted a similar measure when examining
the pre-putt strategies of golfers in conditions designed to manipulate the levels of anxiety
experienced. Anxious golfers took longer over their putts, demonstrating more effortful,
less efficient processing as they tried to set up cues for the location of the target in short-
term memory. Similar results have been found in climbing (e.g., Nieuwenhuys et al., 2008)
where climbers took longer to make each movement decision when they were in an anxious
as opposed to a non-anxious state.

It is evident that cognitive sport psychologists have been able to adopt (and adapt)
measures from human factors and cognitive psychology research, to test the predictions of
PET in laboratory-based sporting tasks. The various measures discussed have their
strengths and limitations, and these should be taken into account before attempting to
adopt them (see Verwey & Veltman, 1996). However, as effort can be viewed as a complex,
multi-dimensional construct the adoption of multiple measures may be necessary to gain a
complete picture as to how effort mediates the influence of anxiety on the performance of
combination of these measures is often used because it is believed that no single index can
describe adequately all subjects’ reactions to mental stress’ (p. 205). Generally, cognitive
sport psychologists have heeded this advice, as all the laboratory-based studies discussed in
this review have adopted multiple measure examinations of the predictions of PET.

**In-event tests of PET**

While the studies highlighted thus far have adopted multiple indices of mental effort, the
testing environment has been confined to laboratory settings due to the high degree of
internal control required to validly and reliably assess the attentional demands of the
various tasks adopted. In effect, this approach has been similar to that adopted in the
mainstream cognitive psychology literature where cognitive tasks are developed specifically
to enable stringent tests of PET’s predictions (e.g., Elliman, Green, Rogers, & Finch, 1997;
Eysenck et al., 2005; Ikeda, Iwanga, & Seiwa, 1996). Despite the clear relevance of PET to
sport performers competing in threatening environments, in-event testing of its predictions
has been less forthcoming. To date only Smith et al.’s (2001) study of volleyball players and
Wilson and Smith’s (2007) study of international hockey players have tested the predictions
of PET in ecologically valid, competition settings.

In Smith et al.’s 2001 study, elite volleyball players were grouped as being either low or
high trait anxious, and assessed over eight home matches involving 31 sets of volleyball.
Effort was measured using the RSME (Zijlstra, 1993) and performance was assessed using
a specially developed performance analysis system. Both low and high trait anxious players
reported increased anxiety and mental effort in more critical sets. However, the low trait
anxious players performed better in these more critical sets compared to less critical sets,
whereas their high trait anxious counterparts performed worse.

In Wilson and Smith’s (2007) study, female international hockey players taking part in
an international competition were assessed over four games categorised as more or less
threatening. Cognitive state anxiety, as indexed by the frequency of performance worry
cognitive intrusions, and subsequent mental effort expenditure were assessed using the
Thought Occurrence Questionnaire for Sport (Hatzigeorgiadis & Biddle, 2000). While
anxiety and mental effort were significantly higher in high criticality games, there was no significant reduction in performance, as assessed by expert coach ratings.

While internal control has to be sacrificed, there are clear advantages of testing the effects of anxiety on performance in such competitive settings. Researchers (e.g., Williams et al., 2002; Wilson et al., 2006) have highlighted how laboratory based manipulations cannot provide levels of ego-threat commensurate with that experienced in real, high pressure sport settings. Although researchers frequently adopt a range of manipulations (e.g., incentives, non-contingent negative feedback, observers etc.) to increase the threat experienced by participants, it may still be difficult to translate lab-based findings to stressful incidents in real sport. One reason for this is that while lab-based manipulations require multiple trials in order to determine consistent behaviour, a sportsperson may only get one chance under pressure. Thus, the degree of internal control possible with laboratory work needs to be weighed against the insights gained into the coping strategies of elite athletes during more realistic sporting situations (c.f., Woodman & Hardy, 2003).

Self-focus theories: an alternative mechanistic account

Self-focus theories provide an alternative explanation for anxiety-induced performance failures, and have also received considerable support in the sport psychology literature (e.g., Baumeister, 1984; Beilock & Carr, 2001; Gucciardi & Dimmock, 2008; Lewis & Linder, 1997; Masters, 1992). Self-focus theorists argue that pressure situations raise anxiety and self-consciousness about performing successfully, which in turn increase the attention paid to skill processes and their step-by-step control. The proposed mechanism of disruption is therefore the effortful allocation of attention to previously automated processes (Lewis & Linder, 1997). There is not space to summarise the findings of studies testing the predictions of the various self-focus theories in this paper (see, Masters & Maxwell, 2004 for a review), however, a small number of studies have tested the somewhat conflicting predictions of PET and self-focus accounts (Mullen & Hardy, 2000; Wilson et al., 2007a,b).

While the findings of these studies are generally more supportive of the predictions of PET over self-focus accounts, some of the results could be supported by either theory. For example, in Wilson et al.’s (2007a) study of golf putting, the poorer performance of the high trait anxious golfers in the high pressure condition could potentially be explained by either a self-focus or an attentional explanation. Furthermore, other studies testing distraction versus self-focus accounts of choking in motor skill tasks have been more supportive of self-focus accounts (e.g., Beilock & Carr, 2001; Gucciardi & Dimmock, 2008; Masters, 1992). It is possible, therefore, that the theories may be somewhat complimentary; self-focus accounts provide a potential explanation for how increased effort may be directed inappropriately, whereas PET may explain how increased effort can aid performance (e.g., Edwards, Kingston, Hardy, & Gould, 2002). A particular strength of PET however, is its ability to account for occasions when performance effectiveness is not significantly impaired despite heightened anxiety (e.g., Wilson et al., 2007a,b).

Direct influences on processing efficiency

The preceding discussion has focused on the basic tenet of PET that anxiety has a motivational role, whereby an anxious performer will instigate additional processing resources in order to limit the potential negative consequences of poor task performance
(Eysenck & Calvo, 1992). In this way, reduced processing efficiency can be thought of as the result of an active decision to maintain performance despite the distracting and resource intensive influence of anxiety. However, while processing efficiency can be defined indirectly in terms of the relationship between the effectiveness of performance and the effort or processing resources invested, anxiety can have a more direct influence on processing efficiency. As Janelle (2002) comments, ‘...when confronted with anxiety-inducing circumstances, the efficiency by which information is processed and acted upon decreases, potentially resulting in performance decrements’ (p. 239).

By considering this more direct impact of anxiety on the efficiency of information processing, cognitive sport psychologists have proceeded to examine PET from a different perspective than their colleagues in mainstream psychology. This approach is based on research adopting a proficiency paradigm, whereby effective (or expert) performance is categorised by more efficient attentional processing (see Hatfield & Hillman, 2001; Mann, Williams, Ward, & Janelle, 2007; Williams & Ford, 2008). By adopting gaze behaviour indices of processing efficiency in realistic settings, cognitive sport psychologists are potentially examining more direct measures of attentional control than their mainstream cognitive psychology counterparts.

Gaze behaviour indices of processing efficiency

Advances in gaze registration systems have allowed researchers to examine visual attention via gaze behaviour analyses in tasks requiring visually guided movement. During gaze registration, both the number of fixations and fixation duration are assumed to provide an index of an individual’s point of interest and relative attention allocation. The longer the eye remains fixated on a target, the more information is thought to be extracted from the display. Additionally, the number and location of visual fixations during a given period of time provides insight into the most pertinent information sources and, most likely, the environmental cues that facilitate decision-making (Vickers, 2007). Eye movements between successive fixations, known as saccades, are believed to suppress information processing (Bridgeman, Hendry, & Start, 1975). Researchers have therefore typically interpreted visual search strategies involving fewer fixations of longer duration to be more efficient, as this allows more time for information extraction.

Support for these inferences has been provided by comparing the gaze behaviour of experts and novices as they perform sporting tasks, or view video footage depicting sporting scenarios. Skilled athletes display more appropriate and efficient visual search strategies than their less skilled counterparts (Williams & Ford, 2008). Efficiency is measured in terms of low search rates characterised by relatively few foveal fixations, highlighting that experts use their knowledge base to pick out the most salient aspects of the display (Moran, Byrne, & McGlade, 2002). A less efficient search rate, as measured by an increased number of short-duration fixations has been found to be indicative of expert-novice differences in a range of sport settings (see Mann et al., 2007, for a meta-analysis of perceptual-cognitive expertise research).

Anxiety and gaze behaviour

In line with the predictions of processing efficiency theory, anxiety has been shown to reduce the efficiency of gaze behaviour in a variety of sporting tasks (Janelle, 2002). Changes in gaze behaviour provide specific insight into how visual attentional control is...
affected in threatening settings, rather than changes in the more generic concept of ‘processing efficiency’. While limited in number, the findings from such studies have been relatively consistent; with anxious participants displaying less efficient visual search strategies (e.g., Murray & Janelle, 2003; Nieuwenhuys et al., 2008) and gaze orientation behaviour (e.g., Behan & Wilson, 2008).

First, in tasks requiring the detection of peripherally presented targets, anxious performers display higher search rates, characterized by more foveal fixations of shorter duration to the target areas compared to in control conditions (e.g., Murray & Janelle, 2003; Williams et al., 2002). This finding has been taken to reflect a decrease in efficiency, as a greater number of fixations are needed to gather the same information previously acquired by fewer fixations when less anxious. Both Murray and Janelle, and Williams and colleagues were unclear as to the specific mechanisms behind this reduced efficiency in visual search; discussing the potential for both attentional narrowing (Easterbrook, 1959) and hypervigilance (Eysenck 1992) effects (see Janelle, 2002 for a discussion).

Secondly, it has also been argued that the use of foveal vision to detect movement in the periphery is inefficient, as peripheral vision can process movement-related information more rapidly (Milner & Goodale, 1995). Williams and Elliott (1999) demonstrated that while karate performers generally maintained foveal fixation on the opponent’s head while simultaneously scanning peripheral vision for task-relevant motion cues, they spent more time fixating on the peripheral threatening stimuli (i.e., the hands for the initiation of a punch or strike) when anxious. Williams et al. (2002), using a table-tennis service return task found that when anxious, participants spent longer tracking the ball with the fovea, whereas, in the low anxiety condition, the information required to guide the action was extracted from the ball’s flight path using the parafovea and peripheral vision.

The third alteration in gaze behaviour caused by anxiety is more relevant to aiming, as opposed to scanning or tracking tasks. Wilson et al. (2007a), examining a golf putting task, found that participants took more glances at the target (i.e., the hole) under conditions designed to elevate anxiety as opposed to control conditions. The authors postulated that the changes may have been due to the interference effects of worry on working memory disrupting the processing of the location and distance cues required to make a successful putt. Nieuwenhuys et al. (2008) adopting a climbing task also found that participants made more and longer fixations to target holds when anxious (i.e., on a higher traverse). This finding indicates that participants needed more time to extract relevant information from the holds when anxious; a less efficient processing strategy.

A more fine-grained analysis of the efficiency and effectiveness of aiming behaviour can be ascertained by examining the duration and timing of the final fixation prior to the initiation of movement; the quiet eye (see Vickers, 1996, 2007). Similar to search rate, where shorter duration fixations are considered to be less efficient, less efficient visual orientation may be characterized by shorter quiet eye periods. Under stressful conditions, therefore, optimal quiet eye periods are likely to be reduced, as performers adopt a less efficient strategy, consisting of more fixations of shorter duration around the target area.

To date, only Behan and Wilson (2008), using a simulated archery task, have examined the influence of anxiety on the quiet eye period from a PET perspective. The authors found that under conditions of elevated cognitive anxiety, optimal visual orientation, as indexed by quiet eye duration, was altered. Participants generally showed reductions in the duration of quiet eye, as they took more fixations around the vicinity of the target than they did in the low pressure condition. These results show that the quiet eye period is
sensitive to increases in anxiety and may be a useful index of the efficiency of visual attention in aiming tasks (Behan & Wilson, 2008).

The preceding discussion reflects the utility of adopting gaze behaviour measures to assess the efficiency of visual attention in anxiety-inducing situations. However, while the specific forms of inefficiency (e.g., increased search rate to peripheral targets, reduced quiet eye period) can be explained by current cognitive approaches, (e.g., hypervigilance; Eysenck, 1992; attentional narrowing; Easterbrook, 1959) there is no over-riding theoretical framework to explain the effect of anxiety on the efficiency of attentional control in aiming and visual search tasks. However, a recent theoretical development of PET may provide a framework by which the preceding gaze behaviour results can be interpreted, and the development of future gaze control research structured.

**Attentional control theory**

Attentional control theory (ACT; Eysenck et al., 2007) assumes that the effects of anxiety on attentional processes are of fundamental importance in understanding how anxiety affects performance. As anxiety is experienced when a current, valued goal is threatened (e.g., Power & Dalgleish, 1997), this causes attention to be allocated to detecting the source of the threat and deciding how to respond. As a result, processing resources are more likely to be diverted from task-relevant stimuli to task-irrelevant ones. This is assumed to be the case irrespective of whether these stimuli are external (e.g., environmental distractors) or internal (e.g., worrying thoughts) (Eysenck et al., 2007). The authors relate this impairment of attentional control to a disruption in the balance of two attentional systems first outlined by Corbetta and Schulman (2002); a goal-directed (top-down) attentional system and a stimulus-driven (bottom-up) attentional system. Generally, anxiety is associated with an increased influence of the stimulus-driven attentional system and a decreased influence of the goal-directed attentional system (Eysenck et al., 2007).

ACT makes more specific predictions regarding lower level functions of the central executive of working memory (Baddeley, 1986, 2001) that are related to the goal-directed attentional system. In this way, ACT overcomes some of the limitations of PET in terms of its lack of precision or explanatory power. While PET suggested that anxiety impairs the processing efficiency of the central executive of working memory, ACT is more precise about the specific functions of the central executive which are most adversely affected by anxiety; namely, the ‘inhibition’ and ‘shifting’ functions (Miyake et al., 2000). The inhibition function involves using attentional control to resist disruption or interference from task-irrelevant stimuli (negative control), whereas the shifting function involves using attentional control to shift the allocation of attention to remain focused on task-relevant stimuli (positive control). It is the impaired functioning of these elements of attentional control (i.e., inhibition and shifting) which is proposed to disrupt the balance between the goal-directed and stimulus-driven attentional systems (Eysenck et al., 2007).

The central prediction of PET, that anxiety impairs processing efficiency more than performance effectiveness, is still retained within ACT. The processing inefficiency caused by the disruption of the inhibition and shifting functions of the central executive does not necessarily lead to decrements in performance effectiveness provided that anxious individuals respond by using compensatory or alternative processing strategies (Eysenck et al., 2007). In outlining future directions for research into ACT, Eysenck et al. discussed the need for investigation into the strategies used by anxious individuals when their
processing becomes inefficient. The alterations in gaze control strategies discussed earlier may provide an opportunity to accomplish this.

Theoretical implications

While some of the specific hypotheses of ACT require relatively ‘controlled’ tasks to isolate the particular functions of the central executive (i.e., inhibition and/or shifting), the theory potentially provides a broader framework for understanding how anxiety may impact on attentional control in more applied settings. Cognitive sport psychologists, with their experience of examining gaze behaviour indices, are ideally placed to test the predictions of ACT in such environments. Future research should therefore attempt to examine how attentional control may be impaired in threatening sporting environments due to an increased influence of the stimulus-driven attentional system at the expense of goal-directed control.

To date, there have been no studies published in the mainstream cognitive psychology literature which have considered the predictions of ACT, although Eysenck et al. (2007) refer to a number of studies which are currently under review. In the sport domain, Nieuwenhuys et al.’s (2008) study of sport climbing referred to the predictions of ACT, however the study was primarily a test of the predictions of PET. The more specific predictions related to impairment of the inhibition function of the central executive, for example, were not considered. Wilson, Vine and Wood (under review) have explicitly tested the predictions of ACT using a basketball free-throw task and the quiet eye period as an objective measure of attentional control. The findings suggested that anxiety impaired the ability of the participants to maintain their goal directed attention on the relevant target location for long enough to process the critical direction and force information required for successful performance. Quiet eye durations were reduced in the threatening condition as participants made more, shorter duration fixations to locations around the target area, with a subsequent drop in performance effectiveness (reduced free-throw percentage accuracy).

More research is therefore required to test the predictions of ACT using a variety of gaze indices in a range of sport settings. For example, an interesting issue raised by ACT is that increased anxiety, and subsequent increased impact of the stimulus-driven attentional system, may not always be detrimental to task performance. While tasks benefiting from a focused orientation of visual attention may be impaired by increased anxiety, performance on tasks in which the stimulus-driven attentional system is particularly influential for performance is likely to be enhanced by anxiety. As anxiety produces preferential attention to, and more rapid detection of, threat-related stimuli (and also to slow disengagement from such stimuli), beneficial effects of anxiety on performance are especially likely when the task involves responding to threat-related stimuli (Eysenck et al., 2007). Testing these predictions on tasks requiring the avoidance of ‘objects’ (e.g., invasion sports), may therefore provide interesting insights into the functionally facilitative influences of anxiety on task performance.

Practical implications

As discussed previously, there have been few studies which have investigated the predictions of PET in ecological environments. However, while PET is primarily a mechanistic theoretical development, it may also provide a framework to support sport psychology
applied work (Wilson & Smith, 2007). PET suggests that feeling nervous, anxious or concerned before competing should not necessarily be considered to be debilitating to performance (c.f., Hardy, 1997). Performers can consider their anxiety to be a useful motivating force, helping them to achieve their goals. The idea that increased anxiety about the aversive consequences of future events might be motivational and an activity that can also be associated with constructive problem solving has been considered in other applied support environments.

For example, McCaul, Mullens, Romanek, Erickson, and Gatheridge (2007) tested a strategy to encourage cigarette smokers to think more frequently about the negative consequences of smoking, reasoning that increasing such thoughts might lead to greater worry and motivation to quit. The participants were prompted (via a programmed alarm watch) at various times during the day to think about different negative consequences associated with smoking. Participants reported increased worry and reports of intrusive thoughts, which had a small but reliable effect on plans to quit.

If athletes are going to experience heightened levels and frequency of worrisome thoughts nearing an event, this worry might as well have a useful purpose (i.e., used for constructive problem solving). For example, performers can use worry about upcoming threatening situations as an opportunity to work on ‘What if...?’ strategies (e.g., Hardy, Jones, & Gould, 1996, p. 170), for how they would like to deal with the situation. In-event, performers can focus effort on ‘controlling the controllables’ in order to cope with the distracting nature of cognitive intrusions (e.g., Hardy et al., 1996; Wilson & Richards, in press).

This second point, regarding dealing with distractions when anxious, can be further developed with the aid of gaze behaviour training techniques. A number of studies have demonstrated the utility of training specific gaze behaviours in order to improve performance in sport settings (e.g., Adolphe, Vickers, & Laplante, 1997; Harle & Vickers, 2001; Williams, Ward, & Smeeton, 2004). The current discussions suggest that such training programmes may also be a useful intervention to enhance attentional control in stressful environments, perhaps as part of a suitably developed pre-shot routine (e.g., Wilson & Richards, in press). By actively maintaining effective gaze behaviour, the negative effects of anxiety on visual attentional control and subsequent performance may be alleviated (Behan & Wilson, 2008).

Conclusions

The purpose of this paper was to review the literature which has examined the predictions of PET (Eysenck & Calvo, 1992) in the sport psychology domain. While the theory was developed primarily for cognitive tasks over 15 years ago, it has received recent interest from cognitive sport psychologists adopting gaze behaviour measures to assess the efficiency of attentional control and information processing. It is evident that the findings from much of this research can be explained by the recent development of PET to consider more explicitly the effect of anxiety on attentional control (ACT; Eysenck et al., 2007). Future research should therefore continue to examine such direct attentional measures of efficiency and attentional control, while also attempting to provide more ecologically valid tests of the theories’ predictions.
References


