TRANSFERABILITY OF QUIET EYE TRAINING IMPROVEMENTS TO NOVEL AIMING TASKS

Abstract

Quiet eye (QE) characteristics are trainable; however, little is known about the transferability into novel aiming tasks. The current study examines transfer from a dart throwing task to a beanbag throwing task. 24 participants were assigned to either a QE training (QET) or technical training (TT) group. Participants completed a pre-test, acquisition phase, post-test and transfer, each with 3 difficultly conditions. Both groups decreased their error from pre- to post-test, the QET group decreased error by significantly more. QET group reported lower error scores and longer QE across the 3 difficulty conditions, whereas the TT group decreased performance in the hard condition. In the transfer test, the QET group reported significantly lower error and longer QE than the TT group. QET improvements learned in one task can be transferred to novel tasks, although task demands and processing requirements may impact the effectiveness of this transfer.

Introduction

In sport, athletes are required to overcome a range of spatial and temporal constraints to successfully navigate their environments. Elite athletes have been reported to develop sophisticated perceptual and cognitive strategies to overcome these demands (Williams et al., 2011). Perceptual-cognitive skill refers to an individual's ability to extract relevant information from their environment and integrate it with their domain-specific knowledge and experience to decide on, and execute, the most appropriate action (Mann et al., 2019). Skilled individuals can recognise patterns (North et al., 2011), utilise postural cues (Causer & Williams, 2015), and use contextual information (Murphy et al., 2016) more effectively than less-skilled individuals. This expert advantage is underpinned by a more refined and systematic visual search strategy to identify and extract critical cues from an environment at specific time points (Mann et al., 2019). In aiming tasks, whilst there is less contextual information to process, athletes are still required to use refined eye movements to process action requirements and execute them accurately and consistently (Wilson et al., 2015). One eye movement variable associated with expertise and successful performance is the quiet eye (QE; Vickers, 1996).

QE is defined as the final fixation on a location for more than 100 ms and within 3° of visual angle before the initiation of a critical action (Vickers, 1996). Longer QE durations have been consistently associated with superior performance, as well as a marker of expertise, in a range of aiming tasks (Wilson et al., 2015). During the QE, it is suggested that the specific movement requirements for a particular action are programmed, with more complex actions requiring longer programming and thus longer QE durations (Williams et al., 2002). Other research suggests that QE may also have a role in online control of the action (Causer et al., 2017) as well as the programming and may also mediate the potentially negative impact of anxiety and fatigue on performance (Vickers & Williams, 2007). There is also evidence that the refined QE behaviours are more beneficial when information processing requirements are high such as unpredictable or complex tasks (Klostermann et al., 2013).

Given the considerable impact of QE on performance (for a review see Lebeau et al., 2016), many researchers have attempted to train individuals to develop more robust QE characteristics (Vine et al., 2014). QE training generally involves using a 'gold-standard' model to compare against the trainee, with instruction and feedback to develop key behaviours, such as an early onset of QE, and a long QE on a specific location (Causer et al., 2012). QE has been successfully trained in a plethora of aiming and interceptive tasks, in a wide range of domains and skill levels (Vine et al., 2014). Among the many advantages, QE training has been shown to increase performance (Vine et al., 2011), reduce muscle activation (Moore et al., 2012), reduce anxiety (He et al., 2024), decelerate heart rate (Moore et al., 2012), and improve movement kinematics (Causer et al., 2011). Despite the effectiveness of QE training and the surfeit of QE training studies, few have explored whether the trained characteristics and performance advantages can transfer into other tasks.

Most QE training studies have traditionally assessed transfer through tests in either high-stress or anxiety-inducing scenarios (Vine et al., 2011), using an adapted version of the same skill (Vickers et al., 2017), or by evaluating performance in a competitive environment (Causer et al., 2011). Under these conditions, performance gains and QE-related characteristics learned from the interventions can often be successfully transferred (Causer et al., 2012). However, some studies report that QE characteristics trained in a specific task may not transfer to other intraskill conditions (Flindall et al., 2020), and in interskill transfer, improvements in performance have been observed without corresponding QE behaviour transfer (Rienhoff et al., 2013). These mixed findings suggest that the likelihood of transfer may depend on the similarity between the original and transfer tasks, particularly in terms of motor, perceptual, and conceptual elements (Schoenfeld et al., 2024; Thorndike, 1914).

This aligns with the theoretical distinction between near and far transfer (Sala et al., 2019). Near transfer occurs when learned skills facilitate the acquisition of new skills that are highly similar in movement patterns, context, or environmental conditions, enabling rapid adaptation. Far transfer, in contrast, involves applying skills to tasks that differ substantially from the original, relying on general cognitive or motor principles rather than direct repetition. Evidence suggests that near transfer is more likely to occur than far transfer, emphasizing the importance of task similarity for successful QE skill transfer (Fransen, 2024; Smeeton et al., 2013). Nevertheless, the effectiveness of near transfer may still vary across populations, indicating that individual factors also play a role (Oppici & Panchuk, 2022).

Given the equivocal reports of QE transfer between tasks, the current study examines whether QE trained participants can transfer any performance improvements and learned QE behaviours from a darts throwing task to a novel beanbag toss. Both tasks share fundamental sensorimotor characteristics, including the requirement to aim at a stationary target and to preprogramme key movement parameters such as force, trajectory, and angular displacement. Additionally, both exhibit comparable temporal structures, characterized by brief execution phases following a period of motor planning and target alignment (Khanjari et al., 2023). Despite these similarities, the tasks differ substantially in their motor execution demands. The beanbag toss predominantly recruits proximal musculature and involves gross arm movements (Fairbrother et al., 2012), whereas the dart throw engages more distal effectors and requires finely tuned coordination of the shoulder, elbow, wrist, and fingers to achieve precise endpoint control. To understand if transfer is impacted by processing requirements (Klostermann et al., 2013), three complexities of each task were included. In line with the robust QE training literature, it was expected that the QE group would reduce their performance error and increase their QE durations significantly more than a group receiving technical training (Gonzalez, Causer, Grey, et al., 2017). These effects were expected to be more pronounced in the more difficult conditions, due to the increased task demands (Klostermann et al., 2013). The performance improvements for the QE group were expected to transfer to the novel aiming task, however, it is unclear whether the QE adaptations would transfer (Rienhoff et al., 2013).

Methods

Participants

The study consisted of 24 participants (mean age: 23.25 ± 4.95) recruited by opportunity sampling. The sample size was determined based on established norms in QE training research, where comparable experimental designs have consistently demonstrated robust effects with similar group sizes. To further contextualise the present sample, a post hoc sensitivity power analysis ($\alpha = .05$; $n = 24$) indicated that the study was primarily powered to detect large effects, while smaller effects may not be reliably detectable. Participants had no previous darts or beanbag toss experience, were right-handed and had normal or corrected vision. Participants were assigned to one of two groups: QE training (QET; n = 12) or technical training (TT; n = 12), which were matched on pre-test error scores. The TT group were given technical instructions related to dart throwing adapted from previous dart studies (Marchant et al., 2007). The QET group received instructions that were developed and informed by previous QE studies (Causer et al., 2011) (see Table 1). To ensure there were no differences in the groups on the transfer task, both groups completed 3 beanbag tosses to a distance not included in the study (2.00 m). An independent t-test showed no significant differences between the groups ($t_{22} = .438$, $p = .66$).

Written consent was provided prior to data collection, and the experiment was approved by the ethics committee of the lead institution.

Table 1

Apparatus

Gaze data was collected using a TobiiGlasses 2 (Stockholm, Sweden) mobile eye tracker. The throwing movements were videotaped using an external camera (Canon Vixia HFM41) that filmed the action in the sagittal plane at 50 Hz. The gaze and throwing videos were monitored during data collection and synchronized later in the laboratory using Adobe Premier Pro. A Unicorn XL double-sided darts board and darts (standard 24.0g) were used. A rectangular beanbag (141.8g) was chosen for the transfer task, as the object would not bounce or roll from where it landed.

Procedure

Participants were fitted with the eye tracking system, which was then calibrated with participants in their 'normal' stance. Prior to testing, participants engaged in 3 practice trials to familiarise themselves with the both the dart throwing task and the beanbag toss transfer. The study consisted of a pre-test, acquisition phase and post-test that required participants to aim at the bullseye on a dart board. The novel transfer task required participants to throw a beanbag underarm towards a target on the floor. The pre-, post- and transfer-tests consisted of a total of 18 trials divided equally between three distances: easy (1.37 m), moderate (1.87 m) and hard (2.87 m). Distances were quasi-randomised to ensure no distance was repeated for more than two trials. During the acquisition phase, all participants completed 90 trials (9 blocks of 10) consisting of 30 trials for each of the three distances, which were randomised. Group instructions were given at the start of the acquisition phase and reinforced after 30 and 60 shots. After completing the acquisition phase, participants were given a 15-minute interval before completing the post-test and then given another 15-minute interval before the transfer test. Testing took place in one session and lasted approximately 120 minutes.

Statistical Analysis

Performance was measured in both aiming tasks using absolute error (cm). Absolute error refers to the distance from the centre of the bullseye/target. During the transfer task, distance was measured from the centre of the beanbag, which was marked by a cross. QE was operationally defined as the final fixation over 100 ms and within 3° of visual angle towards a location prior to the critical phase of movement (Vickers, 1996). The onset of QE was defined as the initiation of the fixation that occurred prior to the start of the backward motion (flexion) of the arm. The offset of QE occurred when the gaze deviated from the location by 3° for more than 100 ms (Vickers, 2007).

A three-way mixed design ANOVA was used to analyse absolute error (*cm*) and QE (ms) between the pre- and post-test, with group (QET, TT) as the between-subject factor, and phase (pre-, post-test) and complexity (easy, moderate, hard) as the within-subject factors. Performance during the transfer-test was analysed using a two-way mixed-design ANOVA, with group (QET, TT) as the between-subject factors and complexity (easy, moderate, hard) as the within-subject factors. Effect sizes were calculated using partial eta squared valued (ηp^2). Greenhouse-Geisser epsilon was used to control for violations of sphericity and the alpha level for significance was set at 0.05 with Bonferroni adjustment used to control for Type I errors.

Results

Absolute error (*cm*)

Pre- to Post-Test

There was no significant main effect for Group ($F_{1,22}$ = .97, p >.05, ηp^2 = .04). There was a significant main effect for Phase ($F_{1,22}$ = 26.34, p <.01, ηp^2 = .55). Absolute error was significantly higher in the pre-test (7.91 $\pm$ 2.85 cm) compared to the post-test (6.08 $\pm$ 2.65 cm; p <.01). There was also a significant Phase x Group interaction ($F_{1,22}$ = 7.85, p =.01, ηp^2 = .26).

Both groups reduced their absolute error from pre- to post-test, however, this decrease was significantly greater for the QET group (mean difference (*MD*) = 2.82 cm) compared to the TT group (*MD* = 0.83 cm) (see figure 1). There was a significant main effect for Complexity ($F_{2,44}$ = 45.53, p <.01, ηp^2 = .67), with error being significantly lower in the easy (5.34 ± 2.13 cm) compared to the moderate (6.46 ± 2.49 cm; p <.05) and hard (9.19 ± 2.57 cm; p <.01) conditions. In addition, absolute error was also significantly lower in the moderate compared to the hard condition (p <.01). There was a significant Complexity x Group interaction ($F_{2,44}$ = 3.41, p <.05, ηp^2 = .13). Absolute error increased for both groups as difficulty increased, with the TT group showing larger increases (easy to moderate *MD* = 1.51 cm; moderate to hard *MD* = 3.42 cm) than QET (easy to moderate *MD* = 0.74 cm; moderate to hard *MD* = 2.05 cm), indicating QET maintained lower errors at higher difficulty. There was no significant Phase x Complexity ($F_{2,44}$ = .23, p >.05, ηp^2 = .01) or Phase x Complexity x Group ($F_{2,44}$ = .62, p >.05, ηp^2 = .03) interaction effects.

Figure 1

Transfer Test

There was a significant main effect for Group ($F_{1,22}$ = 4.44, p <.05, ηp^2 = .17) with absolute error being significantly lower for the QET group (12.78 ± 5.66 cm) relative to the TT group (16.16 ± 4.04 cm). There was also a significant main effect for Complexity ($F_{2,44}$ = 3.59, p <.05, ηp^2 .14). While there was no significant difference in absolute error between the easy and moderate conditions (*MD* .01 cm), there was an increase in absolute error between both the easy and hard (*MD* = 2.29 cm; p < .05) and moderate and hard (*MD* = 2.29 cm; p < .05) conditions. There was a significant Complexity x Group ($F_{2, 44}$ = 3.26, p <.05, ηp^2 = .13) interaction effect. There were no significant differences in error between the complexities for the TT group (all $p > .05$), however, the QE group significantly increased their absolute error from both easy (*MD* = 4.54 cm; $p < .05$) and moderate (*MD* = 4.39 cm; $p < .05$) complexities to the hard complexity (see table 2).

Table 2

QE (*ms*)

Pre- to Post-Test

There was a significant main effect for Group ($F_{1,22} = 62.74$, $p <.01$, $\eta p^2 = .74$) with QE duration being significantly longer for the QET group (2016 $\pm$ 535 ms) in comparison to the TT group (1431 $\pm$ 303 ms). There was also a significant main effect for Phase ($F_{1,22} = 20.50$, $p <.01$, $\eta p^2 = .48$) with QE duration found to be significantly longer in the post-test (1919 $\pm$ 597 ms) relative to the pre-test (1527 $\pm$ 342 ms) (see figure 2). There was a significant Phase x Group ($F_{1,22} = 15.47$, $p <.01$, $\eta p^2 = .41$) interaction. While there was a significant increase in the QE duration of the QET group from pre- to post-test (*MD* = 732 ms), the TT group showed no significant difference in QE duration (*MD* = 0.51 ms). A significant Phase x Complexity ($F_{2,44} = 9.60$, $p <.01$, $\eta p^2 = .30$) interaction was also found. Examination of the mean data shows that while there was an increase in QE duration from pre- to post-test in each of the three complexities, this increase was significantly greater in the hard (*MD* = 567 ms) condition, relative to both the easy (*MD* = 312 ms) and moderate (*MD* = 296 ms) conditions (see figure **2**). Moreover, there was a significant Phase x Complexity x Group ($F_{2,44} = 4.51$, $p = .02$, $\eta p^2 = .17$) interaction effect, with the QET group displaying significantly longer QE durations in the post test in the moderate and hard conditions, compared to the pre-test and the TT group. There was no significant main effect for Complexity ($F_{2,44} = .16$, $p >.05$, $\eta p^2 < .01$), and no significant Complexity x Group ($F_{2,44} = .25$, $p >.05$, $\eta p^2 = .01$) interaction effect.

Transfer Test

There was a significant main effect for Group ($F_{1,22} = 39.42$, $p <.01$, $\eta p^2 = .64$) with the QET group (2556 $\pm$ 472 ms) showing a significantly longer QE duration when compared with the TT group (1244 $\pm$ 472 ms) (see figure 2). There was no significant main effect for Complexity ($F_{2,44} = .90$, $p >.05$, $\eta p^2 = .04$), or Complexity x Group ($F_{2,44} = 2.01$, $p >.05$, $\eta p^2 = .08$) interaction effect.

Figure 2

Discussion

The current study examined the effects of QET on performance and transfer in aiming tasks. Consistent with expectations, the QET group demonstrated significantly longer QE durations during the post-test phase of the dart throwing task, which coincided with significantly lower performance error relative to the TT group. The QET group also displayed significantly longer QE durations during the moderate and hard complexities of the post-test relative to both the pre-test and TT group. The QET group's superior QE durations again corresponded with lower error scores across the three complexity conditions, with the TT group increasing their error significantly more than the QET group between the moderate and hard post-test conditions. Importantly, the QET group maintained their superior gaze control during the transfer test, with significantly longer QE durations resulting in significantly lower error relative to the TT group. However, no significant differences were found in the QE durations of both groups as a function of complexity during the transfer test.

In comparing the efficacy of QET and TT, the current study contributes to an already robust body of research by further reinforcing the benefits of QET in enhancing performance across a range of aiming and interceptive tasks; beyond what is achievable through traditional technical training (Vine et al., 2015; Vine et al., 2014). There are competing theories around the functional role of the QE (Gonzalez, Causer, Miall, et al., 2017), some focusing on programming and online control of action, others on psychological readiness and inhibition of distractors or movement interference. Both theories suggest that QE reflects sustained visual attention that supports motor planning and/or execution. Researchers have shown that internal versus external focus of attention instructions modulate QE duration in dart-throwing (Neugebauer et al., 2020; Querfurth et al., 2016), highlighting an important link between gaze behaviour, attentional control, and performance in goal-directed motor tasks. Given the plethora of literature identifying the benefit of an external focus of attention on performance (Wulf et al., 2010), an alternative explanation of the results may be that engaging in QE expedites skill learning through this mechanism.

The current study also sought to examine the programming hypothesis by determining the impact of task complexity on the efficacy of QET. Based on the premise that the QE period facilitates the pre-programming of movements, thus extending the time available for information processing and motor preparation (Vickers, 2011); it was expected that the QE durations of the QET group would increase linearly as a function of complexity in both aiming tasks. Contrary to expectations, QE durations remained relatively stable across the three post-test complexity conditions of both aiming tasks, supporting claims that task difficulty and QE measures may not necessarily share a monotonic relationship (Walters-Symons et al., 2018). In contrast to previous research, which has shown increases in QE durations as a function of task complexity (e.g., Causer et al., 2017; Williams et al., 2002), the present study revealed no such interaction across the three post-test complexity conditions in either aiming tasks, challenging assumptions that longer QE durations are crucial for facilitating the pre-programming of movements during more complex tasks. The absence of a significant, linear relationship suggests that the role of the QE may be influenced by additional factors, such as task-specific demands, pressure, individual differences or cognitive load, underscoring the need for a more nuanced conceptualisation of the QE's function in motor performance (Leivers et al., 2025).

Previous studies on QE transfer have reported mixed effects across both interskill (Rienhoff et al., 2013) and intraskill (Flindall et al., 2020) tasks. Consistent with Thorndike's (1914) theory of *identical elements*, it was predicted that the perceptual similarities of both aiming tasks in the current study (i.e. fixating on a static target prior to the initiation of movement) would result in the QET group displaying significantly longer QEDs, and significantly lower performance error than the TT group during a novel aiming task. In support of these predictions, the QET group demonstrated a significantly lower absolute error in the transfer test compared to the TT group. Further, the QET group maintained their QE duration improvements from the post-test in the transfer test. Taken together, the QET group's ability to transfer their perceptual superiority to a novel aiming task provides evidence to challenge claims that the QE is highly domain specific, and the transfer to similar aiming tasks does not occur (Rienhoff et al., 2013).

These findings are among the first to provide evidence of the QE's inter-task transferability. As previously alluded to, the earlier work of Rienhoff et al. (2013) remains the only other study to have examined the QE's transfer potential across two different tasks: a basketball free throw and a darts throw. Here, the study findings failed to support predictions of a positive QE transfer among a group of skilled basketball players who, having displayed significantly longer QEDs than a group of less-skilled basketballers during a free-throwing task, were unable to transfer their perceptual superiority to a subsequent dart throwing task. Despite both the free-throwing and dart throwing tasks sharing what Rienhoff and colleagues (2016) described as "several conceptual elements" (pp.6), the researchers later argued that the perceptual components of both aiming tasks were too dissimilar for a transfer to occur, citing differences in their technical characteristics as the reason for this. This is supported by research suggest that this far transfer to tasks sharing fewer similar perceptual, motor, and cognitive elements (Schoenfeld et al., 2024; Thorndike, 1914) is less likely to occur, compared to near transfer (Fransen, 2024; Sala et al., 2019), with more similar elements, such as in the current study. These shared elements enabled the QET group to successfully transfer their training gains from the dart throwing task to the novel aiming task.

However, when examining the complexity data during the transfer task, whilst the QET group maintained their QE in the hard complexity condition, they were unable to maintain their performance, with absolute error not being significantly different to that of the TT group. For novice athletes there may be a ceiling effect of simply engaging in a longer QE duration to improve/maintain performance, this effect has previously been reported for expert athletes (Leivers et al., 2025). In the hard transfer condition, the programming requirements, attention resources required and/or the psychological demands may have reached a limit that led to performance to decline (Hossner, 2016). This suggests that while QET enhances attentional control and motor programming under familiar or moderately demanding conditions, its benefits may diminish when task complexity exceeds the performer's cognitive or motor capacities. Under such constraints, extended QE may reflect compensatory effort rather than efficient information processing or movement calibration (Wilson et al., 2007). Further development of perceptual-motor skills and task-specific expertise is therefore required before the benefits of prolonged QE can be realised in highly complex or novel contexts.

It is also worth noting that the conflicting findings in the few QE transfer papers may also be impacted by the differences in how the QE was defined in these studies. For example, Rienhoff et al. (2013) defined the QE as the final fixation on the target prior to the initiation of the extension phase, whereas in the present study, it was defined relative to the initiation of the flexion phase. Flindall et al. (2020) operationalized QE as the moment of dart release. These discrepancies in definitions may contribute to inconsistent findings, as certain aspects of movement programming or online control could have been overlooked depending on how QE was operationalized. Therefore, it is important for future research that the QE definitions is consistently and accurately applied for studies to be appropriately compared.

Further limitations should be acknowledged. First, the sample size was relatively small (n = 24), which is consistent with much of the QE training literature but may have limited power to detect small or moderate effects, particularly higher-order interactions involving task complexity and transfer. Accordingly, non-significant findings should be interpreted with caution. Second, task complexity was manipulated solely via target distance; other sources of complexity, such as temporal constraints or environmental uncertainty, were not examined. Finally, the absence of kinematic measures means that inferences regarding the mechanisms underlying performance improvements, such as motor programming or online control, remain indirect. Future research should examine QE transfer using larger samples and longitudinal designs to assess the retention and durability of training effects. Investigating transfer across tasks that vary systematically in perceptual, motor, and cognitive similarity, and across different skill levels, would help clarify the boundary conditions under which QE training generalises. Integrating gaze measures with kinematic, biomechanical, or neurophysiological indices may further elucidate the mechanisms underpinning successful transfer.

There are several applied implications for this work, especially within PE and coaching domains. For example, instructors can use QE training techniques to bridge learning between different motor skills that share similar processes or constraints. For instance, when transitioning from skills involving similar visual and motor demands; applying QE strategies could aid in this skill transfer (Vine et al., 2014) and speed up the acquisition and development of these new skills. Furthermore, given the link between QE and anxiety, integrating QE training into curricula could foster adaptability, resilience under pressure, and long-term motor skill development (Vickers, 2009).

The current study is the first to identify that QET can lead to positive interskill performance in novel tasks with novice athletes. These data also show that the underlying trained process of a longer QE durations helped maintain performance improvements in the transfer task. These data can be used to design effective training programmes to teach novel skills efficiently and identifies a future avenue of research to explore how skills are learned and transferred into novel contexts. Future research should also investigate the interaction among QE duration, task difficulty, and skill level to clarify the boundary conditions of QET efficacy.

Figure 1

Absolute error (cm) of the Quiet Eye Training and Technical Training groups in the (a) easy, (b) moderate, and (c) hard conditions during the pre-test, post-test, and transfer-test. Error bars represent standard deviations.

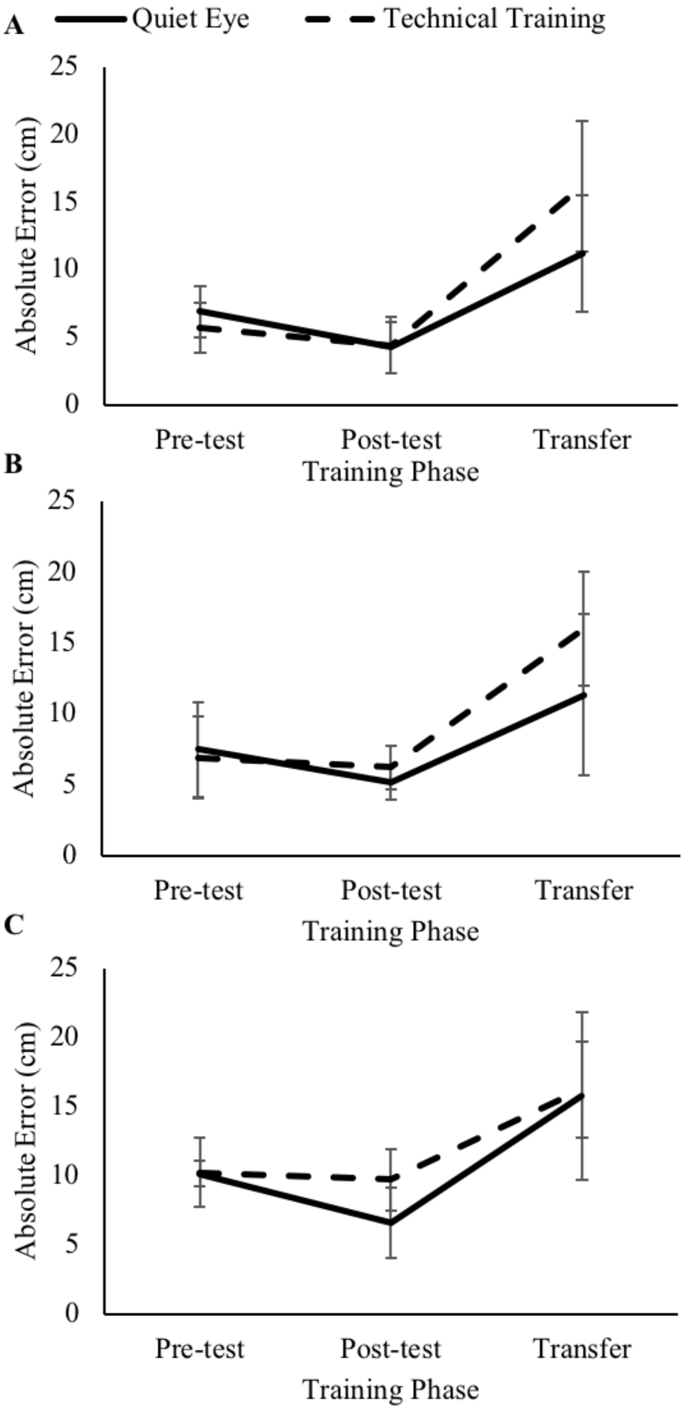

Figure 2

Quiet eye duration (ms) of the Quiet Eye Training and Technical Training groups in the (a) easy, (b) moderate, and (c) hard conditions, during the pre-test, post-test, and transfer-test. Error bars represent standard deviations.

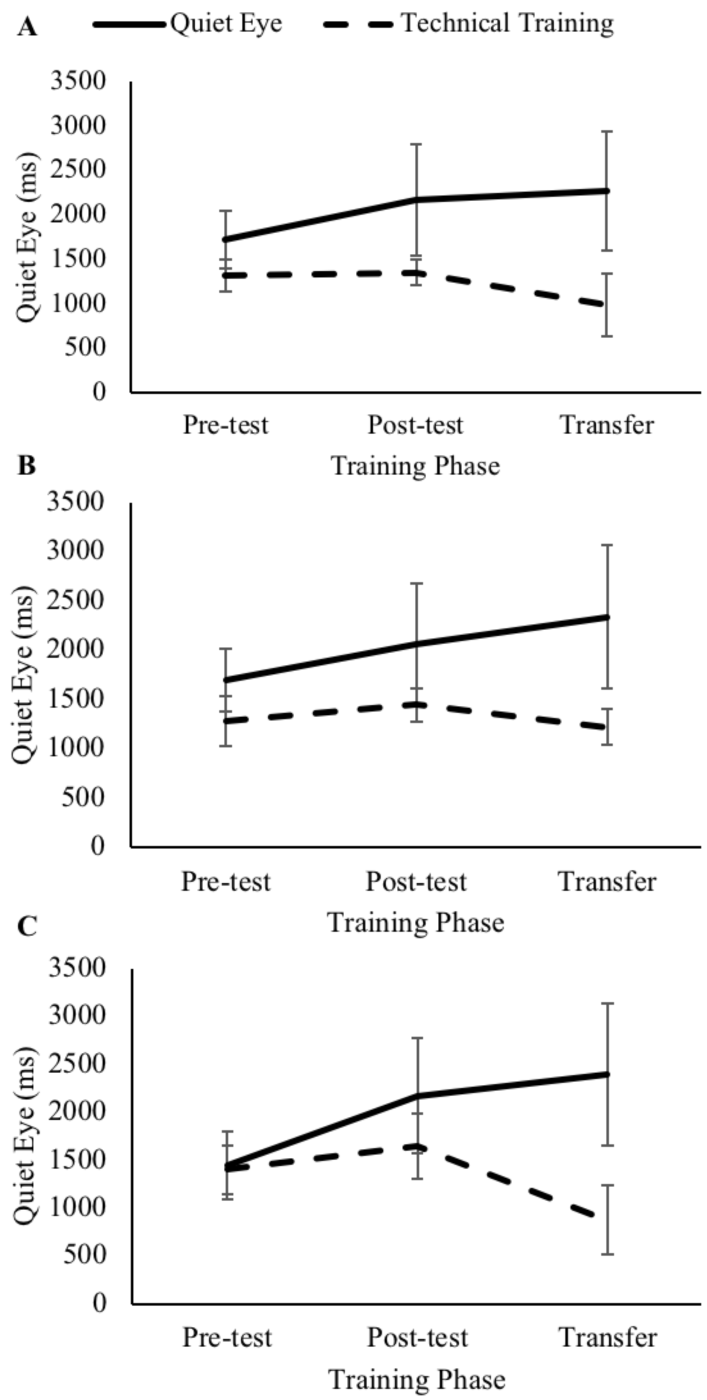

Table 1

Training instructions used for the Technical Training and Quiet Eye training groups.

Steps	Technical training group	Quiet Eye training group
1	Assume stance and feel the weight of the dart.	Assume stance and ensure you have a clear view of the bullseye.
2	Slowly pull dart back towards your ear by bending your elbow.	When aiming, fixate your gaze on the bullseye.
3	When throwing, keep your shoulder still and gently release the dart.	Before performing the action, ensure that your fixation is steady on the bullseye (approximately between 2 and 3 seconds).
4	After releasing the dart, follow-through with your hand.	After throwing a dart, maintain your gaze on the bullseye for at least 200ms.
5	Repeat the same process.	Repeat the same process.

Table 2

Mean (cm) Pre-test, Post-test, Transfer Scores, and Totals by Group and Task Difficulty

Group	Task Difficulty	Pre-test (M ± SD)	Post-test (M ± SD)	Transfer (M ± SD)
Quiet Eye Training	Easy	6.91 (1.86)	4.29 (1.89)	11.22 (4.30)
	Moderate	7.50 (3.33)	5.16 (1.21)	11.37 (5.70)
	Difficult	10.14 (0.92)	6.62 (2.55)	15.76 (6.02)
	Total	*8.18 (2.62)*	*5.36 (2.14)*	*12.78 (5.66)*
Technical Training	Easy	5.72 (1.82)	4.43 (2.06)	16.20 (4.84)
	Moderate	6.93 (2.88)	6.23 (1.54)	16.05 (4.03)
	Difficult	10.25 (2.51)	9.75 (2.21)	16.24 (3.50)
	Total	*7.63 (3.06)*	*6.80 (2.93)*	*16.16 (4.04)*

Note. M = mean; SD = standard deviation.

References

Causer, J., Hayes, S. J., Hooper, J. M., & Bennett, S. J. (2017). Quiet eye contains information on sensorimotor preprograming and online control. *Cognitive Processing*, *18*(1), 47-54. https://doi.org/10.1007/s10339-016-0783-4

Causer, J., Holmes, P. S., & Williams, A. M. (2011). Quiet eye training in a visuomotor control task. *Medicine & Science in Sports & Exercise*, *43*(6), 1042-1049. https://doi.org/10.1249/MSS.0b013e3182035de6

Causer, J., Janelle, C. M., Vickers, J. N., & Williams, A. M. (2012). Perceptual training: What can be trained? In N. J. Hodges & A. M. Williams (Eds.), *Skill Acquisition in Sport: Research, Theory and Practice* (pp. 306-324). Routledge.

Causer, J., & Williams, A. M. (2015). The use of patterns to disguise environmental cues during an anticipatory judgment task. *Journal of Sport & Exercise Psychology*, *37*, 74-82. https://doi.org/10.1123/jsep.2014-0200

Fairbrother, J. T., Laughlin, D. D., & Nguyen, T. V. (2012). Self-controlled feedback facilitates motor learning in both high and low activity individuals. *Frontiers in Psychology*, *3*, 323. https://doi.org/10.3389/fpsyg.2012.00323

Flindall, J., Sinnett, S., & Kingstone, A. (2020). The Quiet Eye and Expertise: Sustained Fixations Do Not Transfer to Unpracticed Throws Among Expert Dart Players. *Journal of Sport and Exercise Psychology*, *42*(4), 269-279. https://doi.org/10.1123/jsep.2019-0217

Fransen, J. (2024). There is No Supporting Evidence for a Far Transfer of General Perceptual or Cognitive Training to Sports Performance. *Sports Medicine*, *54*(11), 2717-2724. https://doi.org/10.1007/s40279-024-02060-x

Gonzalez, C. C., Causer, J., Grey, M. J., Humphreys, G. W., Miall, R. C., & Williams, A. M. (2017). Exploring the quiet eye in archery using field- and laboratory-based tasks.

Experimental Brain Research, *235*, 2843-2855. https://doi.org/10.1007/s00221-017-4988-2

Gonzalez, C. C., Causer, J., Miall, R. C., Grey, M. J., Humphreys, G., & Williams, A. M. (2017). Identifying the causal mechanisms of the quiet eye. *European Journal of Sport Science*, *17*(1), 74-84. https://doi.org/10.1080/17461391.2015.1075595

He, Q., Liu, Y., & Yang, Y. (2024). The effect of quiet eye training on golf putting performance in pressure situation. *Scientific Reports*, *14*(1), 5182. https://doi.org/10.1038/s41598-024-55716-z

Hossner, E. J. (2016). Quiet Eye research – Joan Vickers on target. *Current Issues in Sport Science*, *1*(100). https://doi.org/10.15203/CISS_2016.100

Khanjari, Y., Arabameri, E., Shahbazi, M., Tahmasebi, S., Bahrami, F., & Mobaien, A. (2023). The simultaneous changes in motor performance and EEG patterns in beta band during learning dart throwing skill in dominant and non-dominant hand. *Computer Methods in Biomechanics and Biomedical Engineering*, *26*(2), 127-137. https://doi.org/10.1080/10255842.2022.2048375

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*(5), 1270-1278. https://doi.org/10.1037/a0031499

Lebeau, J. C., Liu, S., Saenz-Moncaleano, C., Sanduvete-Chaves, S., Chacon-Moscoso, S., Becker, B. J., & Tenenbaum, G. (2016). Quiet Eye and Performance in Sport: A Meta-Analysis. *Journal of Sport & Exercise Psychology*, *38*(5), 441-457. https://doi.org/10.1123/jsep.2015-0123

Leivers, H. K., van Paridon, K. N., Allen, P. M., Runswick, O. R., & Timmis, M. A. (2025). The Quiet Eye Period and its Relationship With Task Complexity: Is the Ceiling Effect an Indicator of Expertise? *Percept Mot Skills*, 315125251388328.

https://doi.org/10.1177/00315125251388328

Mann, D. L., Causer, J., Nakamoto, H., & Runswick, O. R. (2019). Visual search behaviors in expert perceptual judgements. In A. M. Williams & R. C. Jackson (Eds.), *Anticipation and Decision Making in Sport* (pp. 59-78). Routledge.

Marchant, D. C., Clough, P. J., & Crawshaw, M. (2007). The effects of attentional focusing strategies on novice dart throwing performance and their task experiences. *International Journal of Sport and Exercise Psychology*, *5*(3), 291-303. https://doi.org/10.1080/1612197X.2007.9671837

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*(7), 1005-1015. https://doi.org/10.1111/j.1469-8986.2012.01379.x

Murphy, C. P., Jackson, R. C., Cooke, K., Roca, A., Benguigui, N., & Williams, A. M. (2016). Contextual information and perceptual-cognitive expertise in a dynamic, temporally-constrained task. *Journal of Experimental Psychology: Applied*, *22*(4), 455-470. https://doi.org/10.1037/xap0000094

Neugebauer, J., Baker, J., & Schorer, J. (2020). Looking to Learn Better - Training of Perception-Specific Focus of Attention Influences Quiet Eye Duration but Not Throwing Accuracy in Darts [Original Research]. *Frontiers in Sports and Active Living*, *Volume 2 - 2020*. https://doi.org/10.3389/fspor.2020.00079

North, J. S., Ward, P., Ericsson, K. A., & Williams, A. M. (2011). Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory*, *19*(2), 155-168. https://doi.org/10.1080/09658211.2010.541466

Oppici, L., & Panchuk, D. (2022). Specific and general transfer of perceptual-motor skills and learning between sports: A systematic review. *Psychology of Sport and Exercise*, *59*, 102118. https://doi.org/https://doi.org/10.1016/j.psychsport.2021.102118

Querfurth, S., Schücker, L., de Lussanet, M. H. E., & Zentgraf, K. (2016). An Internal Focus Leads to Longer Quiet Eye Durations in Novice Dart Players [Original Research]. *Frontiers in Psychology*, *Volume 7 - 2016*. https://doi.org/10.3389/fpsyg.2016.00633

Rienhoff, R., Hopwood, M. J., Fischer, L., Strauss, B., Baker, J., & Schorer, J. (2013). Transfer of motor and perceptual skills from basketball to darts. *Frontiers in Psychology*, *4*, 593. https://doi.org/10.3389/fpsyg.2013.00593

Rienhoff, R., Tirp, J., Strauß, B., Baker, J., & Schorer, J. (2016). The 'Quiet Eye' and Motor Performance: A Systematic Review Based on Newell's Constraints-Led Model. *Sports Medicine*, *46*(4), 589-603. https://doi.org/10.1007/s40279-015-0442-4

Sala, G., Aksayli, N. D., Tatlidil, K. S., Tatsumi, T., Gondo, Y., & Gobet, F. (2019). Near and Far Transfer in Cognitive Training: A Second-Order Meta-Analysis. *Collabra: Psychology*, *5*(1). https://doi.org/10.1525/collabra.203

Schoenfeld, M. J., Thom, J., Williams, J., Stagg, C. J., & Zich, C. (2024). Relationship between skill training and skill transfer through the example of bimanual motor learning. *European Journal of Neuroscience*, *59*(1), 54-68. https://doi.org/10.1111/ejn.16194

Smeeton, N. J., Page, J., Causer, J., Wilson, M., Gray, R., & Williams, A. M. (2013). The BASES Expert Statement on the Effectiveness of Vision Training Programmes. *The Sport and Exercise Scientist*(38), 13.

Thorndike, E. L. (1914). *Educational Psychology: Briefer Course*. Columbia University Press.

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

Vickers, J. N. (2007). *Perception, Cognition and Decision Training: The Quiet Eye in Action*. Human Kinetics.

Vickers, J. N. (2009). Advances in coupling perception and action: the quiet eye as a bidirectional link between gaze, attention, and action. *Progress in Brain Research*, *174*, 279-288. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=19477346

Vickers, J. N. (2011). Mind over muscle: the role of gaze control, spatial cognition and the quiet eye in motor expertise. *Cognitive Processing*, *12*(3), 219-222. https://doi.org/10.1007/s10339-011-0411-2

Vickers, J. N., Causer, J., Stuart, M., Little, E., Dukelow, S., LaVangie, M., Nigg, S., Arsenault, G., Morton, B., Scott, M., & Emery, C. (2017). Effect of the look-up line on the gaze and head orientation of elite ice hockey players. *European Journal of Sport Science*, *17*(1), 109-117. https://doi.org/10.1080/17461391.2016.1220627

Vickers, J. N., & Williams, A. M. (2007). Performing under pressure: the effects of physiological arousal, cognitive anxiety, and gaze control in biathlon. *Journal of Motor Behavior*, *39*(5), 381-394. https://doi.org/10.3200/JMBR.39.5.381-394

Vine, S. J., Lee, D. H., Walters-Symons, R., & Wilson, M. R. (2015). An occlusion paradigm to assess the importance of the timing of the quiet eye fixation. *European Journal of Sport Science*, *17*, 85-92. https://doi.org/10.1080/17461391.2015.1073363

Vine, S. J., Moore, L. J., & Wilson, M. (2011). Quiet eye training facilitates competitive putting performance in elite golfers. *Frontiers in Psychology*, *2*, 1-9. https://doi.org/10.3389/fpsyg.2011.00008

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 Suppl 1,), S235–S242. https://doi.org/10.1080/17461391.2012.683815

Walters-Symons, R., Wilson, M., Klostermann, A., & Vine, S. (2018). Examining the response programming function of the Quiet Eye: Do tougher shots need a quieter eye? *Cognitive Processing*, *19*(1), 47-52. https://doi.org/10.1007/s10339-017-0841-6

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: implications for applied cognitive psychology. *Applied Cognitive Psychology*, *25*(3), 432–442. https://doi.org/10.1002/acp.1710

Williams, A. M., Singer, R. N., & Frehlich, S. G. (2002). Quiet eye duration, expertise, and task complexity in near and far aiming tasks. *Journal of Motor Behavior*, *34*(2), 197-207. https://doi.org/10.1080/00222890209601941

Wilson, M., Causer, J., & Vickers, J. N. (2015). Aiming for excellence: the quiet eye as a characteristic of expertise. In D. Farrow & J. Baker (Eds.), *Routledge Handbook of Sport Expertise* (pp. 22-37). Routledge.

Wilson, M., Smith, N. C., & Holmes, P. S. (2007). The role of effort in influencing the effect of anxiety on performance: testing the conflicting predictions of processing efficiency theory and the conscious processing hypothesis. *British Journal of Psychology*, *98*, 411-428.

Wulf, G., Shea, C., & Lewthwaite, R. (2010). Motor skill learning and performance: a review of influential factors. *Medical education*, *44*, 75-84.