This is a peer-reviewed, post-print (final draft post-refereeing) version of the following published document:

Moore, Lee J, Vine, Samuel J, Smith, Adam N, Smith, Sarah J and Wilson, Mark R (2014) Quiet eye training improves small arms maritime marksmanship. Military Psychology, 26 (5-6). pp. 355-365. doi:10.1037/mil0000039

This is a peer-reviewed, post-print (final draft post-refereeing) version of the following published document. This article may not exactly replicate the final version published in the APA journal. It is not the copy of record.

Published in Military Psychology, and available online at:

http://psycnet.apa.org/?&fa=main.doiLanding&doi=10.1037/mil0000039

We recommend you cite the published (post-print) version.

The URL for the published version is http://dx.doi.org/10.1037/mil0000039

PLEASE SCROLL DOWN FOR TEXT

Quiet Eye Training Improves Small Arms Maritime Marksmanship

AQ: au

Lee J. Moore
University of Exeter and University
of Gloucestershire

Samuel J. Vine
University of Exeter

Adam N. Smith and Sarah J. Smith
Defence Science and Technology Laboratory,
●●●, ●●●

AQ: 1

Mark R. Wilson
University of Exeter

Quiet eye training—teaching task-specific gaze control—has been consistently shown to optimize the acquisition of motor skills. The present study aimed to examine the potential benefits of a quiet eye training intervention in a simulated maritime marksmanship task that involved shooting fast approaching moving targets with a decommissioned general-purpose machine gun. Twenty participants were randomly assigned to a quiet eye trained (QET) or technical trained (TT) group and completed 2 baseline, 20 training, and 2 retention trials on the moving-target task. Compared to their TT counterparts, the QET group displayed more effective gaze control (longer quiet eye durations and greater target locking) and more accurate performance (smaller radial error of both the initial shot and average of all shots) at retention. These findings highlight the potential for quiet eye training to be used to support the training of marksmanship skills in military settings.

Keywords: skill acquisition, attention, motor learning, visuomotor control, simulation

Effective gaze control supports the performance of visually guided motor tasks (Vickers, 2011). Indeed, recent research in sport has demonstrated that when individuals are trained to employ optimal gaze control (e.g., longer quiet eye durations), motor performance can be improved above that of selected control groups (see Causer, Janelle, Vickers, & Williams, 2012; Vine, Moore, & Wilson, 2014 for recent reviews). Despite these encouraging findings, the effectiveness of such training interventions has rarely been examined outside of sport in other domains where efficiently learning and successfully performing visually guided motor tasks is of paramount importance (e.g., military, surgery, and aviation). Thus, the aim of the present study was to examine the effectiveness of a gaze training intervention (quiet eye training) for small arms maritime marksmanship.

Research has examined the gaze control strategies employed in various visually guided motor tasks (see Gegenfurtner, Lehtinen, & Saljo, 2011; Mann, Williams, Ward, & Janelle, 2007 for meta-analyses and reviews). One key gaze strategy that has emerged from this research is the quiet eye (Vickers, 1996). The quiet eye is defined as the final fixation or tracking gaze toward a relevant target in the visuomotor work space within 3° of visual angle (or less) for a minimum of 100 ms. The onset of the quiet eye

occurs prior to the initiation of the critical movement in the task and the offset occurs when the final fixation deviates from the target by more than 3° of visual angle for more than 100 ms (Vickers, 2007). The quiet eye is proposed to reflect an important period of information processing during which the parameters of the movement (e.g., direction and force), as well as the timing and coordination of the limbs, are fine-tuned and programmed (Vickers, 1996). Recent research has supported this assertion using cortical measures of motor programming (e.g., the bereitschaftspotential; Mann, Coombes, Mousseau, & Janelle, 2011) and controlled experimental manipulations (e.g., Klostermann, Kredel, & Hossner, 2013).

The quiet eye has been robustly shown to differentiate varying levels of expertise (*inter*-individual) and proficiency (*intra*individual), with experts having longer quiet eye durations than nonexperts and successful attempts having longer quiet eye durations than unsuccessful attempts. For example, Causer and colleagues (2010) found that elite shotgun shooters displayed longer quiet eye durations than their subelite counterparts during skeet, trap, and double trap disciplines. Furthermore, in all three disciplines, quiet eye durations were longer during successful compared to unsuccessful shots for both elite and subelite shooters (Causer, Bennett, Holmes, Janelle, & Williams, 2010). Importantly, these findings have been consistently reported across a range of near- and far-aiming tasks as well as interceptive and tactical tasks (Vickers, 2007).

The quiet eye has also been shown to be trainable, with subsequent benefits to performance. For example, Causer and colleagues (2011) found that following training, an elite group of shotgun shooters who received a quiet eye training intervention exhibited longer quiet eye durations and higher shooting accuracy than those shooters in a control group (Causer, Holmes, & Williams, 2011). However, the benefits stemming from quiet eye training interventions are not limited to experts. Indeed, research has shown that training novices to understand "where and when" to focus gaze in the time preceding and during the critical movement of a task can expedite skill acquisition in tasks including golf putting (Moore, Vine, Cooke, Ring, & Wilson, 2012; Vine & Wilson, 2010), basketball free-throw shooting (Vine & Wilson,

2011), and laparoscopic surgery (Vine, Masters, McGrath, Bright, & Wilson, 2012; Wilson et al., 2011).

To date, there has been no research that has tested the benefits of quiet eye training interventions for novices in moving-target tasks, tasks that require individuals to anticipate the target's speed and direction before initiating the motor response (Vickers, 2007). Additionally, these interventions have rarely been examined in nonsporting domains where visually guided motor tasks must be efficiently learned and performed. One exception is surgery, where research has shown that gaze training interventions can aid the acquisition of basic laparoscopic surgical skills (e.g., Vine et al., 2012; Wilson et al., 2011). For example, Vine and colleagues found that a gaze trained group displayed superior gaze control consisting of a higher percentage of time spent fixating targets rather than the surgical instruments (i.e., greater target locking) than a control group. Importantly, the gaze trained group also outperformed the control group in the surgical task (i.e., faster completion times and fewer errors) during retention trials (Vine, Chaytor, McGrath, Masters, & Wilson, 2013).

Another domain that might benefit from such gaze training interventions is military training. There are a number of specialist areas within the military where efficiently learning and successfully performing visually guided motor tasks is important for operational effectiveness. Indeed, a number of authors have called for research investigating the effectiveness of interventions aimed at training military-relevant perceptual-cognitive skills in order to enhance military training (Chung, Delacruz, de Vries, Bewley, & Baker, 2006; Vogel-Walcutt, Fiorella, & Malone, 2013). An obvious area to initially focus such research is military marksmanship training, where work to date has predominately focused on technical aspects related to performance (e.g., weapon movements and postural balance; Mononen, Viitasalo, Konttinen, & Era, 2003; Mononen, Konttinen, Viitasalo, & Era, 2007). There is a large body of research (see Wulf 2013 for a review) that has called into question the efficacy of focusing internally on technical skills, and indeed, recent research has demonstrated that such traditional interventions are less effective than quiet eye training inter-

ventions (Moore et al., 2012; Vine & Wilson, 2010, 2011; Wilson et al., 2011).

The current study therefore seeks to address these knowledge gaps and provide a departure point for further applied research into training military-relevant perceptual-cognitive skills. The focus for this initial study was maritime marksman training. Specifically, the current study aimed to examine if a quiet eye training intervention facilitated the acquisition of a small arms maritime marksmanship task to moving targets. We predicted that, during retention trials, the quiet eye trained (QET) group would display superior gaze control (i.e., longer quiet eye durations and greater target locking) and higher shooting accuracy (i.e., lower initial shot and average shot radial error) than a control group who received a training intervention focusing on technical aspects (technical trained [TT] group).

Method

Participants

Twenty participants (male = 14, female = 6; mean age = 30.65; *SD* = 6.33) volunteered to take part in the present study. All participants reported being novice marksmen/women and having limited prior weapon experience and no formal marksmanship training via a demographic questionnaire. Furthermore, all participants were right-handed and had normal or corrected to normal vision (as assessed using a Snellen chart at a distance of 6 m). Ethical approval for the study was granted by the Ministry of Defense Research Ethics Committee prior to the start of data collection. Moreover, prior to each individual testing session, all participants provided written informed consent.

Synthetic Environment

A purpose-built synthetic environment was developed by Newman Spurr Consultancy for the study. The environment consisted of a computer rack containing control computers running Virtual Battle Space 2.0 (VBS2) software. This software ran the task and projected it on to a 180° curved screen with a 3-m radius via three HD projectors mounted overhead on a gantry. Furthermore, a decommissioned machine gun (M240 B) fitted with a potentiometer was in-

corporated into the synthetic environment. Auditory feedback from the task and the machine gun was played via a six-speaker surround sound audio system that was also mounted on the gantry. Tracer shots from the machine gun were visible on the screen and where the shots fell was recorded by the software via the potentiometer following calibration (see Figure 1 for an illustration of the synthetic environment). A custom built graphical user interface was designed to provide accuracy feedback to the experimenters in real time; this gave live statistics on hits, misses, and shots fired. This data was then extracted for subsequent analysis (see ~~Performance section~~). **[F1]**

[AQ: 2]

The task was developed in consultation with military advisers for the study using the VBS2 software and employed throughout the testing period. In this moving-target task, participants were required to shoot at a single target that traveled diagonally in a straight line across the screen (either from left to right or right to left). The weather conditions were set so there was minimal pitch and roll that affected the target. The target started from a distance of 366 m (400 yards) before moving at a speed of 50 knots toward the participant and passing them on the opposite side of screen (i.e., on the left-hand side of the screen if it began on the right-hand side). The target was visible on the screen for a total of 25 s. This task was designed to assess the participants' ability to locate a moving target, and then track that target, predict its path and accurately shoot at it. Thus, this task was considered a moving-target aiming task (Vickers, 2007). On average, participants fired 134 shots at the moving target during the baseline and retention trials.

Measures

Performance. In order to collect as much information on accuracy as possible, objective measures of performance relating to how close participants' shots fell to the targets were employed. Two specific measures of performance were adopted to reflect both the efficiency and effectiveness of aiming and were downloaded directly from the VBS2 software. First, initial shot radial error, defined as the radial error of the first shot taken (measured as the distance between initial shot fall and the target in meters), was calculated to reflect the efficiency of

Figure 1. An illustration of the synthetic environment with replica weapon.

the initial aim. Second, average shot radial error, defined as the mean radial error of all bursts of shots in the task (i.e., the average distance between all shots and the target in meters), was calculated as a measure of shooting effectiveness as the target moved toward and away from the participant. For both measures, a lower radial error value represented more accurate shooting performance.

Gaze. Gaze was measured using an Applied Science Laboratories (Bedford, MA) Mobile Eye Tracker. This lightweight system utilizes two features; the pupil and corneal reflection (determined by the reflection of an infrared light source from the surface of the cornea) to calculate point of gaze (at 30 Hz) relative to eye and scene cameras mounted on a pair of spectacles. 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), was viewed by the research assistant in real time on a laptop (Dell Latitude) installed with Eyevision (Applied Science Laboratories) recording software. Participants were connected to the laptop via a fire wire cable and the researcher and laptop were located behind the participant to minimize distractions. A digital video camera (Fuji, 1661)

was located to the right of the participants, perpendicular to the direction in which they were shooting (i.e., sagittal plane). The view allowed the entire shooting action of each participant to be captured. The video data from both devices was recorded for subsequent offline analyses.

Two gaze measures, quiet eye duration and target locking, were employed in the present study to reflect measures of efficiency and effectiveness of aiming and to temporally link with the two performance measures. Both measures were calculated using Quiet Eye Solutions software (www.QuietEyeSolutions.com). This software time-locks the mobile eye tracker and digital video camera files and allows frame-by-frame coding of the movement phases (i.e., trigger pull) in relation to the coding of the gaze behavior (i.e., fixation location and duration). A fixation was defined as a gaze maintained on an object within 1° of visual angle for a minimum of 100 ms (as Vine et al., 2013).

First, quiet eye duration was measured for the initial shot in each trial to reflect the efficiency by which participants guided their first shot to the moving target. The quiet eye was defined as the final tracking fixation toward the target prior to the trigger pull of the first shot fired. Quiet eye onset occurred when gaze rested on the

target after the onset of the trial and quiet eye offset occurred at trigger pull (Causer et al., 2010; Vickers, 2007). Second, target locking was calculated as a measure of the effectiveness of gaze control on the incoming target throughout the task. Target locking was calculated by subtracting the percentage of time spent fixating other locations (e.g., sea, sky, weapon barrel) from the time spent fixating the target. A positive score indicated that participants spent greater time fixating the target, while a negative score indicated that participants spent greater time fixating other locations. A score of zero indicated that participants spent equal time fixating the target and other locations. Previous research has shown that a strategy consisting of greater target locking is associated with higher levels of expertise and performance in visually guided motor tasks (e.g., laparoscopic surgery; Vine et al., 2012; Wilson et al., 2011).

Procedure

Participants attended the laboratory individually for two testing sessions over the course of a single day. Upon arrival for Session 1, participants were given a health and safety briefing and completed a demographics questionnaire. Next, participants completed the Snellen visual acuity test before being fitted with the mobile eye tracker. Following calibration of the eye tracker, participants were randomly assigned to their training group and received basic weapon handling instructions (the instructions are available from the lead author upon request). These instructions were the same for both groups and all participants practiced these instructions in a brief procedural familiarization task that involved shooting moving targets. If necessary, feedback regarding basic weapon handling was given to participants following this task.

Next, the experimenter gave standardized instructions regarding the moving-target task. The participants then completed two trials of this task while gaze and performance data were continuously recorded. The data from these trials served as baseline data. Following the baseline trials, participants received their respective training interventions (see training instructions below and Table 1). Participants were then trained over 20 repeat trials that were divided into five blocks of four trials interspersed with feedback and a short break to avoid mental and

T1

Table 1
Training Instructions Given to the Quiet Eye Trained (QET) and Technical Trained (TT) Groups During the Training Intervention

QET	TT
1. The group that you have been assigned to is going to be trained to adopt the eye movements of elite military gunman.	1. The group that you have been assigned to is going to be trained to adopt the weapon barrel movements of elite military gunman.
2. We will show you videos showing the eye movements of elite military gunman and we want you to copy what you see.	2. We will show you videos showing the weapon barrel movements of the elite military gunman and we want you to copy what you see.
3. Look how they shift their gaze to the target as quickly as possible.	3. Look how they move the weapon towards the target.
4. Notice how they use their eyes to line up the weapon barrel with the target, switching between fixating on the weapon sights and the target.	4. Notice how they then line up the weapon barrel with the target.
5. When they are satisfied that the weapon barrel is lined up with the target, they keep a steady tracking fixation on the front of the target for approximately 1 s before pulling the trigger.	5. When they are satisfied that the weapon barrel is lined up with the front of the target, they pull the trigger.
6. They then use their peripheral vision to see their initial fall of shot and adjust the line and position of the weapon barrel while maintaining a steady tracking fixation on the front of the target.	6. They then adjust the line and position of the weapon barrel based on the initial fall of shot until the shots begin to hit the target.
7. This steady tracking fixation on the front of the target and the continual adjustment of the line and position of the weapon barrel occur continuously as the target moves across the screen.	7. You notice that they continually adjust the line and position of the weapon barrel as the target moves across the screen.

physical fatigue. After each block, participants received feedback relating to their specific training intervention (see Training Instructions). After three training blocks (12 trials) participants had a break of approximately 3 hr before returning to the laboratory and completing the remaining two training blocks (eight trials).

Upon their return for Session 2, participants were fitted with the mobile eye tracker, which was then calibrated in the same manner as in Session 1. Once the remaining eight training trials were complete (in the same manner as described earlier), participants received standardized instructions relating to the moving-target task and completed two retention trials. Gaze and performance data were again recorded continuously throughout both trials. Importantly, no training instructions were given to either group throughout the retention trials. Finally, following completion of the retention trials, the eye tracker was removed and participants were thanked and debriefed about the aims of the study.

Training Instructions

Participants were randomly assigned to a QET or TT group. Both groups received a training intervention adapted from pilot testing and previous quiet eye training research (e.g., Moore et al., 2012). First, both groups viewed a video of an elite military gunman who exhibited either optimal gaze control (QET) or weapon barrel movements (TT). The experimenter directed both groups to the key features of the elite prototype's gaze control (e.g., notice how they keep a steady tracking fixation on the target before pulling the trigger; QET) or weapon barrel movements (e.g., notice how they then line-up the weapon barrel with the target; TT) while asking questions to elicit their understanding. Second, five specific training instructions were explained to both groups and were coupled to reflect similar phases of the moving-target task (i.e., moving to target, aiming at the target, pulling the trigger, making continual adjustments as target moves across the screen) to minimize differences in the focus and timing of instructions (see Table 1).

These training points were reemphasized to both groups after each training block (i.e., 4 trials), and both groups were given verbal and video feedback regarding their progress and how their gaze control or weapon barrel movements could be further improved. For instance, if the experimenter noticed a participant in the QET group not holding a steady tracking fixation on the target for approximately 1 s before trigger pull, the experimenter reminded the participant of this training instruction using the elite prototype video and encouraged the participant to employ this strategy in future trials. The same feedback process was followed for the TT group if they were not adhering to the technical training instructions (e.g., not lining up the weapon barrel with the target prior to pulling the trigger).

Statistical Analyses

Prior to the main statistical analyses, mean values for each participant during each condition (i.e., baseline or retention) were calculated for initial shot radial error, average shot radial error, quiet eye duration, and target locking. Subsequently, a series of 2 (group: QET vs. TT) $\times$ 2 (condition: Baseline vs. Retention) ANOVAs were conducted on these variables. Significant main and interaction effects were followed up with least significant difference post hoc t tests. Furthermore, effect sizes were calculated using partial eta squared ($\acute{\eta}_p^2$) and Cohen's d.

Results

Performance

Initial shot radial error. The ANOVA on the initial shot radial error data revealed no significant main effects for group, $F(1, 18) = 0.55$, $p = .468$, $\acute{\eta}_p^2 = .03$, or condition, $F(1, 18) = 0.12$, $p = .903$, $\acute{\eta}_p^2 = .00$. However, there was a significant interaction effect, $F(1, 18) = 7.26$, $p = .015$, $\acute{\eta}_p^2 = .29$. Follow-up between-groups analyses indicated that the QET group had a significantly lower initial shot radial error compared to the TT group at retention ($p = .023$, $d = 1.17$), despite having a similar initial shot radial error at baseline ($p = .335$, $d = 0.47$). Furthermore, follow-up within-group analyses indicated that while the QET group reduced their initial shot radial error after training, the TT group's initial shot radial error was greater after training. However, although both of these changes were associated with large

effect sizes, they only neared statistical significance ($p = .092$, $d = 1.25$ and $p = .085$, $d = 1.29$, respectively; see Figure 2, Panel A).[1]

Average radial error. The ANOVA on the average radial error data revealed that there were no significant main effects for group, $F(1, 18) = 0.07$, $p = .799$, $\acute{\eta}_p^2 = .00$, or condition, $F(1, 18) = 2.87$, $p = .107$, $\acute{\eta}_p^2 = .14$. However, there was a significant interaction effect, $F(1, 18) = 10.94$, $p = .004$, $\acute{\eta}_p^2 = .38$. Follow-up between-groups analyses indicated that, while the QET group had a higher average shot radial error than the TT group at baseline, the QET group had a lower average shot radial error than the TT group at retention. However, although both of these differences were associated with large effect sizes, they only approached significance ($p = .071$, $d = 0.91$ and $p = .056$, $d = 0.96$, respectively). Moreover, follow-up within-group analyses indicated that the QET group significantly reduced their average radial error after training ($p = .017$, $d = 1.93$), whereas the TT group's average radial error was not significantly different following training ($p = .147$, $d = 1.06$; see Figure 2, Panel B).

Gaze

Quiet eye duration. The ANOVA on the gaze data revealed that there were significant main effects for group, $F(1, 18) = 18.16$, $p < .001$, $\acute{\eta}_p^2 = .50$, and condition, $F(1, 18) = 10.22$, $p = .005$, $\acute{\eta}_p^2 = .36$. This was qualified by a significant interaction effect, $F(1, 18) = 15.17$, $p = .001$, $\acute{\eta}_p^2 = .46$. Follow-up between-groups analyses indicated that the QET group exhibited significantly longer quiet eye durations than the TT group at retention ($p < .001$, $d = 2.64$), despite having comparable quiet eye durations at baseline ($p = .721$, $d = 0.17$). Furthermore, follow-up within-group analyses revealed that while the QET group significantly increased their quiet eye durations after training ($p = .001$; $d = 3.27$), the TT exhibited no significant change in quiet eye durations following training ($p = .626$; $d = 0.33$; see Figure 3, Panel A).

Target locking. The ANOVA on the target locking data revealed that there was no significant main effect for group, $F(1, 18) = 0.93$, $p = .347$, $\acute{\eta}_p^2 = .05$. However, there was a significant main effect for condition, $F(1, 18) = 4.55$, $p = .047$, $\acute{\eta}_p^2 = .20$, and a significant interaction effect, $F(1, 18) = 4.61$, $p = .046$, $\acute{\eta}_p^2 = .20$.

Follow-up between-groups analyses indicated that, despite displaying similar target locking at baseline ($p = .816$, $d = 0.11$), the QET group displayed greater target locking than the TT group at retention. However, although the latter result was accompanied by a large effect size, it only approached significance ($p = .057$, $d = 0.96$). Follow-up within-group analyses revealed that the QET group significantly increased their target locking after training ($p = .005$, $d = 2.47$), whereas the TT group exhibited no significant change in target locking following training ($p = .994$, $d = 0.01$; see Figure 3, Panel B).

Discussion

Gaze training interventions such as quiet eye training interventions have been shown to aid the acquisition of visually guided motor skills in novices (Moore et al., 2012; Vine & Wilson, 2010, 2011). However, to date, no research has examined if a quiet eye training intervention can expedite the acquisition of a moving-target task among novices. Furthermore, the effectiveness of such training interventions has scarcely been examined in domains other than sport where the timely acquisition of visuomotor skills is of paramount importance (e.g., military, surgery, and aviation). Thus, the present study aimed to examine if a quiet eye training intervention facilitated the acquisition of a maritime marksmanship task to moving targets. It is hoped that the results of this research might lead to similar interventions being employed to improve the training of other military marksmanship tasks, as well as consideration of their potential for wider application to military training.

The performance data revealed that both groups achieved comparable performance levels in the baseline condition, suggesting that the groups started from similar novice levels of performance. As hypothesized, the QET group shot more accurately (i.e., lower initial shot and average radial error) than the TT group during

---

[1] The reduction in performance (increase in radial error) after training for the control group was driven primarily by one participant who displayed a posttraining increase in initial error of 1,380.70 m. The lack of a significant improvement for the quiet eye group was also driven by the results of one participant who revealed an increase in initial shot error of 237.92 m.
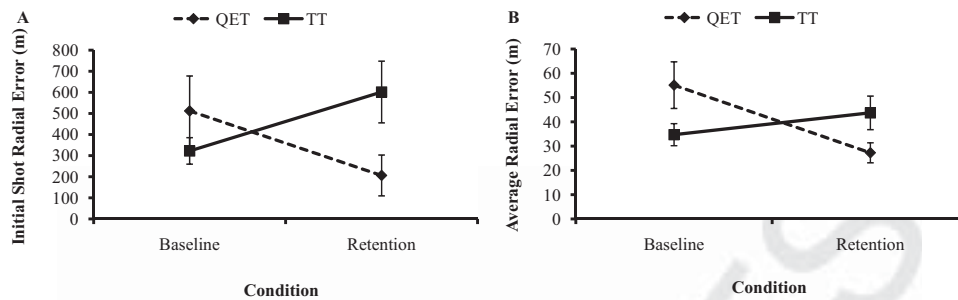
8   MOORE, VINE, SMITH, SMITH, AND WILSON

Figure 2.   Mean (*SE*) initial shot radial error (*m*) (A); and average radial error (*m*) (B) for the quiet eye trained (QET) and technical trained (TT) groups on the moving-target task during baseline and retention conditions.

the retention condition (see Figure 2). Indeed, in contrast to the TT trained group who displayed no change in shooting accuracy, the QET group reduced their initial shot and average radial error after receiving the training intervention. Thus, the performance data support the efficacy of the training intervention for expediting skill acquisition. This study adds to the growing literature base supporting the efficacy of quiet eye training for accelerating the learning of visually guided motor tasks (see Vine et al., 2014 for a review). Indeed, the present study builds on previous research demonstrating that quiet eye training can improve the performance of elite shooters in a moving-target task (i.e., shotgun shooting; Causer et al., 2011), and is first to demonstrate that quiet eye training interventions can also help novices acquire the visuomotor skills necessary to accurately intercept a moving target. Furthermore, the present study is the first to test the utility of a quiet eye training intervention in the military domain, thereby an-

swering calls for research investigating the effectiveness of interventions aimed at training military-relevant perceptual-cognitive skills in order to enhance military training (Chung et al., 2006; Vogel-Walcutt et al., 2013).

The gaze data revealed a similar pattern of results (see Figure 3). First, the gaze data revealed that both groups displayed comparable gaze control in the baseline condition, indicating that any subsequent changes were due to the training instructions provided. Second, as predicted, the QET group displayed more effective gaze control (i.e., longer quiet eye durations and greater target locking) than the TT group during the retention condition. Indeed, while the QET group increased their quiet eye durations and target locking following the training intervention, the TT group exhibited no change in either gaze variable. The gaze data therefore support the effectiveness of the training intervention for optimizing gaze control by extending quiet eye durations and increasing target locking behav-
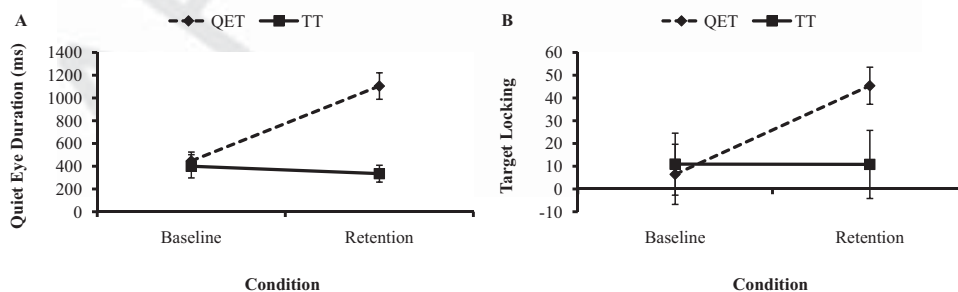

Figure 3.   Mean (*SE*) quiet eye duration (*ms*) (A); and target locking (B) for the quiet eye trained (QET) and technical trained (TT) groups on the moving-target task during baseline and retention conditions.

ior. Support for the optimal nature of a target focused strategy comes from both neuroscience models of visually guided action (Land, 2009) and our pilot work demonstrating that machine gun trainers adopted such a visuomotor strategy.

We propose that by lengthening their quiet eye durations, the QET group spent longer processing the visual information relating to the speed and direction of the moving target as well as fine-tuning and programming the correct motor response (i.e., timing and coordination of body and weapon barrel movements) before pulling the trigger (Causer et al., 2010, 2011). Subsequently, this enhanced processing and programming time resulted in their initial shots landing closer to the target, a key outcome when shooting a suppressive weapon. In addition, we argue that by anchoring gaze on the moving target throughout the task (i.e., target locking; see Vine et al., 2012; Wilson et al., 2011), the QET group provided themselves with a constant, uninterrupted stream of visual information that they used to effectively adjust body and weapon barrel movements as the task unfolded, culminating in their shots landing closer to the target.

The results of the present study have some important implications. From an applied perspective, the results suggest that marksmanship training interventions aimed at improving technical aspects related to performance (e.g., weapon movements) offer little benefit to skill acquisition (see Wulf, 2013). Specifically, Wulf argues that such interventions lead to an internal focus of attention that causes individuals to consciously control their movements and constrain their motor system (constrained action hypothesis; Wulf, 2013). The fact that members of our control group performed worse after training adds support to Wulf's contention for the danger inherent in providing instructions that focus attention internally. Indeed, this is a noteworthy implication given that technically focused interventions have received the most research attention in the marksmanship literature to date (e.g., Mononen et al., 2003) and are commonly used in current military marksmanship training (see Chung et al., 2006 for a review). Instead, marksmanship training interventions that help individuals understand "where and when" to focus gaze in the time preceding and during the marksmanship task should be adopted, as these quiet eye training interventions have been shown to accelerate skill acquisition and benefit subsequent performance under heightened pressure (see Vine et al., 2014 for a review).

The limitations of the present study highlight some potential avenues for future research. The present study used a sample consisting of non-military personnel. Thus, future research is encouraged to replicate the present study with more relevant military personnel such as trainee marksman. The present study only examined short-term retention and so future research should investigate if the gaze control and performance benefits emanating from a quiet eye training intervention are retained over an extended period of time (i.e., delayed retention— see Vine et al., 2013). Third, factors including ship/target pitch and roll as well as the drift associated with the weapon were controlled for in the present study, to minimize their influence. These factors are highly influential in "live-fire" situations and thus future research should examine if the benefits of a simulator-based quiet eye training intervention transfer to more realistic simulations or live-fire scenarios.

Finally, the interpretation of the results is hindered by the fact that the TT control group did not improve following training. It is therefore difficult to determine how much of the significant interaction effect found is due to the benefits of the quiet eye training and how much to the lack of progress of the TT group. The addition of a second control group that received no training instructions but had the opportunity to practice (i.e., a discovery learning group) would have perhaps strengthened the study design. However, in accord with most quiet eye training research, the control group was selected to reflect the current best practice, in order to provide a meaningful comparison for the "new" intervention (e.g., Craig et al., 2008). As in sport (e.g., Vine & Wilson, 2010, 2011), current guidance in marksmanship training has primarily focused on technical aspects (Mononen et al., 2003, 2007); therefore, the choice of such a comparison group could be rationalized. One previous study in laparoscopic training (Wilson et al., 2011) did adopt a three-way comparison and found that the gaze trained group performed significantly better than both a movement trained group and a discovery learning group under multitasking conditions, providing some

support for a relative advantage of quiet eye training. Future research in this area is encouraged to include additional control groups to enable clearer interpretation of findings, although such decisions are frequently influenced by recruitment and funding constraints related to sample size calculations.

To conclude, the results of the present study demonstrate that a quiet eye training intervention can expedite the learning of a simulated small arms maritime marksmanship task to moving targets. These results suggest that quiet eye training interventions should be employed to improve military marksmanship training. Furthermore, the results imply that interventions that focus on training technical aspects related to performance (e.g., weapon movements) should be avoided as they result in inferior skill acquisition. In light of these findings, the potential utility of quiet eye training interventions for training other military-relevant perceptual-cognitive skills should also be considered as a means of improving training efficiency and effectiveness.

References

Causer, J., Bennett, S. J., Holmes, P. S., Janelle, C. M., & Williams, A. M. (2010). Quiet eye duration and gun motion in elite shotgun shooting. *Medicine and Science in Sports and Exercise, 42,* 1599–1608. doi:10.1249/MSS.0b013e3181d1b059

Causer, J., Holmes, P. S., & Williams, A. M. (2011). Quiet eye training in a visuomotor control task. *Medicine and Science in Sports and Exercise, 43,* 1042–1049. doi:10.1249/MSS.0b013e3182035de6

Causer, J., Janelle, C. M., Vickers, J. N., & Williams, M. A. (2012). Perceptual expertise: What can be trained? In N. J. Hodges & M. A. Williams (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 306–323). New York, NY: Routledge.

Chung, G. K. W. K., Delacruz, G. C., de Vries, L. F., Bewley, W. L., & Baker, E. L. (2006). New directions in rifle marksmanship research. *Military Psychology, 18,* 161–179. doi:10.1207/s15327876mp1802_5

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I., & Petticrew, M. (2008). Developing and evaluating complex interventions: The new medical research council guidance. *British Medical Journal, 337,* a1655. doi:10.1136/bmj.a1655

Gegenfurtner, A., Lehtinen, E., & Saljo, R. (2011). Expertise differences in the comprehension of visualizations: A meta-analysis of eye-tracking research in professional domains. *Educational Psychology Review, 23,* 523–552. doi:10.1007/s10648-011-9174-7

Klostermann, A., Kredel, R., & Hossner, E. J. (2013). The "quiet eye" and motor performance: Task demands matter! *Journal of Experimental Psychology: Human Perception and Performance, 39,* 1270–1278. doi:10.1037/a0031499

Land, M. F. (2009). Vision, eye movements, and natural behavior. *Visual Neuroscience, 26,* 51–62. doi:10.1017/S0952523808080899

Mann, D. T. Y., Coombes, S. A., Mousseau, M. B., & Janelle, C. M. (2011). Quiet eye and the bereitschaftspotential: Visuomotor mechanisms of expert motor performance. *Cognitive Processing, 12,* 223–234. doi:10.1007/s10339-011-0398-8

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport & Exercise Psychology, 29,* 457–478.

Mononen, K., Konttinen, N., Viitasalo, J. T., & Era, P. (2007). Relationships between postural balance, rifle stability and shooting accuracy among novice rifle shooters. *Scandinavian Journal of Medicine and Science in Sports, 17,* 180–185. doi:10.1111/j.1600-0838.2006.00549.x

Mononen, K., Viitasalo, J. T., Konttinen, N., & Era, P. (2003). The effects of augmented kinematic feedback on motor skill learning in rifle shooting. *Journal of Sports Sciences, 21,* 867–876. doi:10.1080/0264041031000101944

Moore, L. J., Vine, S. J., Cooke, A., Ring, C., & Wilson, M. R. (2012). Quiet eye training expedites motor learning and aids performance under heightened anxiety: The roles of response programming and external attention. *Psychophysiology, 49,* 1005–1015. doi:10.1111/j.1469-8986.2012.01379.x

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 342–354. doi:10.1037/0096-1523.22.2.342

Vickers, J. N. (2007). *Perception, cognition and decision training: The quiet eye in action.* Champaign, IL: Human Kinetics.

Vickers, J. N. (2011). Mind over muscle: The role of gaze control, spatial cognition, and the quiet eye in motor expertise. *Cognitive Processing, 12,* 219–222. doi:10.1007/s10339-011-0411-2

Vine, S. J., Chaytor, R. J., McGrath, J. S., Masters, R. S. W., & Wilson, M. R. (2013). Gaze training improves the retention and transfer of laparoscopic technical skills in novices. *Surgical Endoscopy, 27,* 3205–3213. doi:10.1007/s00464-013-2893-8

Vine, S. J., Masters, R. S. W., McGrath, J. S., Bright, E., & Wilson, M. R. (2012). Cheating experience: Guiding novices to adopt the gaze strategies of experts expedites the learning of technical laparoscopic skills. *Surgery, 152,* 32–40. doi:10.1016/j.surg.2012.02.002

Vine, S. J., Moore, L. J., & Wilson, M. R. (2014). Quiet eye training: The acquisition, refinement, and resilient performance of targeting skills. *European Journal of Sport Science, 14,* S235–242. doi:10.1080/17461391.2012.683815

Vine, S. J., & Wilson, M. R. (2010). Quiet eye training: Effects on learning and performance under pressure. *Journal of Applied Sport Psychology, 22,* 361–376. doi:10.1080/10413200.2010.495106

Vine, S. J., & Wilson, M. R. (2011). The influence of quiet eye training and pressure on attention and visuomotor control. *Acta Psychologica, 136,* 340–346. doi:10.1016/j.actpsy.2010.12.008

Vogel-Walcutt, J. J., Fiorella, L., & Malone, N. (2013). Instructional strategies for training military-relevant perceptual-cognitive skills. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 57,* 1239–1243. doi:10.1177/1541931213571275

Wilson, M. R., Vine, S. J., Bright, E., Masters, R. S. W., Defriend, D., & McGrath, J. S. (2011). Gaze training enhances laparoscopic skill acquisition and multi-tasking performance: A randomized, controlled study. *Surgical Endoscopy, 25,* 3731–3739. doi:10.1007/s00464-011-1802-2

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology, 6,* 77–104. doi:10.1080/1750984X.2012.723728

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES 1

AQau—Please confirm the given-names and surnames are identified properly by the colors.
■= Given-Name, ■= Surname
The colors are for proofing purposes only. The colors will not appear online or in print.

AQ1—Author: Please provide location for Defence Science and Technology Laboratory.

AQ2—Author: Correct that this should be "Performance" rather than "Performance Measures"?