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Anxiety-induced performance catastrophes: Investigating effort required as an asymmetry factor

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Two studies are reported that test the hypothesis that previous support for the cusp catastrophe model of anxiety and performance, and the hysteresis effect in particular, could have been due to a complex interaction between cognitive anxiety and effort required rather than between cognitive anxiety and physiological arousal. We used task difficulty to manipulate effort required in a letter transformation task. Experiment 1 ($N = 32$) used high levels of trait anxiety together with a competitive environment to induce state anxiety. Experiment 2 ($N = 20$) used a competitive environment with social pressure and ego threat instructions to induce high levels of worry. Both studies revealed significant three-way interactions as hypothesized with follow-up tests showing some support for the hysteresis hypothesis in Study 1, and strong support for the hysteresis hypothesis in Study 2. The findings support a processing efficiency theory explanation of anxiety-induced performance catastrophes and indicate that two cusp catastrophe models of performance may exist; one that incorporates the interactive effects of cognitive anxiety and physiological arousal upon performance and the other that incorporates the interactive effects of cognitive anxiety and effort required upon performance.

Research has repeatedly revealed that high levels of cognitive anxiety can have a detrimental effect upon a number of (varying) tasks and situations. Anxiety has been shown to impair performance on memory tasks, including letter transformation (e.g. Eysenck, 1985) and letter span tasks (e.g. Parfitt & Hardy, 1993), as well as complex motor tasks such as indoor climbing (Pijpers, Oudejans, & Bakker, 2005) and free-throw shooting in basketball (e.g. Hardy & Parfitt, 1991). However, positive anxiety effects have also been recorded on motor tasks (e.g. Calvo & Alamo, 1987), anagram-solving tasks (e.g. Blankstein, Toner, & Flett, 1989), and both free-throw and rebound shooting in basketball (e.g. Hardy & Parfitt, 1991; Parfitt & Hardy, 1993). One model that attempts to provide at least some level of explanation for these contradictory findings is Hardy's (1990) cusp catastrophe model.

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Catastrophe theory was originally developed by the French mathematician René Thom (1975) to model geometrically all the naturally occurring discontinuities in the world. Hardy (1990) proposed the cusp catastrophe model of anxiety and performance as a means of explaining the mixed and apparently contradictory findings that had previously been reported regarding the effects of anxiety upon performance (for reviews, see Eysenck, 1992; Parfitt, Jones, & Hardy, 1990). The model is based on the view that performance anxiety is a multidimensional construct combining a cognitive component, 'negative expectations and cognitive concerns about oneself, the situation at hand and potential consequences' (Morris, Davis, & Hutchings, 1981, p. 541), and a physiological arousal component, defined in this context as 'the organism's natural physiological response to anxiety-inducing situations' (Hardy, 1990, p. 85). The cusp catastrophe model uses this multidimensional conceptualization to predict interactive effects for cognitive anxiety (worry) and physiological arousal upon performance in a three-dimensional model (see Figure 1).

The model proposes that a series of four relationships exists between cognitive anxiety, physiological arousal and performance (Hardy, 1990, 1996). First, it is proposed that cognitive anxiety (worry) has a positive relationship with performance when physiological arousal is low (left face of the model). Second, cognitive anxiety will have a negative relationship with performance when physiological arousal is high (right face of the model). Third, when cognitive anxiety is low, physiological arousal has an inverted U-shaped relationship with performance (see the back face of the model). Finally, when cognitive anxiety is high, increased levels of physiological arousal lead to a catastrophic drop in performance from the upper performance surface (A) to the lower performance surface (B), as indicated by the front face of the model. Furthermore, once this catastrophic drop in performance has occurred, a large reduction in physiological arousal is required to bring performance back on to the upper performance surface. Thus, a central prediction of the catastrophe model is that when cognitive anxiety is high, the path followed by performance is different when physiological arousal is increasing (see path 1 in Figure 1) to the path followed by performance when physiological arousal is decreasing (see path 2 in Figure 1). This horizontal displacement of behaviour (performance) is termed hysteresis, and should occur under conditions of high cognitive anxiety but not under conditions of low cognitive anxiety. Support for the hysteresis effect has been found in both the studies that have directly tested it

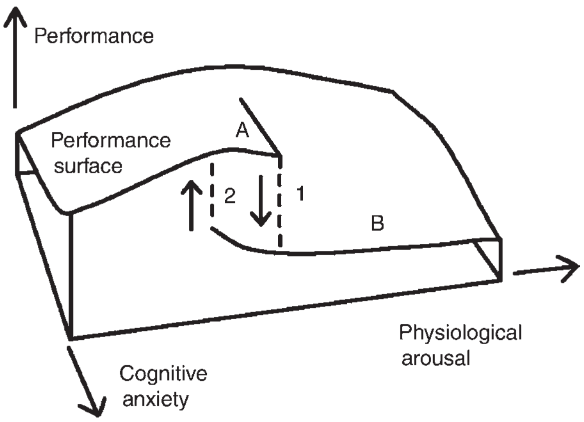

Figure 1. Cusp catastrophe model.

(Hardy & Parfitt, 1991; Hardy, Parfitt, & Pates, 1994). Other predictions of the model have also received some empirical support from various studies of motor performance (see, for example, Edwards & Hardy, 1996; Hardy & Parfitt, 1991; Hardy, Woodman, & Carrington, 2004; Woodman, Albinson, & Hardy, 1997).

Despite some encouraging support, criticisms have been levelled at the model. For example, Gill (1994) criticized the model on its difficulty to test owing to its apparent complexity. Furthermore, while attempting to test the predications of the cusp catastrophe model, Cohen, Pargman, and Tenenbaum (2003) found no support for the hysteresis hypothesis on an indiscriminate dart-throwing task. They claimed that the cusp catastrophe model 'lacks the sound framework necessary to examine the effects of multidimensional anxiety and physiological arousal on motor performance' and that, 'the model fails to provide a tool for accurately describing performance catastrophes' (p. 155). However, Cohen *et al.* failed to include cognitive anxiety as a moderator variable in their test of hysteresis (a basic requirement) and also failed to provide any statistical evidence to support their claims against the hysteresis hypothesis (Woodman & Hardy, 2005). In a later paper, Tenenbaum and Becker (2005) also raised a number of other unsubstantiated criticisms regarding the cusp catastrophe model that Woodman and Hardy summarily dismissed.

One further criticism of research into the hysteresis hypothesis is, however, valid. In previous tests of the hysteresis hypothesis by Hardy and associates (Hardy & Parfitt, 1991; Hardy *et al.*, 1994), physiological arousal was manipulated by means of physical exercise and monitored by measuring heart rate; that is to say, athletes performed under conditions of low and high cognitive anxiety with their heart rate increasing from maximum – 40 beats per minute, to maximum heart rate. Consequently, it is possible that the physiological arousal recorded in these studies reflected the physical effort required to perform the task rather than anxiety-induced physiological arousal (Hardy, 1999). Owing to this possibility, Hardy suggested that there was some ambiguity about the precise nature of the asymmetry factor in the cusp catastrophe model. On the basis of the available evidence, it could be anxiety-induced physiological arousal, exercise-induced physiological arousal, exercise-induced effort or anxiety-induced effort.

In this context, Eysenck and Calvo's (1992) processing efficiency theory is worthy of some consideration. A main prediction of processing efficiency theory is that worry pre-empts some of the processing and storage resources of a limited capacity working memory system (Baddeley, 1986). One consequence of this is that any adverse effects of worry on task performance should be greater on tasks that exert large demands on the capacity of the working memory system. A second important prediction of processing efficiency theory is that worry or cognitive anxiety can serve a motivational function. More specifically, the anxious performer may attempt to increase effort and thereby activate additional processing resources if he/she feels that performance is, or may be, substandard. If successful, such increases in effort increase the available working memory and, consequently, may enhance performance (Eysenck & Calvo, 1992). However, according to earlier versions of the theory (e.g. Eysenck, 1982), increased effort will only occur when performers perceive themselves to have at least a moderate subjective probability of success; that is to say, when they are at least moderately confident. Thus, according to processing efficiency theory, anxiety typically impairs processing efficiency (task performance divided by effort) more than it impairs task performance – hence the theory's name. The predictions of processing efficiency theory have received empirical support from a number of studies (e.g. Calvo, Eysenck, Ramos, & Jiménez, 1994; Derakshan & Eysenck, 1998; Kellogg, Hopko, & Ashcraft, 1999; Murray & Janelle, 2003; Smith, Bellamy, Collins, & Newell, 2001).

Hardy and Parfitt (1991) used the above arguments to suggest that processing efficiency theory could provide one explanation of how cusp catastrophes might occur. As worry (cognitive anxiety) and effort required increase, one might reasonably expect that a point would be reached where performers would no longer perceive themselves to have a moderate subjective probability of success, and so would then withdraw their effort from the task at hand. Once performers have given up in this way, they might need to perceive a considerable reduction in the quantity of effort required before they would feel it worthwhile reinvesting effort in the task. In this way, processing efficiency theory can explain both the sudden decrements in performance and the occurrence of hysteresis predicted by the catastrophe model, provided one assumes that physiological arousal is a reflection of effort required by the task. In fact, Eysenck (1992) argues that this is exactly what the physiological response associated with anxiety is – a reflection of compensatory effort.

In light of the above arguments, the present paper reports two experiments that test Hardy's (1999) assertion that previous evidence in support of the cusp catastrophe model could reflect a complex interaction between cognitive anxiety, (level of) effort required and the direction of change of effort required (rather than between cognitive anxiety and physiological arousal). In order to place attentional demands upon both processing and storage resources of the working memory system (Eysenck & Calvo, 1992), the criterion measure for both studies was a letter transformation test (Hamilton, Hockey, & Rejman, 1977). Experiment 1 used high levels of trait anxiety (Spielberger, Gorsuch, & Lushene, 1970) together with a competitive environment to induce state anxiety. Experiment 2 used a competitive environment with social pressure and ego-threat instructions to induce worry. In both studies, effort required was manipulated by means of task difficulty. It was predicted that hysteresis would occur under conditions of high cognitive anxiety/worry but not under conditions of low cognitive anxiety/worry.

EXPERIMENT 1

Method

Participants

Two hundred and ninety-eight undergraduates from the University of Wales, Bangor, UK, agreed to complete the trait scale of the State-Trait Anxiety Inventory (STAI; Spielberger *et al.*, 1970; see below). Thirty-two participants (18 males and 14 females; *M* age = 20.01, *SD* = 2.63) were further selected on the basis of extreme scores on the trait version of the STAI. Sixteen participants (6 male and 10 female; *M* age = 20.10, *SD* = 2.41) were classified as high trait anxious with all having trait scores of 50 or above (*M* = 55.87, *SD* = 2.68) and 16 (12 male and 4 female; *M* = 19.90, *SD* = 2.89) were classified as low trait anxious with all having trait scores of 28 or below (*M* = 24.86, *SD* = 2.79). Previous research has reported using similar values (e.g. Eysenck & Byrne, 1992; Mogg, Mathews, Bird, & Macgregor-Morris, 1990).

Measures

State Trait Anxiety Inventory

The trait version of Spielberger *et al.*'s (1970) State-Trait Anxiety Inventory was used to assess trait anxiety. The trait part of the inventory has 20 items and uses a Likert-type format with the scale ranging from 1 (*almost never*) to 4 (*almost always*), so that a score between 20 (low) and 80 (high) is recorded for each individual. According to Spielberger, Gorsuch, Lushene, Vagg, and Jacobs (1983), the trait anxiety norms for United States college students is a mean of 38.3 and 40.4 for males and females, respectively. Internal consistency of the measure for college-based students was reported between .73 and .86 (Spielberger *et al.*, 1983).

Competitive State Anxiety Inventory-2

As the nature of the anxiety manipulation included a competitive environment, state anxiety was measured using the Competitive State Anxiety Inventory-2 (Martens, Burton, Vealey, Bump, & Smith, 1990). The CSAI-2 was used in previous tests of the model (Hardy & Parfitt, 1991; Hardy *et al.*, 1994). This inventory contains 27 items, 9 for each of the three subscales (self-confidence, cognitive anxiety and somatic anxiety). The 27 items are measured using a Likert-type scale ranging from 1 (*not at all*) to 4 (*very much so*). Thus, the range of possible scores for each subscale is from 9 (low) to 36 (high). The internal consistency for the three subscales has been demonstrated in several studies with alpha coefficients ranging from 0.79 to 0.90 (Martens *et al.*, 1990). For the purpose of the present study, only the data from the cognitive anxiety subscale were retained for analysis.

Task

Letter transformation task

A letter transformation task (Eysenck, 1985; Hamilton *et al.*, 1977) was used to manipulate effort required (via task difficulty). The task required participants to transform a series of random letter strings (ranging from 1 to 5 letters) a given distance of +4 and within the range of A to V. For example, if a participant was asked to transform one letter e.g. the letter A, the answer would be E (A + 4= E). If a participant was asked to transform five letters e.g. FCRHU, the answer would be JGVLY (FCRHU + 4= JGVLY). Letters were randomly generated by means of a Q-Basic45 program and were presented on a computer monitor.

In one-letter trials, when the letter appeared on the monitor a timer would start, participants would press the return key to clear the screen, type in their response and then press the return key, at which point the timer would stop. When the task required two or more letters to be transformed the participant would press the return key to see the first letter, at which point the timer would start, the participant would then press the return key again to see the second letter (at which point the first letter disappeared) and so on. After seeing all the letters, the participant keyed in their total response one letter at a time, and then stopped the timer by again pressing the return key. Time taken and the percentage of letters correct were used as performance measures.

The participants were given verbal and written instructions on the computer screen immediately before the trial started. The instructions stated that they were required to work through the following problems at a transformation distance of +4. They were asked to wait until they had seen all the letters in each problem before they started transforming them. They were also informed they had to transform all the letters before they could type in the answer. Finally, they were also asked to perform the task as quickly and accurately as possible, as a combination of time taken and correct responses would be used as their performance measure. The next time they pressed the return key the trial would begin. At this point the first letter appeared on the screen.

Procedure

Participants attended two sessions approximately 1 week apart. The first session was a practice session that participants attended individually. This session enabled participants to familiarize themselves with the task, after which written consent was obtained. At the end of the first session, participants were asked to attend a second session a week later in order to complete the study.

This first session consisted of four practice trials at each difficulty level starting with one letter, then two, three, four and five. This was then repeated in reverse order (i.e. five, four, three, two and one). After these practice trials participants had a practice session that was the same as the testing session. For these trials, participants completed 10 trials at each level from one letter through to five and then from five through to one. To counterbalance for order of presentation of direction, half the participants completed the practice session with difficulty increasing and then decreasing (one to five and then five to one letters) and the other half completed the study with difficulty decreasing and then increasing (five to one and then one to five letters).

In the second session, unbeknown to the participants, two participants were timetabled to be present at each of the trials. Upon entering the room, the two participants were told that they would be competing against each other. They were also told that the winner of the session would be entered into a league where the top three performance scores would win cash prizes of £75, £50 and £25 for first, second and third place, respectively. The loser of the session would get nothing. They then sat side by side at two computers separated by a large screen. The participants had a warm-up session consisting of two trials at each of the five levels in their respective directions (i.e. task difficulty increasing then decreasing or vice versa). At the end of the warm-up session, the CSAI-2 was administered. The testing followed immediately with half the participants completing the trials with difficulty increasing then decreasing and the other half completing the trials with task difficulty decreasing then increasing. After every 10 trials at each level, participants were provided with feedback from the monitor on percentage of letters correct and time taken. Each participant was blind to the others' score throughout the study.

Results

Trait anxiety

As mentioned in the Method, the means (and standard deviations) for the low and high trait anxiety groups were 24.86 (± 2.79) and 55.87 (± 2.68), respectively. An independent samples t test showed this difference to be highly significant $t(30) = 32.19, p < .001$.

State anxiety analysis

To test whether the high trait anxiety group had higher levels of state anxiety than the low trait anxiety group, an independent samples *t* test was conducted on the cognitive anxiety subscale of the CSAI-2. For the low trait anxiety group, the mean (± *SD*) for cognitive state anxiety was 14.12 (± 4.73). For the high trait anxiety group, the mean (± *SD*) for cognitive state anxiety was 21.86 (± 3.31). An independent samples *t* test showed that this difference was highly significant $t(30) = 5.25$, $p < .001$. Thus, by using high and low levels of trait anxiety coupled with a competitive environment two distinct cognitive anxiety groups were successfully created. Throughout the rest of the study these two groups are referred to as high or low cognitive anxiety groups.

Performance analysis

To test the hypothesis that hysteresis would occur under conditions of high cognitive anxiety but not under conditions of low cognitive anxiety, two separate three-factor mixed-model analyses of variance ($2 \times 2 \times 5$), with repeated measures on the last factor, were conducted on the two performance scores (i.e. percentage letters correct and total time taken for each 10-trial block). The independent variables were cognitive anxiety (high vs. low), direction (effort required increasing vs. effort required decreasing), and task difficulty level (one letter strings to five letter strings). The Wilks' lambda estimate from the multivariate solution was used for all repeated measures terms.

Percent letters correct

Results revealed no significant main effects for anxiety $F(1, 30) = .00$, $p = .95$ ($\eta^2 = .000$); or direction $F(1, 30) = 0.77$, $p = .38$ ($\eta^2 = .025$). However, results revealed a highly significant main effect for difficulty, $F(4, 27) = 16.65$, $p < .001$ ($\eta^2 = .712$). There were no significant interactions between direction and anxiety group $F(1, 30) = 0.06$, $p = .80$ ($\eta^2 = .002$); or between difficulty and anxiety group $F(4, 27) = 0.31$, $p = .86$ ($\eta^2 = .045$); or between direction and difficulty $F(4, 27) = 1.06$, $p = .39$ ($\eta^2 = .137$). However, as hypothesized, a significant three-factor interaction occurred between direction, difficulty and anxiety group, $F(4, 27) = 2.75$, $p < .05$ ($\eta^2 = .290$).

To explore the three-factor interaction, follow-up tests were conducted in both the high and low cognitive anxiety conditions. The hysteresis hypothesis predicts that under conditions of high anxiety the path followed by performance when effort required (task difficulty) is increasing should be different to the one it follows when effort required is decreasing. More specifically, in the high anxiety condition, there should be a significant drop in performance in the increasing condition and a significant jump in performance in the decreasing condition; however, the significant jump up in the effort decreasing condition should be at a lower level of effort than that at which performance dropped in the effort increasing condition. Conversely, under low anxiety, performance paths in the increasing and decreasing conditions should be relatively smooth and superimposed.

Tukey's HSD *post hoc* tests were performed by hand. A probability level of $< .05$ was used in all follow-up tests. As previous tests of the cusp catastrophe model have shown that hysteresis effects only occur at high levels of physiological arousal (cf. Hardy & Parfitt, 1991; Hardy *et al.*, 1994), follow-up tests were carried out only on levels three, four and five, where hysteresis is predicted to occur. In the high cognitive anxiety group there was a significant drop in performance of 9.21% in the increasing condition between levels four and five. This was accompanied by a significant jump in performance of 11.06% in the decreasing condition between levels four and three. No other differences were significant (see Table 1).

Table 1. Performance cell means (standard deviations) for percentage correct in the increasing and decreasing conditions of both high and low state anxiety groups

	Scores % correct			
	High state anxiety group		Low state anxiety group	
	Direction		Direction	
	Increasing	Decreasing	Increasing	Decreasing
Difficulty level				
Level 1	91.87% (16.01)	92.50% (16.12)	95.62% (6.29)	91.25% (14.08)
Level 2	85.62% (18.96)	87.50% (20.00)	87.18% (10.48)	89.06% (13.19)
Level 3	82.26% (22.46)	83.09% (19.50)	86.61% (7.12)	82.05% (17.03)
Level 4	77.96% (22.38)	72.03% (25.25)	76.09% (14.54)	75.15% (17.06)
Level 5	68.75% (27.37)	64.62% (22.94)	61.12% (13.79)	65.37% (20.24)

In the low state anxiety group there were significant drops in performance in the effort increasing condition of 10.52% between levels three and four, and 14.97% between levels four and five. This was followed by a significant jump in performance in the decreasing condition of 9.78% between levels five and four. No other differences were significant (see Table 1).

Time taken

The results for time taken revealed a highly significant main effect for difficulty, $F(4, 27) = 53.21$, $p < .001$ ($\eta^2 = .887$) showing that as difficulty increased time significantly increased. However there was no significant main effect for anxiety $F(1, 30) = 1.05$, $p = .30$ ($\eta^2 = .034$); or direction $F(1, 30) = 0.21$, $p = .64$ ($\eta^2 = .007$). The interactions revealed no further significant findings; direction and anxiety group $F(1, 30) = 1.61$, $p = .21$ ($\eta^2 = .051$); difficulty and anxiety group $F(4, 27) = 1.04$, $p = .40$ ($\eta^2 = .134$); direction and difficulty $F(4, 27) = 1.31$, $p = .29$ ($\eta^2 = .163$); or direction, difficulty and anxiety group $F(4, 27) = 0.37$, $p = .82$ ($\eta^2 = .052$) (see Table 2 for means and standard deviations).

Discussion

Results revealed the hypothesized significant three-way interaction between anxiety, direction and effort required. Follow-up tests suggested that hysteresis did occur in

Table 2. Performance cell means (standard deviations) for time taken in the increasing and decreasing conditions of both high and low state anxiety groups

	Time taken			
	High state anxiety group		Low state anxiety group	
	Direction		Direction	
	Increasing	Decreasing	Increasing	Decreasing
Difficulty level				
Level 1	4.48	3.98	4.06	3.89
	(1.37)	(1.00)	(0.76)	(0.55)
Level 2	10.24	9.82	10.32	9.46
	(3.24)	(3.03)	(1.92)	(2.67)
Level 3	18.01	17.23	17.84	16.33
	(6.54)	(5.88)	(4.95)	(6.47)
Level 4	26.48	27.40	24.17	23.98
	(8.16)	(8.86)	(8.66)	(7.87)
Level 5	35.58	36.34	32.14	30.09
	(12.84)	(10.80)	(13.37)	(11.39)

the high cognitive anxiety condition. In the low anxiety condition, performance paths were hypothesized to be relatively smooth and superimposed. Follow-up tests revealed that there were significant drops in performance in the increasing condition between levels three to four and four to five. This was matched by a significant jump in the decreasing condition between levels five and four, but there was no matching significant jump between levels four and three. However, although performance paths were not as smooth as hypothesized, it should be noted that the decrease in percentage correct from level three to four (10.5%) was not hugely different from the increase in percentage correct from level four to three (6.9%).

One weakness in the design of Experiment 1 may have been the anxiety manipulation. We used high levels of trait anxiety and a competitive environment to induce high levels of state cognitive anxiety. The competitive environment consisted of two individuals competing against one another (with performance scores being confidential), where the winner had the opportunity to receive a cash prize. However, winning the competitive session only resulted in a slim chance of winning some prize money. Furthermore, the consequences of poor performance with this manipulation were quite low. For example, if halfway through the experiment participants did not feel that they had any chance of success, they could withdraw effort from the task without any major apparent consequences other than wasted time.

Experiment 2 aimed to extend and clarify the present findings. It used a social anxiety manipulation where prize money was awarded on the basis of both team and individual scores as opposed to just an individual's score. With this manipulation, failure in one's own performance would become detrimental to the whole team. Making performance public (rather than confidential) should, according to previous research, increase task importance, effort and persistence (Seijts, Meertens, & Kok, 1997).

EXPERIMENT 2

Method

Participants

Forty undergraduates from the University of Wales, Bangor, UK, volunteered for the study. There were 33 males and 7 females aged 18–35 years ($M = 20.76$, $SD = 2.84$).

Measures

Worry-Emotionality Inventory

The measure of state anxiety used in Experiment 1 was changed for Experiment 2. As the CSAI-2 was conceptualized and developed within a sport setting, we had concerns that it might not be the most appropriate measure to use in a non-sport laboratory setting with a non-sport task. State anxiety was therefore measured using Morris *et al.* (1981) revised Worry-Emotionality Inventory (WEI). The WEI is a measure of state test anxiety separating worry (cognitive anxiety) from emotionality (the somatic response to anxiety). The inventory has five items in each subscale and is scored on a Likert-type format ranging from 1 (*The statement does not describe my present condition very well*) to 5 (*The statement describes my present condition very well*). Thus, a score of 5 (low) to 25 (high) can be recorded for each participant. The internal consistency for the WEI has been shown to be high with alpha coefficients exceeding 0.80 (Skinner & Brewer, 1999). For the purpose of this study, only the data from the worry subscale were retained for analysis.

Task

The same letter transformation task was used as in Experiment 1.

Procedure

In case participants withdrew effort from the task in Experiment 1 because of no apparent consequences other that wasted time, Experiment 2 was designed to increase the consequences of doing so. Participants were tested in eight teams of five; each team attended two sessions approximately 1 week apart. The first session was identical to that described in Experiment 1, with the only difference being that participants attended in groups of five rather than alone. The second session used a competitive environment to elevate worry. To achieve this, at the start of the second testing session each team was told that they would compete against the other teams for a cash prize of £50. However, the prize would be offered only to the highest scoring member of the highest scoring team. It was emphasized that each participant was part of a team and that it was the team's average score that would determine the winner. Consequently, if an individual performed poorly then the team's average score would suffer, thus lessening the chances of any individual from that team winning. At the start of the main testing session participants were reminded that their individual scores would be compared with those obtained from their other team members. Each individual was also told that a full report of the results would be circulated to each team member after the experiment. Furthermore, as each team member was seated side by side, each was aware of the others' progress throughout the study. At the start of the second session, the team had a warm-up consisting of two trials at each of the five levels in their respective directions (difficulty increasing then decreasing, or difficulty decreasing then increasing). At the end of the warm-up, the WEI was administered, followed immediately by the commencement of the competitive test.

Results

State worry analysis

In order to create two highly distinct worry groups, the participants were median split on the worry subscale of the WEI, with the middle 20 worry scores removed. This left 20 participants for the final analysis, 16 males and 4 females (*M* age $= 20$, $SD = 2.44$). The mean age ($\pm SD$) for the high worry group was 20.60 (± 3.21) and consisted of 8 males and 2 females. The mean age for the low worry group was 19.40 (± 1.17) and consisted of 8 males and 2 females. The means ($\pm SD$) for the worry scores were 16.82 (± 1.83) for the high worry group and 6.64 (± 1.32) for the low worry group. An independent samples t test confirmed that this difference was highly significant $t(18) = 14.28$, $p < .001$.

Performance analysis

The main performance data were analysed in exactly the same way as in Experiment 1 using a three-factor (worry × direction × difficulty level) analysis of variance with repeated measures on the final factor.

Percent letters correct

Results revealed no significant main effects for anxiety $F(1, 18) = .53$, $p = .47$ ($\eta^2 = .029$); or direction $F(1, 18) = 1.05$, $p = .31$ ($\eta^2 = .055$). However, results revealed a highly significant main effect for difficulty, $F(4, 15) = 15.25$, $p < .001$ ($\eta^2 = .803$). There was no significant interaction between direction and anxiety group $F(1, 18) = 0.05$, $p = .82$ ($\eta^2 = .003$); or between difficulty and anxiety group $F(4, 15) = 0.57$, $p = .68$ ($\eta^2 = .132$); or between direction and difficulty $F(4, 15) = 1.05$, $p = .41$ ($\eta^2 = .219$). However, as hypothesized, a significant three-factor interaction occurred between direction, difficulty and anxiety group, $F(4, 15) = 3.37$, $p < .05$ ($\eta^2 = .474$).

To explore the three-factor interaction, follow-up tests were conducted on the high and low worry conditions. As in Experiment 1, it was hypothesized that, in the high worry condition, there would be a significant drop in performance in the effort increasing condition and a significant jump in performance in the effort decreasing condition; this significant jump should be at a lower level of effort required than where it dropped in the increasing condition. In the low worry condition, performance paths in the effort increasing and effort decreasing conditions were hypothesized to be relatively smooth and superimposed.

Tukey's HSD *post hoc* tests were performed by hand. A probability level of $< .05$ was used in all follow-up tests. Results revealed that, in the high worry group, there was a significant drop in performance of 15.15% in the effort increasing condition between levels four and five. This was accompanied by a significant jump in performance of 13.73% in the effort decreasing condition between levels four and three. No other significant differences were revealed (see Table 3).

Table 3. Performance cell means (standard deviations) for percentage correct in the increasing and decreasing conditions of both high and low worry groups

	Scores % correct			
	High state anxiety group		Low state anxiety group	
	Direction		Direction	
	Increasing	Decreasing	Increasing	Decreasing
Difficulty level				
Level 1	100% (.00)	99% (3.16)	96% (8.43)	98% (4.21)
Level 2	95% (4.08)	92% (7.14)	90% (11.54)	88% (6.32)
Level 3	85.66% (12.67)	88.98% (7.71)	81.31% (15.89)	80.31% (17.25)
Level 4	82.75% (10.50)	75.25% (9.46)	76% (17.99)	77.50% (20.74)
Level 5	67.60% (13.05)	69.60% (16.93)	69.80% (22.59)	65.40% (28.42)

In the low worry condition there was one marginally significant jump in performance of 12.10% in the decreasing condition between levels five and four. No other significant differences were revealed (see Table 3).

Time taken

The results for time taken revealed a highly significant main effect for difficulty, $F(4,\ 15) = 32.68,\ p < .001\ (\eta^2 = .897)$ showing that as effort increased time significantly increased. However, there was no significant main effect for anxiety $F(1,\ 18) = .05, p = .83\ (\eta^2 = .003)$; or direction $F(1,\ 18) = 0.27, p = .60\ (\eta^2 = .015)$. The interactions revealed no further significant findings; direction and anxiety group $F(1,\ 18) = 0.96,\ p < .34\ (\eta^2 = .051)$; difficulty and anxiety group $F(4,\ 15) = 1.28$, $p = .32\ (\eta^2 = .255)$; direction and difficulty $F(4,\ 15) = 1.35,\ p = .29\ (\eta^2 = .265)$; direction, difficulty and anxiety group $F(4,\ 15) = 0.65, p = .63\ (\eta^2 = .148)$ (see Table 4 for means and standard deviations).

Discussion

The findings replicated those of Study 1, in that there was a significant three-way interaction between worry, direction and task difficulty. Additionally, the hysteresis effect in the high worry condition was rather clearer in Experiment 2 than Experiment 1, as was the absence of hysteresis in the low worry condition.

GENERAL DISCUSSION

The main aim of the present study was to test Hardy's (1999) proposition that previous evidence of performance catastrophes could reflect a complex interaction between

Table 4. Performance cell means (standard deviations) for time taken in the increasing and decreasing conditions of both high and low worry groups

	Time taken			
	High state anxiety group		Low state anxiety group	
	Direction		Direction	
	Increasing	Decreasing	Increasing	Decreasing
Difficulty level				
Level 1	3.61	3.97	3.94	4.19
	(0.62)	(0.92)	(0.98)	(1.00)
Level 2	11.13	11.54	12.74	12.14
	(2.75)	(4.43)	(4.38)	(3.66)
Level 3	20.85	20.48	22.06	22.89
	(4.93)	(5.95)	(8.36)	(9.99)
Level 4	31.46	34.66	32.46	29.24
	(10.77)	(14.18)	(16.87)	(9.10)
Level 5	43.33	49.49	41.52	41.31
	(15.34)	(23.40)	(23.45)	(15.77)

cognitive anxiety, effort required and direction of change in effort required rather than between cognitive anxiety and physiological arousal. According to early versions of Eysenck and Calvo's (1992) processing efficiency theory (e.g. Eysenck, 1982), the potentially positive motivational effects of cognitive anxiety should only occur if participants perceive themselves to have at least a moderate probability of success. In the present study, it was hypothesized that when worry was high, as effort required increased, there would come a point when high anxious individuals would no longer perceive themselves to have a moderate probability of success, and would therefore withdraw effort from the task. Furthermore, once performers had given up in this way, it was hypothesized that they would then require a considerable reduction in the level of effort required before they would feel it worthwhile reinvesting effort. In both experiments, this hysteresis hypothesis was supported.

These results are interesting because they offer an entirely cognitive explanation of the effects of anxiety upon performance, whereby such effects arise as the result of a complex interaction between cognitive anxiety and effort required. This sort of explanation is entirely consistent with processing efficiency theory in which physiological arousal and emotionality are regarded only as physiological symptoms of any increased effort that the performer invests; that is to say, they have no causal role in performance effects (Eysenck, 1992; Eysenck & Calvo, 1992). However, it is somewhat at odds with previous studies that have suggested that anxiety-induced physiological arousal may be an important influence upon performance (Burton, 1988; Fenz & Epstein, 1967, 1968; Gould, Petlichkoff, Simons, & Vevera, 1987; Parfitt & Hardy, 1993; Parfitt & Pates, 1999). It is perhaps important to note that the criterion tasks in those studies all involved a strong motor component, while the criterion tasks in the studies used by Eysenck and Calvo (1992) to formulate processing efficiency theory were generally cognitive tasks. Of course, the fact that evidence exists to support a complex interaction between cognitive anxiety and effort required does not rule out the possibility that a (similar) interaction also exists between cognitive anxiety and physiological arousal. Future research might attempt to clarify this situation by devising alternative paradigms to test these two models – or, indeed, a third cusp catastrophe model (of self-confidence and task importance) that has been proposed by Carver and Scheier (1998) but, to the best of the current authors' knowledge, has not yet been empirically tested. In a similar vein, the fact that a cusp catastrophe model of anxiety and performance is consistent with both sets of complex interactions that have been obtained does not mean that such models are the only means of modelling these interactions. Nevertheless, catastrophe models are the only models currently available that predict such interactive effects.

It is interesting to note that in both of the present studies, worst performance occurred under conditions of low anxiety (Study 1, level five, 61.1%; Study 2, level five, 65.4%). The fact that relatively poor performance occurs in a low anxiety condition is consistent with previous research on performance catastrophes by Hardy and Parfitt (1991) and Hardy *et al.* (1994). In both these studies, participants' best performances were significantly better in the high cognitive anxiety condition than in the low cognitive anxiety condition. Furthermore, their worst performances were significantly worse in the high cognitive anxiety condition than in the low cognitive anxiety condition. However, because of the between-groups design used in the present study, it was not possible to test for such effects here. From a processing efficiency theory perspective, all of these findings suggest that the (positive) motivational effects of anxiety can, and often do, outweigh the (negative) cognitive effects.

It is worth noting the important, albeit somewhat implicit, role that self-confidence (subjective probability of success) played in developing the current hypotheses from Eysenck and Calvo's (1992) processing efficiency theory and Hardy's (1990) cusp catastrophe model. As previously noted, in Eysenck's (1982) earlier theorizing, this role of self-confidence was explicitly stated, but in the more formally developed version of processing efficiency theory (Eysenck & Calvo, 1992) no such mention was made. The present authors suspect that this omission does not reflect a change of thinking on Eysenck's part, but rather a tactical decision because of the difficulty of finding evidence in previous published research to support the inclusion of self-confidence. Such a decision would not be surprising given the complexity of experimental design that would be required to collect such evidence. Nonetheless, some evidence does exist to support the inclusion of self-confidence in a processing efficiency theory framework. In a test of a higher order butterfly catastrophe model, Hardy *et al.* (2004) found that self-confidence moderated the interactive effects of cognitive anxiety and somatic anxiety. Specifically, they found that when highly confident performers were cognitively anxious, they were more able to tolerate the effects of increased somatic anxiety before experiencing performance loss. This finding is clearly consistent with Eysenck's (1982) earlier theorizing on the role of self-confidence.

Task importance and task relevance may also have influenced the present findings. Mean performance scores in Study 2 (where consequences of failure were high) were almost always higher than comparable scores in Study 1 (see Tables 1 and 3, respectively). It is likely that as the consequences of failure increase, the importance of performing well on the task increases. For example (as previously stated), Seijts *et al.* (1997) found that perceived importance of the task (public speaking) moderated the relationship between goal level and performance. They found that participants who perceived the task as unimportant appeared to reduce effort and persistence when very difficult goals were set, which led to a substantial decrease in performance. Conversely, participants who perceived the task to be important maintained their effort and persistence, even when faced with very difficult goals. Several other researchers (see, e.g. Parfitt, Jones, & Hardy, 1990) have also pointed to the importance of situationally relevant and meaningful criterion tasks from a design perspective. The present study could clearly be criticized from this perspective as importance and situational relevance were artificially stimulated. This criticism is particularly relevant in any study in which participant motivation is a key variable.

There are other limitations to the present studies. According to Carver and Scheier (1998), sensed rate of progress towards a goal is a key determinant of positive or negative affect. For example, if rate of progress is satisfactory, positive affect will arise. If rate of progress is slower than expected, negative affect will arise. As testing in the present studies took on average 45 minutes to complete, there may have been large fluctuations in participants' anxiety states depending on whether they perceived their rate of progress to be satisfactory or not. Such random changes in anxiety could clearly have clouded the present findings. However, by their random nature, they cannot account for the fairly systematic results obtained.

Another limitation of the study concerns the use of multiple ANOVAs and hence the use of multiple comparisons which may lead to the likelihood of committing a Type I error (significant findings when in fact there are none). However, owing to the systematic findings across both experiments (identical main effects and interactions) and identical hysteresis effects in the high anxiety conditions a Type I error seems highly unlikely. Furthermore, due to the fact that we used ANOVAs and multiple comparisons to identify *a priori* specified pattern of results, the chances of such results being obtained by chance is extremely low.

A final limitation of the present studies is that no measure of effort invested was taken. Such a measure would go some way to confirming (or otherwise) the roles of effort required and effort invested in the performance effects obtained. It may also explain the non-significant findings in the performance measure time-taken. For example, according to processing efficiency theory (Eysenck & Calvo, 1992), individuals who are experiencing high levels of worry and anxiety may invest extra effort in the task in order to prevent substandard performances. Consequently, as the present results indicate, performance times between low and high anxious individuals should be similar, but highly anxious individuals should report significantly higher levels of effort in order to perform the task. Future research might consider using either a self-report measure of effort (e.g. Zijlstra, 1993), a psychophysiological measure (e.g. Mullen, Hardy, & Tattersall, 2005), or both, to monitor effort required and effort invested throughout testing.

To conclude, the present studies have shown support for the hysteresis hypothesis within the framework of a cusp catastrophe model of anxiety and performance, based upon a complex interaction between cognitive anxiety and effort required. The findings also lend support to a processing efficiency theory explanation of anxiety-induced performance catastrophes, and encourage further exploration of the precise role of self-confidence within a processing efficiency theory framework.

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