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ORIGINAL ARTICLE

Practice with anxiety improves performance, but only when anxious: evidence for the specificity of practice hypothesis

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Abstract We investigated for the first time whether the principles of specificity could be extended to the psychological construct of anxiety and whether any benefits of practicing with anxiety are dependent on the amount of exposure and timing of that exposure in relation to where in learning the exposure occurs. In Experiment 1, novices practiced a discrete golf-putting task in one of four groups: all practice trials under anxiety (anxiety), non-anxiety (control), or a combination of these two (i.e., the first half of practice under anxiety before changing to non-anxiety conditions, anxiety-control, or the reverse of this, control-anxiety). Following acquisition, all groups were transferred to an anxiety condition. Results revealed a significant acquisition-to-transfer decrement in performance between acquisition and transfer for the control group only. In Experiment 2, novices practiced a complex rock climbing task in one of the four groups detailed above, before being transferred to both a high-anxiety condition and a low-anxiety condition (the ordering of these was counterbalanced across participants). Performance in anxiety transfer was greater following practice with anxiety compared to practice without anxiety. However, these benefits were influenced by the timing of anxiety exposure since performance was greatest when exposure to anxiety occurred in the latter half of acquisition. In the low-anxiety transfer test, performance was lowest for those who had practiced with anxiety only, thus providing support for the specificity of practice hypothesis. Results demonstrate that the specificity of learning principle can be extended to include the psychological construct of anxiety. Furthermore, the specificity advantage appears dependent on its timing in the learning process.

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Practice with anxiety improves performance, but only when anxious: evidence for the specificity of practice hypothesis

The failure to perform to one's normal ability as a result of state anxiety occurs regularly in numerous perceptual and psychomotor domains. In attempts to explain this phenomenon, two somewhat competing theoretical positions have emerged in the literature: one that is based on distraction; and one that is based on self-focus. Distraction theorists (e.g., Wine, 1971) propose that pressure causes an individual's attention to be partially consumed by task-irrelevant stimuli (e.g., worry) that consume resources of the working memory system, thus leading to decrements in performance (see also Baddeley, 1986; Eysenck, Derakshan, Santos, & Calvo, 2007). Self-focus theorists (e.g., Baumeister, 1984) propose that pressure raises self-consciousness/awareness thus increasing the attention that is allocated to the skill. However, the net result of this increase in self-awareness is a breakdown of normal automatic processes and skilled performance. While both distraction and self-focus theories have received empirical support (e.g., Beilock & Carr, 2001; Hardy, Mullen, & Jones, 1996; Hardy, Mullen, & Martin, 2001; Mullen, Hardy, & Tattersall, 2005; Pijpers, Oudejans, & Bakker, 2005), surprisingly little research attention has been paid to understanding how practicing with anxiety could minimize the likelihood of performance breaking down under anxiety.

Henry (1968) proposed that the best learning experiences are those that most closely approximate the movements of the target skill and the environmental conditions of the target context (i.e., specificity of practice). In support of this, research has shown specificity effects for both the source of sensory information available during practice and the emotional state of the learner during practice. For example, when participants practice under specific sensory conditions during acquisition, a change in these conditions during transfer causes a significant decrement in performance both early and late in practice, with the effect often being greater the more experience one has gained under specific practice conditions (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau, Marteniuk, Girouard, & Dugas, 1987; Tremblay & Proteau, 1998, 2001). It has been proposed that participants develop a movement plan to optimize the sensory information present during acquisition and that this movement plan is specific to the information that is available during practice (Elliott, Chua, Pollock, & Lyons, 1995; Khan & Franks, 2000; Khan, Franks, & Goodman, 1998; Mackrous & Proteau, 2007). Hence, if the practice conditions are changed, the movement plan previously developed is no longer appropriate for successful performance.

Similarly, research has shown that learning is enhanced when there is high congruity between a learner's mood state during acquisition and subsequent recall. The rationale here stems from Gilligan and Bower's (1983) network theory of affect, which states that emotions can be regarded as units within a semantic network that connects related events, ideas, and muscular patterns. The activation of a unit results in a spreading of this activation through the network to related units. As such, associations are formed between units relating to the skill to be learned (i.e., a particular muscular pattern) and the unit activated due to the learner's mood state. When the learner is required to recall what was learned, the mood state at that time leads to the activation of the appropriate emotion unit and subsequently to those units associated with it. If there is a match between mood at learning and mood at the time of recall, then the activation of the units of what is to be remembered is increased and recall is enhanced (Bower, Monteiro, & Gilligan, 1978; Schare, Lisman, & Spear, 1984). Thus, recall performance is greatest when the mood at the time of recall matches the mood that was present at the time of learning.

Although anxiety has been shown to adversely affect performance (e.g., Craft, Magyar, Becker, & Feltz, 2003; Woodman & Hardy, 2003) no previous research has explicitly investigated anxiety effects under a specificity of learning framework. To date, the focus has been directed towards investigating the skill acquisition conditions under which anxiety may subsequently have less of an adverse effect on performance. Studies that have sought to investigate this process have primarily chosen to manipulate the learning environment such that the learners' knowledge associated with movement production of the skill is either developed implicitly (i.e., unconsciously) or explicitly (i.e., consciously; Hardy, Mullen, & Jones, 1996; Masters, 1992). Using this paradigm, researchers have shown that tasks are more likely to break down under anxiety if performers have accumulated accessible and conscious task-relevant knowledge used to control movement (Masters & Maxwell, 2008). Specifically, Masters (1992) proposed that if explicit learning can be minimized (i.e., knowledge of learning is reduced) then the typically observed breakdown of automatic processes under pressure is less likely to occur in future pressure situations, as the performer has no access to explicit knowledge.

The notion that proceduralized motor skills (acquired *with* explicit knowledge) are more likely than non-proceduralized motor skills to break down under conditions of anxiety was further investigated by Beilock and Carr (2001). After practicing a golf putting task under one of three conditions (control; self-consciousness; dual-task) participants were required to perform the task under a high-pressure situation both early and late in practice. When pressure was introduced early, performance was improved in all training conditions. Since novices are assumed to be concerned with the step-by-step procedures of skill performance (Fitts & Posner, 1967), it was suggested that the increase in attention to movement control (as a result of the increased pressure) served to enhance performance. Conversely, in the latter stages of learning, the presence of pressure resulted in a performance decrement, thus supporting the notion that proceduralized motor skills break down under pressure. Interestingly, however, this performance decrement was only observed in the control and dual-task conditions. Those individuals in the self-consciousness condition were unaffected by the presence of pressure. As such, the results demonstrated an alternative skill acquisition technique to that of adopting implicit learning strategies to reduce the negative performance effects of anxiety. That is, it appears training under conditions of self-consciousness can lead to a reduction in the performance decrements typically experienced under anxiety.

More recently, Oudejans and colleagues have shown that following training under conditions of mild anxiety, performance on hand gun shooting (Oudejans, 2008), basketball free throws (Oudejans & Pijpers, 2009), and dart throwing (Oudejans & Pijpers, 2010) did not deteriorate in subsequent anxiety-inducing conditions. Whilst these experiments demonstrate that performers can more effectively acclimatize to anxiety following practice under anxiety, the methodologies were designed such that participants in the anxiety training conditions completed all training under conditions of anxiety. Thus, it is not clear whether the positive effects of training with anxiety are due to specificity effects, i.e., whether the performance in the anxiety post test increases as a function of the amount of practice experienced when anxious. Furthermore, by asking participants to complete all their practice under conditions of anxiety, Oudejans and colleagues were unable to investigate if it is important to consider where during the learning process anxiety should be introduced to achieve the most efficacious training effects. Thus, in the present investigation we were interested in whether the positive effects of practicing with anxiety shown by Oudejans and colleagues (Oudejans, 2008; Oudejans & Pijpers, 2009; 2010) adhere to the principles of specificity, i.e., whether they are dependent on the amount of exposure to anxiety and the timing of that exposure in relation to where in learning the exposure occurs.

To achieve this, participants practiced a golf putting task under anxiety throughout practice, anxiety either in the early or late stages of acquisition, or without anxiety (i.e., control condition). Following acquisition, all participants were transferred to an anxiety condition. The anxiety condition during acquisition should result in greater congruity between the conditions at learning and the conditions of the anxiety transfer test. Thus, it was hypothesized that this increased congruity (i.e., greater specificity of learning) would result in performance benefits under subsequent anxiety conditions. Also, if the protective effect of practicing with anxiety is dependent on the amount of exposure to anxiety during acquisition, one would expect the participants in the anxiety throughout acquisition condition to show greater performance robustness under the anxiety transfer test compared to when anxiety is induced only in the early or late stage of acquisition.

As well as investigating the exposure effects of practicing with anxiety, we were interested in whether the timing of exposure to anxiety during learning influences the efficacy of practicing with anxiety. To achieve this we investigated performance differences between the groups that experienced only half of acquisition with anxiety (i.e., during either the first half of or the second half of learning) to see whether the benefits of exposure to anxiety during acquisition are greater if participants begin practicing under conditions of anxiety from the start of learning or only once they have achieved a certain level of proficiency at the task (without anxiety). It was expected that the benefits of practicing with anxiety would be greater for those participants who were exposed to anxiety from the start of learning. This is due to one or a combination of two possibilities: (1) performers' developing a strong and robust semantic network that connects the mood state, ideas, and muscular patterns associated with the golf putt early in the learning process; (2) participants develop a representation of the skill that is adapted to the conditions from the start of learning (i.e., anxiety). As such, the earlier in the learning process that the mood is associated with the task, the more robust the performance will be in relation to that mood.

Experiment 1: Method

Participants

Thirty-two right-handed university students participated in the experiment (12 women, 20 men; mean age = 20.2 ± 1.6 years, age range 18–26 years). All participants were novice golfers, naïve to the hypothesis being tested and provided written informed consent before taking part in the study. The experiment was carried out according to institutional ethical guidelines for research involving human participants.

Apparatus

Golf putts were performed on an Astroturf surface using a standard KT25 Prosimmon putter and a standard Slazenger Raw Distance 432 dimple pattern golf ball. The start position was a 3 cm diameter circle located on the center line of the putting surface 40 cm from the rear edge (see Fig. 1). The target hole (10 cm diameter) was located 225 cm (centre to centre) from, and directly in line with, the start position. To increase task complexity, the putting surface included a 90-cm incline slope of 22 degrees that started 72 cm from the start position. The surface was then flat for the remaining distance to the target hole (65 cm). Final ball position was recorded using a Casio Digital Camera (QV-2900UXCF) which was mounted to the ceiling 295 cm directly above the target hole. Digital images were relayed directly to a Compusys 3.00 GHz computer for analysis.

Anxiety questionnaire

Cognitive anxiety was assessed via the Mental Readiness Form-3 (MRF-3; Krane, 1994). The MRF-3 comprises three single-item factors that are each scored on an 11-point Likert scale: cognitive anxiety from 1 (not worried) to 11 (worried); somatic anxiety from 1 (not tense) to 11 (tense); and self-confidence from 1 (confident) to 11 (not confident). For the purpose of the present study only the cognitive anxiety factor was used.

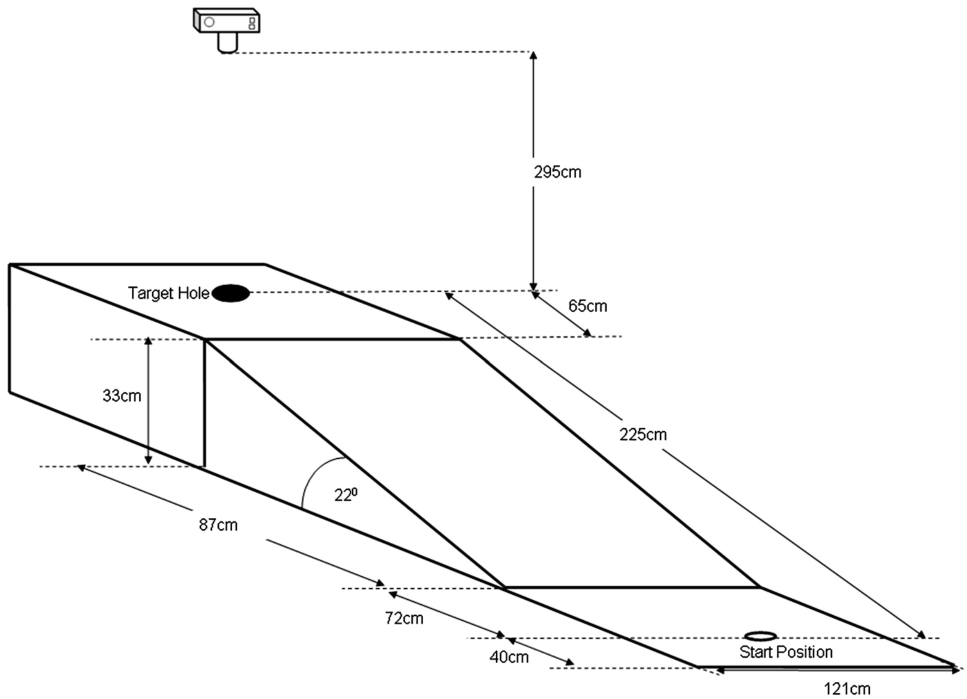

Fig. 1 A schematic of the putting apparatus in Experiment 1

Task and procedure

At the start of testing, participants were informed that the purpose of the investigation was to examine the accuracy of golf putting over a period of practice trials. It was explained that the goal of the task was to putt the ball as accurately as possible and that putting performance would be assessed by the number of successful putts and the distance from the hole on unsuccessful putts. In all conditions participants completed a total of 300[1] acquisition putts consisting of six blocks of 50 putts each. Following each block, participants were given a short break (approximately 5 min) to minimize potential fatigue effects. Each participant was randomly assigned to one of four acquisition conditions: (1) in the control group participants completed all 300 acquisition putts under normal (low anxiety) conditions; (2) in the anxiety group participants were informed that each putt was being recorded for later analysis by a professional golfer. They were also informed, before the start of putting that they had been awarded £ 30 and that ten pence (£ 0.10) would be removed from this total for each unsuccessful putt[2]; (3) in the anxiety-control group, participants performed the first 150 trials under conditions of anxiety identical to those described above except that total prize money was reduced from £30 to £15.[3] Following the putts under anxiety, participants then completed a final 150 putts under normal (low anxiety) conditions identical to that of the control group; (4) in the control-anxiety group, participants followed the same procedure to that of the anxiety-control group with the exception that the order of the anxiety and the control putting conditions was reversed.

Immediately following acquisition, all participants were given a 15-min break after which they completed a transfer test that consisted of 25 putts under conditions of anxiety. Specifically, participants were informed of their mean putting performance from the final 25 trials of their acquisition and told that they would be eligible to win £30 if they improved their performance by 15 % over the next 25 putts. However, it was also made clear to participants that for them to secure the £ 30, their percentage of improvement would need to be the highest of all individuals partaking in the experiment.

In order to ensure that anxiety had been successfully manipulated, all participants completed the MRF-3 on three separate occasions: immediately before the start of acquisition; at the start of the fourth block (i.e., following the

[1] This amount of putting trials was chosen on the basis that pilot studies in the same laboratory had revealed performance asymptote with this amount of practice. Furthermore, Beilock and Carr (2001) have demonstrated performance that is asymptotic in nature following a total of 270 trials from 9 different putting locations (i.e., 30 trials from each); the present experiment contained only one putting location resulting in a less complex learning task.

[2] 30 GBP is equivalent to 60.06 USD; 0.10 GBP is equivalent to 0.20 USD (exchange rates taken from the interbank rate on the last day of data collection (20.03.08).

[3] The reduction in the potential prize was in line with the reduction in the number of trials where anxiety was present (i.e., 300 for the anxiety condition and 150 for the anxiety control condition). Thus, a single putt in either of the anxiety conditions had the same loss associated with an unsuccessful performance.

removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively); and at the start of transfer (i.e., before the competition block of 25 putts).

Performance and analyses

Putting performance was measured via number of successful putts (NSP) and mean radial error (MRE). MRE was the absolute distance from the ball to the center of the hole (cf. Mullen, Hardy, & Tattersall, 2005).

Analyses

The effectiveness of the anxiety interventions, as measured by the MRF-3, was assessed by a 4 (group: control; anxiety; anxiety-control; control-anxiety) × 3 [time: pre (immediately before acquisition); mid (immediately prior to block 4); and transfer (immediately prior to transfer)] ANOVA with repeated measures on the second factor. Performance data (NSP and MRE) were analyzed during the acquisition phase using separate 4 Groups (control; anxiety; anxiety-control; control-anxiety) × 6 blocks (1–6) ANOVAs with repeated measures on the second factor. In order to assess the effect of anxiety on performance in the transfer test, both NSP and MRE were further submitted to separate four group (control; anxiety; anxiety-control; control-anxiety) × 2 experimental phase (acquisition; transfer) ANOVAs with repeated measures on the second factor. The last 25 putts of the acquisition phase and the 25 transfer putts were used in this analysis. To investigate the effects of introducing anxiety at different stages of learning we compared the change in performance of the control-anxiety group at the midpoint of acquisition (i.e., the last 25 trials of the final block of control conditions to the first 25 trials following the introduction of anxiety) to the change in performance of the control group between the last 25 trials of acquisition and the 25 trials of the anxiety transfer test using an independent *t* test. The rationale here is that the change from control conditions to anxiety conditions occurred half way through learning (early transfer) in the control–anxiety group whereas the control group were not transferred to the anxiety condition until the end of acquisition (late transfer). Thus, greater performance decrements in late transfer compared to the early transfer would demonstrate specificity of practice.

All significant effects were broken down using Tukey's HSD post hoc procedures ($p < 0.05$)

Results

Anxiety

The anxiety data are shown in Table 1. The ANOVA revealed a significant main effect of group ($F_{3,28} = 11.66$, $p < 0.001$, $\eta^2 = 0.55$) and time ($F_{2,56} = 45.68$, $p < 0.001$, $\eta^2 = .62$). Of more central interest, there was a significant group × time interaction ($F_{6,56} = 19.53$, $p < 0.001$, $\eta^2 = 0.67$). Breakdown of this interaction revealed that the anxiety manipulation was successful within the acquisition and transfer phases where targeted and that the anxiety levels reported within the acquisition and transfer anxiety phase manipulations were not significantly different from one another.

Table 1 Experiment 1 mean (SD) anxiety immediately before the start of acquisition (pre); at the start of the 4th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively) (mid); and at the start of transfer (i.e., before the competition block of 25 putts) (transfer)

Group	Time		
	Pre	Mid	Transfer
Control	2.50 (*1.20*)	2.00 (*0.54*)	6.00 (*1.31*)*
Anxiety	5.25 (*1.28*)	5.88 (*1.25*)	5.75 (*1.75*)
Anxiety-control	5.75 (*1.04*)	2.50 (*0.92*)*	6.00 (*0.93*)*
Control-anxiety	2.50 (*0.93*)	5.87 (*1.13*)*	7.00 (*0.92*)

* Signifies a significant within subject change in anxiety from the previous time point at 95 % ($p < 0.05$)

Number of successful putts

Acquisition

Means and *SD*s are reported in Table 2. The analysis revealed no significant main effect for group ($F_{3,28} = .21$, $p = 0.89$, $\eta^2 = 0.02$) or block ($F_{5,140} = 1.46$, $p = 0.21$, $\eta^2 = 0.05$) and no significant interaction between the two factors ($F_{15,140} = 1.46$, $p = 0.13$, $\eta^2 = 0.14$).

Acquisition versus transfer

Similar to the acquisition analysis, no significant main effects or interactions were observed (group main effect $F_{3,28} = 1.86$, $p = 0.16$, $\eta^2 = 0.16$; experimental phase main effect $F_{1,28} = 0.19$, $p = 0.66$, $\eta^2 = 0.01$; group × experimental phase interaction $F_{3,28} = 1.20$, $p = 0.33$, $\eta^2 = 0.11$).

Mean radial error

Acquisition

Means and *SD*s are reported in Table 2. The ANOVA revealed a significant main effect for block ($F_{5,140} = 9.54$, $p < 0.001$, $\eta^2 = 0.25$) (see Fig. 2). Specifically, all participants significantly improved putting accuracy over each block of trials for the first 150 putts [block 1 (mean

Table 2 Experiment 1 means and *SD*s for all performance-dependent variables as a function of group (c = control; a = anxiety; a-c = anxiety-control; c-a = control-anxiety) and experimental phase

Variable	Group	Experimental phase						
		Acquisition block						Anxiety transfer
		1	2	3	4	5	6	High
NSP	c	6.88	8.25	7.88	7.75	9.63	10.13	4.25
		3.52	*3.20*	*2.80*	*3.45*	*4.90*	*5.03*	*1.16*
	a	6.50	8.88	8.50	9.13	9.13	6.00	6.63
		1.07	*3.52*	*2.45*	*3.04*	*2.42*	*1.51*	*2.62*
	a-c	8.25	7.25	9.13	10.25	8.00	8.63	5.63
		1.04	*1.67*	*2.03*	*3.15*	*2.20*	*3.66*	*0.92*
	c-a	8.25	8.00	8.88	7.25	7.25	7.63	4.88
		1.67	*2.33*	*4.26*	*2.55*	*1.67*	*2.45*	*0.64*
MRE	c	471.17	429.59	434.76	431.96	408.72	342.21	466.20
		134.41	*128.06*	*135.85*	*133.60*	*167.33*	118.19	236.88
	a	518.67	517.41	449.09	430.33	440.67	425.88	300.89
		203.19	*236.59*	*198.95*	*150.14*	*183.94*	222.50	113.33
	a-c	491.41	426.17	391.97	310.94	307.47	341.88	335.93
		128.95	*134.30*	*188.01*	*185.76*	*212.76*	258.89	198.78
	c-a	413.34	402.89	365.81	420.71	350.89	323.57	302.09
		144.30	*120.71*	*122.69*	*122.55*	*105.87*	115.15	105.26

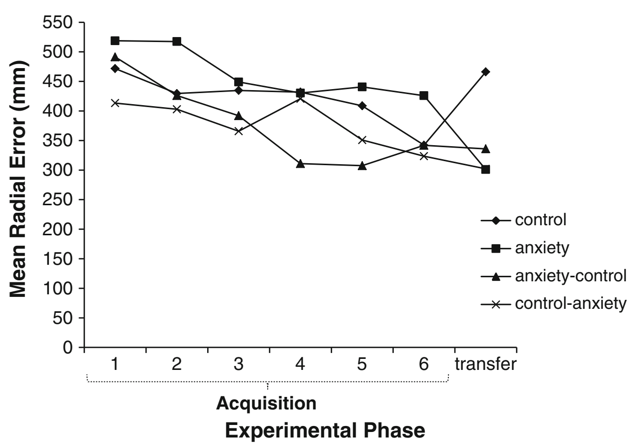

Fig. 2 Experiment 1 mean radial error during acquisition as a function of condition and block (*1* trials 1–50; *2* trials 51–100…; *6* trials 251–300; transfer, anxiety transfer trials)

473.65 mm); block 2 (mean 444.01); block 3 (mean 410.41 mm) after which putting accuracy reached asymptote since blocks 4 (mean 398.48), 5 (mean 376.96), and 6 (mean 358.38)] were not significantly different to one another. Thus, similar to previous research (e.g., Beilock & Carr, 2001; Hardy, Mullen, & Jones, 1996; Masters, 1992), performance asymptote occurred after approximately 200 practice trials. No group main effect or interaction was revealed ($F_{3,28} = 0.58$, $p = 0.63$, $\eta^2 = .06$ and $F_{15,140} = 1.38$, $p = 0.17$, $\eta^2 = 0.13$, respectively).

Acquisition versus transfer

As shown in Fig. 2, the MRE transfer ANOVA revealed a significant group × experimental phase interaction ($F_{3,28} = 3.23$, $p < 0.05$, $\eta^2 = 0.26$). Breakdown revealed that the control group showed a significant decrement in performance from acquisition to transfer whilst the anxiety group showed a significant improvement. The performance of the other two groups did not significantly change from acquisition to transfer. Finally, performance at transfer was significantly worse for the control condition compared to the other three conditions.

Introducing anxiety early and late in practice

Comparison of the changes in performance from inducing anxiety half-way through acquisition (i.e., control-anxiety group) and at the end of acquisition (i.e., control group) revealed that the decrement in performance was greater in the late transfer (MRE = −108.96) compared to the early transfer (MRE = −54.89) ($t_{14} = -2.84$, $p = 0.089$) but only at the 0.1 α level.

Discussion

The objective of the current investigation was to examine whether the principles of specificity (Gilligan & Bower, 1983; Henry, 1968, Proteau, 1992) could be extended to the psychological construct of anxiety. Whilst specificity effects have previously been shown to be robust when examining sensory information (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau et al., 1987; Tremblay & Proteau, 1998, 2001) the hypothesis has not previous been explored in the anxiety and stress and performance literature. As such, we investigated whether acquiring a motor skill under conditions of anxiety removed the performance decrement typically observed in skilled movement production when anxiety is present (i.e., choking). We also tested whether any positive effects of practicing with anxiety on subsequent anxious performances are dependent on the amount of exposure to anxiety during acquisition and the timing of that exposure. The results demonstrated that learning under conditions of anxiety led to more robust performance under future conditions of anxiety and that learning without exposure to anxiety leaves one particularly vulnerable to its effects in subsequent performances.[4] Hence, consistent with studies that have shown that learning is specific to sensory conditions (Elliott, Pollock, Lyons, & Chua, 1995; Khan & Franks, 2000; Khan et al., 1998; Mackrous & Proteau, 2007) and mood state (Bower et al., 1978; Gillian & Bower, 1983; Schare et al., 1984) during acquisition, the present results indicate that specificity of learning extends to the psychological construct of anxiety.

Interestingly, and somewhat surprising, was the finding that missed putts actually finished closer to the hole in transfer compared to acquisition in the anxiety group. Whilst this may be an artifact of variability within the data set, another possible explanation for this increase in performance is that the time period, although relatively short, between acquisition and transfer allowed for some learning consolidation in the anxiety group and that the continued exposure to anxiety during acquisition increased post-acquisition stress-hormone which lead to an increase in learning (also see Cahill, Gorski, & Le, 2003). While one might also expect an increase in performance in the mixed practice groups following the period of consolidation, it is possible that these groups had less increases in stress-hormone compared to the anxiety only group because of the reduced exposure to anxiety period during practice. Future research may wish to investigate this possibility further.

Further support that learning is specific to the amount of exposure to anxiety during acquisition was revealed from the comparison between the change in performance of the control-anxiety group when anxiety was induced at the midpoint of acquisition and the change in performance of the control group between the end of acquisition to the anxiety transfer test. Here performance decrements were greater in late transfer compared to early transfer suggesting that the more participants practiced in non-anxious conditions the more they were dependent on the presence of those conditions for successful performance. This finding is consistent with observations from studies on manual aiming in which removing visual feedback was more detrimental late in learning compared to early in practice (Proteau et al., 1987; Khan et al., 1998) suggesting that the specificity effect could also be extended to the psychological construct of anxiety.

While the results of the present study demonstrated evidence for specificity of learning, there were no performance differences between the anxiety-control and control-anxiety groups at the final transfer phase. A possible explanation for this could be due to the complexity of the to-be-learned task. That is, a golf putt can be described as a simple discrete skill that is closed in nature (i.e., the task involves relatively few movements, has a very obvious beginning and end and is not subject to external factors such as time constraints; Schmidt & Lee, 2005). Thus, although anxiety from the start of acquisition negatively affected performance, possibly due to consuming resources of working memory (Eysenck et al., 2007), this was not sufficient to reduce learning. Perhaps introducing anxiety from the start of practice in a more complex and open skill would disrupt the acquisition process to such a degree as to increase learning time and reduce the benefits of training with anxiety from the start of practice as seen in the present investigation. This possibility was investigated in Experiment 2.

Experiment 2

The purpose of Experiment 2 was twofold: (1) to investigate when learning with anxiety is most appropriate for a complex task and (2) to further investigate whether the principles of specificity (Gilligan & Bower, 1983; Henry, 1968; Proteau, 1992) should be extended to the psychological construct of anxiety. The results of Experiment 1 revealed no performance differences in the anxiety transfer

[4] The results referred to centre around the findings of the MRE variable. Given the observations of previous pioneering research that have adopted golf putting tasks to investigate stress and performance (Mullen, Hardy & Tatersall, 2005; Mullen, Hardy, & Tattersall, 2005), it is not unusual to observe null effects between groups in the dichotomous variable of NSP. For this reason the outcome performance dependent variables of the present experiment were both dichotomous (NSP) and continuous (MRE) in nature. Since performance was the primary objective of the present investigation, the inclusion of a continuous variable was essential to measure performance in objective detail. This is especially important given that participants were explicitly aware that the task only afforded a single putt and that performance was measured on both the number of successful putts and the distance the ball finished from the hole on unsuccessful putts.

test between participants who practiced either with anxiety from the start or from the midpoint of acquisition; only the control group performed significantly worse at transfer. Since it is possible that this null finding was a result of the low complexity of the to-be-learned skill, Experiment 2 investigated whether similar findings would be observed when the to-be-learned skill was of a more complex nature.

The design and procedure of Experiment 2 were largely similar to those of Experiment 1. However, two major methodological changes were made. First, to investigate whether the movement developed when practicing with anxiety is specific to those conditions we introduced a second (low anxiety) transfer test. If specificity of learning extends to practicing with anxiety, one would expect a decrement in performance for participants who practice with anxiety when they are transferred to a non-anxious condition (i.e., they experience a change in the environmental context or mood under which the task was learned). Second, a more complex whole body climbing task (involving the control of multiple movement components that were subject to a time pressure constraint) was adopted to investigate whether performance is influenced by the timing of anxiety induction during acquisition.

Method

Participants

Thirty-two novice climbers participated in Experiment 2 (4 women, 28 men; mean age 26.35, SD ± 2.22 years, age range 18–49 years). All participants reported no prior climbing experience, were naïve to the hypothesis being tested and gave their informed consent prior to taking part in the study. The experiment was carried out according to the institutional ethical guidelines for research involving human participants.

Apparatus

Climbing moves were performed wearing well-fitted standard rock shoes (Scarpa Vantage) on an indoor climbing wall, the floor of which was covered by a standard safety crash mat. The wall itself contained a 5.5-m long low-level traverse (a horizontal sequence of climbing movements where the mean hold height was 1.23 m from the floor, SD ± 0.46 m) with a UK technical difficulty of 4a (easy).[5] The height of the traverse meant that participants could simply step on and off the climb with ease at any point without safety risk. Consequently, the safety equipment typically associated with vertical climbing was not required. The 4a easy difficulty of the traverse was determined by three independent expert climbers who each held an up-to-date Mountain Instructor Award and had more than 10 years of climbing experience (37 years combined experience). Cognitive anxiety was measured using the MRF-3 and task effort was measured using a retrospective 1 (no effort) to 10 (maximal effort) Likert scale (see Mullen et al., 2005). All climbs were recorded on a Sony digital video camera recorder (DCR-DVD106) positioned at a height of 1.2 m, in line with the middle of the traverse and at distance from the climbing wall such that the entire 5.5 m traverse was clearly visible.

Task and procedure

At the start of testing, participants were informed that the purpose of the investigation was to examine the speed and accuracy of climbing over a period of practice trials. It was explained that the goal of the task was to climb as quickly and as fluently as possible. In all conditions participants completed a total of 100 acquisition climbs consisting of ten blocks of ten trials split equally over 2 days. A 1-min break was given between trials and participants were afforded a 10-min break between blocks within which they were required to perform forearm recovery stretching exercises. Participants were instructed to perform each stretch three times and to hold the stretch for a total of 20 s. Similar to Experiment 1, each participant was randomly assigned to one of four acquisition conditions (each containing an equal number of males and females): (1) in the control group all acquisition trials were performed under normal (low anxiety) conditions; (2) in the anxiety group participants were informed that they were being videoed and that recordings would be watched and evaluated by an elite professional climber. They were also informed that the evaluations of their performance and the other participants would be displayed on a poster in text format for all other participants to view and that the best performer would be rewarded with the choice of one of four outdoor activity sessions (e.g., a day's climbing with a qualified mountain guide for two); (3) in the anxiety-control group the first half of acquisition was performed under conditions identical to that of the anxiety group and the remaining half were conducted under conditions that matched those of the control group (low anxiety); (4) in the control-anxiety group, participants followed the same procedure to that of the anxiety-control group with the exception that the order of the anxiety and the control conditions was reversed.

Immediately following acquisition, all participants were given a 1-h break after which they completed two transfer

[5] Strictly speaking. UK technical climbing grades are open ended, but typically start at 4 are subdivided into "a", "b", and "c" and progressively increase in difficultly up to 8c.

tests that consisted of ten climbs each. Anxiety transfer was performed under anxiety conditions and low-anxiety transfer was performed under normal conditions (the order of the transfer tests was counterbalanced across participants). To manipulate anxiety, participants were informed of their mean climbing performance from the last ten trials of acquisition and told that if they improved their performance by 15 % over the next ten trials they would be eligible to win a choice of outdoor activity sessions (these were identical to those available during the acquisition phase). However, it was also made clear to participants that for them to secure the prize, their percentage of improvement would need to be the highest of all individuals partaking in the experiment.

In order to ensure that anxiety had been successfully manipulated all participants completed the MRF-3 on four separate occasions: immediately before the start of acquisition; at the start of the 6th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively); and at the start of both transfer tests. To measure effort, participants completed the self report effort scale following block 5 and block 10 of acquisition and at the end of both anxiety transfer and low-anxiety transfer.

Performance and analyses

Similar to Pijpers et al. (2005), for each trial, the time of traverse (TOT), number of performed movements (NOPM), number of explored movements (NOEM), and number of ventured movements (NOVM) were determined from the DVD recordings.[6] TOT was calculated as the time interval between the release of the first hold until the grasp of the final hold on the traverse. NOPM was defined as the number of moves made during the climb; a move was classified as the releasing of a hold and making contact with another hold that was used for support. NOEM was defined as the number of times a hold was touched without that hold being subsequently used as support. NOVM was calculated as the number of times a hold was released and then the limb was returned to the same hold.

In order to accurately determine each dependent variable, the DVD recordings of each trial were rated simultaneously by two assessors. Both assessors were blind to the experimental hypotheses, competent with the calculation of all measures, and had access to this information during their assessments.[7]

Analysis

MRF-3 data were assessed separately by a 4 (group: anxiety; control; anxiety-control; control-anxiety) × 4 [time: pre (immediately prior to acquisition); mid (immediately prior to acquisition block 6); anxiety transfer (immediately prior to anxiety transfer); and low-anxiety transfer (immediately prior to low-anxiety transfer)] ANOVA with repeated measures on the second factor. Effort data were submitted to a similar 4 (group: anxiety; control; anxiety-control; control-anxiety) × 4 [time: mid (immediately following trial 50 of acquisition); end (immediately following the final trial of acquisition); anxiety transfer (immediately following anxiety transfer); and low-anxiety transfer (immediately following low-anxiety transfer)] ANOVA with repeated measures on the second factor. Performance data (TOT, NOPM, NOEM, and NOVM) were analyzed during the acquisition phase using separate 4 (group: anxiety; control; anxiety-control; control-anxiety) × 2 (day: day 1, day 2) × 5 (block: blocks 1–5) ANOVAs with repeated measures on the last two factors. In order to assess the effect of the transfer tests (anxiety and normal conditions) on performance, TOT, NOPM, NOEM, and NOVM were further submitted to separate 4 (group: anxiety; control; anxiety-control; control-anxiety) × 3 (experimental phase: acquisition; anxiety transfer; low-anxiety transfer) ANOVAs with repeated measures on the second factor. The final ten trials of the acquisition phase (i.e., the last block of day 2) and the ten trials in both transfers were used in these analyses. Similar to Experiment 1, to investigate the effects of introducing anxiety at different stages of the learning process we conducted an independent *t* test on the change in TOT from block 1–5 for the control-anxiety group and block 10 to anxiety transfer for the control group.

All significant effects were broken down using Tukey's HSD post hoc procedures ($p < 0.05$).

Results

Anxiety

Means and *SD*s are reported in Table 3. The ANOVA revealed a significant main effects of group

[6] Since the instructions given to participants were to climb as quickly and as fluently as possible, good performance would be indicative of lower traverse times and fewer movements (the latter is particularly true for both the number of explored and number of ventured movements that are indicative of uncertain movements) (See Pijpers et al., 2005).

[7] In order to ensure the reliability of both the performance measure and judges competency at using it, we conducted inter-judge reliability at each trial block for each performance dependent variable. For the time of traverse the mean R^2 for the 12 trial blocks (10 acquisition and 2 transfer) was 0.95 (SD ± 0.04), whereas the mean R^2 was 0.85 (SD ± 0.05), .89 (SD ± 0.03) and .89 (SD ± 0.06) for the number of performed, number of explored and number of ventured movements, respectively.

Table 3 Experiment 2 mean (SD) anxiety immediately before the start of acquisition (pre); at the start of the 6th block (i.e., following the removal or the addition of anxiety in the anxiety-control and control-anxiety conditions, respectively) (mid); at the start of the anxiety transfer test (transfer 1); and at the start of the low-anxiety transfer test (transfer 2)

Group	Time			
	Pre	Mid	Transfer 1	Transfer 2
Control	1.00 (*0.83*)	1.00 (*0.85*)	9.50 (*0.75*)*	2.00 (*1.07*)*
Anxiety	9.38 (*0.74*)	8.38 (*0.52*)	9.50 (*0.76*)	2.75 (*1.28*)*
Anxiety-control	8.75 (*0.88*)	1.50 (*0.92*)*	9.50 (*0.75*)*	2.00 (*1.06*)*
Control-anxiety	1.13 (*0.84*)	9.38 (*0.74*)*	8.75 (*0.89*)	2.13 (*1.25*) *

* Signifies a significant within subject change in anxiety from the previous time point at 95 % ($p < 0.05$)

Table 4 Experiment 2 mean (SD) effort scores immediately following the end of block 5 (i.e., following the 50th trial of acquisition) (mid); immediately following the end of acquisition (i.e., the 100th trial) (end); immediately following the end of the anxiety transfer test (transfer 1); immediately following the end of the low-anxiety transfer test (transfer 2)

Group	Time			
	Mid	End	Transfer 1	Transfer 2
Control	7.75 (*1.03*)	8.00 (*0.75*)	8.25 (*0.46*)	7.88 (*0.84*)
Anxiety	8.00 (*0.75*)	7.75 (*0.46*)	8.00 (*0.76*)	7.63 (*0.74*)
Anxiety-control	8.13 (*0.99*)	8.00 (*0.53*)	8.63 (*0.51*)	7.88 (*0.64*)
Control-anxiety	7.88 (0.64)	8.13 (*0.64*)	8.25 (*0.71*)	8.38 (*0.74*)

($F_{3,28} = 117.92$, $p < 0.001$, $\eta^2 = 0.99$) time ($F_{3,84} = 331.74$, $p < 0.001$, $\eta^2 = 0.92$) together with a significant group × time interaction ($F_{9,84} = 97.62$, $p < 0.001$, $\eta^2 = 0.91$). As in Experiment 1, breakdown of this interaction revealed that the anxiety manipulation was successful in the acquisition and transfer phases where targeted and that the anxiety levels experienced in both the acquisition and transfer phase anxiety manipulations were not significantly different from one another.

Effort

Analysis of the effort data revealed no significance for either the main effects (group: $F_{3,28} = 0.88$, $p = 0.46$, $\eta^2 = 0.09$; time: $F_{3,84} = 2.12$, $p = 0.095$, $\eta^2 = 0.07$) or the interaction ($F_{9,84} = 0.79$, $p = 0.61$, $\eta^2 = 0.07$). Thus, effort was similar for all groups and did not differ between anxiety and low-anxiety situations (see Table 4).

Performance variables

For reasons of brevity, statistical values for all performance dependent variables have been omitted from the text and reported in Table 5.

Time of traverse (TOT)

Acquisition

All means and *SD*s are reported in Table 6. As shown in Fig. 3, significant main effects for group, day, and block were observed, in addition to significant group × day, group × block, day × block, and group × day × block interactions. The breakdown of the triple interaction indicated that whilst traverse times in all groups significantly decreased over day 1 (blocks 1–5) this decrease was significantly greater in the control and control-anxiety groups compared to both the anxiety and anxiety-control groups. Furthermore, traverse times significantly increased from the end of day 1 (block 5) to the start of day 2 (block 6) for the anxiety, control, and control-anxiety groups with this increase being significantly greater in the control-anxiety group. In the anxiety-control group, however, time of traverse significantly decreased from block 5 to block 6. Finally, whilst time of traverse significantly decreased over day 2 from block 6 to block 10 in all groups, this decrease was significantly greater in the control and anxiety-control groups compared to the anxiety and control-anxiety groups.

Acquisition versus transfer

As shown in Fig. 4, the analysis revealed a significant main effect of group and experimental phase as well as a significant group × experimental phase interaction. Breakdown of this interaction revealed that the transfer performance of the control and anxiety groups significantly decreased when the conditions at transfer did not match those of acquisition. Specifically, the traverse times of the control group were significantly greater in the high-anxiety transfer test compared to both acquisition and low-anxiety transfer (acquisition and low-anxiety transfer were not significantly different), whereas, the time of traverse for the anxiety group remained constant between acquisition and the anxiety transfer and significantly increased from these levels in the low-anxiety transfer test. Traverse times in the anxiety-control group significantly increased between acquisition and anxiety transfer, whereas those of the control-anxiety group remained constant and significantly decreased between acquisition and the low-anxiety transfer test. Between-group comparisons revealed that, time of traverse at anxiety transfer was significantly lower in both the control-anxiety and anxiety-control groups (mean 32.00 and 33.25, respectively) compared to the remaining

Table 5 Experiment 2 statistical values for each performance dependent variable for both acquisition and acquisition versus transfer analyses

Variable	Acquisition: Factor(s)	F	df	p	η^2	Acquisition versus transfer: Factor(s)	F	df	p	η^2
TOT	Group	281.08	3.28	<0.001	0.97	Group	51.98	3.28	<0.001	0.85
	Day	23.43	1.28	<0.001	0.46	Experimental phase	137.90	2.56	<0.001	0.83
	Block	86.12	4.112	<0.001	0.76	Group × experimental phase	85.73	6.56	<0.001	0.90
	Group × day	838.07	3.28	<0.001	0.99					
	Group × block	4.45	12.112	<0.001	0.32					
	Day × block	6.16	4.112	<0.001	0.18					
	Group × day × block	8.42	12.112	<0.001	0.47					
NOPM	Group	12.36	3.28	<0.001	0.57	Group	19.34	3.28	<0.001	0.68
	Day	4.88	1.28	<0.05	0.15	Experimental phase	5.73	2.56	<0.05	0.17
	Block	198.64	4.112	<0.001	0.88	Group × experimental phase	14.17	6.56	<0.001	0.60
	Group × day	9.31	3.112	<0.05	0.50					
	Group × block	3.32	12.112	<0.001	0.26					
	Day × block	4.42	4.112	<0.05	0.13					
	Group × day × block	1.98	12.112	<0.05	0.18					
NOEM	Group	62.93	3.28	<0.001	0.87	Group	80.26	3.28	<0.001	0.89
	Day	13.74	1.28	<0.001	0.72	Experimental phase	153.86	2.56	<0.001	0.85
	Block	68.29	4.112	<0.001	0.71	Group × experimental phase	89.15	6.56	<0.001	0.91
	Group × day	284.34	3.112	<0.001	0.97					
	group × block	3.45	12.112	<0.001	0.27					
	Day × block	7.85	4.112	<0.001	0.22					
	Group × day × block	2.69	12.112	<0.05	0.22					
NOVM	Group	82.21	3.28	<0.001	0.89	Group	17.51	3.28	<0.001	0.65
	Day	17.25	1.28	<0.001	0.38	Experimental phase	240.87	2.56	<0.001	0.90
	Block	139.77	4.112	<0.001	0.83	Group × experimental phase	120.54	6.56	<0.001	0.93
	Group × day	80.30	3.112	<0.001	0.90					
	Group × block	6.56	12.112	<0.001	0.41					
	Day × block	4.57	4.112	<0.05	0.14					
	Group × day × block	13.85	12.112	<0.001	0.59					

groups (control mean 39.00; anxiety mean 34.75; the anxiety group was significantly lower than the control group). Furthermore, the control-anxiety group had significantly lower traverse times compared to both the anxiety and control group, whilst the control group had significantly longer traverse times compared to all other groups. Finally, traverse times in all groups were significantly different at low-anxiety transfer. Specifically, time of traverse was fastest in the control group (mean 23.63) followed by the control-anxiety (mean 28.38), anxiety-control (mean 33.25), and anxiety groups (mean 38.63).

Introducing anxiety early and late in practice

The results of the t-test between the change in TOT from block 1 to 5 (early transfer) for the control-anxiety group and block 10 to anxiety transfer (late transfer) for the control group revealed that the decrement in performance was significantly greater in late transfer (TOT $= -16.00$) compared to early transfer (TOT $= -10.50$) ($t_{14} = -6.07$ $p = 0.001$).

Number of performed movements (NOPM), number of explored movements (NOEM), and number of ventured movements (NOVM)

Acquisition

Means and SDs are reported in Table 6. As shown in Table 5 and Fig. 5, the analyses of the NOPM, NOEM, and NOVM all revealed significant main effects for group, day, and block, as well as significant group × day, group × block, day × block, and group × day × block interactions.

Table 6 Experiment 2 means and SDs for all performance-dependent variables as a function of group and experimental phase

Variable	Group	Experimental phase											
		Acquisition block										Anxiety transfer	
		1	2	3	4	5	6	7	8	9	10	High	Low
TOT	c	28.5	27.6	26.8	25.8	24.1	28.0	25.8	24.2	23.7	23.0	39.0	23.6
		0.92	*1.59*	*0.99*	*0.64*	*0.99*	*1.41*	*1.36*	*1.04*	*1.03*	*0.93*	*1.77*	*0.52*
	a	34.7	34.6	33.7	33.7	33.3	35.7	34.3	34.2	34.2	33.6	34.7	38.6
		0.88	*1.06*	*0.71*	*1.03*	*1.59*	*0.46*	*0.52*	*1.28*	*1.58*	*1.59*	*1.39*	*1.69*
	a-c	35.2	34.7	34.2	34.0	34.6	28.8	27.5	25.7	24.7	24.1	33.2	30.2
		0.71	*1.03*	*1.04*	*0.53*	*0.91*	*1.12*	*0.76*	*1.28*	*1.28*	*0.83*	*2.12*	*4.09*
	c-a	28.2	27.7	27.2	25.8	24.6	35.1	34.5	34.0	33.7	33.5	32.0	28.3
		1.03	*0.70*	*0.71*	*0.83*	*0.92*	*0.64*	*0.93*	*0.53*	*0.89*	*1.06*	*1.51*	*1.06*
NOPM	c	27.6	27.0	25.8	24.5	23.3	25.1	23.5	23.3	22.5	21.8	28.6	21.8
		0.74	*0.76*	*1.13*	*0.76*	*1.06*	0.64	1.06	0.92	0.53	1.12	3.66	1.55
	a	31.3	30.0	28.7	28.0	28.1	29.8	29.13	28.5	28.4	28.5	27.88	29.5
		3.11	*2.67*	*3.06*	*2.32*	*2.16*	2.10	2.23	1.77	2.26	1.90	1.88	2.61
	a-c	31.2	30.2	28.6	28.5	28.1	27.8	27.0	25.8	25.3	24.87	26.7	27.2
		2.76	*2.96*	*2.77*	*2.56*	*2.90*	0.64	0.75	1.22	1.16	0.99	1.28	1.48
	c-a	27.6	27.1	26.1	25.6	23.7	29.8	29.63	28.1	27.5	27.1	24.6	24.6
		0.74	*0.83*	*1.36*	*0.74*	*0.07*	3.72	*4.24*	2.99	2.61	2.29	0.74	1.06
NOEM	c	4.8	4.5	3.8	3.6	2.9	4.0	3.5	3.0	2.3	1.6	11.1	2.3
		0.35	*0.75*	*0.64*	*0.51*	*0.35*	*0.76*	*0.92*	*0.53*	*0.46*	*0.51*	*0.83*	*0.74*
	a	9.2	8.25	8.6	9.0	8.0	9.8	9.0	7.5	8.1	7.8	7.3	8.0
		1.48	*1.04*	*1.06*	*1.69*	*0.76*	*1.88*	*1.19*	*0.53*	*0.83*	*0.71*	*0.46*	*0.01*
	a-c	10.5	10.6	9.1	9.0	9.5	5.3	4.3	3.3	3.1	3.0	8.1	5.8
		1.69	*2.06*	*1.35*	*1.19*	*1.77*	*1.06*	*1.18*	*1.03*	*0.64*	*0.53*	*0.83*	*1.03*
	c-a	5.1	4.0	3.8	2.8	2.25	11.1	9.5	7.9	7.6	7.9	7.0	5.1
		1.12	*0.01*	*0.64*	*0.64*	*0.71*	*2.36*	*1.51*	*0.64*	*0.51*	*0.35*	*1.06*	*1.25*
NOVM	c	6.7	5.8	4.8	3.8	2.9	4.1	2.3	1.0	0.6	0.1	14.4	1.1
		1.67	*2.25*	*2.49*	*2.76*	*2.36*	*1.24*	*0.70*	*1.41*	*0.91*	*0.35*	*1.69*	*0.99*
	a	10.6	10.5	10.0	9.5	9.6	10.5	9.7	9.5	8.8	8.6	9.0	8.9
		0.91	*0.76*	*0.53*	*0.92*	*1.06*	*0.76*	*1.16*	*0.93*	*2.18*	*2.33*	*2.14*	*2.10*
	a-c	11.3	11.1	10.4	9.9	9.8	6.8	4.3	3.0	1.13	1.0	9.6	6.6
		1.03	*0.99*	*0.92*	*1.12*	*1.16*	*1.35*	*0.70*	*1.42*	*1.36*	*0.93*	*0.91*	*1.41*
	c-a	6.3	5.8	4.4	3.9	1.9	10.5	10.4	10.8	9.75	10.4	8.8	6.1
		0.92	*1.39*	*2.13*	*1.55*	*1.24*	*0.75*	*0.92*	*1.04*	*1.16*	*0.92*	*1.91*	*1.13*

c control, *a* anxiety, *a-c* anxiety-control, *c-a* control-anxiety

Breakdown of the interactions revealed that number of movements significantly decreased during acquisition when trials were being performed only under control conditions. Specifically, number of movements decreased over day 1 (blocks 1–5) for the control-anxiety group, day 2 (blocks 6–10) for the anxiety-control group, and over both days (from block 1 to block 10) for the control condition.

Acquisition versus transfer

The acquisition versus transfer data for the NOPM, NOEM, and NOVM are shown in Fig. 6. The analyses of all variables (see Table 5) revealed significant main effects for group and experimental phase as well as significant group × experimental phase interactions. These main effects and interactions showed the same significant pattern of results to that of the time of traverse data. Thus, for reasons of brevity the data have been summarized; the control group experienced only a significant decrease in performance from acquisition to anxiety transfer; the anxiety group experienced only a decrement in performance between acquisition and low-anxiety transfer; the control-anxiety maintained performance between acquisition and anxiety transfer, whereas performance was significantly

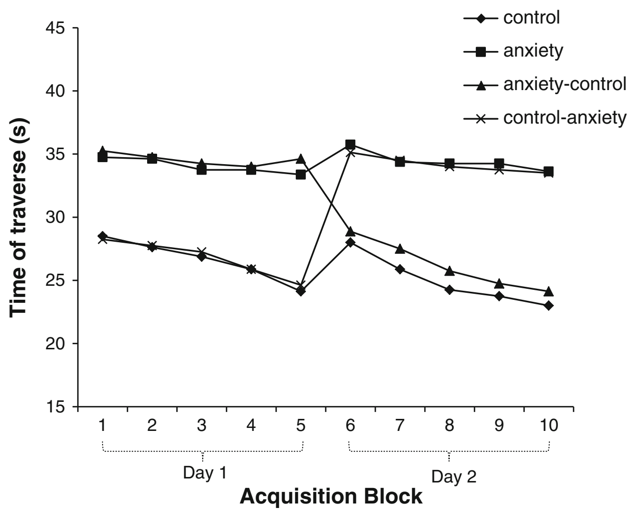

Fig. 3 Experiment 2 time of traverse (s) during acquisition as a function of group and block (*1* trials 1–10; *2* trials 11–20…; *10* trials 91–100)

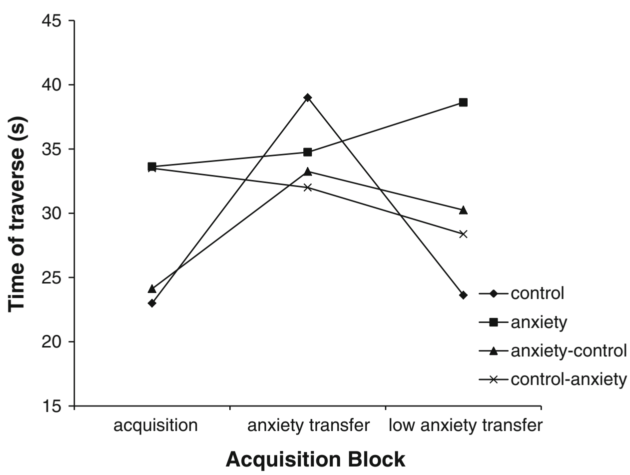

Fig. 4 Experiment 2 time of traverse (sec) as a function of group and experimental phase; acquisition (last 10 trials), anxiety transfer and low-anxiety transfer

greater in the low-anxiety compared to both the anxiety transfer and acquisition phases; the anxiety-control group significantly decreased performance from acquisition to anxiety transfer.

Discussion

The purposes of Experiment 2 were to further investigate the possibility that the specificity of learning theoretical framework (Gilligan & Bower, 1983; Henry 1968; Proteau, 1992) can explain the positive effects of practicing with anxiety and to examine when in the learning process practicing with anxiety is most appropriate for a complex task. Similar to Experiment 1, results showed that the

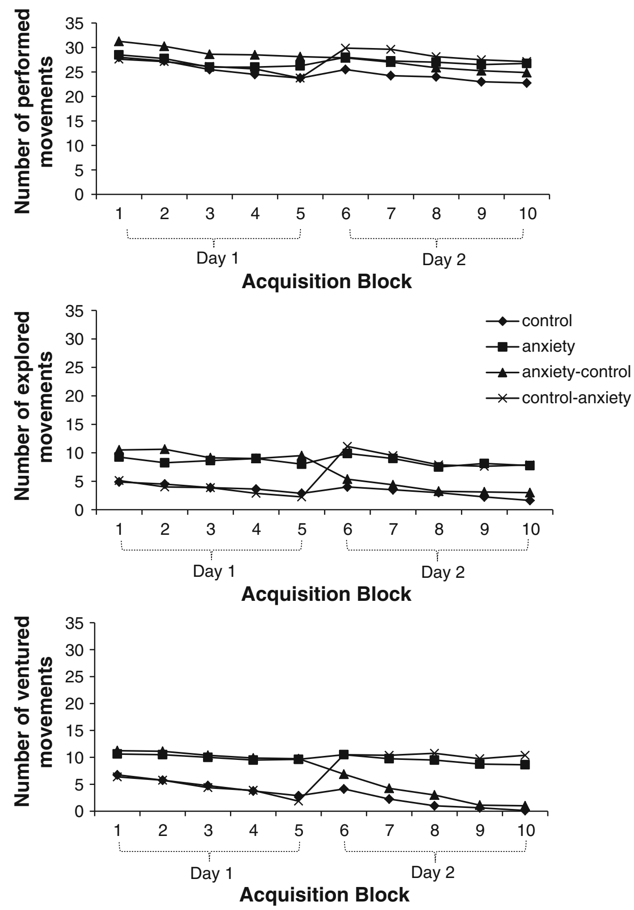

Fig. 5 Experiment 2 number of performed movements (*top*), number of explored movements (*middle*) and number of ventured movements (*bottom*) as a function of group and acquisition block (*1* trials 1–10; *2* trials 11–20…, *10* trials 91–100)

manipulation of anxiety was successful where targeted. In addition, task effort was similar for all groups and did not change as a result of the presence of anxiety.

The results of the performance data between acquisition and anxiety transfer for the control and anxiety groups are consistent with findings from Experiment 1. That is, practice under conditions of anxiety leads to more robust performance under future conditions of anxiety compared to non-anxiety practice conditions and learning without exposure to anxiety leaves one particularly vulnerable to its effects in subsequent performances. The results at the additional low-anxiety transfer test revealed that climbing times of the anxiety group significantly increased from acquisition to transfer, whereas there was no change between acquisition and transfer for the control group. Thus, performance decreased in both the control group and anxiety group when the transfer test resulted in a change in the conditions under which the skill had been practiced. These findings support a specificity perspective since those participants who practiced under conditions of anxiety

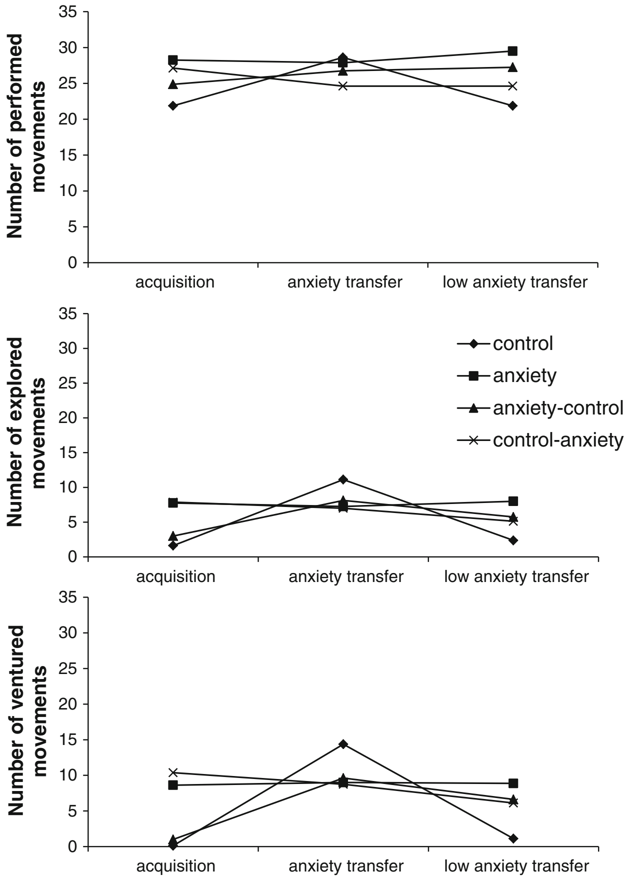

Fig. 6 Experiment 2 number of performed movements (*top*), number of explored movements (*middle*) and number of ventured movements (*bottom*) as a function of group and experimental phase; acquisition (last 10 trials), transfer 1 (anxiety) and transfer 2 (low-anxiety/control)

likely created associations during acquisition between the emotions of anxiety and the movements of the to-be-learned skill. As such, they developed representations of the movement during acquisition that were adapted to the presence of anxiety, whereas those participants in the control group developed movement representations that were adapted to the absence of anxiety. These findings are again consistent with evidence from manual aiming studies in which performance decrements have been observed following both the withdrawal (Proteau et al., 1987; Khan et al., 1998) and the addition of visual feedback (Proteau et al., 1992). Experiment 2 thus offers further direct evidence for the principles of specificity of practice in the context of affect, namely anxiety.

Comparison between the anxiety-control and control-anxiety groups enabled us to investigate when in the learning process practicing with anxiety is most appropriate. Unsurprisingly, traverse times for these groups only significantly improved during the low-anxiety (control) acquisition conditions and the analysis of the performance data at the midpoint of acquisition (i.e., the removal of anxiety and the introduction of anxiety for the anxiety-control and control-anxiety groups, respectively) revealed that the presence of anxiety negatively affected performance. Specifically, the control-anxiety group significantly increased traverse times following the introduction of anxiety, whereas the opposite was true for the anxiety-control group. Of more interest, with regard to investigating when in acquisition introducing anxiety is most appropriate, were the between-group differences in performance at anxiety transfer and low-anxiety transfer. Here, traverse times were greater in the low-anxiety transfer test for the anxiety-control group compared to the control-anxiety group. Thus, for practice conditions which included both anxiety and non-anxiety training, experiencing anxiety from start of learning was less effective in subsequent low-anxious situations compared to practice where anxiety was not introduced until later in the learning process. Importantly, the performance at anxiety transfer was significantly greater in both the anxiety-control and control-anxiety groups compared to the anxiety group alone. These findings indicate that a mix of both anxiety and control conditions during learning results in more robust performance in subsequent anxiety situations compared to practicing only with anxiety.

The specificity and the timing of anxiety introduction findings of time of traverse data are also supported by the number of movements performed (NOPM) and number of uncertain movements performed (NOEM, NOVM). Here data revealed that the performance at low-anxiety transfer was greatest in the control condition (acquisition to transfer congruent condition) and lowest in the anxiety condition (acquisition to transfer incongruent condition). Revealing that a change in learning conditions (i.e., the removal of anxiety) resulted in both a significant decrement in performance and a significantly reduced performance compared to situations where acquisition and transfer conditions were matched. Furthermore, the significant difference between the anxiety-control and control-anxiety groups at the low-anxiety transfer test (anxiety-control being significantly lower than control-anxiety) suggests that anxiety from the start of learning is detrimental to subsequent low-anxiety performance conditions.

General discussion

The main purpose of the present study was to investigate if the positive effects of practicing with anxiety (Oudejans 2008; Oudejans & Pijpers, 2009, 2010) can be explained through a specificity of learning perspective by investigating if these effects are dependent on the amount of exposure to anxiety and the timing of that exposure in the learning process. We investigated these issues using both a discrete golf putting task ("Experiment 1") and a more complex climbing ("Experiment 2") task.

The finding from both Experiments that learning with anxiety eliminated choking provided support for both mood and condition-congruent learning theories [e.g., the network theory of affect (Gilligan & Bower, 1983); specificity of learning (Henry, 1968); specificity of practice (Proteau, 1992)]. As explained earlier, the network theory of affect proposes that emotions be regarded as units within a network connecting related events, ideas, and muscular patterns. The activation of a unit creates somewhat of a 'domino' effect and other related units are also activated. As a result, a network is created between the emotional mood state at the time of learning and the muscular patterns of the to-be-learned skill (i.e., anxiety and the movements involved in golf putting in "Experiment 1" and climbing in "Experiment 2"). In the present investigation, it may have been that the anxiety condition in the transfer test served to activate the emotions associated with this mood state which in turn resulted in the activation and subsequent recall of the muscular patterns required during transfer of the learned golf putting action of Experiment 1 and the climb in Experiment 2. As such, those participants who created a network during acquisition between the emotions of anxiety and the movements of the to-be-learned skill (i.e., those who experienced anxiety while practicing) were better able to recall the required action during the subsequent anxiety transfer test. Further support for these mood congruent learning effects can be found in the results of the control (low anxiety) transfer introduced in Experiment 2. Here, participants who had received all practice under anxiety significantly increased climbing times from that of acquisition to the non-anxiety transfer test. Thus, when the transfer test resulted in a change in the conditions under which the skill had been learned (i.e., the absence of anxiety), a decrement in performance was observed.

This pattern of results can also be explained by the specificity principle. Henry (1968) proposed that the best learning experiences are those that most closely approximate the movements of the target skill and the environmental conditions of the target context, whilst Proteau (1992) and other researchers (Elliott et al., 1995; Khan & Franks, 2000; Khan et al., 1998; Mackrous & Proteau, 2007) suggest that participants develop movement plans during acquisition that are adapted and specific to the conditions available at the time of learning. As such, a change in the conditions under which the skill has been learned results in these movement plans no longer being appropriate for successful performance. This may explain why the only group to experience a decrement in performance during transfer to an anxious condition in Experiment 1 and Experiment 2 was that of the control. The movements developed by the participants in these groups were likely adapted to the conditions experienced during learning (i.e., the absence of anxiety) and thus a change in the conditions experienced between learning and transfer resulted in the movement no longer being effective for accurate performance.

Research investigating the specificity hypothesis has revealed that the effect is enhanced through increased practice (Khan et al., 1998; Proteau & Cournoyer, 1990; Proteau et al., 1987; Proteau et al., 1992; Proteau et al.,1998). The results of the current investigation support this phenomenon when one considers the analyses of the early and late transfer effects. Specifically, we compared the change in performance of the control-anxiety group at the midpoint of acquisition (i.e., the last block of control conditions to the introduction of anxiety) to the change in performance of the control group between the end of acquisition and the anxiety transfer test. Since the change from control conditions to anxiety conditions occurred at the midpoint of practice (early transfer) in the control-anxiety group and at the end of practice (late transfer) for the control group, greater performance decrements in late transfer compared to the early transfer would demonstrate specificity of practice. The results of these analyses revealed that the decrement in performance was greater in late transfer for both Experiment 1 and Experiment 2. These findings offer support for the specificity exposure effects hypothesized in that of the current investigation and the findings of previous research on specificity of practice (Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993; Proteau et al., 1987; Tremblay & Proteau, 1998, 2001) and thus lend further support for considering this hypothesis when attempting to explain the choking phenomenon.

Investigating the effects of introducing anxiety at different stages of the learning process revealed in both experiments that those participants in the anxiety-control group significantly increased performance following the switch in acquisition conditions, whereas those in the control-anxiety groups decreased performance. Furthermore, the performance (for all dependent variables) in both the anxiety and low-anxiety transfer tests of Experiment 2 was greater in the control-anxiety group compared to anxiety-control group. These findings suggest that training with anxiety from the start of learning may actually be detrimental to skill learning. It is likely that the presence of anxiety at this cognitive stage of learning increases the task demands to a level that reduces the efficiency of the learner (Eysenck et al., 2007) and the effectiveness of the performer's learning strategies. However, this notion is task dependent, since the performance differences between the anxiety-control and control-anxiety groups seen at the midpoint of acquisition were only present at transfer in

Experiment 2 (the more complex climbing task). As such, introducing anxiety from the beginning of acquisition disrupts the learning process to such a degree as to reduce the benefits of training with anxiety from the start of learning only in the more complex task.

Whilst the present investigation demonstrated specificity effects, both experiments adopted short delays between the completion of acquisition and the start of the transfer test (15 min in Experiment 1 and 1 h in Experiment 2). This was to ensure that the methodologies were in line with the seminal articles investigating specificity in manual aiming (e.g., Proteau et al., 1987, Proteau, 1992) and the experiments of Oudejans and Pijpers (2009) investigating training with anxiety on basketball and dart throwing. However, subsequent to completion of the current investigation, personal communication from the pioneer of the specificity hypothesis (Luc Proteau) clarified that the rationale for short delays in the manual aiming studies were due to the nature of the control group (typically a no vision condition). If longer delays between acquisition and transfer tests had been utilized, participants in the control group would have had visual feedback to control their everyday movements between the end of practice and the retention/transfer test. The availability of this feedback would have likely washed out any potential differences in transfer between the experimental group, where visual feedback is available during practice, and the no-vision control group. It appears that in the present investigation, longer delays between acquisition and transfer would unlikely result in the same confounding factor since the independent variable (anxiety) would not likely be experienced during that period to the same extent as the independent variable (vision) of the manual aiming studies. As such, future research should investigate the anxiety specificity effect with greater time intervals between the completion of training and the start of transfer to see if the specificity effects reported are more permanent in nature.

In conclusion, the specificity principle that has emerged from the motor learning literature offers an explanation for choking. That is, performance decrements occur due to a change in the conditions under which the task is practiced, both when conditions change from control to anxiety and anxiety to control. As such, the specificity principle should be considered in future research investigating the choking phenomenon. In addition, results revealed that training under anxiety should be adopted as a process for eliminating choking. Whilst performers and practitioners may find it difficult to replicate the anxiety experienced in 'real' high-pressure situations (i.e., a soccer penalty shoot out in the final of a cup game), utilizing anxiety manipulations similar to those in the present investigation (i.e., both internal and external competition together with incentives for loss) can still provide an effective training environment. Finally, the significantly greater performance of the control-anxiety group compared to the anxiety-control group in both the anxiety and low-anxiety transfer tests of Experiment 2 indicates that for more complex skills one should avoid introducing anxiety into training until later in the learning process. These findings highlight that introducing anxiety from the start of acquisition disrupts the learning strategies and results in less than optimum performance both in subsequent anxious and non-anxious situations.

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