ORIGINAL ARTICLE

Quiet eye training aids the long-term learning of throwing and catching in children: Preliminary evidence for a predictive control strategy.

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RUNNING HEAD: Quiet eye training in children

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Abstract

Quiet eye training (QET) may be a more effective method for teaching children to catch than traditional training (TT) methods, but it is unclear if the benefits accrued persist in the long term. Thirty children were randomly allocated into a QET or TT group and, while wearing a mobile eye tracker, underwent baseline testing, training and two retention tests over a period of eight weeks, using a validated throw and catch task. During training, movement related information was provided to both groups, while the QET group received additional instruction to increase the duration of their targeting fixation (QE1) on the wall prior to the throw, and pursuit tracking (QE2) period on the ball prior to catching. In both immediate (R1) and delayed (R2, six-weeks later) retention tests, the QET group had a significantly longer QE1 duration and an earlier and longer QE2 duration, compared to the TT group, who revealed no improvements. A performance advantage was also found for the QET compared to TT group at both R1 and R2, revealing the relatively robust nature of the visuomotor alterations. Regression analyses suggested that only the duration of QE1 predicted variance in catch success post-training, pointing to the importance of a pre-programming visuomotor strategy for successful throw and catch performance.

Introduction

The quiet eye (QE) has emerged as a feature of expertise in targeting and interception tasks (see Wilson, Causer, & Vickers, 2015). Defined as the final fixation (or tracking gaze) on a critical location or target prior to the onset of the final movement (Vickers, 1996), the QE is a critical period when sensory information is synthesised to both plan (pre-programme) and control (online) the appropriate motor response. A meta-analysis by Mann, Williams, Ward, and Janelle (2007) found that experts maintained a QE duration that was, on average, sixty-two percent longer than non-experts across tasks that were as diverse as rifle shooting and volleyball service return. Importantly, not only is QE a marker of superior performance in visually guided tasks, but novices can be taught to adopt this gaze strategy; significantly improving performance when compared to traditional coaching instructions (Causer, Janelle, Vickers, & Williams, 2012; Wilson et al., 2015).

Until recently QE studies have solely used adult populations, however recent research has extended these findings in order to attempt to understand the development of motor skill proficiency in children. In the first study that examined the QE in children, Wilson, Miles, Vine, and Vickers (2013) found differences in QE duration explained differences in throwing and catching ability; more highly coordinated children maintained earlier and longer QE durations and caught more balls than their less coordinated counterparts. Moreover, this study found that the tracking gaze duration on the ball (QE2) predicted the relationship between catching ability and performance. A follow-up study utilised these findings in order to test the effectiveness of a quiet-eye training (QET) intervention (Miles, Vine, Wood, Vickers, & Wilson, 2014). Lower coordinated children (catching ~ 50% of balls at pre-test) were taught how to adopt the longer QE durations of skilled performers while learning the same throwing and catching task. Results revealed that children who received QET significantly increased their QE duration in both the throw (QE1; aiming) and catch (QE2; tracking) phase of the task. QET participants also improved their catching performance (from 48% to 70% success), whereas the scores of the control group, who received standard technical training, did not significantly improve (from 51% to 55% success). Importantly, and contrary to Wilson et al. 2013, Miles et al. (2014) found that only QE1 duration predicted catching success.

Miles et al. (2014) suggested that the extended pre-throw QE fixation (QE1) on the wall provided a “virtual target” that resulted in throws directed more centrally toward this fixated location. With gaze resting near the bounce point, QET participants were able to more quickly locate and track the ball (QE2) after it bounced, thus providing earlier information to prepare the interception attempt (Hayhoe, Mennie, Sullivan, & Gorgos, 2005; Wilson et al., 2013). The longer durations of QE1 and QE2 were postulated to provide evidence of an extended period for the cognitive pre-programming and parameterisation of the movement (Klostermann, Koedijker, & Hossner, 2013a; Klostermann, Kredel, & Hossner, 2013b; Vickers, 2007; Williams, Singer, & Frehlich, 2002).

According to this predictive control strategy explanation (Panchuk & Vickers, 2009), earlier and longer QE periods provide sufficient processing time to determine the optimal target (pre-throw), and predict the timing and location of interception (catch), and to plan the movements required for the successful execution of these actions. The benefit of this strategy for children may be that generating an internal forward model through pre-programming provides stability to a child’s motor system by determining the outcome of the movement before the slower sensorimotor feedback becomes available (Williams J. et al., 2011; Williams J., Omizzolo, Galea, & Vance, 2013).

The main aim of the present study was to extend the work of Miles et al. (2014) in order to test the efficacy of QET for facilitating the long-term learning of throwing and catching skill in children using a six week delayed retention test. We hypothesised that the QET advantage found by Miles et al. (2014) would be maintained at a delayed retention test. Specifically, we predicted that there would be a significant interaction effect for QE variables and performance, with QET children having earlier and longer QE1 and QE2, and superior performance following training (at R1) and after a de-training period (R2) than their TT counterparts.

A secondary aim was to increase our understanding of *how* QET impacts the motor performance of children. We wanted to make use of the two-part nature of the sequential throwing and catching task to explore the interrelationship and transition between the aiming and interception phases. Based on Miles et al. (2014; 2015) we proposed that a longer QE1 duration would be predictive of an earlier QE2 onset and subsequently a longer QE2 duration. The relative importance of QE1 and QE2 in supporting accurate catching performance was examined with exploratory follow-up regression analyses.

Methods

Participants

Thirty-five children aged between 8-10yrs were recruited from primary schools in the South West of England [1]. The children were screened using the Movement Assessment Battery for Children-2 (MABC-2; Henderson, Sugden, & Barnett, 2007) to ensure they were not likely to have developmental coordination disorder (DCD) and to eliminate possible ceiling effects in catching ability. No children were classified as being at risk of DCD (mean percentile rank = 42.10, *SD* = 20.78) and all had normal vision. Five children scored above 80% in the catching task and were consequently excluded from the study. The remaining 30 children were randomly divided into two training groups: a QET group (6 males, 9 females) and a TT group (8 males, 7 females). Ethical approval was obtained from a local ethics committee and full participant and parental consent was obtained prior to commencing the study.

Task

The throwing and catching task from the MABC-2 (8-10 year age bracket) was used in order to aid comparison with previous studies (Wilson et al., 2013; Miles et al., 2014). It requires participants to stand behind a line 2m from a blank wall and throw a tennis ball under-arm at the wall and catch it before it bounces. In line with MABC-2 instructions the task was first explained to the participant by the tester and demonstrated once, before the participants were given 5 practice attempts.

Apparatus

Each participant was fitted with an Applied Science Laboratories' Mobile Eye gaze registration system (ASL, Bedford, MA), which measures point of gaze at 30Hz. A 30Hz Digital SLR camera (Finepix S6500fd) was placed on a tripod 3m to the right of the throw line at the approximate shoulder height of the participant capturing a side on view (sagittal plane) of the participant's movements (at 30Hz).

Procedure

Each participant individually attended three separate testing sessions. During the initial assessment session (Baseline) each participant completed the MABC-2, was fitted with the eye-tracker, and completed the baseline measurement of the throwing and catching task. The second session was carried out one week later and comprised of the training intervention followed by ten immediate retention (R1) trials of the throwing and catching task without any instructions. The final testing session took place 6 weeks after the training phase and participants were again calibrated to the eye tracker and completed ten delayed retention (R2) trials of the throwing and catching task without any instruction. At the end of the testing period each child and their parents were debriefed as to the purpose of the study and were awarded a £10 shopping voucher for their participation.

Training Interventions

To train the throwing and catching elements of the task the participants were shown a video of an expert model performing each coaching point, overlaid with group-specific visual prompts and verbal instructions. The TT instructions were based on standard instructions that highlight the participant's movements. The QET group also received these standard instructions with additional gaze instructions to optimise the targeting (pre-throw; QE1) and tracking (pre-catch; QE2) durations (See Table 1)[2]. After watching each video, participants were asked to summarise the training points to demonstrate their understanding, before they performed 30 practice attempts of the throwing and catching task. A researcher reiterated key points from the videos after every 5 trials. These were movement-focused instructions for the TT group such as "cup your hands around the ball", and gaze focused instructions for the QET group such as "watch the ball closely". Once the participant completed the training for the separate throw and catch elements of the task (60 total practice trials), they were then shown a short summary video and completed a final 25 practice attempts of the complete task.

****Insert Table 1 near here****

Measures

QE measures were analysed in a frame-by-frame manner using Quiet Eye Solutions software (www.quieteyesolutions.com).

Targeting fixation (QE1). QE1 was a visual fixation located on a virtual target on the wall (that remained within 1° of visual angle for more than 100ms) prior to and during the throw phase of the task. QE1 onset was defined as the final fixation duration prior to the initiation of foreswing of the throwing arm[3]. The offset of QE1 occurred when gaze deviated from the virtual target location by more than 1° of visual angle for longer than 100ms.

Tracking gaze (QE2). QE2 was the final tracking gaze on the tennis ball after it rebounded from the wall during the catch phase of the task. The QE2 onset was defined as the start of the final tracking gaze on the ball (for more than 100ms) before the grasping action was attempted, or the trial ended [4]. The QE2 offset occurred when the tracking gaze deviated off the ball for more than 100ms (Wilson et al., 2013; Miles et al., 2014).

Flight time. Ball flight times were calculated using frame-by-frame analysis (30 Hz) of the external video camera footage, in order to provide a measure of how the task was performed (Wilson et al., 2013). Flight time 1 (FT1: hand to wall) was the time from the ball release to the wall contact point and reflects the speed and trajectory of the throw. Flight time 2 (FT2: wall to hand) was the time from the wall contact point to the trial end and is dependent on both the initial throw parameters and the catch technique adopted (Miles et al., 2014; Wilson et al., 2013).

Performance. Catch success was scored (success vs failure), using the sagittal motor video data, and expressed as the percentage of the 10 trials that were successfully caught at baseline, R1 and R2.

Data Analysis

The QE, flight time and performance variables were entered into separate 2x3 mixed-model analyses of variance (ANOVA). The intervention group was the between measures factor (TT vs QET), and test (Baseline [BL] vs Retention 1 [R1] vs Retention 2 [R2]) was the repeated measures factor. A Greenhouse-Geisser correction was used if the assumption of sphericity was violated, and uncorrected degrees of freedom were reported, along with the corrected probability values and epsilon value. As our hypotheses predict significant group x test interaction effects, only these are reported when they supersede separate main effects. Partial eta squared was calculated to estimate effect sizes (η_p^2) and LSD *post hoc* tests were used to investigate significant main and interaction effects.

Linear regression analyses were first used to follow-up on significant interaction effects, to determine the relative importance of measures in predicting performance after training, and to explore the interrelationship between indices of gaze across the throwing and catching phases of the task.

Results

Quiet Eye (QE)

Due to technical problems with the eye tracker, a number of trials could not be analysed. Out of 900 trials conducted, a total of 160 trials were excluded for QE1 (TT = 60; QET = 100) and a total of 204 trials were excluded for QE2 (TT = 97; QET = 107).

QE1 (ms). ANOVA revealed a significant group x test interaction for QE1 onset, $F_{1,56} = 9.43$, $p < 0.01$, $\eta_p^2 = 0.25$ (Figure 1a). Post hoc analyses of the between group effects revealed there were no significant differences in QE1 onset at BL (mean difference 76ms, $p = 0.20$) or at R2 (mean difference 198ms, $p = 0.12$) however the QET group had significantly earlier QE1 onsets at R1 (mean difference 503ms, $p < 0.01$). Within group post hoc analyses revealed no significant differences between the

QE1 onset times of the TT group (p's > 0.45). The QET group had a significantly earlier QE1 onset at R1 (mean difference 632ms, $p < 0.01$) and R2 (mean difference 337ms, $p = 0.01$) compared to baseline. Their QE1 onset was significantly later at R2 in comparison to R1 (mean difference -296ms, $p = 0.03$).

There was no significant group x test interaction for QE1 offset, $F_{2,56} = 0.06$, $p = 0.94$, $\eta_p^2 < 0.01$. There were also no significant main effects for test, $F_{2,56} = 0.17$, $p = 0.85$, or for group, $F_{1,28} = 0.45$, $p = 0.51$ (Figure 1b). There was a significant group x test interaction for QE1 duration, $F_{2,56} = 8.73$, $p < 0.01$, $\varepsilon = 0.77$, $\eta_p^2 = 0.24$ (Figure 1c). Post hoc analyses of the between group effects revealed there was no significant difference in QE1 duration at BL (mean difference 42ms, $p = 0.55$), however the QET group had a significantly longer QE1 duration at R1 (mean difference 550ms, $p < 0.01$), and at R2 (mean difference 234ms, $p < 0.01$) in comparison to the TT group. Within group post hoc analyses revealed no significant improvements in QE1 duration for the TT group throughout the tests (p's > 0.23). The QET group significantly increased their QE1 duration from BL to R1 (mean difference 604ms, $p < 0.01$) and BL to R2 (mean difference 241ms, $p < 0.01$). However, there was a significant decrease in QE1 duration between R1 and R2 (mean difference -363ms, $p < 0.01$).

****Insert Figure 1 near here****

QE2 (ms). ANOVA revealed a significant group x test interaction for QE2 onset, $F_{2,56} = 4.73$, $p = 0.01$, $\eta_p^2 = 0.14$ (Figure 2a). Post hoc analyses revealed no significant differences between the intervention groups at BL (mean difference 1ms, $p = 0.98$) however, at R1 the QET group had a significantly earlier QE2 onset than the TT group (mean difference 59ms, $p < 0.01$) and they were able to maintain this earlier QE2 onset at R2 (mean difference 63ms, $p < 0.01$). The within group analyses revealed that the QE2 onset of the TT group did not significantly change throughout the tests (p's > .63). The QET group however significantly reduced the time to QE2 onset from BL to R1 (mean difference -53ms, $p < 0.01$) and they maintained this earlier QE2 onset from BL to R2 (mean difference -56ms, $p < 0.01$). There was no significant difference in QE2 onset between R1 and R2 (mean difference -3ms, $p = 0.86$).

ANOVA revealed no significant group x test interaction for QE2 offset, $F_{2,56} = 0.12$, $p = 0.89$, $\eta_p^2 < .01$. There were also no significant main effects for test, $F_{2,56} = 1.22$, $p = 0.30$, or for group, $F_{1,28} = 1.40$, $p = 0.25$ (Figure 2b). There was however a significant group x test interaction for QE2 duration, $F_{2,56} = 3.76$, $p = 0.03$, $\eta_p^2 = 0.12$ (Figure 2c). Post hoc analyses revealed no significant difference between the groups' QE2 duration at BL (mean difference 12ms, $p = 0.72$) but the QET had significantly longer QE2 durations at R1 (mean difference 81ms, $p < 0.01$) and at R2 (mean difference 96ms, $p < 0.01$). The within group analysis found no significant differences for the TT group over the tests (p's > 0.06). The QET group extended their QE2 duration between BL and R1 (mean difference 66ms. $p = 0.01$) however, their QE2 duration at R2 was not significantly longer than at BL (mean difference -43ms, $p = 0.16$). There was also no significant difference in QE2 duration between R1 and R2 (mean difference 22ms, $p = 0.12$).

****Insert Figure 2 near here****

Flight Time

Flight time 1. ANOVA revealed no significant group x test interaction, $F_{2,56} = 0.62$, $p = 0.54$, and no main effects for test, $F_{1,28} = 0.44$, $p = 0.51$, or group, $F_{2,56} = 0.96$, $p = 0.39$, for FT1 (Figure 3a).

Flight time 2. ANOVA also revealed no significant group x test interaction, $F_{2,56} = 1.13$, $p = 0.33$, and no main effects for test, $F_{1,28} = 0.43$, $p = 0.57$, or group, $F_{2,56} = 1.64$, $p = 0.20$, for FT2 (Figure 3b).

Performance

Catching success (%). ANOVA revealed a significant group x test interaction, $F_{2,56} = 3.64$, $p = 0.03$, $\eta_p^2 = 0.12$ (Figure 3c). Post hoc analysis revealed no significant difference between the groups at BL (mean difference = 0%, $p = 1.00$), and the difference at R1 only approached significance (mean difference = 16%, $p = 0.09$). The QET group did however score significantly higher than the TT group at R2 (mean difference = 23%, $p = 0.01$). The within group analysis revealed no significant change in performance for the TT children throughout the tests (*p's* > 0.18). The QET group however significantly increased performance from BL to R1 (mean difference = 25%, $p < 0.01$), and BL to R2 (mean difference = 29%, $p < 0.01$). There was no significant difference in catch success between R1 and R2 (mean difference = 5%, $p = 0.39$)[6].

****Insert Figure 3 near here****

Regression Analyses

QE1 and QE2. Regression analyses on the post-training data revealed that QE1 duration significantly predicted the variance in QE2 onset ($R^2 = 0.40$, $b = -0.10$, $p < 0.001$), and QE2 duration ($R^2 = 0.40$, $b = 0.14$, $p < 0.001$). QE2 onset also significantly predicted QE2 duration ($R^2 = 0.40$, $b = -0.92$, $p < 0.001$).

Gaze and performance. The linear regression analyses revealed that for the gaze measures that revealed significant post training interaction effects, only QE1 duration significantly predicted catch success ($R^2 = 0.13$, $b = 0.03$, $p = 0.05$). There was no significant relationship between QE1 onset ($R^2 = 0.06$, $b = -0.02$, $p = 0.19$);

QE2 onset (R^2 = 0.07, b = -0.13, p = 0.17); QE2 duration (R^2 = 0.04, b = 0.07, p = 0.31) and performance.

Discussion

This study aimed to build on the findings of Miles et al. (2014) by determining if QET leads to longer-term improvements in motor learning for children, compared to TT training. It is critical that more skill acquisition research employs delayed retention tests to take into account issues related to skill decay during de-training periods, if interventions are to demonstrate utility in real-world environments (Arthur, Bennet, Stanush, & McNelly, 1998; Wulf, Shea, & Lewthwaite, 2010). In the current study, the QET children revealed better task performance both immediately after training (R1) and in the delayed retention test (R2), however significant between-group differences were only present at R2. These findings add to the literature supporting the benefits of QET in expediting the skill acquisition of ‘novice’ performers in comparison to traditional coaching, and provide the first evidence that a brief QET protocol can produce a long-term training effect in the throwing and catching skill of children.

The secondary aim of this study was to develop our understanding of how QET impacts on the visuomotor control strategy of children. As predicted, the QET children significantly increased both their targeting (QE1) and interceptive (QE2) QE durations from baseline to R1 and R2, whereas their TT counterparts did not. Interestingly, the between group differences in QE durations were driven by earlier onsets, rather than later offsets, in both QE measures.

The pre-throw instructions to the QET group focused on maintaining a long fixation prior to the throw, so the lack of group differences in QE1 offset may not be too surprising. QE1 offset occurs almost concurrently with ball release in both groups and this timing may simply reflect the task demands. The lack of difference in QE2 offset time would appear to be due to ceiling effects in available tracking time, rather than a failure of the QET group to follow their instructions ('…to track the ball into their hands'; Table 1). Indeed, when the QE2 offset data (Figure 2b) are considered with respect to the flight time 2 data (Figure 3b), it would appear that there is a natural departure point when gaze will come off the ball before the completion of the catch attempt. The QET group's QE2 offset after training was only ~65ms before trial end, whereas the TT group's offset was a little earlier (~120ms). Despite not being taught to do so, it would appear that following training, even the TT children tracked the ball right up until the last available moments.

The two-part nature of the throwing and catching task also allowed us to determine if earlier pick-up of visual information through both phases of the task assisted with the planning and parameterisation of the subsequent catch attempt. The regression analyses demonstrated that QE1 explained variance in both the onset of QE2 and its subsequent duration. While no measure of throwing accuracy was available (the MABC-2 task stipulates throwing to a blank wall), these results are strongly suggestive of an important pre-programming role for QE1: A longer QE1 duration supports more accurate far-aiming (throwing) performance, which in turn provides a more accurate estimation of the bounce point, which enables an earlier pick up of the ball after it bounces (QE2 onset), and a longer tracking gaze as the ball travels towards the participant (QE2 duration).

Interestingly, the regression analyses did not support a functional role for longer QE2 durations (cf. Wilson et al., 2013), with QE1 duration alone predicting variance in catching performance. In effect, QE1 appears to assist in the pre-programming of not only the initial throw parameters, but also the subsequent catch parameters. Less variable and more accurate throws enable a catch attempt to be planned using predictive information based on stored internal models of movement control (Hayhoe McKinney, Chajka, & Pelz, 2012; Wolpert, Miall, & Kawato, 1998) and bal1/object properties (Hayhoe et al 2005). This explanation would suggest that more accurate throwing reduces the necessity for a longer tracking gaze (QE2) on the ball, as the ball flight is no longer as variable. While our data only tentatively support this interpretation, they provide an interesting departure point for future studies examining the role of gaze in sequential, inter-related tasks. For example, it would be interesting to examine manipulations to the standard ball trajectory off a wall that would reduce the quality of the predictive information from a longer QE1 and an accurate throw.

The results of the current study do contradict findings from some previous studies using the same MABC-2 throw and catch task (i.e., Wilson et al 2013; Miles et al. 2015), which found that QE2 duration was the best predictor of performance. However, these contradictions may be explained by differences in the degree to which participants' motor coordination is impaired. Miles et al. (2015) and Wilson et al. (2013) sampled from children with developmental coordination disorder and children with very low catching ability respectively (baseline catching success ~ 35%), whereas this study used typically developing children of relatively 'normal' ability (baseline catching success ~ 50%; see also Miles et al., 2014). Less coordinated individuals appear to rely more on an online control strategy in this task whereas more coordinated individuals utilise a strategy based on earlier, predictive information, perhaps due to their greater accuracy in the throwing component of the task. It is known that the predictive control of action is a fundamental impairment in children with DCD (Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013), which coupled with reduced throwing accuracy would lead to a reliance on later, online information. These differences in the mechanisms by which children of varying abilities appear to perform this task warrants further exploration in subsequent studies.

There are several limitations to this study that need to be considered when interpreting these findings. First, we had no control over the children's activities over the 6-week de-training period, so we cannot be sure if all refrained from practicing. Second, we propose that QE1 induces more accurate throwing yet we never measured this due to the MABC-2 task requiring a throw to a blank wall. Future research may wish to explore the accuracy of the throw phase more explicitly by having children throw to a target. Finally, the QET group received explicit instructions to pause for 2 seconds before throwing, whereas the TT group only had generic instructions to "… take your time" (Table 1). As QE1 duration explains the most variance in performance, this variation in instructions may be a critical determinant of between group differences. In effect, the performance advantage of QET may be more related to improved pre-task self-regulation, rather than visuomotor mechanisms (Vine, Moore & Wilson, 2014). Future research should test this postulation using objective psychophysiological indices (e.g., cardiac deceleration; Moore, Vine, Cooke, Ring, & Wilson, 2012) and by exploring participants' perceptions of control (Wood & Wilson, 2012).

In summary, this study provides more evidence for the effectiveness of QET to assist with the acquisition and retention of motor skills, over an extended period of time. Children who received instructions that helped them adopt the QE of an expert child performing the throw and catch task were able to improve their catching performance and increase their QE durations, and critically these changes largely remained after a 6 week period of de-training. The findings of this study also support an important role for pre-planning a movement during an early stable QE fixation, which leads to an earlier and longer tracking gaze on the ball. However, future experimental research should test this relationship by manipulating or removing the ability to predict bounce location and direction, and by examining more process-orientated kinetic and kinematic measures in order to explore *if* and *how* QET produces more coordinated movement patterns in children.

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Table 1: A summary of the instructions for the adapted QET and TT videos.

	QET Video 1	TT Video 1
Phase 1: The Throw	[General Introduction] Look at the scene view [highlighted]. See how the girl takes her time to aim at a spot on the wall before she throws?	[General Introduction] Look at the scene view [highlighted]. See how the girl takes her time before she throws?
	Now look at the side on view [highlighted]. Notice how the girl throws the ball with a smooth arm action.	Now look at the side on view [highlighted]. Notice how the girl throws the ball with a smooth arm action.
	[Scene view highlighted] To make a good throw, focus your eyes on the target and count to two before you start a smooth throwing action	[Side-on view highlighted] To make a good throw, take your time, then throw at a target using a smooth throwing action.
	Remember, aim at your target, count to two, and then a smooth throw	Remember, take your time, and concentrate on a smooth swing of your throwing arm.
Phase 2: The Catch	Look at the scene view [highlighted]. Can you see how the girl watches the ball as soon as it hits the wall and keeps her eye on it all the way back to her outstretched hands?	Look at the scene view [highlighted]. Can you see how the girl concentrates on the ball as it flies back to her outstretched hands?
	Now look at the side on view [highlighted]. Can you see how the girl cups her hands together to catch the ball?	Now look at the side on view [highlighted]. Can you see how the girl cups her hands together to catch the ball?
	[Scene view highlighted] To make a good catch, it's really important that you keep your eye on the ball from as soon as it hits the wall, until it comes back into your cupped hands.	[Side on view highlighted] To make a good catch, it's really important that you concentrate on the ball and cup your hands together.
	Remember, focus on the target when throwing, but this time try really hard to watch the ball bounce, and then watch the ball right back into your hands.	Remember to throw with a smooth arm action, but this time you need to concentrate really hard on the ball and cup your hands together to make the catch
Phase 3: The Review	OK, so far you have learned two training points.	OK, so far you have learned two training points.
	[Scene view highlighted] To throw, you need to take your time to aim at the target, count to two in your head, before smoothly throwing the ball.	[Side on view highlighted] To throw, you need to take your time before you smoothly throw the ball at the target.

[Scene view highlighted] To catch, you need to keep your eye on the ball from its bounce on the wall right until it comes back into your cupped hands. Now lets try and put this all together in the final practice session.	[Side on view highlighted] To catch, you need to concentrate on the ball, and cup your hands together to catch it when it comes back to you. Now lets try and put this all together in the final practice session.
Remember the two training points: Firstly focus on the target for two seconds and throw smoothly	Remember the two training points: Firstly, take you time to throw with a smooth arm action.
And secondly keep your eye on the ball and cup your hands ready for the catch.	And secondly concentrate on the ball and cup your hands ready for the catch.

Footnotes

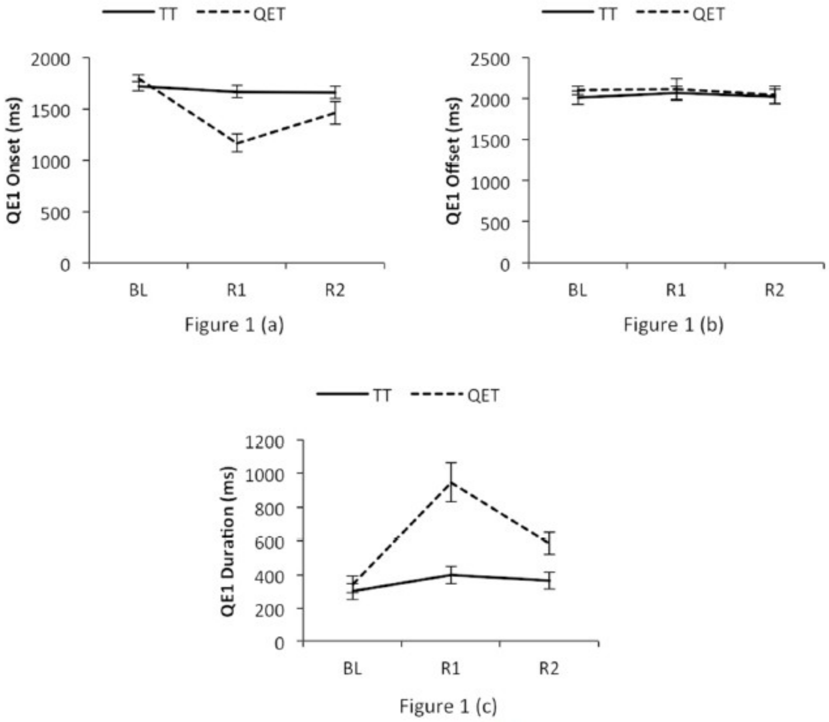
1. Note that this is a totally different sample to that used in Miles et al. (2014).
2. Participants in Miles et al.'s (2014) QET group did not receive any technical instructions, leading to suggestions from a reviewer that the training advantage for the QET group may have simply been due to the advantages of an external focus of attention, compared to an internal focus of attention (see Wulf, 2013). In the current study the QET group received the same technical (internally focused) instructions as the TT group in addition to their gaze instructions.
3. In Miles et al (2014) ball release was suggested as the final movement; however, other research in throwing (Klostermann et al., 2013a; Klostermann et al., 2013b) has adopted the foreswing of the arm as being more reflective of pre-planning the throw.
4. On trials when no catch was made, trial end was determined when the ball contacted the participant's hands or any part of their body, when the ball contacted another surface (e.g. bounced), or when it crossed the throw line.
5. Note that all these analyses were performed on the collapsed sample to provide a wider range of results for comparison, and more power.
6. Note that a more sensitive measure of catching technique based on an 11 point rating scale (see Miles et al. 2014, Miles et al. 2015) revealed a similar interaction effect; $F_{2,56} = 4.66$, $p = 0.01$, $\eta_p^2 = 0.14$. Again, there were no significant differences in the catching technique of the TT group throughout the tests (p's > 0.54), however the QET group significantly improved their technique from BL to R1 (mean difference = 1.25, $p < 0.01$) and from BL to R2 (mean difference = 1.81, $p < 0.01$).
7.

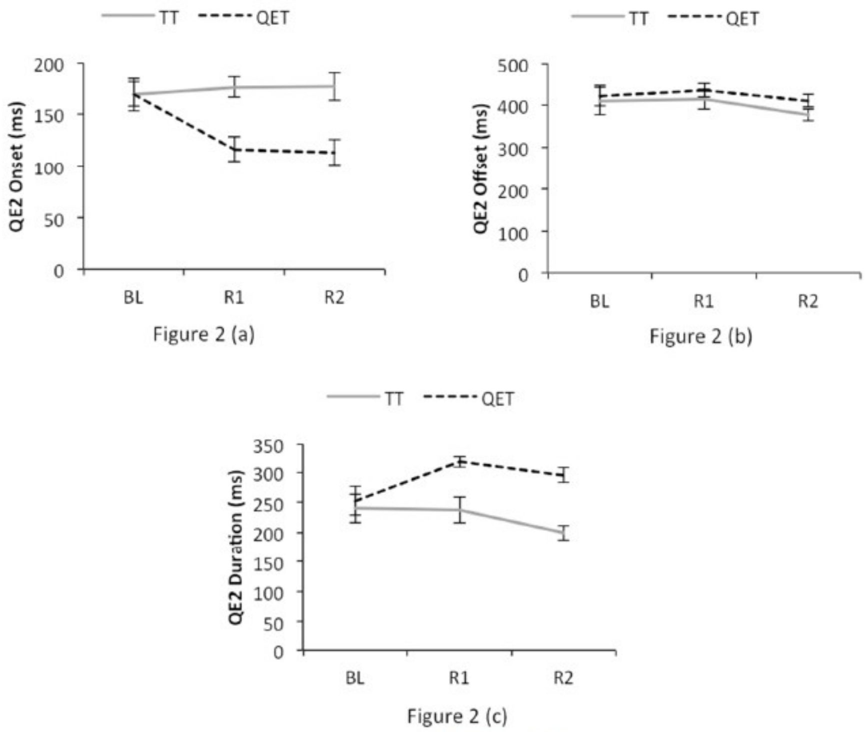
Figure captions

Figure 1: Mean (± s.e.m.) targeting fixation (QE1) onset (a), offset (b) and duration (c) for the QET and TT groups across Baseline, Immediate Retention (R1) and Delayed Retention (R2) tests.

Figure 2: Mean (± s.e.m.) tracking gaze (QE2) onset (a), offset (b) and duration (c) for the QET and TT groups across Baseline, Immediate Retention (R1) and Delayed Retention (R2) tests.

Figure 3: Mean (± s.e.m.) flight time 1 (FT1: ball release to wall contact) (a), flight time 2 (FT2: wall contact to trial end) (b), and percentage catch success (c) for the QET and TT groups across Baseline, Immediate Retention (R1) and Delayed Retention (R2) tests.


TT
QET
QE1 Onset (ms)
2000
1500
1000
500
0
BL
R1
R2
Figure 1 (a)
TT
QET
QE1 Offset (ms)
2500
2000
1500
1000
500
0
BL
R1
R2
Figure 1 (b)
TT
QET
QE1 Duration (ms)
1200
1000
800
600
400
200
0
BL
R1
R2
Figure 1 (c)


TT
QET
QE2 Onset (ms)
BL
R1
R2
Figure 2 (a)
TT
QET
QE2 Offset (ms)
BL
R1
R2
Figure 2 (b)
TT
QET
QE2 Duration (ms)
BL
R1
R2
Figure 2 (c)

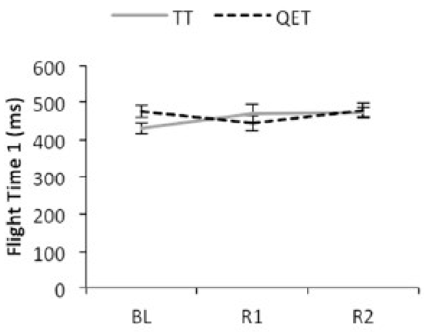


Figure 3 (a)

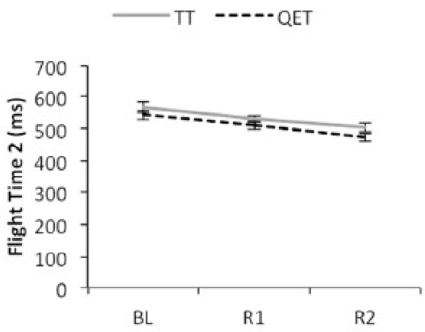


Figure 3 (b)

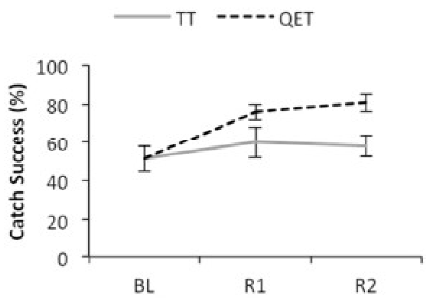


Figure 3 (c)