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Samuel J. Vine; Mark R. Wilson

University of Exeter,

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Quiet Eye Training: Effects on Learning and Performance Under Pressure

SAMUEL J. VINE AND MARK R. WILSON

University of Exeter

The aim of this study was to examine the efficacy of quiet eye (QE) training in optimizing the learning and performance under pressure of novices in a putting task. Fourteen participants performed 40 pre-test putts and were randomly allocated into a QE training or control group. They then performed 320 acquisition phase putts and a further 120 test putts in a retention-transfer (pressure)-retention design. The QE-trained group maintained more effective attentional control and performed significantly better in the pressure test compared to the control group. Furthermore, longer QE periods were associated with better performance across all test putts.

Understanding how the acquisition and mastery of aiming skills may be optimized is a popular focus of research in sport psychology. Several different theoretical perspectives have been proposed which point to the role of attention in expediting learning and maintaining robust performance under conditions reflective of performance settings (e.g., ego-threatening conditions). Three of the most frequently cited approaches, Masters’ (1992) conscious processing hypothesis, Singer’s (2000) five-step strategy, and Wulf, McNevin, and Shea’s (2001) constrained action hypothesis, all implicate the negative impact of focusing inwards on the mechanics of the skill during motor learning. Indeed, both Singer and Wulf et al. (2001) explicitly recommend an external focus of attention during execution to help improve learning and maintain performance (see Singer, 2000, 2002; Wulf, 2007, for reviews). The aim of the current study was to examine the efficacy of an intervention designed to guide visual attentional control via quiet eye training to optimize the learning and performance under pressure of novice golfers in a putting task.

The Quiet Eye

Current research adopting gaze-tracking technology shows that when a high level of motor skill performance is attained, gaze is directed to the most important targets and objects in the visual-performance workspace (e.g., Vickers, 2007; Williams & Ford, 2008). Mainstream neuroscience research also suggests that the neural mechanisms regulating goal-directed movements profit from the accurate and timely spatial information of the foveated target (Land, 2009; Neggers & Bekkering, 2000). A particular gaze termed the quiet eye (QE; Vickers, 1996) has been shown to underlie higher levels of skill and performance in a wide range of aiming and interceptive skills (see Vickers, 2007, for a review). The QE has been defined as
the duration of the final fixation towards a relevant target prior to the execution of the critical phase of movement and has been accepted within the literature as a measure of optimal visual attentional control. Vickers (1996) suggests that the QE allows for a period of cognitive pre-programming of movement parameters while minimizing distraction from other environmental or internal cues.

Vickers (1996) used Posner and Raichle’s (1994) conceptualization of three neural networks (posterior orienting, anterior executive, and vigilance networks) to provide support for her postulations of how the QE may provide this “quiet focus.” The posterior orienting network, responsible for the location of gaze in space, may be used by performers to hold a stable and steady gaze on the target as well as preventing disengagement of this location to other locations. The anterior executive then acts to understand what is being seen and may account for adjustments in the timing of fixations in relation to the movement (longer QE periods), improving accuracy. The vigilance network is responsible for coordinating both of these networks and ensures there is no interference during sustained focus, something that is particularly relevant during periods of high pressure.

In golf putting specifically, the seminal study investigating the role of gaze control in mediating performance was carried out by Vickers (1992). The findings revealed proficiency differences in scan paths during the alignment phase of the putt, as well as differences in the timing and orientation of gazes during the putting action itself. Expert performers maintained a final fixation (QE) on the center or back of the ball that was initiated prior to the execution of the initial movement of the putter head away from the ball and lasted for approximately 2 s. Conversely less skilled golfers had a final fixation that lasted for only 1 to 1.5 s.; a finding that has since been corroborated by Vickers (2007) and Wilson and Pearcey (2009).

The QE has not only been shown to be indicative of superior performance, but has also been demonstrated to be trainable. Harle and Vickers (2001) utilized a QE training protocol in an attempt to improve the free throw accuracy of near-elite basketball players. The QE of each member of the team was recorded and viewed relative to an elite prototype in a feedback session using vision-in-action data (Vickers, 1996). Participants were then taught a 3-step QE training regime aimed at improving their visuomotor control. Results showed that not only did the team significantly increase their QE durations and free-throw percentages in a laboratory setting, but after two seasons in competitive play they had improved their free-throw percentage by 23%. This finding is particularly noteworthy as a recent examination of free-throw statistics suggests that the average free-throw percentages at the highest levels of the game have not significantly improved since the conception of the free-throw in the 1960s (75% in National Basketball Association, 69% in College basketball; Branch, 2009).

To date there are no published studies examining the efficacy of a QE training regime for golf putting, or for novice performers in any sport. The lack of research examining QE training with novice performers is perhaps surprising given that such an approach provides a functional way to optimize external attention; postulated as a critical aspect of optimal motor skill learning (e.g., Singer, 2000; Wulf, 2007). For example, Singer (1988, 2000), incorporated focusing attention on a key external component of the task (e.g., dimples on a golf ball) as the third step of his 5-step pre-shot routine for optimal motor learning. He proposed that such an external focus helped to create an optimal state for performance, and prevented learners from focusing on internal thoughts or body mechanics (Singer, 2000).

Wulf and colleagues (see Wulf, 2007) have consistently demonstrated that an external focus of attention (on the effect of the movement) is superior for motor learning to an internal focus of attention (on the mechanics of the skill). Although much of this research has focused on postural tasks, Wulf’s research in aiming tasks (e.g., golf chip shots) has also implicated an external focus of attention as critical for motor learning and performance (Bell & Hardy, 2009; Wulf,
Lauterbach, & Toole, 1999; Wulf & Su, 2007). Research by Zachary, Wulf, Mercer, and Bezodis (2005) examined the electromyography (EMG) activity of performers taking basketball free throws and found that when instructed to focus externally on the hoop (as opposed to the snapping motion of the wrist), performance improved. The performance improvements evident when participants were instructed to focus externally were also accompanied by reduced EMG activity in the shooting arm. The authors suggested that this may reflect a reduction in “noise” in the motor system, leading to greater accuracy. Interestingly, the explanation given by Zachary et al. (2005) for the benefits of target focused attention is similar to the mechanisms by which Vickers suggests the QE may work. However, a potential strength of QE training is that not only is the target of the focus of attention considered, but also its optimal duration and timing relative to the key movement components of the task.

Anxiety and Motor Skill Performance

Although optimizing the learning of motor skills is important, most sports are performed in situations of high levels of ego-threat. Anxiety has been shown to influence attentional control, and as a result, much research aimed at understanding the anxiety-performance relationship has focused on the underlying attentional mechanisms (see Janelle, 2002; Wilson, 2008, for reviews). Recent research has demonstrated that optimal attention, as indexed by QE, may be impaired (shorter QE durations) under heightened levels of anxiety (Behan & Wilson, 2008; Vickers & Williams, 2007; Wilson, Vine & Wood, 2009). Importantly, while reduced QE durations were associated with degraded performance, performers who maintained their optimal QE durations from control conditions also maintained performance. Vickers and Williams (2007) suggest that the act of allocating attention externally to critical task information (via the QE) appears to protect athletes from the normally debilitating effects of anxiety. Behan and Wilson (2008) and Wilson and Richards (2010) have therefore suggested that QE training programs may be a useful intervention to enhance attentional control (indicated by longer QE durations) in pressurized environments.

Aims

The aims of this research were to test the efficacy of a QE-training regime designed to experimentally manipulate the visual attentional control of novice performers in a golf-putting task. We predicted that participants in a QE-trained group would perform better in both a retention test (designed to assess learning) and a pressure test (under ego-threatening instructions), compared to those in a control group (technical instruction only), due to more optimal (external) attentional control. Specifically, we hypothesized that the following:

1. The QE-trained group would demonstrate better performance and attentional control (longer QE durations) in retention tests compared to their control group counterparts.
2. The QE-trained group would maintain attentional control (QE duration) and performance at retention test levels in a high threat condition (pressure test). In comparison, control group participants would display significantly poorer performance levels and attentional control in high pressure, compared to retention test conditions.
METHODS

Participants

Fourteen male undergraduate students (M age, 20.30 years, SD = 1.15) volunteered to take part in the study. All participants declared having little or no experience in golf or putting (Wulf et al., 1999; Wulf & Su, 2007) and all were right-handed. Seven additional participants had agreed to take part in the study and attended the laboratory for calibration with the eye tracker. However, we were unable to calibrate the eye tracker for three of these participants and the other four dropped out during the training period. Local ethics committee approval was obtained prior to the start of testing and participants provided written informed consent.

Apparatus

Putts were taken from 10 feet (3.33m) to a circular target (5cm radius), on an artificial putting surface, using a standard golf putter (Ben Sayers M7) and standard size (4.17 cm diameter) white golf balls. Nine concentric circles surrounded the central target (increasing by 5 cm in radius) to allow for a measure of performance error to be recorded. This “archery target” set up is consistent with previous research into golf putting (e.g., Wulf et al., 1999). Gaze was recorded throughout the testing period using an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye Tracker. This lightweight device uses two features, reflection of infrared light from the pupil and cornea, to calculate point of gaze (at 25 hz) relative to eye and scene cameras mounted on a pair of spectacles. A laptop (Dell Inspiron6400) installed with “Eyevision” (ASL) recording software was incorporated with the system. A circular cursor, representing 1° of visual angle with a 4.5-mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ± 0.5° visual angle; 0.1° precision), is recorded for offline analysis. Participants were connected to the laptop via a 10m fire wire cable, allowing for near normal mobility. The experimenter and equipment were located behind the participant to minimize distraction.

Measures

Performance

Performance in pre-test, acquisition and test phases was measured in terms of performance error (distance from the target circle) utilizing the aforementioned concentric circles. If the ball landed in the target circle, a score of 10 was given, if it landed in the next concentric circle then a score of 9 was given, out to a final circle representing 1 point. If the ball did not land in a circle then a score of 0 was given. As each phase was performed in blocks of 40 putts, a summative score was recorded, giving a maximum attainable score of 400 for each block.

State Anxiety

Cognitive state anxiety was measured before every 10 putts throughout the test phase using the Mental Readiness Form 3 (MRF-3, Krane, 1994). The MRF-3 has three, bipolar; 11-point Likert scales that are anchored between worried-not worried for the cognitive anxiety scale, tense-not tense for the somatic anxiety scale, and confident-not confident for the self confidence scale. The MRF-3 is a shorter and more expedient alternative to the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990) and Krane’s validation work revealed correlations between the MRF-3 and the CSAI-2 subscales of .76 for cognitive anxiety, .69 for somatic anxiety and .68 for self- confidence. The MRF-3 has also been used in
previous research examining the impact of cognitive anxiety on golf putting (Wilson, Smith, & Holmes, 2007).

**Quiet Eye (QE) Period**

We operationally defined the QE for golf putting as the final fixation towards the ball prior to the initiation of the back swing (as Vickers, 1992, 2007; Wilson & Pearcey, 2009). QE offset occurred when the gaze deviated from the ball by 1° of visual angle for more than 3 frames (120 ms).

**Movement Durations**

Three subcomponents of the putting action were used to help calculate the QE period, based on guidelines derived from previous research (see Vickers, 2007). The preparation began when the club-head was first set square behind the ball, the backswing began with the first observable backward movement of the club-head away from the ball, and the fore-swing began with the first observable forward movement of the club-head and lasted until contact with the ball. The movement time durations for each subcomponent were determined by an experimenter via frame-by-frame analysis of the ASL Mobile Eye video footage using quiet eye solutions software (see Data Analysis section).

**Procedure**

Participants attended individually and after reading the written information and signing the informed consent were given a chance to familiarize themselves with the surroundings. When they verbally stated that they were ready to commence, participants were then fitted with the eye tracker and calibration took place. Participants adopted their putting stance and were then asked to fixate in turn on one of six golf balls placed on the mat in front of them; four balls were placed in a square approximately half a meter in front of their feet and two balls were placed half a meter away from the target hole perpendicular to the direction of putting. Calibration was repeated every 10 shots to ensure that the eye tracker had not slipped, if this occurred then a recalibration was performed and the testing continued (this happened on only four occasions throughout the whole testing period).

The pre-test acquisition and testing phases took place over a total of eight days and were scheduled as follows. On the morning of Day 1, a measure of performance and QE were recorded for the first block of 40 putts. This data acted as a baseline (pre-test) measure, and ensured that the eye tracker was working correctly. During the afternoon of Day 1, participants began their assigned training regime (QE or control) and performed a further 80 putts (2 blocks of 40). The group-specific training points were repeated to each participant before the start of each block of 40 putts (see Training Protocol section). Three blocks of 40 putts were then performed on days two and three to complete a total of 360 putts; 9 blocks in total (one pre-test block and eight blocks in the assigned training regime). The duration of the acquisition phase and the number of putts taken is congruent with previous training studies for self-paced motor skills (e.g., Lam, Maxwell & Masters, 2009; Masters, 1992; Poolton, Masters, & Maxwell, 2005; Poolton, Maxwell, Masters & Raab, 2006).

On Day 5, participants returned and performed a retention test, consisting of a single block of 40 putts without the guidance associated with their training regime. On Day 8, participants performed a transfer (pressure) test, which consisted of 40 competition putts, aimed at manipulating levels of cognitive anxiety. Finally, participants performed a second retention test (identical to Retention Test 1) to form the typically adopted A-B-A (retention-transfer (pressure)-retention) design across 120 putts (as Lam et al., 2009). Three participants
deviated slightly from this routine due to time commitments. One participant started late, so performed the acquisition phase on Days 3, 4 and 5 and then retention and pressure tests on Days 8 and 9. Two participants performed the pressure test and retention test 2 on Day 9 instead of Day 8. Finally, participants were thanked and debriefed about the aims of the study and offered the opportunity to withdraw their data. No participants withdrew due to concerns about the deceptive element of the research.

Training Protocol

Participants were randomly assigned to either a QE-training or control group. The control group received coaching guidance related to the mechanics of their putting action and stroke (derived from www.abc-of-golf.com; www.bbc.co.uk/sport). The QE-trained group received the same basic coaching instructions as the control group, but also received a specific QE-training element (derived from Vickers, 2007). The training instructions consisted of 5 key points in each case (see Table 1). Each of the technical and gaze instructions were coupled to reflect the same phase of the putt (i.e., preparation, aiming, putter-ball alignment, swing, and follow through) to minimize differences in the focus and timing of the instructions. The relevant training points (either coaching points or both coaching and QE) were repeated to each participant at the start of each block of 40 putts.

Anxiety Manipulation

Several techniques consistent with previous research were used to manipulate levels of cognitive anxiety for the pressure test (see, Wilson et al., 2009). First, a competition was set up whereby participants were informed that the individual with the best score would receive a £50 cash reward. Second, participants were told that their scores would be compared with others taking part and may be used as part of a presentation to their fellow students. Finally, non-contingent feedback was used, whereby participants were informed that their previous 40 putts (retention test 1) would put them in the bottom 30% when compared to those who had already taken part in the competition. They were told to try and improve upon their performance otherwise their data would be of no use for the study.

Table 1
Instructions Given during the Training Protocol

<table>
<thead>
<tr>
<th>QE training instructions</th>
<th>Technical instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assume stance and ensure that gaze is on the back of the ball.</td>
<td>Stand with legs hip width apart and keep your head still.</td>
</tr>
<tr>
<td>Fixate the hole. (Fixation should be made no more than three times).</td>
<td>Maintain relaxation of shoulders and arms.</td>
</tr>
<tr>
<td>Your final fixation should be on the back of the ball and for no longer than 2–3 seconds.</td>
<td>Keep the putter head square to the ball.</td>
</tr>
<tr>
<td>No gaze should be directed to the club head or shaft during the putting action.</td>
<td>Perform a pendulum-like swing and accelerate through the ball.</td>
</tr>
<tr>
<td>Your fixation should remain steady for 200–300 ms after contact with the ball.</td>
<td>Maintain a still head after contact.</td>
</tr>
</tbody>
</table>
Data Analysis

Video data from the Mobile Eye were analyzed after the testing period using quiet eye Solutions software (www.QuietEyeSolutions.com). This software allows for detailed frame-by-frame coding of both the motor action (recorded from the Mobile Eye’s scene camera at 25Hz) and the gaze behavior of the performer, creating “vision-in-action” data. The software then automatically calculates the QE and movement durations. Consistent with previous QE research (e.g., Behan & Wilson, 2008; Vickers & Williams, 2007; Wilson et al., 2009), a subset of putts (every fourth) was selected for analysis. The experimenter was blind to the status (training group) of each participant at the point of analyzing the video data. This data was saved using a descriptor that did not reveal participants’ status, which was only accessed when the data needed to be grouped for subsequent statistical analyses.

Statistical Analysis

Acquisition phase performance data (including initial pre-test phase) were subjected to a 2 (Group) × 9 (Block) mixed design analysis of variance (ANOVA). Anxiety and movement duration data for the test phase (retention 1, pressure, retention 2) were subjected to a 2 (Group) × 3 (Test) mixed design analysis of variance (ANOVA). Performance and QE data were subjected to a 2 (Group) × 4 (Test) mixed design analysis of variance (ANOVA). In the latter analysis, as well as comparing the three conditions from the test phase, pre-test phase (Block 1) data were included to assess learning. Significant main effects were followed up with Bonferroni corrected post hoc t tests; interaction effects were followed up with simple t tests and effect sizes were calculated using Partial Eta squared ($\eta_p^2$) for omnibus comparisons. Linear regression analysis was also performed on the QE and performance variables for the test phase, to assess the degree to which QE durations predicted variance in performance.

RESULTS

Acquisition Phase Performance

ANOVA revealed a significant main effect for block, $F(8,96) = 9.54, p < .001, \eta_p^2 = .44$, indicating that all performers significantly improved throughout the acquisition phase. Significant improvements in performance from baseline (pre-test) occurred from block 4 onwards ($p < .05$). There was no main effect for group, $F(1,12) = 3.02, p = .11, \eta_p^2 = .20$, and no interaction effect, $F(8,96) = 1.04, p = .40, \eta_p^2 = .08$, suggesting that the rate of acquisition was similar for both groups. The acquisition phase performance data is presented in Figure 1.

Cognitive Anxiety

ANOVA revealed a significant main effect for test, $F(2,24) = 58.76, p < .001, \eta_p^2 = .83$, with anxiety being significantly higher during the pressure test than retention tests 1 ($p < .01$) and 2 ($p < .001$). There was no significant main effect for group, $F(1,12) = 0.22, p = .64, \eta_p^2 = .02$, and no interaction effect, $F(2,24) = 1.33, p = .28, \eta_p^2 = .10$, revealing that both groups reported similar levels of anxiety. While cognitive anxiety was the main focus of the analysis, the self-report data from all 3 scales of the MRF-3 are presented in Table 2.
Movement Durations

Preparation

ANOVA revealed no significant main effect for test, $F(2,24) = 0.45, p = .64, \eta_p^2 = .04$, however there was a significant main effect for group, $F(1,12) = 16.98, p < .005, \eta_p^2 = .59$, indicating that the QE-trained group displayed significantly longer preparation times across all three tests. There was no significant interaction effect, $F(2,24) = 0.10, p = .89, \eta_p^2 = .01$.

Table 2
Mean (Standard Deviation) Scores from MRF-3 Questionnaire and Movement Durations for Quiet Eye (QE)-Trained and Control Groups Across Pressure and Retention Tests

<table>
<thead>
<tr>
<th></th>
<th>Retention 1</th>
<th>Stress</th>
<th>Retention 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>QE-trained</td>
<td>Control</td>
<td>QE-trained</td>
</tr>
<tr>
<td>Cognitive Anxiety</td>
<td>2.77</td>
<td>2.22</td>
<td>6.2</td>
</tr>
<tr>
<td></td>
<td>(0.91)</td>
<td>(0.52)</td>
<td>(1.2)</td>
</tr>
<tr>
<td>Somatic Anxiety</td>
<td>2.57</td>
<td>2.38</td>
<td>5.75</td>
</tr>
<tr>
<td></td>
<td>(0.44)</td>
<td>(1.05)</td>
<td>(1.34)</td>
</tr>
<tr>
<td>Self Confidence</td>
<td>7.22</td>
<td>6.8</td>
<td>3.25</td>
</tr>
<tr>
<td></td>
<td>(1.36)</td>
<td>(1.14)</td>
<td>(0.97)</td>
</tr>
<tr>
<td>Preparation (ms)</td>
<td>5164.71</td>
<td>1270.28</td>
<td>5605.71</td>
</tr>
<tr>
<td></td>
<td>(2319.62)</td>
<td>(1261.06)</td>
<td>(2229.70)</td>
</tr>
<tr>
<td>Back-swing (ms)</td>
<td>592.06</td>
<td>506.85</td>
<td>652.57</td>
</tr>
<tr>
<td></td>
<td>(105.88)</td>
<td>(112.70)</td>
<td>(130.79)</td>
</tr>
<tr>
<td>Fore-swing (ms)</td>
<td>320.31</td>
<td>370.28</td>
<td>312</td>
</tr>
<tr>
<td></td>
<td>(41.78)</td>
<td>(73.75)</td>
<td>(55.52)</td>
</tr>
</tbody>
</table>

Figures and tables have been extracted from their respective positions in the text. The main content focuses on the results from an experiment comparing quiet eye (QE)-trained and control groups in terms of movement durations and questionnaire scores. The figures and tables are presented in a natural text format, adhering to the guidelines provided.
**Back-swing**

ANOVA revealed no significant main effect for test, $F(2,24) = 0.99, p = .38, \eta_p^2 = .08$, however there was a significant main effect for group, $F(1,12) = 6.78, p < .05, \eta_p^2 = .36$, indicating that the QE-trained group displayed significantly longer back-swing times across all three tests. There was no significant interaction effect, $F(2,24) = 0.10, p = .90, \eta_p^2 = .001$.

**Fore-Swing**

ANOVA revealed no significant main effect for test, $F(2,24) = 1.13, p = .33, \eta_p^2 = .09$, or group, $F(1,12) = 1.86, p = .19, \eta_p^2 = .14$, and no significant interaction effect, $F(2,24) = 0.31, p = .73, \eta_p^2 = .03$. All phases of movement data are presented in Table 2.

**Pre-Test and Test Phase Performance**

ANOVA revealed significant main effects for group, $F(1,12) = 4.99, p < .05, \eta_p^2 = .29$ and test, $F(3,36) = 24.15, p < .001, \eta_p^2 = .67$, and a significant interaction effect, $F(3,36) = 3.96, p < .05, \eta_p^2 = .25$. Follow up $t$ tests showed that there were no significant performance differences between groups for pre-test ($p = .74$), retention test 1 ($p = .12$), or retention test 2 ($p = .12$), suggesting that the degree of learning was similar for both groups. However, the control group did perform significantly worse than the QE-trained group in the pressure test ($p < .005$). Within groups, the QE-trained group displayed significant improvements in performance between pre-test and retention test 1 ($p < .001$) but no significant differences between retention test 1 and the pressure test ($p = .32$) or retention test 2 and the pressure test ($p = .55$). There was also no significant difference between retention test 1 and retention test 2 ($p < .05$) indicating that no further learning had occurred during the test phase. The control group displayed significant improvements in performance between pre-test and retention test 1 ($p < .01$) and reductions in performance between retention test 1 and the pressure test ($p < .01$) and retention test 2 and pressure test ($p < .01$). The control group also displayed no significant difference between retention test 1 and retention test 2 ($p = .58$). Pre-test and test phase performance data are presented in Figure 2.

**Pre-Test and Test Phase QE**

ANOVA revealed a significant main effect for group $F(1,12) = 81.99, p < .001, \eta_p^2 = .87$ and test, $F(3,36) = 41.13, p < .001, \eta_p^2 = .77$, and a significant interaction effect $F(3,36) = 21.55, p < .001, \eta_p^2 = .64$. Follow up $t$ tests revealed no significant QE differences between groups for pre-test ($p = .38$), however there was a significant difference between groups at retention test 1 ($p < .01$), the pressure test ($p < .01$) and retention test 2 ($p < .01$). Within groups, the QE-trained group displayed a significant increase in QE from pre-test to retention test 1 ($p < .001$), and a significant decrease in QE from retention test 1 to the pressure test ($p < .05$), but not between retention test 2 and the pressure test ($p = .26$). There was also no significant difference in QE between retention test 1 and retention test 2 ($p = .87$). The control group displayed significant improvements in QE from pre-test to retention test 1 ($p < .05$), but a significant decrease in QE from retention 1 ($p < .01$) and retention test 2 ($p < .05$) to the pressure test. There was also no significant difference in QE for the control group between retention test 1 and retention test 2 ($p = .76$). Pre-test and test phase QE data are presented in Figure 2.
Figure 2. Putting performance (score/400) and QE (ms) for quiet eye (QE) trained and control group across the 4 tests (pre-test, retention test 1, pressure test & retention test 2).

Regression Analysis

Results from the regression analysis revealed that QE period predicted 36% of the variance in performance during the test phase ($R^2 = .358, \beta = .60, p < .001$).

DISCUSSION

The aim of this research was to examine the efficacy of a quiet eye (QE) training regime aimed at optimizing the learning and performance under pressure of a golf-putting task. Previous research has highlighted the benefits of focusing externally during the acquisition and performance of a motor skill. QE training is therefore a practical technique to guide an external focus of visual attention while also guiding its timing in relation to critical movements (visuomotor control).

Learning

There were no differences in the performance levels of both groups at baseline (pre-test), indicating that both groups started from similar novice levels of performance. Results revealed a significant improvement in performance for both groups from pre-test to retention test 1, indicating that a degree of learning had occurred (Figure 2). The absence of any significant differences in performance between retention tests 1 and 2 for each group suggests some level of stability of learning had been attained. However, it is unlikely that full automaticity has been achieved for these participants after only 480 repetitions (see Masters, 1992; Mullen & Hardy, 2000). Although the QE-trained group demonstrated better performance in retention tests 1 and 2 than their control group counterparts, this difference was not significant (see Figure 2). The results from the acquisition phase (Figure 1) also suggest that both groups’ performance had improved in a similar manner.
The QE data (Figure 2) revealed that both groups had similar QE durations at baseline (pre-test), suggesting that any subsequent changes in duration should be the result of the training instructions provided. As expected, the QE-trained group had longer QE durations compared to their control group counterparts throughout the test conditions. Interestingly, while the significant increase in QE duration for the QE trained participants from pre-test to retention test 1 was expected, there was also a significant increase in QE duration for the control group. Despite receiving no explicit instructions related to gaze control, these participants appear to have developed more effective visuomotor control through discovery learning over repeated skill attempts. However, the mean QE at retention 1 test for the control group (1411.43 ms, $SD = 372.86$) is still significantly lower than that of the QE-trained participants in the current study (3521.86 ms, $SD = 540.60$) and is more representative of the QE duration of less expert putters (i.e., between 1 and 1.5 seconds; as reported in Vickers, 2007).

Results from the putter movement duration data indicate that the QE-trained group displayed significantly longer preparation and back swing durations than their control group counterparts. As both groups had the same technical instructions related to movement control, these differences are likely due to the alterations in visuomotor control derived from the extended QE durations (see also Zachary et al., 2005). This is a potentially important finding as it indicates that visual-attentional training may craft a change in the mechanics of the putting stroke, although the instructions focus only on gaze control (cf. Harle & Vickers, 2001). Neuroscience research provides support for this contention, in that it has been reliably demonstrated that eye movements to informative locations in a scene tend to precede motor actions, which are then guided, monitored, and ultimately terminated under vision supervision (Land, 2009). The role of strategic gaze behavior in optimizing accurate motor control has been demonstrated reliably in tasks as varied as pointing (Sarlegna, Blouin, Bresciani, Bourdin, Vercher, and Gauthier, 2003), reaching and grasping (Neggers & Bekkering, 2000), driving (Wilson, Stephenson, Chattington, & Marple-Horvat, 2007), and household activities (Land, Mennie, & Rusted, 1999).

In contrast to the predictions of hypothesis 1, the QE-trained group did not perform better than the control group in retention tests 1 and 2, despite having significantly longer QE periods (see Figure 2). It cannot therefore be stated that a QE training program expedites the learning of golf putting for novice participants. However, the results from the regression analysis lead to the suggestion that longer QE periods are indicative of superior performance. Furthermore, although differences in performance in the retention tests were non-significant, they were in the predicted direction. The lack of statistical difference is likely due to individual variations in performance within the groups and the lack of power caused by the relatively small sample size. Indeed, this explanation is supported by a subsequent analysis of the data at an individual level. The top three performance scores during retention test 1 (mean, 333.33, $SD = 9.29$) were from participants from the QE-trained group with long mean QE durations (mean, 3561.33 ms, $SD = 326.35$). In contrast, the bottom 3 performance scores were from participants from the control group (mean, 279.67, $SD = 5.03$), who had much shorter mean QE durations (mean, 1372.00, $SD = 267.82$).

**Pressure Effects**

The MRF-3 data supports the effectiveness of the anxiety manipulation, in that both groups were significantly more anxious during the pressure test than the retention tests. The reported anxiety levels are similar to those found in other laboratory (e.g., Wilson, Smith et al., 2007; Wilson et al., 2009) and competitive (e.g., Krane, 1994; Smith, Bellamy, Collins, & Newell, 2001) environments. While there were no group-differences in the level of anxiety reported...
by the participants, the effect of this anxiety on each group’s performance was different, as hypothesized (hypothesis 2). Specifically, while the control group performed significantly worse in the pressure test than the retention tests, the QE-trained group managed to maintain pressure test performance at retention test 1 levels (Figure 2).

Although the interaction effect found for the performance data supports our prediction that QE training may act in some way to protect the performer from the negative effects of anxiety, the actual QE data results are not fully supportive of our hypotheses. Follow-up tests on the QE data revealed that there was a significant decrease in QE duration from retention test 1 to the pressure test for both the control and QE-trained groups (see Figure 2). This finding is in accord with recent research testing attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), which has demonstrated that anxiety impairs visual-attentional control and acts to cut short the QE period of performers (Behan & Wilson, 2008; Wilson et al., 2009). However, if QE training did not help anxious participants to maintain attentional control at retention test levels, how was performance maintained under pressure by these participants?

A re-examination of the QE data in Figure 2 appears to provide some answers to this unexpected finding. The control group displayed a significant reduction in QE from retention to pressure test (of 482 ms), reducing their average QE to 894 ms. Previous research has demonstrated that durations of less than one second are insufficient to produce consistently accurate performance (Vickers, 1992; Vickers, 2007). Although the QE-trained group also displayed a significant reduction in QE (of 410 ms), this only reduced their QE to an average of 2.8 seconds, a figure that previous research has shown to be indicative of accurate performance (Vickers, 1992; Vickers, 2007). We therefore suggest that despite anxiety significantly reducing the QE period, this remained within an optimal zone and above a critical threshold for performance to be maintained (see Behan & Wilson, 2008).

One concern with our interpretation of the performance results related to changes in target-directed gaze control, is that both groups also received technical instructions; with the QE-trained group effectively receiving additional (as opposed to distinct) training instructions. Therefore, the superior performance under pressure of the QE-trained group may have been simply due to that group receiving a greater volume of instruction (both technical and gaze related) and this is acknowledged as a limitation of the study. Subsequent research should therefore attempt to replicate our findings by adopting distinctly different training protocols to avoid the potentially confounding effect of the volume of training instructions received.

The rational for our decision to include both technical and gaze-related coaching points for the QE-trained group was based on Masters’ (1992) conscious processing (reinvestment) hypothesis, and concerns with providing explicit technical instructions to only the control group. A consistent finding in the golf putting literature (see Masters, 1992; Mullen & Hardy, 2000; Wilson et al., 2007) is that performers are likely to choke under pressure if they reinvest in the explicit knowledge base underlying skilled performance. Indeed the results of our control group support Masters’ predictions that explicit learning may cause performers to choke under pressure. However, the QE-trained group was able to maintain performance despite being provided with the same explicit instructions. This finding suggests that QE training may help performers maintain a focus on the critical stimuli underpinning optimal performance and away from task-unproductive cues (like movement mechanics).

An alternative explanation is that QE training might create a form of implicit learning, where learners are partially protected from developing explicit rules by focusing only on the external target, and not movement control. However, as we did not assess the number of explicit rules generated by both groups (Masters & Maxwell, 2008), it is not possible to determine if QE training does act to reduce the accrual of explicit knowledge (cf. analogy learning, Lam et al., 2009). Whatever the specific mechanisms, it is evident that novice golfers
were able to maintain performance despite significant increases in self-reported anxiety when directed to attend to a single, external cue. Future research should examine the degree to which QE training may aid the accrual of implicit knowledge, to better understand the mechanisms through which QE training may expedite robust skill learning.

A word of caution is that, unlike in previous QE-training studies, (e.g., Harle and Vickers, 2001; Vickers & Adolphe, 1997) the present study did not analyze the transfer effects to “real” competition. Williams and Grant (1999), state that, “few studies have attempted to determine whether the pre- to- post test improvement observed in clinical settings transfer to the sport domain” (p.198). Therefore, a limitation is that the transfer of the potential benefits of training the QE to the competitive world of golf cannot be made. Future research should attempt to test the efficacy of QE training for competitive golfers and assess performance both under laboratory conditions and on the course.

It is also acknowledged that the analysis of the putter movement was limited, in that it focused only on temporal changes in the phases of the swing path, as opposed to more detailed kinematic analyses (e.g., Cooke, Kavussanu, McIntyre, & Ring, 2010; Poolton et al., 2005). Subsequent studies might seek to adopt such measures to determine if more effective attentional control might influence processes underpinning performance (e.g., more consistent putter head position at contact). However, it is not clear that such kinematic analyses always provide more insight into the processes underlying putting performance under pressure. For example, despite assessing a wide range of kinetic and kinematic variables, Mullen and Hardy (2000) found no conclusive “process” changes due to pressure, despite putting performance being significantly impaired. Furthermore, recent research by Karlsen, Smith, and Nilsson (2008) found that the putting stroke itself may have limited influence on the amount of putts holed. These authors found that the direction variability in the putting strokes of elite players was very low and should relate to 95% of 4m putts being holed (given perfect conditions). However, statistics from the Professional Golfers’ Association (PGA) Tour for the 2009 season reveal that the percentage of putts holed from ten to fifteen feet is less than 30% (PGA Tour Putting Statistics, 2009).

Implications

From an applied perspective the findings of this study have some important implications. The benefits to performance under pressure of QE training highlighted in this study offer an insight into a potential future direction for golf coaching. Much of the guidance currently given by coaches focuses upon the mechanics of the movement and draws an individual’s attention inwards, something that has been shown to be counterproductive (Wulf, 2007). However, difficulties may be encountered when attempting to direct a performer’s focus of attention to external sources (Bell & Hardy, 2009) and away from explicit movement rules (Masters & Maxwell, 2008). QE training may act as a practical and easily applicable training regime that acts to focus an individual’s attention correctly, and help optimally coordinate gaze and motor control.

From a sport psychology perspective, a key goal is to help performers deal with the emotional and cognitive factors inherent in performing in ego-threatening situations (e.g., Hardy, Jones, & Gould, 1996; Zinsser, Bunker, & Williams, 2006). Pre-performance routines, consisting of behavioral and cognitive elements, have been proposed as a useful strategy for maintaining concentration and perceptions of control in pressurized environments (Moran, 1996). As discussed in the Introduction, Singer’s 5-step strategy has been shown to facilitate learning and performance in a number of laboratory and field studies (see Singer, 2000; 2002). It focuses on creating the conditions for a “just do it” performance state, and emphasizes that
optimally focused attention is best achieved by selecting one, appropriate external cue. The QE may be seen as a part of the pre-performance routine, helping the performer focus on what he or she can control (an external, process-related cue) rather than on non-productive (internal) thoughts and emotions (see, Wilson & Richards, 2010).

An important consideration when attempting to guide attention via directing external fixations is the degree to which the location of overt gaze is reflective of the target of covert attention. Some practitioners (e.g., Singer, 2000; Vickers, 2007) suggest that directing attention externally via gaze control might make it more difficult for performers to also focus on internal thoughts. Indeed, neuroscience research suggests that there is substantial overlap between the areas of the cortex involved in shifting gaze and shifting covert attention (e.g., Corbetta, 1998; Shipp, 2004), and that it is difficult to shift the point of gaze without shifting attention (Henderson, 2003). However, practitioners must recognize that while gaze may be directed to the external cue, covert attentional shifts (e.g., cognitive intrusions; Sarason, 1988) may still take place during the QE period. Any psychological training program aiming to help athletes cope with performing in pressure environments should therefore also consider the impact of these internal thoughts and emotions (see Zinsser et al., 2006).

To conclude, the current study investigated the efficacy of a QE training regime, aimed at optimizing the learning and subsequent maintenance of performance under pressure of golf putting. Results indicated that QE training acted to protect performers from the adverse effects of anxiety by maintaining effective QE fixation durations and attentional control. The group data did not support our predictions that QE-trained participants would show significantly improved learning compared to their control group counterparts. However, an examination of individual performance and QE data revealed supportive results for the best and worst performing participants. These results suggest that future research on potential expediency of learning benefits from QE training is warranted. From an applied perspective, QE training may provide a useful method to guide visuomotor skill training and a psychological technique to aid performance under pressure.

FOOTNOTE

1. The use of a retention test, designed to assess the stability of learning is consistent with previous motor learning research (e.g., Lam et al., 2009; Poolton et al., 2005; Salmoni, Schmidt, & Walter, 1984; Wulf & Su, 2007).

REFERENCES


