The role of effort in influencing the effect of anxiety on performance: Testing the conflicting predictions of processing efficiency theory and the conscious processing hypothesis

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The aim of this study was to test the conflicting predictions of processing efficiency theory (PET) and the conscious processing hypothesis (CPH) regarding effort’s role in influencing the effects of anxiety on a golf putting task. Mid-handicap golfers made a series of putts to target holes under two counterbalanced conditions designed to manipulate the level of anxiety experienced. The effort exerted on each putting task was assessed though self-report, psychophysiological (heart rate variability) and behavioural (pre-putt time and glances at the target) measures. Performance was assessed by putting error. Results were generally more supportive of the predictions of PET rather than the CPH as performance was maintained for some performers despite increased state anxiety and a reduction in processing efficiency. The findings of this study support previous research suggesting that both theories offer useful theoretical frameworks for examining the relationship between anxiety and performance in sport.

Anxiety’s influence on performance continues to be one of the main research interests for sport psychologists (Hanin, 2000). Anxiety has consistently been viewed as an emotion characterized by negative affect that impairs motor performance (Eysenck, 1996). In extreme cases, this can lead to ‘choking’; the acute performance decrements that occur under circumstances of heightened incentive for good performance (Baumeister, 1984). Two recent theories offer frameworks through which a better understanding of the anxiety–performance relationship may be gained; the conscious processing hypothesis (CPH) (Masters, 1992) and processing efficiency theory (PET) (Eysenck & Calvo, 1992).

The CPH is a self-focus theory which suggests that pressure situations raise anxiety and heighten self-consciousness about performing successfully. This heightened self-consciousness causes performers to attempt to control previously automated skilled movements to ensure they are performed correctly.

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behaviour consciously. In doing so, the control disrupts the fluency associated with expert performance (Masters, 1992). By ‘reinvesting’ in the knowledge base that supports performance, the process causes a breakdown of automated movement units into a more consciously controlled sequence of smaller, separate units. This process slows performance and creates opportunity for error at each transition between units (Masters, 1992).

In contrast, PET predicts that cognitive anxiety, in the form of worry, reduces the processing and storage capacity of working memory, reducing the resources available for a given task. This prediction is similar to those of distraction theories (such as cognitive interference theory; Sarason, 1988), which propose that worry causes a diversion of attention from task-relevant cues. PET further predicts that, as well as occupying working memory capacity, worry may stimulate increases in on-task effort, compensating for reduced performance effectiveness. 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, where processing efficiency refers to the relationship between the effectiveness of performance and the effort or processing resources invested (Eysenck & Calvo, 1992).

Research into the influence of anxiety on sport performance has mainly focused on sensorimotor skills in an attempt to explain choking under pressure (Beilock & Carr, 2001). As an example of such a skill, golf putting has recently been used to test the competing predictions of distraction and self-focus explanations of choking. A series of studies by Beilock and Carr demonstrated that choking occurred as a result of explicitly monitoring the mechanics of the putting stroke in response to self-consciousness and achievement anxiety. The authors proposed that performance pressure elicited maladaptive efforts to impose step-by-step monitoring and control of procedural knowledge that would have run more automatically and efficiently had the monitoring not intervened.

In a follow-up study, Beilock, Carr, MacMahon, and Starkes (2002) used two separate dual tasks to provide further support for self-focus effects. In the distraction task, participants had to perform a secondary auditory-tone monitoring task while putting. In the skill-focused task, participants had to say ‘stop’ aloud when they felt they were at the end of the follow-through of their putting swing. The results showed that putting performance was not affected by completing the distraction task. When participants had to attend to a specific component of the golf swing, they experienced performance decrements in comparison to both single-task practice performance and distraction conditions. It was claimed that these results demonstrated that performance of well-learned tasks could be compromised by attending to skill execution, whereas, attention was available for the processing of distracting secondary task information.

Recent studies of golf putting by Mullen and colleagues (e.g. Mullen & Hardy, 2000; Mullen, Hardy, & Tattersall, 2005) have adopted a similar design to Beilock et al.’s (2002) study in order to test the predictions of the CPH. Mullen et al. adopted two secondary tasks which were conducted concurrent to the putting task: a ‘task relevant’ condition where participants concentrated on a self-generated verbal cue (e.g. ‘short back, firm through’, ‘count 1–2’) for each putt, and a ‘task irrelevant’ condition in which participants had to count the number of high pitched tones delivered during the putt. These were compared with a single task condition where golfers were instructed to putt normally. In contrast to the findings of Beilock et al., the results from this study were more supportive of a distraction as opposed to a self-focus explanation of anxiety. Performance was impaired in the high anxiety task relevant and task irrelevant conditions.
Both distraction and self-focus theories attempt to account for performance declines. However, it is important to note that the support for the predicted negative influence of cognitive anxiety on sports performance is less than would be expected (e.g., Carver & Scheier, 1988; Clark III, 2002; Collins & Smith, 1997). In the recent Mullen et al. (2005) study, in the single task condition, mean putting error was lower in the high anxiety compared with the low anxiety condition. As the single task condition provided the closest approximation to ‘real’ golf putting, this may be the most relevant finding. In support of this finding, in a study of golf tournament performance, McKay, Selig, Carlson, and Morris (1997) found no support for the view that cognitive anxiety negatively influences performance. Cognitive anxiety prior to competition improved performance of the 18-hole score compared with a baseline performance.

While the CPH cannot fully explain these findings, PET can account for the facilitative influences of anxiety on performance through compensatory mental effort. Most of the support for PET’s predictions comes from research in mainstream psychology; particularly on tasks with high mental demand (see Eysenck, 1996 for a review). For example, in a study involving a reading task, Calvo, Eysenck, Ramos, and Jiminez (1994) found no performance differences in comprehension score between a group of low trait anxious (LTA) and high trait anxious (HTA) readers during a reading test. However, HTA individuals used less efficient reading techniques (longer reading time, more verbalizations and more reading regressions) than their LTA counterparts.

While PET has been primarily applied to the examination of test anxiety, it is broad enough to have application for motor tasks (Calvo & Ramos, 1989; Eysenck & Calvo, 1992; Murray & Janelle, 2003). It is relevant to tasks which place demands on the working memory system and as Eysenck and Calvo highlight, ‘there are probably very few tasks which make no demands at all on the working memory system’ (p. 428). Most sporting tasks require information to be stored and processed either during or before their completion and there is the potential for anxiety to affect these processes. The predictions of PET have recently been tested in a variety of sport settings including golf putting (e.g., Mullen & Hardy, 2000), table-tennis (e.g., Williams, Vickers, & Rodrigues, 2002) and simulated rally racing (e.g., Murray & Janelle, 2003; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006).

The predicted influence of mental effort on performance differs considerably between PET and the CPH (Hardy, 2002). The CPH predicts that increased effort leads to performance decrements as attention is transferred to effortful, higher order, controlled processes (Mullen & Hardy, 2000; Mullen et al., 2005). From a PET perspective, increasing effort on a task may partially or completely compensate for the distracting effects of anxiety (Eysenck & Calvo, 1992). Rather than being viewed as a form of regression of control, effort is viewed as a form of active coping, whereby concern over suboptimal performance leads to the allocation of additional processing resources to tasks, or the initiation of alternative processing strategies (Eysenck & Calvo, 1992).

There have been few attempts to explore the different predictions of the two theories using validated measures of effort. Although Mullen and Hardy’s (2000) study considered the predictions of PET, it was reported as a secondary aim, conducted using a single-item, non-validated, self-report measure of effort. In a more recent study, Mullen et al.’s (2005) single-task results supported the predictions of PET, although, surprisingly, no reference to the theory was made. The authors improved upon their original study by including a psychophysiological index of mental effort – heart rate variability (HRV). Although rarely used in sport psychology research, measures of HRV have been employed in human factors research examining fundamental links between
psychological processes and physiological functions (e.g. Bernston et al., 1997; Izso & Lang, 2000). Previous research (see Jorna, 1992 for a review) has found that the beat-to-beat fluctuation of the heart rhythm, the inter-beat interval (IBI), decreases under conditions that require increased mental effort or conscious processing.

HRV is influenced by a number of different physiological systems. Therefore, studies investigating mental effort have utilized spectral analyses to decompose the total variation of a data series into its frequency components (Jorna, 1992). When this frequency analyses is performed on IBI data, the signal is decomposed into components that can be associated with three major biological mechanisms (Mulder, 1992). The frequency band 0.07–0.14 Hz has been identified as most sensitive to mental effort and has been used successfully to detect differences between task complexity in laboratory studies (Mulder, Mulder, Meijman, Veldman, & Van Roon, 2000), flight studies involving pilots (Veltman & Gaillard, 1996; Veltman, 2002) and driving studies (e.g. De Waard, Van der Hulst, & Brookhuis, 1999). Data lower than 0.07 Hz are considered unreliable to variations in mental effort as they are affected by linear and non-linear trends (e.g. temperature regulation). Data above 0.14 Hz tend to be affected by variations in respiratory activity (Mulder et al., 2000).

The aim of this study was to test the conflicting predictions of PET and the CPH regarding the role of effort in influencing the effects of anxiety on golf putting performance. The study adopted multiple, validated indices of effort (see Hilburn & Jorna, 2001; Izso & Lang, 2000; Mullen & Hardy, 2000), in an attempt to understand which theory may offer the stronger explanation for anxiety’s influences on performance. A further objective for the study was to adopt a more ecologically valid design to test the theories. Rather than adopt a dual-task design (e.g. Beilock et al., 2002; Mullen & Hardy, 2000; Mullen et al., 2005), the golfers were free to prepare and execute each putt as they chose. This allowed for the analysis of their behaviour and invested effort while preparing to putt.

The decision to include behavioural measures was based primarily on the findings of Calvo et al.’s (1994) research into comprehension in reading tasks. They found that although performance in a comprehension test was similar, HTA readers required additional processing time to acquire an amount of information equivalent to that acquired by LTA readers. Similarly, golfers who take longer over their putts may be demonstrating more effortful, less efficient processing as they try to set up cues for the location of the target and also for the distance of the target in short-term memory. Although putting will not place as great a demand on working memory capacity as reading, the preparation phase of the putt can be resource intensive. It has been suggested that while the execution of a motor skill itself may be automatic, other crucial aspects of performance, such as scanning and decision making, may have a significant cognitive component (Konttinen & Lyytinen, 1993).

Further support for an examination of increased pre-putt time under threat comes from Masters’ (1992) original study testing the predictions of the CPH. Masters found that the time taken to complete a series of putts was longer in a high pressure as opposed to low pressure condition. Masters did not examine this finding in terms of working memory effects, but reflected that performers slowed down in the evaluative situation in order to minimize errors. Combining the findings of both the Calvo et al. (1994) and Masters (1992) studies, it is proposed that the reduction of transient storage capacity caused by anxiety (Eysenck & Calvo, 1992) will cause a similar effect in the motor task of putting as the cognitive task of reading.

A more detailed analysis of the participants’ behaviour in the period between addressing the ball and initiating the backswing was also carried out. Calvo et al. (1994)
found that as well as taking longer to read the passages, the high anxious readers also made more reading regressions of the text as they rechecked what they had previously read. Similarly, recent research in sporting environments (e.g. Murray & Janelle, 2003) has used changes in visual search strategies to show effortful and less efficient processing. Murray and Janelle found that although task performance did not suffer under anxiety-inducing conditions, participants required more fixations to peripheral targets in completing the task, compared with control conditions. From a golf perspective, Vickers' (1992) putting study also found that in the final seconds of the pre-putt movement, poorer putters adopted a similar inefficient strategy, categorized by more and shorter duration glances at the hole.

Both the CPH and PET predict that state anxiety will be higher in incentive conditions owing to the perceived increased threat in the environment. PET also predicts that the reported state anxiety of LTA golfers would be lower than that of HTA golfers. Both theories also state that increased anxiety will result in an increase in mental effort; reinvestment in conscious processing in the CPH and the motivational function of anxiety in PET. In the current study, the predicted increase in effort may be shown through increases in self-report, behavioural and psychophysiological indices. Furthermore, PET also predicts that HTA participants should exert higher levels of mental effort (or demonstrate lower efficiency) than LTA participants on tasks on which their performance is comparable.

There are also some similarities with regards how the two theories predict anxiety will influence performance. If performance decreases with increased effort investment, support would be offered for the CPH. However, PET can also account for this finding. Increased effort may not be sufficient to compensate for the debilitating effects of anxiety on performance effectiveness (i.e. processing efficiency and performance effectiveness might be degraded). PET would predict that negative effects of anxiety on performance effectiveness are more likely for HTA performers as they are likely to have higher levels of cognitive anxiety in threatening situations. If, however, performance is maintained or improved under conditions where anxiety is raised and this is associated with increased effort, support would be provided for the predictions of PET alone. The CPH cannot account for a positive effect of increased effort on performance effectiveness.

Method
Participants
Eighteen golfers aged 19–60 (mean age = 38.6 years, SD = 16.61) volunteered to take part in this study. All participants were right-handed golfers with a handicap range of 10–18 (mean handicap = 14.3, SD = 2.77). Medium-handicap golfers were chosen as evidence suggests (e.g. Mullen & Hardy, 2000) that they may be more likely to be influenced by the anxiety manipulations used in the study while still being of sufficient ability to be consistent in putting performance. The participants had the study explained to them in written and verbal form. They provided written informed consent prior to participation. The study was approved by the local institutional ethics committee.

Measures
Trait anxiety
The Sport Anxiety Scale (SAS) (Smith, Smoll, & Schutz, 1990) was used to measure multidimensional sport competition trait anxiety. The SAS consists of 21 items which
measure reactions to competition that are rated on a four-point scale. These items are divided into three subscales: nine items measuring somatic anxiety; seven items measuring worry; and five items measuring concentration disruption. The subscales demonstrate high internal consistency and test–retest reliability; reported to be .77 for the full scale and .71, .70 and .68 for the somatic anxiety, worry and concentration disruption scales, respectively (Smith et al., 1990). For the purpose of this study, only the cognitive anxiety subscale of the SAS was used to classify participants as either high or low in trait cognitive anxiety (cf. Smith, Bellamy, Collins, & Newell, 2001).

**Competitive state anxiety**

The Mental Readiness Form-Likert (MRF-L) was developed by Krane (1994) as a shorter and more expedient alternative to the Competitive State Anxiety Inventory-2 (CSAI-2: Martens, Burton, Vealey, Bump, & Smith, 1990) and has been used to obtain anxiety measures immediately prior to and during performance. As Thomas, Hanton, and Jones (2002) have highlighted, the ability to access in-event anxiety states is critical to testing the predictions of PET. The MRF-L has three, bipolar, 11-point Likert scales which are anchored between: worried to not worried for the cognitive anxiety scale; tense to not tense for the somatic anxiety scale; and confident to not confident for the self-confidence scale. Krane showed correlations between the MRF-L items and the CSAI-2 subscales of .76 for cognitive anxiety, 0.69 for somatic anxiety and .68 for self-confidence. Since the aim of the present study was to investigate the mechanism(s) for the role of worry and effort in influencing performance, the cognitive anxiety scale of the MRF-L provided the main focus for the research (cf. Smith et al., 2001).

**Effort: Self-report measure**

Self-reported mental effort was measured using the Rating Scale for Mental Effort (RSME) (Zijlstra, 1993). The reliability of the scale across a range of laboratory and real-life settings has been shown to be acceptable ($r = .88$ in laboratory and $r = .78$ in work settings (Zijlstra, 1993)). The scale has also been found to correlate strongly with validated psychophysiological indices of mental effort, for example, spectral variations in heart period variability (Zijlstra, 1993). The RSME consists of a vertical axis scale with a range of 0–150, with nine descriptive indicators ranging from 3 (not effortful) to 114 (awfully effortful). Participants are asked to mark a point on the scale which reflects the amount of mental effort invested in task performance.

**Effort: Psychophysiological measure**

Heart rate was monitored throughout each block of putting using a short-range telemetry method (POLAR S810). This comprised a transmitter attached around the chest and a receiver on the wrist. IBIs were calculated automatically by the equipment during each recording epoch (the time taken to perform the putt in each condition). The first and last 30 seconds of recorded data were removed from analysis, as these data are most likely to be affected by non-stationarity (cf. Jorna, 1992). The raw IBI data was filtered using the automatic algorithm in the Polar Precision Performance SW analysis software, set at moderate filtering level. The algorithm uses median and moving average-based filtering methods to substitute detected errors with corrected values. A preview function allowed the first author to examine the filtered data alongside the raw data before accepting changes. Results for all participants, across all conditions, showed that
the percentage of IBIs that fell outside this correction rate and required smoothing was sufficiently low (mean percentage = 1.5, SD = 1.23).

The smoothed data were analysed with HRV Analysis Software (Biomedical Signal Analysis Group, University of Kuopio, Finland) (Niskanen, Tarvainen, Ranta-Aho, & Karjalainen, 2004). Frequency domain analysis used an autoregressive statistical method. Optimal autoregressive model order was calculated using the forward backward linear least squares method, which indicated a fixed model order of 16 (see Niskanen et al., 2004). To remove the influence of a large low frequency baseline trend component, detrending of the data was performed using a smoothness prior based method (Taraveinen, Ranta-Aho, & Karjalainen, 2002). Frequency domain power is presented in ms².

Effort: Behavioural measures
The first of two behavioural measures used in the study was the time taken for the participants to initiate their backswings once they had ‘addressed’ the ball. Preparation time was measured by counting video frames (50 Hz field rate) from when the participant first lined up the putt (i.e. first observable glance at the target) until the performer started the backswing. A more detailed analysis of each participant’s behaviour was conducted in the period between addressing the ball and initiating the backswing. The mean number of glances at the target was measured by frame analysis of covert video footage for each participant.

Performance
Absolute error from the hole served as the performance outcome measure (cf. Beilock & Carr, 2001; Mullen & Hardy, 2000). Mean absolute error was calculated for each series of putts. Adhesive markers were used to mark the final position of the ball on each putt and a tape measure used to measure the distance from the hole at the end of each series of putts. The markers were removed after measurement.

Apparatus
Testing took place on a 5 × 4-metre carpeted indoor putting green (Verdegrass LE92P, Verde Sports, UK). Standard size (4.27-centimetre diameter), competition standard white golf balls were used by all participants. Participants used their own putters. A Panasonic MS4 video camera with a shutter speed of 1/2000 was used to film the putters’ set-up, 90° to the mark from which they putted from. This camera remained in the same position throughout the testing period.

Experimental conditions
Each participant performed under two counterbalanced conditions: a low pressure and a high pressure condition. In the low pressure condition, non-evaluative instructions were provided to participants asking them to ‘try and get the ball as close to the hole as possible’. To emphasize the non-evaluative nature of the environment further, participants were told that the purpose of this part of the study was to collect data on the characteristics of the putting carpet. They were also told that their putting scores would be grouped with the other participants and compared with putting data that would be gathered from a grass putting green at a later date.
In the high pressure condition, the participants were made aware of the video camera. Participants were informed that the video of their putting strokes would be analysed by a golf professional to check for swing faults and to be scored with reference to an expert’s putting stroke. They were also informed that their putting score would be normalized for ability and compared with the scores of the other participants in the study. A league table of results was created and displayed on their golf course notice board. Participants were also informed that the winner of this phase of the study would be awarded £50 prize money. This type of experimental manipulation using ego-threatening instructions has been shown to be successful in raising anxiety in a number of golf-based studies (e.g. Hardy, Mullen, & Jones, 1996; Masters, 1992; Mullen & Hardy, 2000).

The video camera collected visual search data throughout the testing period. However, the experimenter overtly demonstrated turning it on and off for the high pressure condition. The red LED that illustrated that the camera was recording was masked to avoid identifying its presence during performance.

Procedure
After providing their written informed consent, participants completed the SAS (Smith et al., 1990) and were ranked with reference to their trait anxiety. Participants attended individually for the testing session and were informed that the researcher was interested in the effects of different conditions on putting performance. The participants had their chests swabbed with alcohol before the heart rate monitor was attached. The POLAR electrodes were coated in electrode gel to reduce impedance. They completed a 5-minute habituation period on the putting surface and then sat quietly reading a golfing magazine for 7 minutes to allow a baseline resting heart rate and IBI to be obtained from the middle 5 minutes (cf. Jorna, 1992).

Following this period, the experimental team explained the self-report measures to the participants. Previous research has indicated that education is important if single report measures of anxiety are adopted (Thomas et al., 2002). Participants were then taken through a familiarization condition in which they completed the specific testing protocol. This was to ensure that all participants had a chance to familiarize themselves with the specific putts to be adopted and the process of reporting their mental effort and state anxiety levels before the testing phase began.

The putting task required participants to putt a golf ball, as accurately as possible, from a mark on the carpet surface to five different Professional Golf Association regulation holes, 10.8 centimetres in diameter, set at different angles to the mark. Two of the holes were 3 metres away (at 35° to the left and 45° to the right of the mark); two were 3.3 metres away (at 20° left and 25° to the right) and one was 3.6 metres away from the mark (perpendicular to the mark).

This arrangement was similar to that adopted by Beilock and Carr (2001). However, in their study only one hole was used and the golfer moved to various positions. In the present study, measurement of cardiac function required extraneous movement to be minimized to reduce the potential confounding effects of physical activity masking mental effort effects on HRV (Jorna, 1992). Participants followed a random alternation of putting to the five holes. Each hole was numbered and the participants were informed by the researcher which target to aim for before each putt.

With the exception of the content of the evaluation instructions, the procedure was identical for both conditions. Each participant provided a self-report of their pre-performance anxiety levels by completing the MRF-L prior to commencing the 20-putt
series. Following the first 10 putts, participants provided a self-report measure of the mental effort they invested in the previous putts, using the RSME, and again reported their MRF-L value before completing a further 10 putts. After the second series of 10 putts, the RSME was administered to determine the effort involved in making the second series of 10 putts. The value for the self-reported data, used in the analysis for each condition, was the mean of the two series. Allowing participants to report anxiety and effort levels at the mid-point of the testing condition was proposed to overcome some of the problems associated with using only pre-competition measures of self-report variables (e.g., Jones, 1995). The single-item self-report measures allowed measures of anxiety and effort to be taken in a short break during the competition period.

Data analysis
To determine the effect of manipulation of pressure on performance and effort variables, scores for the dependent variables were analysed with a mixed design 2 × 2 ANOVA (condition [low pressure, high pressure] × trait anxiety [LTA, HTA]). The independent grouping variable of trait anxiety was included to determine whether participants high in trait anxiety were more affected by the manipulation, as would be predicted by PET. The cardiac data was subjected to a mixed design 3 × 2 ANOVA to include the resting condition cardiac data in addition to the two putting conditions (cf. Veltman & Gaillard, 1996). Effect sizes (γ) for main effects were calculated as outlined in Howell (1987) using control condition (low pressure) standard deviation for repeated measure effects and pooled standard deviation for independent group effects. Significant interaction effects were followed up by analysing the difference scores between conditions (high threat–low threat) for each group, using an independent t test (α < .05).

Results
Self-reported trait anxiety (SAS)
Participants’ scores on the cognitive subscale of the SAS were used to divide the group at the median point of the scores obtained (cf. Smith et al., 2001). As a consequence, two groups were identified: LTA (N = 9; mean SAS score = 12.4, SD = 2.72 on the cognitive anxiety subscale) and HTA (N = 9; mean SAS score = 18.5, SD = 2.01 on the cognitive anxiety subscale). An independent t test on the two groups’ scores confirmed anxiety distinction between the two groups (t(16) = 5.01, p < .001).

To ensure that the trait anxiety distinction used in the analyses was not confounded by playing ability (measured by handicap or familiarization condition performance), two independent t tests were carried out. The mean handicap for each group was identical (mean handicap = 14.3, SD = 3.33, for LTA and mean handicap = 14.3, SD = 2.32, for HTA participants) and, therefore, t(16) = 0.00, p = 1.00. For baseline performance (measured by performance in the familiarization condition) the mean distance from the hole for the LTA grouping was 18.6 cm, SD = 6.06 cm and 16.6 cm, SD = 3.61 cm for the HTA golfers. This difference was not significant (t(16) = 0.83, p = .42).

Self-reported state anxiety (MRF-Likert)
ANOVA revealed significant main effects for test condition (F(1, 16) = 18.32, p < .01, γ = 0.65), demonstrating that the manipulation of anxiety was successful. There was also a significant main effect for trait anxiety grouping (F(1, 16) = 146.84, p < .01,
γ = 4.47) and a significant interaction effect \(F(1, 16) = 5.26, p < .05\). Although both groups were more anxious in the competitive condition this effect was more marked for the HTA participants \(t(16) = 2.29, p < .05, \gamma = 1.15\). The self-report state anxiety ratings for the HTA and LTA groups are presented in Figure 1.

**Self-reported effort (RSME)**

ANOVA revealed a significant main effect for condition \(F(1, 16) = 33.53, p < .01, \gamma = 0.45\), but not for trait anxiety grouping \(F(1, 16) = 1.01, p = .33, \gamma = 0.15\). Tukey HSD tests indicated that this significant effect for condition was evident for both groups: LTA \(p < .005\), HTA \(p < .001\). A significant interaction effect was also evident \(F(1, 16) = 18.86, p < .01\). Although both groups reported significantly higher effort in the competitive condition, this effect was more marked for the HTA golfers \(t(16) = 4.32, p < .01, \gamma = 2.18\). The RSME effort ratings for the HTA and LTA groups are presented in Figure 2(a).

**Heart rate variability (Low frequency power)**

The \(3 \times 2\) ANOVA conducted on the HRV data revealed a significant main effect for condition \(F(2, 32) = 6.16, p < .01\). Subsequent post-hoc analyses (Tukey HSD) indicated that there were significant differences between resting HRV and high pressure HRV \(p < .05\) and between resting HRV and low pressure HRV \(p < .05\). The difference between the low pressure HRV and the high pressure HRV was not significant \(p = .87\). There was no significant main effect for trait anxiety grouping \(F(1, 16) = 2.00, p = .18\) and no significant interaction effect \(F(2, 32) = 0.10, p = .90\). The HRV results for the HTA and LTA groups are presented in Figure 2(b).

**Time to initiate backswing**

ANOVA of the time taken to initiate the backswing of the putt once the ball had been addressed revealed a significant main effect for test condition \(F(1, 16) = 16.92, p < .01, \gamma = 0.55\) but not for trait anxiety grouping \(F(1, 16) = 0.26, p = .62\). The interaction effect between condition and grouping approached significance \(F(1, 16) = 3.12, p = .09\), with the HTA golfers taking relatively longer than their
The pre-shot times for the HTA and LTA groups are presented in Figure 3(a).

**Number of glances at target during the pre-shot period**

ANOVA of the number of glances at the target hole during the pre-shot routine revealed a significant main effect for test condition ($F(1, 16) = 9.71, p < .01, \gamma = 0.30$) but not for trait anxiety grouping ($F(1, 16) = 0.11, p = .75$) or for the interaction effect ($F(1, 16) = 2.23, p = .16$). All golfers made more glances at the target hole in the high pressure condition. The mean data for the number of glances at the target hole are presented in Figure 3(b).

**Performance data**

ANOVA of the performance error (distance from the hole) data revealed no significant main effects for condition ($F(1, 16) = 1.50, p = .247, \gamma = 0.14$) or grouping variable ($F(1, 16) = 2.25, p = .16, \gamma = .59$). The interaction effect approached significance ($F(1, 16) = 4.11, p = .08$). LTA golfers’ performance was slightly higher in the high pressure condition whereas HTA golfers’ performance was worse than in the low pressure condition ($t(16) = 1.92, p = .08, \gamma = 0.97$). Tukey HSD post hoc tests indicated that the LTA participants’ improvement in performance under threat was not
significant \( p = .52 \), but that the performance decrements for the HTA participants under threat was significant \( p < .05 \). The performance error scores for both groups are presented in Figure 4.

**Discussion**

The main aim of this study was to test the predictions of the CPH (Masters, 1992) and PET (Eysenck & Calvo, 1992) in golf putting. Although both theories have received recent attention in the sport psychology literature, there has been little research examining the apparently conflicting predictions of the two theories. A second aim was to investigate the role of mental effort in the anxiety-performance relationship.

**Cognitive state anxiety**

The cognitive anxiety data (MRF - Figure 1) supports the effectiveness of the experimental manipulations in elevating worry. Further, the significant interaction effect found provides support for PET’s prediction that dispositionally high anxious performers worry more in threatening situations than LTA performers. Eysenck and Calvo (1992) have proposed that high anxious individuals tend to devote more of their processing resources to worry, therefore increasing the probability of detecting a
mismatch between expected and actual performance. This means that HTA individuals are more motivated than LTA individuals to allocate additional effort to task performance. As the CPH also considers effort (in the form of additional processing resources) to increase when performers are anxious, a number of indices (self-report, behavioural, psychophysiological) were adopted as concomitants of mental effort/conscious processing. These are discussed below.

Mental effort

With regards the self-reported effort data (RSME – Figure 2a), there was a significant main effect for condition. Both groups reported exerting significantly more mental effort in the high pressure, compared with the low pressure condition. This supported the predictions of both theories. There was also a significant interaction effect evident, indicating that the HTA golfers reported expending relatively more effort in the high pressure condition, supporting the specific predictions of PET.

The HRV data (Figure 2b) did not support the hypothesis that effort would be greater under pressure. HRV was only sufficiently sensitive to distinguish between rest and task changes in mental effort and not differences between the task conditions. This finding was similar to Mullen et al.’s (2005) results. In their study, mid-frequency band power 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 the task of putting may introduce non-stationarity into the IBI time series owing to respiratory effects which were not controlled for in either study. In this respect, Veltman and Gaillard (1996) have highlighted that sudden increases in respiratory volume (e.g. employed as a somatic anxiety relaxation strategy) will increase the HRV in the low frequency band (0.07–0.14 Hz) even when the frequency of the respiratory cycle is outside this band (0.14–0.4 Hz). Future research using HRV as an index of mental effort in sporting tasks should consider respiration effects.

Pre-putt behaviour

The strategic behavioural measures of effort adopted – time spent setting up the putts (Figure 3a) and glances at the target during this time (Figure 3b) revealed significant effects for condition. All golfers were less efficient in their pre-putt behaviour in the high threat condition; taking longer over their putts and making more rechecking glances at

Figure 4. Performance error as measured in centimetres from the hole that the ball came to rest.
the target. These main effects for condition are consistent with the self-reported effort data and are similar to Calvo et al.'s (1994) findings for reading comprehension. The increase in the time taken to initiate a putt once the ball had been addressed supports Eysenck and Calvo's (1992) postulation that impaired processing efficiency produced by anxiety can be detected by lengthened processing time. Further support is also provided for research which has examined the effect of anxiety on visual search behaviour (e.g. Murray & Janelle, 2003; Wilson et al., 2006). Increased anxiety led to a less efficient visual search strategy categorized by more glances back to the target location than were required when not anxious.

Previous research in sport (e.g. Jackson & Baker, 2001) has found that pre-performance routines may increase in time when the performer feels under pressure, supporting the findings of this study. PET argues that this additional time is 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. Research by Laabs (1973) investigating memory of the location and distance of a target in a simple point and position task provides support for this viewpoint. Laabs' research demonstrated that distance cues are especially susceptible to rapid decay. Memory of distance decayed in a few seconds without interference and in a much faster time when interference was introduced. As previously discussed, PET proposes that anxiety consumes resources in working memory and reduces transient storage capacity (Eysenck & Calvo, 1992). This potentially causes anxious golfers to have to recheck the distance and position of the target from the ball, or affect the outcome of the putt (too long or too short). Therefore, the behavioural measures adopted in this study offer insight into how golfers may adopt different pre-putt strategies to try and compensate for the debilitating effects of worry on working memory.

**Performance**

The final hypothesis sought to investigate whether there were different effects of anxiety and effort on performance. Both theories predict similar findings regarding the anxiety and effort data but the effects on performance can be diametrically opposed. The non-significant main effect for condition supports the predictions of PET rather than the CPH, as it suggests that performance effectiveness was maintained at the expense of processing efficiency. Such a pattern of results has been shown to be supportive of the predictions of PET in previous research in mainstream psychology (e.g. Elliman, Green, Rogers, & Finch, 1997; Ikeda, Iwanga, & Seiwa, 1996) and sporting contexts (e.g. Murray & Janelle, 2003).

It is evident, however, that when examined in isolation the HTA golfers did not maintain their performance in the high threat condition. As these golfers also reported significantly more effort and had significantly less efficient pre-putt behaviour, this result could be explained by both the CPH and PET. The CPH would propose that the increased effort exerted by these golfers focused inwards in an attempt to control their putting technique (Masters, Polman, & Hammond, 1993). From a processing efficiency standpoint the compensatory effort exerted was not sufficient to overcome the deficits in working memory caused by the high anxiety experienced by the HTA individuals. A number of studies testing PET in sporting contexts have found similar findings, whereby performance effectiveness as well as processing efficiency were negatively affected by increased anxiety for HTA participants (e.g. Smith et al., 2001; Wilson et al., 2006).

It is difficult to determine therefore, which theory best explains the performance results for the HTA individuals. Although it may be reasonable to consider controlled
processing as a direct function of the amount of mental effort invested (as suggested by Mulder, 1986 and Zijlstra, 1993), this analysis proposes that indices of effort can be equated directly to indices of conscious processing. Given that mental effort is often considered a multidimensional construct (e.g. Hart & Staveland, 1988) it is unlikely that such a simplification of the data can be made. One way in which future research might determine explicitly whether increased effort leads to conscious processing is by examining changes in the movement patterns of individuals performing motor skills under anxiety. However, although recent research investigating movement parameters in wall-climbing tasks by Pijpers, Oudejans, Holsheimer, and Bakker (2003) and Pijpers, Oudejans, and Bakker (2005) has supported the predictions of the CPH, previous research has failed to identify consistent patterns of regression for movement patterns under pressure (e.g. Mullen & Hardy, 2000 in golf putting; and Williams et al., 2002 in table-tennis). Care must therefore be taken to ensure that appropriate and sensitive movement measures are adopted.

To conclude, this study analysed the role of mental effort in influencing anxiety’s effect on performance. Both PET and the CPH have shown promise as theoretical frameworks for examining the relationship between anxiety, effort and performance in motor tasks. Indeed, in a recent study investigating theoretical explanations of catastrophic performances in sport, Edwards et al. (2002) concluded that, ‘In total, the findings suggest that the best explanation currently available may be a combination of processing efficiency theory and the conscious processing hypothesis’ (p. 14). The current study is the first to compare the predictions of the two theories while adopting multiple, validated measures of effort.

The performance results for the LTA individuals challenge recent research which has investigated golf putting under pressure (e.g. Beilock & Carr, 2001; Mullen & Hardy, 2000). Instead of being debilitating to performance, increased effort on the task for these individuals compensated for the negative influence of anxiety on performance, as predicted by PET. The results for the HTA individuals could be explained by either theoretical position, as it was not possible to ascertain whether their decline in performance while anxious was due to conscious processing or attentional resource effects. These findings suggest that owing to its consideration of compensatory effort, PET may be more flexible than the CPH in explaining performance effects due to pressure. However, further research is required to determine which theory might offer the best explanation as to how anxiety may influence performance across different tasks and for different populations. It may also be interesting to examine links between increased effort deployment and conscious processing, as highlighted by Edwards et al. (2002). This should lead to a greater understanding of how the CPH and PET may combine and interact to explain both performance maintenance and decrements under threat.

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Anxiety, effort, and putting performance


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