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Quiet eye training in children

1 **ORIGINAL ARTICLE**

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

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14 RUNNING HEAD: Quiet eye training in children

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25 acquisition

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Abstract

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

18

1 **Introduction**

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

14 Until recently QE studies have solely used adult populations, however recent
15 research has extended these findings in order to attempt to understand the
16 development of motor skill proficiency in children. In the first study that examined
17 the QE in children, Wilson, Miles, Vine, and Vickers (2013) found differences in QE
18 duration explained differences in throwing and catching ability; more highly
19 coordinated children maintained earlier and longer QE durations and caught more
20 balls than their less coordinated counterparts. Moreover, this study found that the
21 tracking gaze duration on the ball (QE2) predicted the relationship between catching
22 ability and performance. A follow-up study utilised these findings in order to test the
23 effectiveness of a quiet-eye training (QET) intervention (Miles, Vine, Wood, Vickers,
24 & Wilson, 2014). Lower coordinated children (catching ~ 50% of balls at pre-test)
25 were taught how to adopt the longer QE durations of skilled performers while

1 learning the same throwing and catching task. Results revealed that children who
2 received QET significantly increased their QE duration in both the throw (QE1;
3 aiming) and catch (QE2; tracking) phase of the task. QET participants also improved
4 their catching performance (from 48% to 70% success), whereas the scores of the
5 control group, who received standard technical training, did not significantly improve
6 (from 51% to 55% success). Importantly, and contrary to Wilson et al. 2013, Miles et
7 al. (2014) found that only QE1 duration predicted catching success.

8 MILES et al. (2014) suggested that the extended pre-throw QE fixation (QE1)
9 on the wall provided a “virtual target” that resulted in throws directed more centrally
10 toward this fixated location. With gaze resting near the bounce point, QET
11 participants were able to more quickly locate and track the ball (QE2) after it
12 bounced, thus providing earlier information to prepare the interception attempt
13 (Hayhoe, Mennie, Sullivan, & Gorgos, 2005; Wilson et al., 2013). The longer
14 durations of QE1 and QE2 were postulated to provide evidence of an extended period
15 for the cognitive pre-programming and parameterisation of the movement
16 (Klostermann, Koedijker, & Hossner, 2013a; Klostermann, Kredel, & Hossner,
17 2013b; Vickers, 2007; Williams, Singer, & Frehlich, 2002).

18 According to this predictive control strategy explanation (Panchuk & Vickers,
19 2009), earlier and longer QE periods provide sufficient processing time to determine
20 the optimal target (pre-throw), and predict the timing and location of interception
21 (catch), and to plan the movements required for the successful execution of these
22 actions. The benefit of this strategy for children may be that generating an internal
23 forward model through pre-programming provides stability to a child’s motor system
24 by determining the outcome of the movement before the slower sensorimotor

1 feedback becomes available (Williams J. et al., 2011; Williams J., Omizzolo, Galea, &
2 Vance, 2013).

3 The main aim of the present study was to extend the work of Miles et al.
4 (2014) in order to test the efficacy of QET for facilitating the long-term learning of
5 throwing and catching skill in children using a six week delayed retention test. We
6 hypothesised that the QET advantage found by Miles et al. (2014) would be
7 maintained at a delayed retention test. Specifically, we predicted that there would be a
8 significant interaction effect for QE variables and performance, with QET children
9 having earlier and longer QE1 and QE2, and superior performance following training
10 (at R1) and after a de-training period (R2) than their TT counterparts.

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

19 **Methods**

20 **Participants**

21 Thirty-five children aged between 8-10yrs were recruited from primary
22 schools in the South West of England¹. The children were screened using the
23 Movement Assessment Battery for Children-2 (MABC-2; Henderson, Sugden, &
24 Barnett, 2007) to ensure they were not likely to have developmental coordination
25 disorder (DCD) and to eliminate possible ceiling effects in catching ability. No

1 children were classified as being at risk of DCD (mean percentile rank = 42.10, $SD =$
2 20.78) and all had normal vision. Five children scored above 80% in the catching task
3 and were consequently excluded from the study. The remaining 30 children were
4 randomly divided into two training groups: a QET group (6 males, 9 females) and a
5 TT group (8 males, 7 females). Ethical approval was obtained from a local ethics
6 committee and full participant and parental consent was obtained prior to
7 commencing the study.

8 **Task**

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

15 **Apparatus**

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

21 **Procedure**

22 Each participant individually attended three separate testing sessions. During
23 the initial assessment session (Baseline) each participant completed the MABC-2, was
24 fitted with the eye-tracker, and completed the baseline measurement of the throwing
25 and catching task. The second session was carried out one week later and comprised

1 of the training intervention followed by ten immediate retention (R1) trials of the
2 throwing and catching task without any instructions. The final testing session took
3 place 6 weeks after the training phase and participants were again calibrated to the eye
4 tracker and completed ten delayed retention (R2) trials of the throwing and catching
5 task without any instruction. At the end of the testing period each child and their
6 parents were debriefed as to the purpose of the study and were awarded a £10
7 shopping voucher for their participation.

8 **Training Interventions**

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

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

25 **Measures**

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

3 **Targeting fixation (QE1).** QE1 was a visual fixation located on a virtual
4 target on the wall (that remained within 1° of visual angle for more than 100ms) prior
5 to and during the throw phase of the task. QE1 onset was defined as the final fixation
6 duration prior to the initiation of foreswing of the throwing arm³. The offset of QE1
7 occurred when gaze deviated from the virtual target location by more than 1° of visual
8 angle for longer than 100ms.

9 **Tracking gaze (QE2).** QE2 was the final tracking gaze on the tennis ball after
10 it rebounded from the wall during the catch phase of the task. The QE2 onset was
11 defined as the start of the final tracking gaze on the ball (for more than 100ms) before
12 the grasping action was attempted, or the trial ended⁴. The QE2 offset occurred when
13 the tracking gaze deviated off the ball for more than 100ms (Wilson et al., 2013;
14 Miles et al., 2014).

15 **Flight time.** Ball flight times were calculated using frame-by-frame analysis
16 (30 Hz) of the external video camera footage, in order to provide a measure of how
17 the task was performed (Wilson et al., 2013). Flight time 1 (FT1: hand to wall) was
18 the time from the ball release to the wall contact point and reflects the speed and
19 trajectory of the throw. Flight time 2 (FT2: wall to hand) was the time from the wall
20 contact point to the trial end and is dependent on both the initial throw parameters and
21 the catch technique adopted (Miles et al., 2014; Wilson et al., 2013).

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

25 **Data Analysis**

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

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

15 Results

16 Quiet Eye (QE)

17 Due to technical problems with the eye tracker, a number of trials could not be
18 analysed. Out of 900 trials conducted, a total of 160 trials were excluded for QE1 (TT
19 = 60; QET = 100) and a total of 204 trials were excluded for QE2 (TT = 97; QET =
20 107).

21 **QE1 (ms).** ANOVA revealed a significant group x test interaction for QE1
22 onset, $F_{1,56} = 9.43, p < 0.01, \eta_p^2 = 0.25$ (Figure 1a). Post hoc analyses of the between
23 group effects revealed there were no significant differences in QE1 onset at BL (mean
24 difference 76ms, $p = 0.20$) or at R2 (mean difference 198ms, $p = 0.12$) however the
25 QET group had significantly earlier QE1 onsets at R1 (mean difference 503ms, $p <$
26 0.01). Within group post hoc analyses revealed no significant differences between the

1 QE1 onset times of the TT group (p 's > 0.45). The QET group had a significantly
2 earlier QE1 onset at R1 (mean difference 632ms, $p < 0.01$) and R2 (mean difference
3 337ms, $p = 0.01$) compared to baseline. Their QE1 onset was significantly later at R2
4 in comparison to R1 (mean difference -296ms, $p = 0.03$).

5 There was no significant group x test interaction for QE1 offset, $F_{2,56} = 0.06$, p
6 $= 0.94$, $\eta_p^2 < 0.01$. There were also no significant main effects for test, $F_{2,56} = 0.17$, p
7 $= 0.85$, or for group, $F_{1,28} = 0.45$, $p = 0.51$ (Figure 1b). There was a significant group
8 x test interaction for QE1 duration, $F_{2,56} = 8.73$, $p < 0.01$, $\varepsilon = 0.77$, $\eta_p^2 = 0.24$ (Figure
9 1c). Post hoc analyses of the between group effects revealed there was no significant
10 difference in QE1 duration at BL (mean difference 42ms, $p = 0.55$), however the QET
11 group had a significantly longer QE1 duration at R1 (mean difference 550ms, $p <$
12 0.01), and at R2 (mean difference 234ms, $p < 0.01$) in comparison to the TT group.
13 Within group post hoc analyses revealed no significant improvements in QE1 duration
14 for the TT group throughout the tests (p 's > 0.23). The QET group significantly
15 increased their QE1 duration from BL to R1 (mean difference 604ms, $p < 0.01$) and
16 BL to R2 (mean difference 241ms, $p < 0.01$). However, there was a significant
17 decrease in QE1 duration between R1 and R2 (mean difference -363ms, $p < 0.01$).

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

19 **QE2 (ms)**. ANOVA revealed a significant group x test interaction for QE2
20 onset, $F_{2,56} = 4.73$, $p = 0.01$, $\eta_p^2 = 0.14$ (Figure 2a). Post hoc analyses revealed no
21 significant differences between the intervention groups at BL (mean difference 1ms, p
22 $= 0.98$) however, at R1 the QET group had a significantly earlier QE2 onset than the
23 TT group (mean difference 59ms, $p < 0.01$) and they were able to maintain this earlier
24 QE2 onset at R2 (mean difference 63ms, $p < 0.01$). The within group analyses
25 revealed that the QE2 onset of the TT group did not significantly change throughout

1 the tests (p 's > .63). The QET group however significantly reduced the time to QE2
 2 onset from BL to R1 (mean difference -53ms, $p < 0.01$) and they maintained this
 3 earlier QE2 onset from BL to R2 (mean difference -56ms, $p < 0.01$). There was no
 4 significant difference in QE2 onset between R1 and R2 (mean difference -3ms, $p =$
 5 0.86).

6 ANOVA revealed no significant group x test interaction for QE2 offset, $F_{2,56} =$
 7 0.12, $p = 0.89$, $\eta_p^2 < .01$. There were also no significant main effects for test, $F_{2,56} =$
 8 1.22, $p = 0.30$, or for group, $F_{1,28} = 1.40$, $p = 0.25$ (Figure 2b). There was however a
 9 significant group x test interaction for QE2 duration, $F_{2,56} = 3.76$, $p = 0.03$, $\eta_p^2 = 0.12$
 10 (Figure 2c). Post hoc analyses revealed no significant difference between the groups'
 11 QE2 duration at BL (mean difference 12ms, $p = 0.72$) but the QET had significantly
 12 longer QE2 durations at R1 (mean difference 81ms, $p < 0.01$) and at R2 (mean
 13 difference 96ms, $p < 0.01$). The within group analysis found no significant
 14 differences for the TT group over the tests (p 's > 0.06). The QET group extended their
 15 QE2 duration between BL and R1 (mean difference 66ms, $p = 0.01$) however, their
 16 QE2 duration at R2 was not significantly longer than at BL (mean difference -43ms, p
 17 = 0.16). There was also no significant difference in QE2 duration between R1 and R2
 18 (mean difference 22ms, $p = 0.12$).

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

20 **Flight Time**

21 **Flight time 1.** ANOVA revealed no significant group x test interaction, $F_{2,56} =$
 22 0.62, $p = 0.54$, and no main effects for test, $F_{1,28} = 0.44$, $p = 0.51$, or group, $F_{2,56} =$
 23 0.96, $p = 0.39$, for FT1 (Figure 3a).

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

3 **Discussion**

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

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

23 The pre-throw instructions to the QET group focused on maintaining a long
24 fixation prior to the throw, so the lack of group differences in QE1 offset may not be
25 too surprising. QE1 offset occurs almost concurrently with ball release in both groups

1 and this timing may simply reflect the task demands. The lack of difference in QE2
2 offset time would appear to be due to ceiling effects in available tracking time, rather
3 than a failure of the QET group to follow their instructions ('...to track the ball into
4 their hands'; Table 1). Indeed, when the QE2 offset data (Figure 2b) are considered
5 with respect to the flight time 2 data (Figure 3b), it would appear that there is a natural
6 departure point when gaze will come off the ball before the completion of the catch
7 attempt. The QET group's QE2 offset after training was only ~65ms before trial end,
8 whereas the TT group's offset was a little earlier (~120ms). Despite not being taught
9 to do so, it would appear that following training, even the TT children tracked the ball
10 right up until the last available moments.

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

22 Interestingly, the regression analyses did not support a functional role for
23 longer QE2 durations (cf. Wilson et al., 2013), with QE1 duration alone predicting
24 variance in catching performance. In effect, QE1 appears to assist in the pre-
25 programming of not only the initial throw parameters, but also the subsequent catch

1 parameters. Less variable and more accurate throws enable a catch attempt to be
2 planned using predictive information based on stored internal models of movement
3 control (Hayhoe McKinney, Chajka, & Pelz, 2012; Wolpert, Miall, & Kawato, 1998)
4 and ball/object properties (Hayhoe et al 2005). This explanation would suggest that
5 more accurate throwing reduces the necessity for a longer tracking gaze (QE2) on the
6 ball, as the ball flight is no longer as variable. While our data only tentatively support
7 this interpretation, they provide an interesting departure point for future studies
8 examining the role of gaze in sequential, inter-related tasks. For example, it would be
9 interesting to examine manipulations to the standard ball trajectory off a wall that
10 would reduce the quality of the predictive information from a longer QE1 and an
11 accurate throw.

12 The results of the current study do contradict findings from some previous
13 studies using the same MABC-2 throw and catch task (i.e., Wilson et al 2013; Miles et
14 al. 2015), which found that QE2 duration was the best predictor of performance.
15 However, these contradictions may be explained by differences in the degree to which
16 participants' motor coordination is impaired. Miles et al. (2015) and Wilson et al.
17 (2013) sampled from children with developmental coordination disorder and children
18 with very low catching ability respectively (baseline catching success ~ 35%),
19 whereas this study used typically developing children of relatively 'normal' ability
20 (baseline catching success ~ 50%; see also Miles et al., 2014). Less coordinated
21 individuals appear to rely more on an online control strategy in this task whereas more
22 coordinated individuals utilise a strategy based on earlier, predictive information,
23 perhaps due to their greater accuracy in the throwing component of the task. It is
24 known that the predictive control of action is a fundamental impairment in children
25 with DCD (Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013), which

1 coupled with reduced throwing accuracy would lead to a reliance on later, online
2 information. These differences in the mechanisms by which children of varying
3 abilities appear to perform this task warrants further exploration in subsequent studies.

4 There are several limitations to this study that need to be considered when
5 interpreting these findings. First, we had no control over the children's activities over
6 the 6-week de-training period, so we cannot be sure if all refrained from practicing.
7 Second, we propose that QE1 induces more accurate throwing yet we never measured
8 this due to the MABC-2 task requiring a throw to a blank wall. Future research may
9 wish to explore the accuracy of the throw phase more explicitly by having children
10 throw to a target. Finally, the QET group received explicit instructions to pause for 2
11 seconds before throwing, whereas the TT group only had generic instructions to "...
12 take your time" (Table 1). As QE1 duration explains the most variance in
13 performance, this variation in instructions may be a critical determinant of between
14 group differences. In effect, the performance advantage of QET may be more related
15 to improved pre-task self-regulation, rather than visuomotor mechanisms (Vine,
16 Moore & Wilson, 2014). Future research should test this postulation using objective
17 psychophysiological indices (e.g., cardiac deceleration; Moore, Vine, Cooke, Ring, &
18 Wilson, 2012) and by exploring participants' perceptions of control (Wood & Wilson,
19 2012).

20 In summary, this study provides more evidence for the effectiveness of QET to
21 assist with the acquisition and retention of motor skills, over an extended period of
22 time. Children who received instructions that helped them adopt the QE of an expert
23 child performing the throw and catch task were able to improve their catching
24 performance and increase their QE durations, and critically these changes largely
25 remained after a 6 week period of de-training. The findings of this study also support

- 1 an important role for pre-planning a movement during an early stable QE fixation,
- 2 which leads to an earlier and longer tracking gaze on the ball. However, future
- 3 experimental research should test this relationship by manipulating or removing the
- 4 ability to predict bounce location and direction, and by examining more process-
- 5 orientated kinetic and kinematic measures in order to explore *if* and *how* QET
- 6 produces more coordinated movement patterns in children.

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

	QET Video 1	TT Video 1
Phase 1: The Throw	<p>[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?</p> <p>Now look at the side on view [highlighted]. Notice how the girl throws the ball with a smooth arm action.</p> <p>[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</p> <p>Remember, aim at your target, count to two, and then a smooth throw</p>	<p>[General Introduction] Look at the scene view [highlighted]. See how the girl takes her time before she throws?</p> <p>Now look at the side on view [highlighted]. Notice how the girl throws the ball with a smooth arm action.</p> <p>[Side-on view highlighted] To make a good throw, take your time, then throw at a target using a smooth throwing action.</p> <p>Remember, take your time, and concentrate on a smooth swing of your throwing arm.</p>

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Phase 2: The Catch	<p>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?</p> <p>Now look at the side on view [highlighted]. Can you see how the girl cups her hands together to catch the ball?</p> <p>[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.</p> <p>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.</p>	<p>Look at the scene view [highlighted]. Can you see how the girl concentrates on the ball as it flies back to her outstretched hands?</p> <p>Now look at the side on view [highlighted]. Can you see how the girl cups her hands together to catch the ball?</p> <p>[Side on view highlighted] To make a good catch, it's really important that you concentrate on the ball and cup your hands together.</p> <p>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</p>
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Phase 3: The Review	<p>OK, so far you have learned two training points.</p> <p>[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.</p>	<p>OK, so far you have learned two training points.</p> <p>[Side on view highlighted] To throw, you need to take your time before you smoothly throw the ball at the target.</p>
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[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.

Remember the two training points:
Firstly focus on the target for two seconds and throw smoothly

And secondly keep your eye on the ball and cup your hands ready for the catch.

[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, take you time to throw with a smooth arm action.

And secondly concentrate on the ball and cup your hands ready for the catch.

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Footnotes

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- 3 1. Note that this is a totally different sample to that used in Miles et al. (2014).
- 4 2. Participants in Miles et al.'s (2014) QET group did not receive any technical
5 instructions, leading to suggestions from a reviewer that the training advantage
6 for the QET group may have simply been due to the advantages of an external
7 focus of attention, compared to an internal focus of attention (see Wulf, 2013).
8 In the current study the QET group received the same technical (internally
9 focused) instructions as the TT group in addition to their gaze instructions.
- 10 3. In Miles et al (2014) ball release was suggested as the final movement;
11 however, other research in throwing (Klostermann et al., 2013a; Klostermann et
12 al., 2013b) has adopted the foreswing of the arm as being more reflective of pre-
13 planning the throw.
- 14 4. On trials when no catch was made, trial end was determined when the ball
15 contacted the participant's hands or any part of their body, when the ball
16 contacted another surface (e.g. bounced), or when it crossed the throw line.
- 17 5. Note that all these analyses were performed on the collapsed sample to provide
18 a wider range of results for comparison, and more power.
- 19 6. Note that a more sensitive measure of catching technique based on an 11 point
20 rating scale (see Miles et al. 2014, Miles et al. 2015) revealed a similar
21 interaction effect; $F_{2,56} = 4.66$, $p = 0.01$, $\eta_p^2 = 0.14$. Again, there were no
22 significant differences in the catching technique of the TT group throughout the
23 tests (p 's > 0.54), however the QET group significantly improved their
24 technique from BL to R1 (mean difference = 1.25, $p < 0.01$) and from BL to R2
25 (mean difference = 1.81, $p < 0.01$).
- 26 7.

1 Figure captions

2

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

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

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

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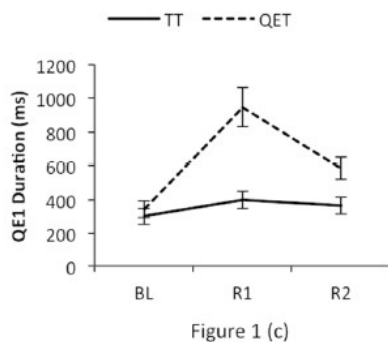
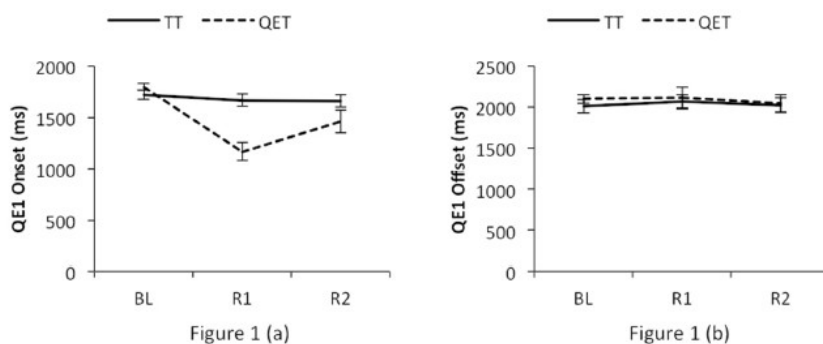
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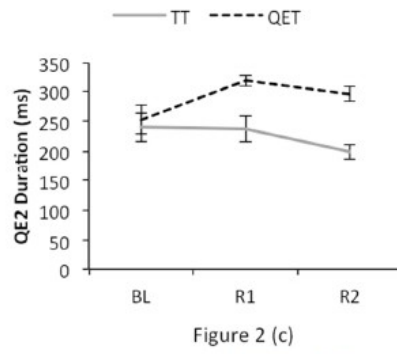
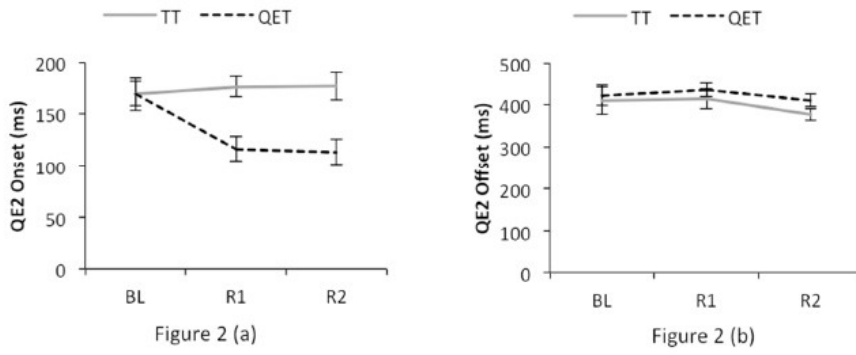
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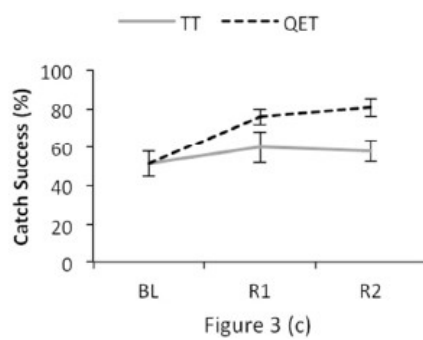
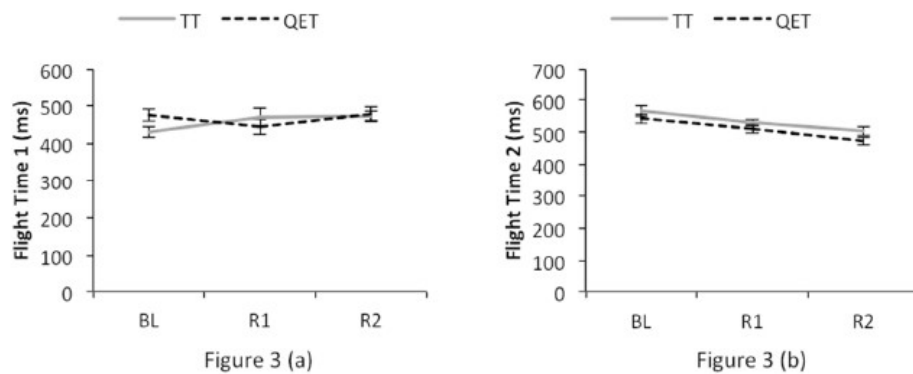


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Quiet eye training in children



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