Quiet Eye and Performance in Sport: A Meta-Analysis

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Abstract

Research linking the "quiet eye" (QE) period to subsequent performance has not been systematically synthesized. In this paper we review the literature on the link between the two through non-intervention (Synthesis 1) and intervention (Synthesis 2) studies. In the first synthesis, 27 studies with 38 effect sizes resulted in a large mean effect ($\bar{d}$ = 1.04) reflecting differences between experts' and novices' QE periods, and a moderate effect size ($\bar{d}$ = .58) comparing QE periods for successful and unsuccessful performances within individuals. Studies reporting QE duration as a percentage of the total time revealed a larger mean effect size than studies reporting an absolute duration (in ms). The second synthesis of 9 articles revealed very large effect sizes for both the quiet-eye period ($\bar{d}$ = 1.53) and performance ($\bar{d}$ = .84). QE also showed some ability to predict performance effects across studies.

Keywords: vision, perceptual-cognitive skill, sport expertise, attention

Quiet Eye and Performance in Sport: A Meta-Analysis

For nearly four decades, researchers have sought to better understand the psychological factors underlying expert performance (Starkes & Ericsson, 2003). Deliberate practice, motivation, and mental skills are recognized as crucial factors for attaining expert performance (Ericsson, Krampe, & Tesch-Romer, 1993; Hardy, Jones, & Gould, 1996; Mallett & Hanrahan, 2004). Along with these factors, perceptual-cognitive skills have emerged to be critical for skillful performance. Perceptual-cognitive skills include pattern recognition, the use and extraction of anticipatory cues, visual search strategies, and signal detection (Janelle & Hillman, 2003). Initial scientific effort on gaze behavior revealed that experts use fewer eye fixations, for longer durations, than non-experts across a wide range of sports (Mann, Williams, Ward, & Janelle, 2007; Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008; Williams, Davids, Burwitz, & Williams, 1993). Gaze behavior has been studied predominantly in terms of location, duration, and frequency of fixations *during* the movement. However, Vickers (1992) claimed that the gaze behavior prior to movement initiation, termed the "*quiet eye*," is a crucial factor differentiating successful from less successful performances.

The quiet-eye (QE) is defined as "the final fixation or tracking gaze that is located on a specific location or object in the visuo-motor workspace within 3° of visual angle for a minimum of 100ms. The onset of the QE occurs prior to the final movement in the task and the offset occurs when the gaze deviates off the object or location by more than 3° of visual angle for a minimum of 100ms, therefore the QE can carry through and beyond the final movement of the task" (Vickers, 2007, p. 280). It has been suggested that during the QE period task-relevant environmental cues are processed, and motor programs are retrieved and coordinated for the successful completion of the task (Vickers, 1996a, 1996b). Some studies have lent support to the motor-programming/preparation function of the QE period (Janelle et al., 2000; Mann, Coombes, Mousseau, & Janelle, 2011). Janelle et al. (2000) studied rifle shooting and found that experts displayed a longer QE period along with a more pronounced hemispheric asymmetry than non-experts. In another study with low- and high-handicap golfers, Mann et al. (2011) revealed that the low-handicap athletes exhibited longer QE periods and greater “bereitschafts” potential amplitude (i.e., characteristic of greater movement preparation) than the high-handicap group. Other studies that have manipulated task demands and QE duration (by manipulating the onset of the last fixation before movement unfolding) found that more complex tasks required longer QE durations, and only under a high information-processing load was a longer QE duration beneficial (Klostermann, Kredel, & Hossner, 2013; Williams, Singer, & Frehlich, 2002).

Several attempts have been made to explain the effect of the QE period on performance. The first studies on QE examined free throws in basketball and revealed that expert players fixate longer on the target, combined with an early fixation offset as the shooting unfolds (Vickers, 1996a, 1996b). The importance of this sequence of gaze control was conjectured in the location-suppression hypothesis (Vickers, 1996b). Specifically, before shooting, the expert player locates a particular target early and maintains quiet-eye fixation for a full second before initiating the shot. As the hands initiate the shot and the ball enters the visual field, fixation offset occurs and vision is suppressed. Vickers (1996a) explains these results in light of Posner and Raichle’s work (1997) that identified three neural networks for optimal vision control. These networks include (a) the orienting attentional network, (b) the executive attentional network, and (c) the vigilance network, which coordinates both systems. The orienting network is responsible for guiding attentional resources to relevant environmental cues. The executive network is implicated in recognizing that a specific cue fulfills a specific goal. After the relevant cue has been identified, the vigilance network maintains attention on this critical cue. Hence, longer QE duration is a reflection of better coordination of attentional resources by the vigilance network. By maintaining attention on the target, an extended QE period prevents performance from being disrupted by irrelevant environmental cues. In addition, studies have shown that under certain conditions, a shift in gaze cannot occur without a preceding shifting of attention (Corbetta et al., 1998). In this manner, the quiet-eye duration is a reflection of the organization of critical neural networks necessary for the optimal control of visual attention.

A more recent account of the visual-attention motor networks involved in the QE effect has been provided by Vickers (2012). This explanation takes into account the dorsal attentional network (DAN) and the ventral attentional network (VAN). Both the DAN and VAN send information to the frontal lobes via two different routes (Corbetta, Patel, & Shulman, 2008; Corbetta, & Shulman, 2002; Milner & Goodale, 1995). The DAN projects from the occipital lobe to the frontal lobe via the parietal lobe, while the VAN projects to the frontal areas via the temporal lobes. These two distinct neural circuits explain the different but complementary roles of both attentional networks (Vossel, Geng, & Fink, 2014). The main function of the DAN is to maintain focus of attention by blocking any stimuli that may intrude from the VAN system. The VAN includes the hippocampus and amygdala, which are responsible for recording memories and emotional control, respectively. The role of the VAN is to direct attention to unexpected stimuli, similar to a bottom-up control. It has been suggested that a longer QE acts as a mental buffer that prevents intruding thoughts or emotions arising in the hippocampus and amygdala from distracting attention (Vickers, 2012). By activating the DAN at the expense of the VAN, the QE increases the focus of attention and protects against irrelevant thoughts and emotions.

Maintaining attention on critical external cues under stressful situations is another possible mechanism through which the QE can support performance. An extended QE period may indirectly affect motor performance by helping performers focus attention externally towards a single crucial cue (Vine, Moore, & Wilson, 2011; Wulf, 2007). Vickers and Williams (2007) suggested that the act of directing attention externally to critical task information (via the QE) insulates athletes from the normally debilitating effects of anxiety. A theoretical account of this effect is given by *Attentional Control Theory* (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007). ACT identifies two attentional systems: the *goal directed system* and the s*timulus driven system*. The goal directed system is a top-down system that is influenced by current goals and expectations. Conversely, the stimulus driven attentional system responds to prominent or noticeable stimuli and is described as a bottom-up system. Under normal (i.e., non-stressful) conditions a balance exists between these two attentional systems. Under stressful situations, human processing resources are diverted toward task irrelevant and threatening stimuli, and thus anxiety disrupts attention by increasing the influence of the stimulus driven attentional system at the expense of the more efficient goal directed system (Eysenck et al., 2007; Wilson, 2008). By directing attention on a task relevant goal (i.e., the target), the QE period stimulates the use of the goal directed system and allows for a better balance between the two attentional systems. Directing attention to specific external relevant cues under stressful conditions is thus another plausible mechanism through which QE can help performance.

An alternative theoretical explanation has also been provided from the ecological-psychology and dynamic-system perspectives. Researchers adopting this framework claim that the function of the QE is to facilitate the orientation of the body in space and allow the skilled execution of movements that are adjusted for the temporal and spatial constraints of the task (Oudejans, Koedijker, Bleijendaal, & Bakker, 2005; Oudejans, van de Langenberg, & Hutter, 2002). The QE optimizes optic flow and allows a better orientation of the performer in relation to critical environmental demands. A prolonged fixation helps performance by continuously updating the relation between the athlete and the object, in order to best determine force, direction, or velocity. This updating is performed at a subconscious level and does not require cognitive processing (Oudejans et al., 2005).

There is currently no consensus in explaining the role of the quiet eye in enhanced visuomotor skills. Vickers (2009) suggested that a successful theoretical model explaining the role of the quiet-eye in performance must take into account both rapid dynamic tasks (i.e., less than 200ms) and 'slower' tasks (i.e., more than 200 ms). Cognitive theories have been relevant to explain movements over 200ms because there is adequate time for cognitive processing to occur. In contrast, the ecological models better explain movements under 200ms in which the time constraints do not allow a major role for cognition (Vickers, 2007). All things considered, Vickers claims that "regardless of the theoretical perspective taken, there is considerable research evidence showing that the quiet-eye period is a perception-action variable that defines higher levels of skill and performance" (2007, p. 287).

The Current Synthesis

To our knowledge, only one meta-analysis has partially examined the importance of the QE period (Mann et al., 2007). Mann and colleagues quantified expertise differences on various perceptual-cognitive skills (e.g., response time and accuracy, number and duration of visual fixations, and length of quiet-eye period). Six effect sizes (ESs) for the QE period had a moderate-to-large mean effect ($\bar{r}_{pb}$= .62). No moderators were studied due to the small number of studies. After more than 20 years of research on the QE, and with the recent publication of QE intervention studies (e.g., Moore, Vine, Cooke, Ring, & Wilson, 2012; Wood & Wilson, 2012), a meta-analytic review of the QE literature is warranted. We synthesize the findings reporting on the relationship between the QE and performance, and explore factors moderating this relationship.

Hypotheses

The literature on the QE is divided into two types of research: (1) non-intervention studies, and (2) intervention studies. In an effort to be comprehensive, we consider both types of research, but treat them separately. Following roughly the order in which studies arose, non-intervention studies are reviewed first, followed by intervention studies. For the non-intervention studies, we hypothesize that more skillful performers possess a longer QE period than less skillful ones, and that within individuals successful performance is associated with a longer QE period than is unsuccessful performance. For the intervention studies, we hypothesize that QE training will result in longer QE durations and enhanced performance compared to the control condition. We also predict a positive correlation between degree of QE-period improvement and performance outcome.

Moderating Variables

Several moderators were identified from the literature. These are source of data, setting, design, manipulation of anxiety/pressure, type of motor task, and QE measurement.

Source of data. Publication bias is a primary source of unreliable results in meta-analysis and a threat to its validity (APA, 2008; Rothstein, 2008; Shadish, Cook, & Campbell, 2002). We examined whether the study's status (i.e., published or unpublished) leads to a statistically different QE and/or performance effect size (ES).

Setting. Studies on the QE took place both in the laboratory and on the field. Because laboratory studies control for external variables potentially affecting performance, we tested if different effects emerged in studies taking place either in a controlled environment versus on the field.

Design. In studies without an intervention (i.e., in which participants were not trained to improve their QE period), two types of contrast were identified: within-individual and between-individuals. The within-individual contrast compares the lengths of QE periods for successful and unsuccessful performance outcomes of each participant. In contrast, the between-individuals ES compares QE periods between two separate groups, experts and non-experts. We tested whether these two designs lead to differences in ESs.

Manipulation of anxiety/pressure. Anxiety and pressure were sometimes manipulated, in studies both with and without interventions. As noted, anxiety has been widely reported to shift gaze behaviors towards threatening stimuli (Eysenck et al., 2007), thus increasing the influence of the stimulus-driven attentional system to the detriment of the goal directed system

(Eysenck et al., 2007; Wilson, 2008). We expected QE duration to be lower while performing under anxiety, leading to smaller ESs under anxiety conditions compared to normal conditions.

Type of motor task. Perceptual strategies of experts and novices are task dependent (Williams & Davids, 1995; Williams, Davids, Burwitz, & Williams, 1993, 1994). A common classification of sports is based on whether the task is self-paced (i.e., the performer controls the rate at which the skill is executed) or externally-paced (i.e., the performer must react to external events in order to control his/her movement). Most research on the QE has focused on self-paced sports (e.g., golf putting, basketball free throws). Only a few studies have examined externally-paced skills such as volleyball-serve reception, and goal keepers' responses to penalty kicks (soccer) or to shots (ice hockey). Athletes typically cannot control the duration of the preparation period in externally-paced sports, leaving them with less opportunity to control their QE period. Thus, we tested whether the type of motor task (i.e., self-paced vs. externally-paced) influenced the QE duration.

QE measurement. The method by which the QE is measured is an important variable to consider. The technology used (i.e., eye-tracker brand) was similar across all studies; thus, we did not expect differences deriving from the measurement tool. However, Vickers (1996a, 1996b) introduced a specific paradigm, *vision-in-action* (VIA) to measure the QE period. This paradigm aims at increasing the reliability of the QE measure by synchronizing recordings from an external camera (capturing physical movement) to those from the eye-tracker camera. We coded this measurement paradigm to test whether it has an impact on the respective QE ESs.

Additionally, the QE period was measured using two different methods: absolute or relative. The absolute measure of the QE period corresponds to the time (ms) between the QE onset and QE offset. Alternatively, the relative measure corresponds to the QE duration divided by the total time of the action (i.e., QE period plus movement time). This represents the percentage of the time that the athlete is engaged in the quiet eye relative to the duration of execution of the entire skill. Since motor skills vary in duration and complexity, it was deemed important to account for this variable.

Finally, because of the evolution of the QE definition, the authors noticed some discrepancies in terms of fixation definition and the operationalization of the QE offset. In particular, fixation duration was set at either 100ms or 120ms and the visual angle from the target was selected at either 1°or 3°. We compared these different values to test whether they impacted the QE ES. The operationalization of the QE offset also differed across studies, with some authors using the beginning of the movement as a criterion, and other authors selected the target-fixation offset that can happen after the final movement started. Both operationalizations of QE-period offset were also tested to see if they account for differences in ESs.

Method

Literature Search and Inclusion Criteria

The literature search was conducted using seven databases: SPORTDiscus, ScienceDirect, EBSCO, PsycNet, Web of Science, Research Gate, and SCOPUS. SPORTDiscus was chosen because it is considered the most comprehensive and relevant database for sport studies providing full text for indexed journals; ScienceDirect, EBSCO, PsycNet and Web of Science are considered high-quality and commonly used databases in this research area. One of the main experts in QE research, Dr. Joan N. Vickers (University of Calgary), suggested the inclusion of Research Gate and SCOPUS. In addition, we searched book chapters, references from key studies and reviews, and gray literature: Dissertations and theses, conference presentations that reported primary research, and other unpublished material obtained from several prominent authors* who study QE. The search strategy combined the following terms: *quiet eye* AND *sport*, *gaze control* AND *sport*, *gaze* AND *sport, and gaze behavior*. These key words were searched in full documents. The criteria for inclusion were that the study (a) was published before July 2014, (b) was written in English, Chinese, French or Spanish, (c) was sport related (e.g., medicine and law-enforcement were excluded; nevertheless, two studies involving throwing and catching a ball were included because the motor elements of these tasks are a part of many sports), (d) provided QE and performance data, (e) used independent samples (i.e., multiple studies were not performed with the same participants), and (f) included sufficient data to calculate ESs. Next, studies were divided into two categories: (a) those that did not include QE training or any intervention, but compared novices'/less successful performance to experts'/successful performance (included in Synthesis 1), and (b) those that presented QE training interventions (included in Synthesis 2).

The search generated 35 studies, of which 26 were finally included in Synthesis 1, yielding 36 ESs. Nine articles were included in Synthesis 2 yielding 15 ESs for QE and 14 ESs for performance. All the articles were written in English, except one included in Synthesis 2 that was written in Chinese. Additionally, three articles were unpublished. Figure 1 describes the different steps of the selection process.

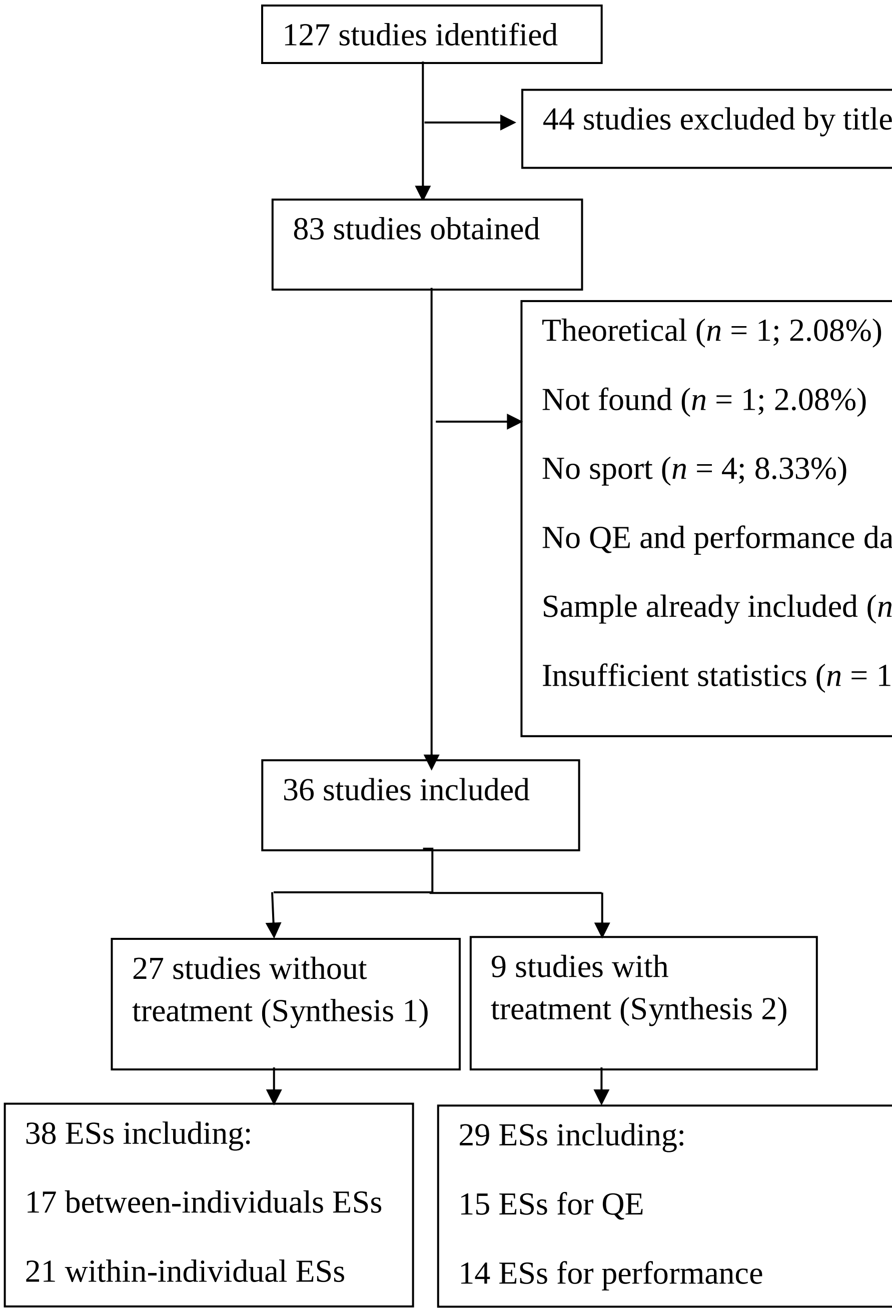


***Figure 1*.** Identification of studies included in the meta-analysis.

Data Extraction

Two raters (C. S.-M. and J.-C. L. for Synthesis 1; S. L. and J.-C. L. for Synthesis 2) independently coded all the studies. The variables in the coding sheet were first elaborated using a focus group involving five raters (C. S.-M., J.-C. L., S. L., S. S.-C., and S. C.-M.). The first draft was then tested on three articles by the first three raters separately and the categories were further adjusted. The final coding sheet included the following dimensions: extrinsic characteristics, setting, participants, methodology, measures and results (coding sheets are available from the authors upon request). The extracted data were entered into an Excel file and checked by two different raters (S. S.-C. and S. C.-M.). Inter-rater reliability was calculated using Cohen's Kappa coefficient for each variable. Values higher than .7 were considered appropriate. Discrepancies were resolved by discussion.

Quality Assessment

The methodological quality of each article included in Synthesis 1 or 2 was evaluated using the 12 items presented in Appendix 1. Studies were evaluated by two coders (J.-C. L and S.L.). Inter-rater reliability for each item was calculated using Cohen's Kappa coefficient. Values higher than .7 were considered appropriate. Discrepancies were resolved by discussion.

ES Calculation

In the present review, values from Cohen's *d* family of ES were calculated due to the comparative nature of our research question. Cohen's (1988) standards were used in interpreting our ESs. Specifically, ES values of .2, .5, and .8 were interpreted as small, medium, and large ES, respectively. In order to calculate ESs and their associated variances, descriptive statistics (i.e., means, SD/SEM values, and *n*) were collected by either searching the article or contacting author(s). In cases where neither method led to data, we used the ruler function of Adobe Acrobat Reader X Pro to obtain values from graphs. Hedges' (1981) correction was employed to eliminate bias from all calculated ES estimates. Three special cases arose in the ES calculation process. First, when growth scores from intervention studies were used, we standardized the difference in the mean gain scores between the treatment and control groups using the average of the pretest and posttest SDs. This produced an effect size that accounted for pretest differences but that also was in the score-scale metric (not the gain score metric). Second, when multiple measures of the same construct were available, we used different strategies for obtaining means and SDs. The mean was always the average of all the means measured. For example, when intervention studies had measures at baseline, retention 1, and retention 2, retention 1 and 2 means were collapsed and compared to the baseline measure. For SDs, the larger SD value was selected when two SD measures were reported, whereas the median SD value was chosen when more than two SD estimates were available. Last, 14 studies generated multiple ESs (including seven papers from Synthesis 1 and seven papers from Synthesis 2).[1] Specifically, seven studies produced ESs in situations with- and without- pressure manipulation; one golf study produced one ES on level green carpet and another ES on sloped green carpet; two studies made available both absolute and relative measures of the QE ES; one study yielded six ESs because it consisted of three different samples and each sample produced both a within-individual ES (successful vs. unsuccessful performance) and a between-individuals ES (expert vs. novice). Finally, three studies produced ESs on both self-paced and externally-paced motor tasks.

Statistical Analysis Strategy

We used the *Metafor* package for R (R Core Team, 2014), and followed Borenstein, Hedges, Higgins, and Rothstein's (2011) recommendations for conducting the analysis. Specifically, we chose the random-effects model *a priori* due to the diversity of study characteristics (e.g., sport studied). We also calculated *Q* statistics to test our model assumptions. Once the model was supported, the between-studies variance parameter τ^2 was estimated using the restricted maximum-likelihood (REML) method. We checked for publication bias using both the *Egger test* (Egger, Smith, Schneider, & Minder, 1997) and *trim and fill* procedure (Duval & Tweedie, 2000a, 2000b). A funnel plot based on trim and fill illustrated the possible missing studies. Last, potential predictors for between-studies variance were examined using a meta-regression model (i.e., mixed-effects model). When the *Q* test failed to support our random-effects model assumptions, we stayed with random-effects models (due to previous conceptual reasons) followed by publication-bias checks and exploration of meaningful moderators.

Among the 38 ESs of Synthesis 1, 17 represented between-individual ESs and 21 were within-individual ESs. Accordingly, ESs were grouped and analyzed separately. For Synthesis 2, 15 ESs for QE and 14 ESs for performance were calculated. QE ESs and performance ESs were also analyzed separately and their relationship was explored.

Results

Inter-Rater Reliability

Appendices 2 and 3 present the reliability coefficients obtained for the different coded variables across non-intervention and intervention studies respectively. All the values obtained were acceptable; concretely, for non-intervention studies, 29 reliability coefficients were considered very good and seven substantial (Landis & Koch, 1977); and for intervention studies, 43 were very good and five substantial.

Appendix 4 presents the reliability coefficients for the variables used to measure the methodological quality of the studies. All variables showed very good reliability coefficients, except for the type of controls used and the use of imputation for intervention studies, which obtained only substantial coefficients. We studied the relationship between the variables representing quality and ESs.

Synthesis 1: Non-Intervention Studies

Study Characteristics and Quality Assessment

The main features of the studies included in Synthesis 1 are listed in Table 1. Studies were published between 1996 and 2014. The topic seems to have received much interest recently, with more than 50% of the included studies published in 2009 or later. One study was a doctoral thesis, while the other 34 were published articles.

Table 1. *Main characteristics of coded studies without interventions*

Study	Sport	N	Loc	Anx	VIA	Mot	Res	QE
Behan & Wilson (2008)	Archery	20	F	Yes	No	S	W	R
Campbell & Moran (2014)	Golf	45	L	No	No	S	B	A
Causer et al. (2010)	Shooting	16	F	No	No	S	BO	R
Causer et al. (2011)	Shooting	16	F	Yes	Yes	I	W	A
Janelle et al. (2000b)	Rifle Shooting	1	L	No	No	S	W	A
Jannelle et al. (2000a)	Shooting	25	L	No	Yes	S	B	A

Mann et al. (2011)	Golf	20	L	No	No	S	B	A
Martell (2010)	Basketball	11	L	No	Yes	S	W	A
McPherson & Vickers (2004)	Volleyball	5	F	No	Yes	I	B	A
Nagano et al. (2006)	Soccer	8	L	No	Yes	S	W	A
Nibbeling et al. (2012)	Dart-Throwing	20	L	Yes	No	S	B	A
Panchuk & Vickers (2006)	Hockey	8	F	No	Yes	I	W	A
Panchuk & Vickers (2009)	Ice Hockey	8	F	No	Yes	I	W	R
Park (2005)	Tennis	8	L	No	Yes	I	W	R
Piras & Vickers (2011)	Soccer	7	F	No	Yes	I	W	A
Rienhoff et al. (2012)	Dart-Throwing	29	L	Yes	No	S	B	A
Rienhoff et al. (2013)	Archery	20	L	Yes	No	S	W	R
Kim et al. (2007)	Badminton	14	F	No	Yes	I	B	R
Lee et al. (2009)	Pistol Shooting	10	F	Yes	Yes	S	B	A
van Lier et al. (2008)	Golf	6	L	No	Yes	S	W	A
Vickers (1996)	Basketball	10	L	Yes	No	S	W	A
Vickers & Adolphe (1997)	Volleyball	12	F	No	Yes	I	B	A
Vickers & Williams (2007)	Biathlon Shooting	10	L	Yes	Yes	S	W	A
Vine et al. (2013)	Golf	50	L	Yes	Yes	S	W	A
Wilson & Pearcy (2009a)	Basketball	26	L	No	No	S	B	A
Wilson & Pearcy (2009b)	Basketball	16	L	No	Yes	S	W	A
Wilson et al. (2013)	Throwing/catching Ball	32	L	No	No	BO	B	A

Note. N = sample size; Loc = study location (F = field where the sport takes place; L = laboratory); Anx = pressure situations are introduced as a mean to manipulate anxiety; VIA = use of Vision-In-Action; Mot = motor task (S = self-paced - motor skills are initiated by the athletes; I = Interceptive - the athletes have to react and intercept an object; Res = type of research (B = differences between experts and novices, or high and low skills athletes are studied; W = Within – only experts or novices participate; their best and worst performance is compared; BO = both); QE = Quiet eye period measure (A = Absolute - quiet eye duration is the time-lapse measure in milliseconds or seconds; R = Relative - absolute quiet eye duration over the total time of the movement, representing the percentage in which an athlete was engaged in the quiet eye over the duration of the whole skill.

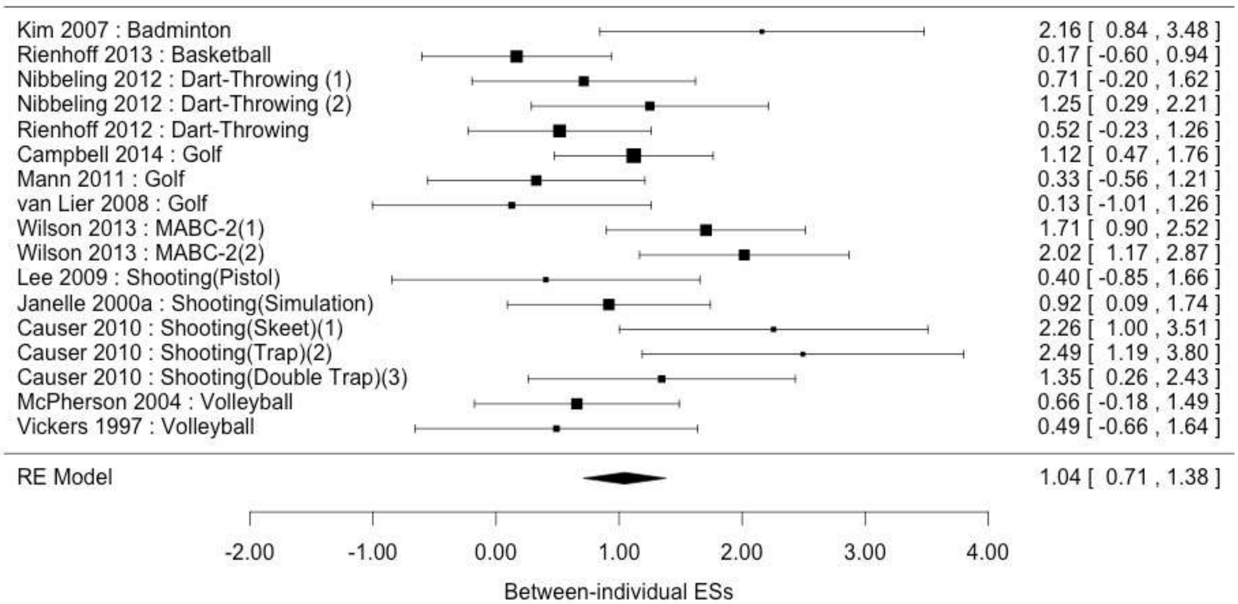
Appendix 5 presents the main methodological characteristics of the studies included in Synthesis 1. In all studies, at least one dependent variable was standardized; all dependent variables were measured at all measurement occasions and there was no follow-up period. Participants were not randomly assigned because groups were formed based on inherent characteristics (e.g., skilled and less-skilled players); nevertheless, some extraneous variables were controlled to enhance the equivalence between groups (e.g., handedness, normal vision). In 70.4% of studies the inclusion and exclusion criteria for selecting participants were provided. Fixation was well defined in 55.6% of studies (i.e., specifying angle and time on target for the QE period) and at least vaguely defined in 18.5% of studies (i.e., specifying only angle or time on target). The most common designs involved one group that provided repeated measures (48. 1%), or more than one group that also provided repeated measures (44.4%). 92.6% of studies had more than one measurement occasion. Measurement occasions ranged from 2 to 10 (M = 3.37; SD = 1.86) and were averaged to get a mean value. In 84.6% of occasions, a control technique was applied; 73.1% of studies used constancy (i.e., maintaining constant the procedure and measurements in both experimental and control groups).

Statistical Analysis

Between-individuals studies. A significant homogeneity test was observed for between-individuals ESs (see Figure 2a), with Q (df = 16) = 34.39, $p < .005$. I^2 showed that 53.55% of the total variability of the between-individuals ESs could be attributed to true between-studies differences. Therefore, choosing the random-effects model was supported and model parameters were estimated. The weighted mean effect was large, at $\overline{d}$ = 1.04 (SE = .17, p < .001), with $\hat{\tau}^2$ = 0.26. The population SD of the true effects, τ = 0.51 suggests that 95% of the true between-individuals ESs will lie within approximately ± 1 around the mean, or between 0.04 and 2.04. This is a wide range of true effects, but all are positive.

Egger's test was non-significant (p > .16) suggesting symmetry in the funnel plot, a graphical display for the detection of publication bias. The trim-and-fill method also suggested no missing studies in the funnel plot, implying little chance of publication bias. Given the consistent results of both the Egger test and the trim-and-fill method, publication bias was not considered to be likely for the between-individuals ESs of Synthesis 1. The analysis of the mixed-effects models for study features revealed *absolute* (i.e., reporting an absolute QE duration in ms vs. as a percentage of the entire movement duration) as a significant predictor of the between-individuals ESs (see Table 2), with studies using absolute measures reporting ESs that were 1.18 standard-deviation units smaller than those in studies using relative measures. No other moderators reached significance. The mixed-effects model for *absolute* accounted for almost half (49.97%) of the between-individuals ES variability.

2a


Kim 2007 : Badminton 2.16 [0.84 , 3.48]
Rienhoff 2013 : Basketball 0.17 [-0.60 , 0.94]
Nibbeling 2012 : Dart-Throwing (1) 0.71 [-0.20 , 1.62]
Nibbeling 2012 : Dart-Throwing (2) 1.25 [0.29 , 2.21]
Rienhoff 2012 : Dart-Throwing 0.52 [-0.23 , 1.26]
Campbell 2014 : Golf 1.12 [0.47 , 1.76]
Mann 2011 : Golf 0.33 [-0.56 , 1.21]
van Lier 2008 : Golf 0.13 [-1.01 , 1.26]
Wilson 2013 : MABC-2(1) 1.71 [0.90 , 2.52]
Wilson 2013 : MABC-2(2) 2.02 [1.17 , 2.87]
Lee 2009 : Shooting(Pistol) 0.40 [-0.85 , 1.66]
Janelle 2000a : Shooting(Simulation) 0.92 [0.09 , 1.74]
Causer 2010 : Shooting(Skeet)(1) 2.26 [1.00 , 3.51]
Causer 2010 : Shooting(Trap)(2) 2.49 [1.19 , 3.80]
Causer 2010 : Shooting(Double Trap)(3) 1.35 [0.26 , 2.43]
McPherson 2004 : Volleyball 0.66 [-0.18 , 1.49]
Vickers 1997 : Volleyball 0.49 [-0.66 , 1.64]
RE Model 1.04 [0.71 , 1.38]
-2.00 -1.00 0.00 1.00 2.00 3.00 4.00
Between-individual ESs

2b

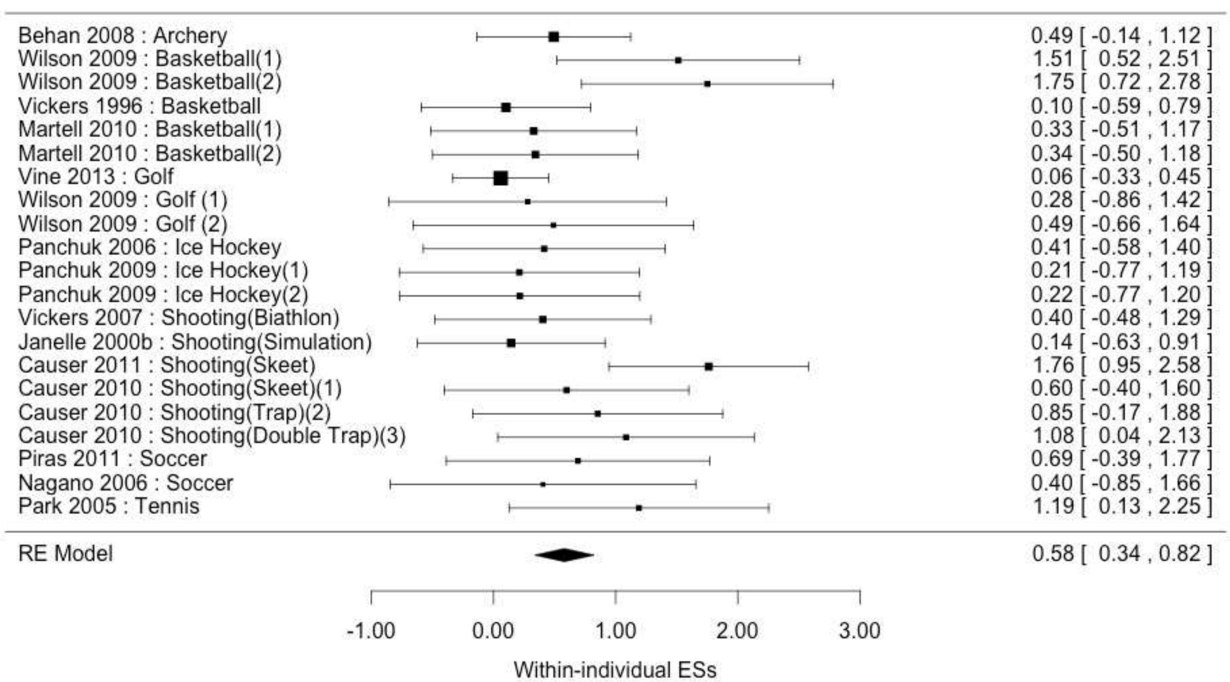

Behan 2008 : Archery 0.49 [-0.14 , 1.12]
Wilson 2009 : Basketball(1) 1.51 [0.52 , 2.51]
Wilson 2009 : Basketball(2) 1.75 [0.72 , 2.78]
Vickers 1996 : Basketball 0.10 [-0.59 , 0.79]
Martell 2010 : Basketball(1) 0.33 [-0.51 , 1.17]
Martell 2010 : Basketball(2) 0.34 [-0.50 , 1.18]
Vine 2013 : Golf 0.06 [-0.33 , 0.45]
Wilson 2009 : Golf (1) 0.28 [-0.86 , 1.42]
Wilson 2009 : Golf (2) 0.49 [-0.66 , 1.64]
Panchuk 2006 : Ice Hockey 0.41 [-0.58 , 1.40]
Panchuk 2009 : Ice Hockey(1) 0.21 [-0.77 , 1.19]
Panchuk 2009 : Ice Hockey(2) 0.22 [-0.77 , 1.20]
Vickers 2007 : Shooting(Biathlon) 0.40 [-0.48 , 1.29]
Janelle 2000b : Shooting(Simulation) 0.14 [-0.63 , 0.91]
Causer 2011 : Shooting(Skeet) 1.76 [0.95 , 2.58]
Causer 2010 : Shooting(Skeet)(1) 0.60 [-0.40 , 1.60]
Causer 2010 : Shooting(Trap)(2) 0.85 [-0.17 , 1.88]
Causer 2010 : Shooting(Double Trap)(3) 1.08 [0.04 , 2.13]
Piras 2011 : Soccer 0.69 [-0.39 , 1.77]
Nagano 2006 : Soccer 0.40 [-0.85 , 1.66]
Park 2005 : Tennis 1.19 [0.13 , 2.25]
RE Model 0.58 [0.34 , 0.82]
-1.00 0.00 1.00 2.00 3.00
Within-individual ESs

Figure 2. Forest plots of random-effects model for between-individual (a) and within-individual (b) ES of Synthesis 1. The ESs are sorted according to sport type. Multiple ESs from individual studies are marked by numbers in parentheses. MABC-2 = Movement Assessment Battery for Children, Second Edition.

Table 2. *Final mixed-effects model for between-individual ESs of Synthesis 1.*

Regression Model			Overall Model Statistics	
Variable	Estimate	SE	Index	Value
Intercept	2.01^{***}	0.36	Q_{residual} (df=13)	22.91
absolute	-1.18^{**}	0.40	Q_{model} (df=1)	8.82^{**}
			R^2 =	49.97%

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. Absolute = absolute measure of QE period.

Within-individual studies. The homogeneity test for the within-individual ESs was not significant (Figure 2b), with Q (df = 20) = 30.40 (p > .06). However, I^2 suggested that 36.21% of the total variability of within-individual ESs came from between-studies differences. We adhered to the random-effects model for parameter estimation. The mean effect was significantly different from zero, with $\overline{d}$ = 0.58 (SE = .12, p < .001), and the between-studies variance of $\hat{\tau}^2$ = 0.11 suggests that 95% of the true effects likely fall between -0.07 and 1.23. This is a narrower range than was found for the between-individuals effects.

The Egger test reached significance (p < .04). The trim-and-fill method suggested adding 2 studies on the right side of the funnel plot of the data. With this addition, the size of the mean effect increased from moderate to moderate-to-large. The adjusted mean was $\overline{d}$ = 0.68 (SE = .12, p < .001), with $\hat{\tau}^2$ = 0.16. Thus, consistent evidence supported that publication bias was likely for the within-individual ESs in Synthesis 1, and the pattern of potential missing values led to stronger effects than the sample data showed. The analysis of mixed-effects models revealed no significant predictors of the within-individual ESs. Appendix 6 shows the intercorrelations among the moderators of Synthesis 1. Because the highest correlation was $r = -.59$, moderators do not appear highly confounded with each other in our analysis.[2]

Synthesis 2: Intervention Studies

Study Characteristics and Quality Assessment

All the studies included in Synthesis 2 were published between 2010 and 2014. The main features of these articles are listed in Table 3. Description of the samples was highly detailed (see Table 3), with mean age and sport specified in all studies, and the age standard deviation reported in 88.9% of studies. Characteristics of the intervention were also made explicit, such as the period (100%), intensity (88.9%), whether the intervention targeted individuals or groups (88.9%), and exclusion criteria (100%).

Table 3. *Main characteristics of coded studies with interventions*

Study	Sport	N	Loc	Anx	VIA	Mot	Res
Causer et al. (2011)	Shotgun shooting	20	L	No	Yes	I	B
Lan & Dai (2010)	Basketball	35	L	No	No	S	W
Miles et al. (2014)	Catching	16	F	No	Yes	S	W
Moore et al. (2012)	Golf	40	F	Yes	No	S	W
Vine et al. (2011)	Golf	22	F/L	Yes	Yes	S	B
Vine & Wilson (2010)	Golf	14	F	Yes	Yes	S	W
Vine & Wilson (2011)	Basketball	20	L	Yes	No	S	W

Wood & Wilson (2011)	Soccer	20	F	Yes	No	S	B
Wood & Wilson (2012)	Soccer	20	F	Yes	No	S	B

Note. N = sample size; Loc = study location (F = field where the sport takes place; L = laboratory); Anx = pressure situations are introduced as a mean to manipulate anxiety; VIA = use of Vision-In-Action; Mot = motor task (S = self-paced - motor skills are initiated by the athletes; I = Interceptive - the athletes have to react and intercept an object; Res = type of research (B = differences between experts and novices, or high and low skills athletes are studied; W = Within – only experts or novices participate; their best and worst performance is compared)

Concerning methodological characteristics (see Appendix 7), inclusion and exclusion criteria for units were provided in all studies. The design was experimental in 77.8% of studies, while the remaining 22.2% were quasi-experiments with some extraneous variables controlled. Attrition was not noted in 55.6% of studies; in other studies, attrition ranged from 18.52 to 33.33% of the original sample. Differential-attrition information between groups was provided in one study, and in only one study did authors use statistical methods for imputing missing data. Follow-up periods ranged from 0 to 2 months. Moreover, 88.9% of studies had more than one measurement occasion; this variable ranged from 1 to 9 (M = 3.56; SD = 2.35); all the variables were measured on all the occasions. In most cases (88.9%), at least one dependent variable was standardized, and in 77.8% of the occasions, the variables were clearly defined.

Statistical Analysis

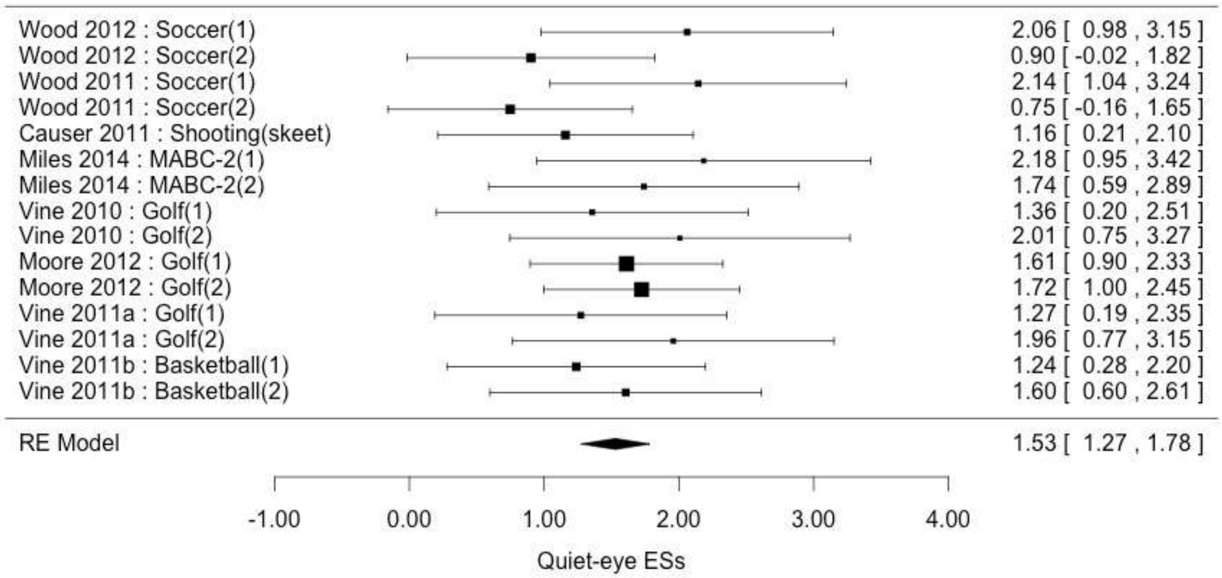
Quiet-eye effects. The homogeneity test for the quiet-eye ESs was non-significant, Q (df = 14) = 10.61, p = 0.72, and I^2 indicated that less than 0.01% of the total variability of the quiet eye ESs comes from between-studies differences. However, a random-effects model was still chosen to estimate parameters. The mean ES was very large at $\bar{d}$ = 1.53 (SE = .13, p < .001), with $\hat{\tau}^2 < 0.01$ in the population of quiet-eye ESs (see Figure 3a). This value of $\hat{\tau}^2$ suggests that

95% of the true effects will lie within a band of approximately ± 0.20 around the mean, or between 1.33 and 1.73.

Egger's test resulted in a non-significant effect (p > .31), and the funnel plot based on trim-and-fill revealed only one potential missing study, on the left. Therefore, the average effect was re-estimated as $\overline{d}$ = 1.49 (SE = .13, p < .001), with $\hat{\tau}^2 < 0.01$, a very large ES similar to the previous estimate (i.e., $\overline{d}$ = 1.53). Analyses of mixed-effects models identified no significant predictors of quiet-eye ESs.

Performance effects. The homogeneity test for performance ESs also failed to reach significance, Q (df = 13) = 9.61, p < 0.73, and I^2 suggested that less than 0.01% of the total variability in performance ESs came from the between-studies differences. Consistent with previous analyses, we used a random-effects model to estimate parameters. We found a large mean effect, $\overline{d}$ = 0.84 (SE = .12, p < .001), with $\hat{\tau}^2 < 0.01$, in the population of performance ESs (see Figure 3b). Egger's test was marginally significant with p = 0.052. The funnel plot based on trim-and-fill suggested four missing studies on the left. Incorporating these potentially missing studies, the mean effect was adjusted from a large ES (i.e., $\overline{d}$ = 0.84) to a moderate-to-large one (i.e., $\overline{d}$ = 0.69, SE = .11, p < .001, with $\hat{\tau}^2 < 0.01$). Based on the bias impact criterion (Borenstein et al., 2011), the quiet-eye ESs were more resistant to publication bias than were the performance ESs. Analysis of mixed-effects models identified no significant predictors of the performance ESs.

3a



3b

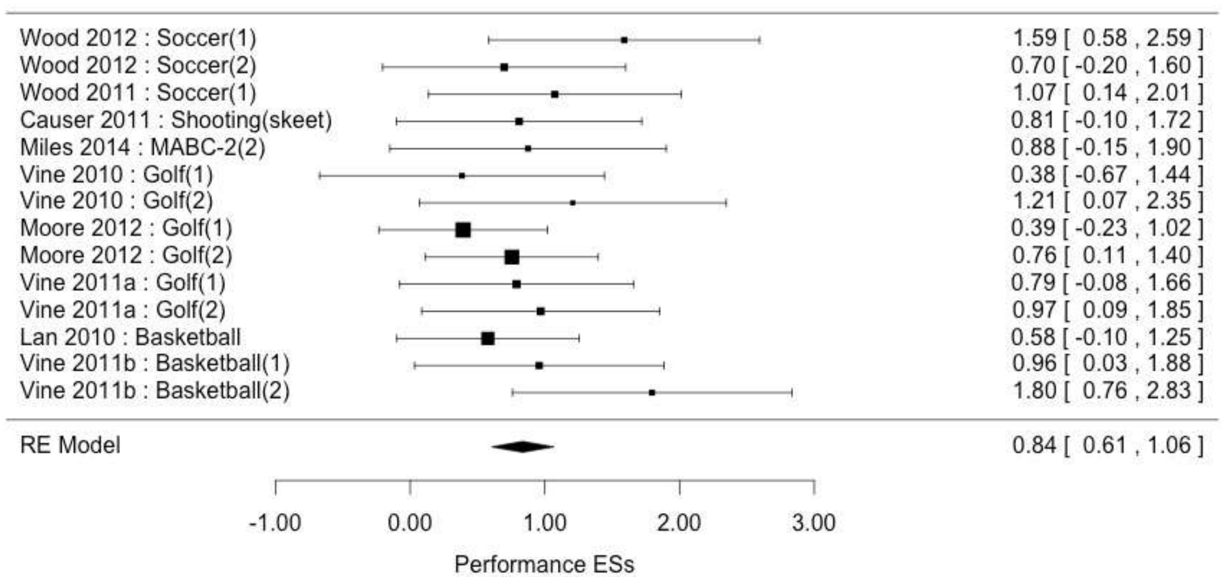


Figure 3. Forest plots of the random-effects model for quiet-eye (a) and performance (b) ES of Synthesis 2. The ESs are sorted according to sport type. Multiple ESs from identical studies are marked by numbers in parentheses. MABC-2 = Movement Assessment Battery for Children, Second Edition.

The correlation between the quiet-eye ES and performance ES was also explored (see Figure 4). An outlier was identified because of its distance from the regression line. A closer examination revealed that this data point is the only one (among 14 pairs) whose performance ES is larger than its quiet-eye ES. Because we expected the trained variable (i.e., QE) to show a larger change than the outcome variable (i.e., performance), we performed a sensitivity analysis. For the complete dataset the correlation coefficient between the QE ES and the performance ES was $r = .45$ ($p = .12$). After removing the outlier from the dataset, a significant and strong correlation coefficient was observed ($r = .58$, $p = .049$). To help interpret the QE-performance relationship across intervention studies, we ran a weighted regression based on the outlier-free data. The regression treated the performance ES as outcome and quiet-eye ES as predictor. The weighted regression analysis revealed that QE is a marginally significant predictor of performance across intervention studies, $\hat{\beta} = .40$ ($SE = .24$, $p = .060$).

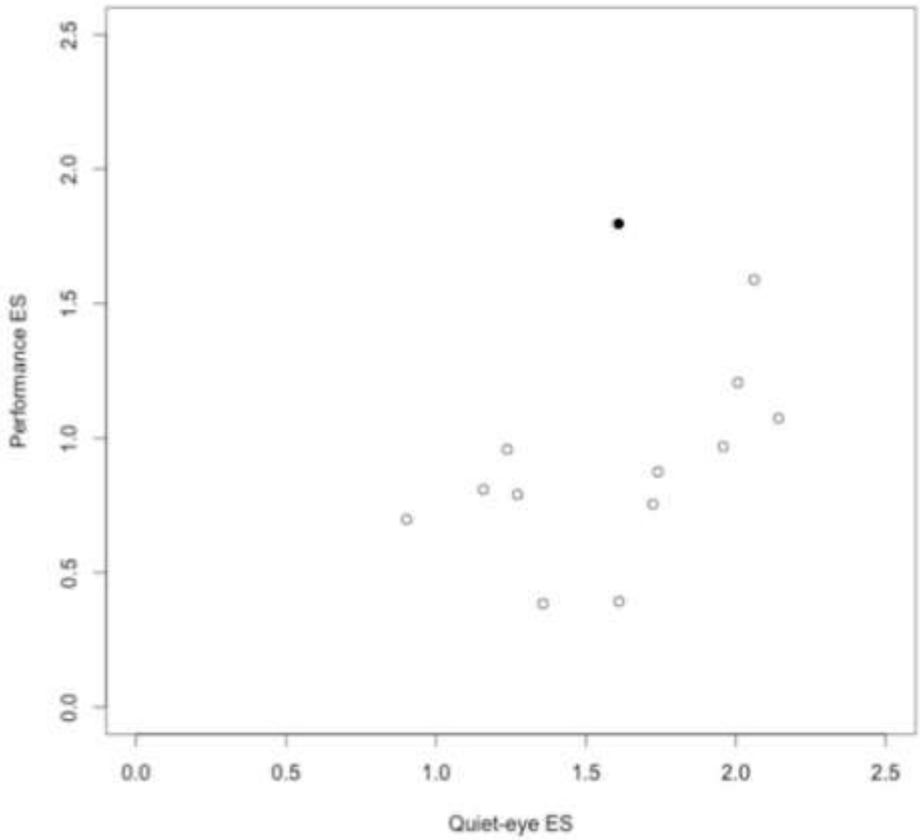


Figure 4. Scatterplot showing relationship between the quiet-eye and performance effects. The solid dot represents the suspected outlier.

Discussion

The aim of this study was to provide a quantitative synthesis of the literature on the QE in sports settings by analyzing both intervention and non-intervention studies. In Synthesis 1 we examined non-intervention studies, and estimated the magnitude of the difference in QE duration between expertise levels, and between successful and unsuccessful performances within the same individuals. In Synthesis 2, we estimated the magnitude of the QE duration and performance differences between individuals who received QE training and those from comparable control groups (or following ordinary training regimens). Additionally, we analyzed the relationship between the QE duration and performance effects. In both Syntheses we fit meta-regression models to examine potential moderators. The review of the intervention studies and the examination of potential moderators expand on the QE literature that was previously reviewed quantitatively by Mann and colleagues (2007) or narratively by Wilson, Causer, and Vickers (2015). This review constitutes, to our knowledge, the first meta-analysis specifically targeting the QE period in sports.

Synthesis 1: Non-Intervention Studies

A large mean ES ($\overline{d}$ = 1.04) was found for the between-individuals differences in the QE period. This ES is larger than the moderate-to-large ES reported by Mann et al. (2007) in their meta-analysis, and in line with previously reported expert-novice differences (Janelle et al., 2000; Vickers, 1996a, 1996b). Overall, experts use a substantially longer QE period than do novices, across sports. Moreover, within-individual differences were moderate ($\overline{d}$ = 0.58), but substantially smaller than the average difference between experts and novices. Additionally, this average ES is smaller than the mean obtained by Mann and colleagues (2007).

Several explanations can account for the smaller ES found in the within-individual studies compared to the between-individual studies. First, inconsistency among QE researchers in defining and selecting successful/unsuccessful trials within participants may have resulted in a lower ES. For example, many studies have participants keep performing until an equal number of successful and unsuccessful trials have been reached. Participants in some studies (e.g., van Lier et al., 2008) performed 45 trials, whether they were successful or not. Another study (Vine et al., 2013) had golfers putt until they missed one, and considered the single missed putt as an unsuccessful outcome. Using one trial versus the mean of several trials can lead to QE durations of different quality and possibly different lengths, especially when it comes to short durations of less than a second. The reliability of a measure based on just one trial is clearly questionable. Second, greater differences are expected between participants than in intra-individual fluctuations. This is especially true when the between-persons comparisons contrast participants of different skill levels. Furthermore, motor-learning research (Schmidt & Lee, 2011) has maintained that as performers accumulate more experience on a certain task, intra-individual differences (i.e., variability) decrease substantially. Last, publication bias may have led to a deflated ES, as the trim-and-fill method suggested an additional 2 studies should appear above the mean, which raised the ES from 0.58 to 0.68.

A moderator analysis performed for the between-individuals studies revealed that the method of measuring the QE duration accounted for almost half of the QE-effect variability. Studies reporting a relative measure of QE duration (i.e., a percentage of the total movement time) had a larger mean ES than studies reporting an absolute duration (in ms). Perhaps the tasks studied required relatively short movements (usually less than a second, e.g., putting in golf, kicking a ball, or shooting a rifle); an absolute measure of the QE period (hundreds of milliseconds) may be less sensitive than measures of percentages of the total movement time for such tasks. More scientific effort is needed to explore the QE periods for longer movement times, and to compare absolute to relative measures within the same study. Contrary to our hypotheses, none of the other moderators (i.e., setting, manipulation of anxiety, type of motor task, and Vision-In-Action measurement paradigm) was found to be statistically significant. The relatively small number of studies of the QE phenomenon, combined with rather low power, may account for this finding. Indeed for the moderator analyses, *post hoc* power analyses (Hedges & Pigott, 2004) showed that the highest level of power was only .429, for the one-tailed test of the effect of using anxiety inducements. All other power levels for non-significant moderator tests were at least .10 lower.

Synthesis 2: Intervention Studies

Nine studies with QE interventions were reviewed and two types of ES were extracted. The first type measured the mean difference between training and control groups on the length of the QE period. The second tapped the difference in performance between the two groups. Large mean ESs were found for both the QE and performance outcomes; however, the former was larger than the latter (i.e., $\overline{d}$ = 1.53 vs. $\overline{d}$ = 0.84). This difference between the effects for the QE period and for performance is expected, because the QE period is the intended target of the interventions. The observed performance enhancement is a byproduct of having a better focus of attention on a single external cue, and overall better motor preparation for the movement (Vine et al., 2011; Wulf, 2007).

The large average QE ES suggests that the quiet-eye training is a successful intervention to prolong the final fixation of gaze before the initiation of movement. These results are in line with the literature showing that the quiet-eye period not only has an effect on performance, but also that gaze behavior can be learned and trained (e.g., Vine et al., 2011; Wood & Wilson, 2011).

The moderate-to-large mean ES obtained for the performance indicates that interventions aimed at prolonging the QE period also indirectly affect task performance. A marginally significant regression coefficient ($\hat{\beta}$ = .40, *SE* = .24) of quiet-eye ES on performance ES across studies offers insight on the overall quantitative connection between the two variables, at least within the ES range studied. That is, performance tends to improve by almost half of a standard deviation with an increase of one standard deviation in QE duration. Furthermore, the meaningful influence of QE on performance was also supported by individual studies. For example, Nibbeling, Oudejans, and Daanen (2012) showed that, under a high anxiety condition, the final visual fixation of dart throwers predicted over 63% of performance variance.

The promising results obtained for the intervention studies call for including QE training as part of the training regimen in practice because athletes show considerable room for QE improvement (i.e., $\overline{d}$ =1.53). Although access to eye-tracking technology is not universal due to its price and complexity, the idea of experimentally manipulating the beginning and the end of the last fixation before movement initiation (as in Klostermann et al., 2013) can be a useful training method to enhance performance. Moreover, the study by Vine, Lee, Moore, and Wilson (2013) opens the door to studying the QE period after movement – what was termed the "*quiet-eye dwell time"* (Vickers, 1992). Their study showed that QE durations for golfers during and after putter movement were negatively related to disruptions in attentional control, and short durations were associated with subsequently hampered performance. Furthermore, Klosterman and colleagues (2013) developed a paradigm for examining QE as an independent variable, allowing corroboration of earlier findings on a possible causal link between QE and performance. Additionally, they found that QE played a fundamental functional role in the facilitation of information processing; especially in conditions with increased task demands.

The results obtained in this meta-analysis signify the QE period as a key perceptual-cognitive variable affecting performance. By extending the final fixation before movement initiation, performers are better able to retrieve and coordinate motor programs for the successful completion of the task (Vickers, 1996a, 1996b). During the QE period, the performer is actively picking a specific target and maintains the focus on that single target. This period of focused attention leads to less susceptibility to attention disruption caused by irrelevant cues (Posner & Raichle, 1997). This allows for stronger performance even under anxiety or high cognitive load (Vickers & Williams, 2007). Coupled with these gains in attention and focus, the prolonged fixation allows the performer to better prepare for action execution (Mann et al., 2011) which ultimately enhances performance.

The finding that only one potential moderator variable was related to the size of the QE effects can be viewed in two ways. To the extent that we assume the set of studies reviewed is complete and representative, the lack of significant moderators testifies to the robustness and generality of the QE effect. This reflects what Cook (1993) refers to as “heterogeneous irrelevancies” – factors that vary but do not impact our study outcomes. Finding heterogeneous irrelevancies supports broader generalizations. On the other hand, the power of this synthesis to detect moderator effects was relatively low. More studies, or larger studies, would enable stronger assessments of the moderator effects[3].

Limitations and Future Research Directions

One limitation of the present meta-analysis is the focus on sport performance. Some studies have examined the relation between the quiet-eye period and performance in other domains (e.g., law enforcement, surgery). It may be of interest to compare the current results with QE findings in domains outside of sport, and to explore whether our findings generalize across domains.

A non-significant homogeneity test was found for the intervention studies, indicating that they were very consistent, and no significant moderators emerged. Additionally, most of the intervention studies were designed similarly (e.g., having baseline, training, retention 1, transfer, and retention 2 time points), and the populations studied were very similar (i.e., young adults). The majority of the studies used a sample size of 10 participants or less per group. Hence, more intervention studies are needed with larger and more diverse samples and domains in order to identify potential moderators affecting training to lengthen the QE period.

Although most of our intervention studies (with the exception of Wood & Wilson, 2012) used a QE-training protocol targeting only gaze behaviors, no information on the effectiveness of each component of the protocol is provided. Also no follow-ups have been performed in these studies, which leads one to wonder whether the benefits are maintained in the long term.

Another limitation of the extant QE literature is the existence of some variability in the definition of fixation duration (either 100ms or 120ms) and deviation angle from the target (1° or

3°). Even if the fixation definitions of the studies included in this review are consistent with Vickers' 2007 definition of the QE, the results might vary in the case of a small target. We tested both fixation durations and angles as moderators in all our models, and neither of them revealed a significant effect on the results. Nonetheless, we suggest developing a common, clearer, operational definition of fixation duration and angle from the target that defines the QE period. Future studies can address this issue by directly comparing the data obtained from different fixation definitions within the same study. While our cross-study comparisons are informative, and these definitional variations are not confounded with other study features, within-study comparisons would provide stronger evidence on this matter.

Furthermore, the QE literature can also benefit from a consensus on the operationalization of the offset of the QE period. Due to the evolution of the QE definition, some authors used the beginning of the final movement as the offset of the QE while other authors used the target fixation offset that can happen after the final movement started. 26 out of the 36 studies included in this review used the beginning of the final movement as the QE offset, due to the natural constraints of the tasks. 10 studies use the fixation offset as the end of the QE period, as useful information was still available after the final movement starts. These 10 studies represent 5 sports, and only studies on shooting and basketball[4] show inconsistency in their operationalization of QE offset. Hence, only 2 sports (out of 11) differ in their definition on the end (but not the beginning) of the QE period. Together with the fact that 26 out of 36 studies were consistent in their definition of the QE, the agreement within and between sports is large but a complete consensus has not been reached yet. Such a consensus will also facilitate the comparison of QE duration across studies. These differences in QE offset operationalization did not, however, relate to the size of the QE effect in our data.

The results obtained in this meta-analysis are in line with our main hypotheses. Higher-level athletes used a longer QE period, and longer duration is associated with enhanced performance. This relationship between the QE duration and performance is true not only when experts and novices are compared, but also is evident when successful and less successful performances within the same participant are contrasted. Our results extend those found in the previous review of the QE literature (Mann et al., 2007) by identifying different ESs based on the use (or not) of an intervention protocol, and the isolation of the measurement method of the QE period (i.e., absolute vs. relative) as a moderator. Finally, we found that intervention programs designed to lengthen the QE period are effective in extending the gaze behaviors, which ultimately lead to performance improvement.

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References

References marked with an asterisk indicate studies included in the meta-analysis.

** Papers included in Synthesis 1*

*** Papers included in Synthesis 2*

APA Publications, Communications Board Working Group on Journal and Article Reporting Standards (2008). Reporting standards for research in psychology: why do we need them? What might they be? The *American Psychologist*, *63*, 839–851. doi:10.1037/0003-066X.63.9.839

*Behan, M., & Wilson, M. (2008). State anxiety and visual attention: The role of the quiet eye period in aiming to a far target. *Journal of Sports Sciences*, *26*, 207-215. doi:10.1080/02640410701446919

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis*. Chichester, West Sussex: John Wiley & Sons.

*Campbell, M. J., & Moran, A. P. (2014). There is more to green reading than meets the eye! Exploring the gaze behaviours of expert golfers on a virtual golf putting task. *Cognitive Processes, 15*, 363-372. doi:10.1007/s10339-014-0608-2

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

*Causer, J., Holmes, P. S., Smith, N. C., & Williams, A. M. (2011). Anxiety, movement kinematics, and visual attention in elite-level performers. *Emotion*, *11*, 595-602. doi:10.1037/a0023225

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

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Psychology Press.

Cook, T. D. (1993). A quasi-sampling theory of the generalization of causal relationships. *New Directions for Program Evaluation*, *1993*, 39-82. doi: 10.1002/ev.1638

Corbetta, M., Akbudak, E., Conturo, T. E., Snyder, A. Z., Ollinger, J. M., Drury, H. A., Linenweber, M. R., ... Shulman, G. L. (1998). A common network of functional areas for attention and eye movements. *Neuron, 21*, 761-73. doi:10.1016/S0896-6273(00)80593-0

Corbetta, M., Patel, G., & Shulman, G.L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, *58*, 306–324. doi:10.1016/j.neuron.2008.04.017

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201−215. doi:10.1038/nrn755

Duval, S. J., & Tweedie, R. L. (2000a). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56*, 455–463. doi:10.1111/j.0006-341X.2000.00455.x

Duval, S. J., & Tweedie, R. L. (2000b). A nonparametric "trim and fill" method of accounting for publication bias in meta-analysis. *Journal of the American Statistical Association, 95*, 89–98. doi: 10.1080/01621459.2000.10473905

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal, 315*, 629-634.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406. doi:10.1037/0033-295X.100.3.363

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*, 336−353. doi:10.1037/1528-3542.7.2.336

Hardy, L., Jones, G., & Gould, D. (1996). *Understanding psychological preparation for sport: Theory and practice of elite performers.* Chichester, UK: Wiley.

Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational and Behavioral Statistics, 6*(2), 107-128. doi: 10.3102/10769986006002107

Hedges, L. V., & Pigott, T. D. (2004). The power of statistical tests for moderators in meta-analysis. *Psychological Methods*, *9*, 426–445. doi:10.1037/1082-989X.9.4.426

Janelle, C. M., & Hillman, C. H. (2003). Expert performance in sport: Current perspective and critical issues. In J. L. Starkes & K. A. Ericsson (Eds.), *Expert Performance in sports: Advances in research on sport expertise.* Champaign, IL: Human Kinetics.

*Janelle, C. M., Hillman, C. H., Apparies, R. J., Murray, N. P., Meili, L., Fallon, E. A., & Hatfield, B. D. (2000). Expertise differences in cortical activation and gaze behavior during rifle shooting. *Journal of Sport & Exercise Psychology, 22*, 167-182.

*Janelle, C. M., Hillman, C. H., & Hatfield, B. D. (2000). Concurrent measurement of electroencephalographic and ocular indices of attention during rifle shooting: An exploratory case study. *International Journal of Sport Vision*, *6*, 21-29.

*Kim, S., Lee, S., Ryu, D., Kim, C., & Lee, S. (2007). How do national badminton players utilize advanced visual cues to anticipate an attacker's intent? *Journal of Sport & Exercise Psychology, 29(Supp.)*, 97.

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

**Lan, S-L., & Dai, Q-H. (2010). Jingyan xunlian zai lanqiu faqiu jishu jiaoxue zhongde shiyan yanjiu [Research on quiet eye training in free throw teaching]. *Junshi Tiyu Jinxiu Xueyuan Xuebao, 29*, 94-96.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*, 159–174. doi: 10.2307/2529310

*Lee, S. -M., Kim, S., & Park, S. -H. (2009). Self -paced sport events under temporal constraints: Visual search, quiet eye, expertise and constrained performance time in far aiming tasks. *International Journal of Applied Sports Sciences, 21*, 146-161.

*Lier, W. V., Kamp, J., & Savelsbergh, G. J. (2008). Gaze in golf putting: Effects of slope. *International Journal of Sport Psychology*, *41*, 160-176.

Mallett, C. J., & Hanrahan, S. J. (2004). Elite athletes: Why does the ‘fire’ burn so brightly? *Psychology of Sport and Exercise, 5,* 183-200. doi:10.1016/S1469-0292(02)00043-2

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

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

*Martell, S. G. (2010). *The optimal quiet eye period and the regulation of visual information in complex aiming* (Order No. NR69492). Available from ProQuest Dissertations & Theses Full Text. (848965768). Retrieved from http://search.proquest.com/docview/848965768?accountid=4840

*McPherson, S. L., & Vickers, J. N. (2004). Cognitive control in motor expertise. *International Journal of Sport and Exercise Psychology*, *2,* 274-300. doi:10.1080/1612197X.2004.9671746

**Miles, C. A., Vine, S. J., Wood, G., Vickers, J. N., & Wilson, M. R. (2014). Quiet eye training improves throw and catch performance in children. *Psychology of Sport and Exercise*, *15*, 511-515. doi:10.1016/j.psychsport.2014.04.009

Milner, A.D., & Goodale, M.A. (1995). *Visual brain in action*. Oxford: Oxford University.

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

*Nagano, T., Kato, T., & Fukuda, T. (2006). Visual behaviors of soccer players while kicking with the inside of the foot. *Perceptual and Motor Skills*, *102*, 147-156. doi:10.2466/PMS.102.1.147-156

*Nibbeling, N., Oudejans, R. R., & Daanen, H. A. (2012). Effects of anxiety, a cognitive secondary task, and expertise on gaze behavior and performance in a far aiming task. *Psychology of Sport and Exercise, 13*, 427-435. doi:10.1016/j.psychsport.2012.02.002

Nieuwenhuys, A., Pijpers, J.R., Oudejans, R.R.D., & Bakker, F.C. (2008). The influence of anxiety on visual attention in climbing. *Journal of Sport & Exercise Psychology*, *30*, 171–185.

Osterlind, S. J. (1992). *Constructing test items: Multiple-choice, constructed-response, performance, and other formats*. Boston, MA: Kluwer Academic Publishers.

Oudejans, R. R. D., van de Langenberg, R. W., & Hutter, R. I. (2002). Aiming at a far target under different viewing conditions: Visual control in basketball jump shooting. *Human Movement Science*, *21*, 457–480. doi:10.1016/S0167-9457(02)00116-1

Oudejans, R. R. D., Koedijker, J. M., Bleijendaal, I., & Bakker, F. C. (2005). The education of attention in aiming at a far target: Training visual control in basketball jump shooting. *International Journal of Sport Psychology*, *3*, 197–221. doi:10.1080/1612197X.2005.9671767

*Panchuk, D., & Vickers, J. N. (2006). Gaze behaviors of goaltenders under spatial–temporal constraints. *Human Movement Science*, *25*, 733-752. doi:10.1016/j.humov.2006.07.001

*Panchuk, D., & Vickers, J. N. (2009). Using spatial occlusion to explore the control strategies used in rapid interceptive actions: Predictive or prospective control? *Journal of Sports Sciences*, *27*, 1249-1260. doi:10.1080/02640410903156449

*Park, S. H. (2005). The change of gaze behavior, eye-head coordination, and temporal characteristics of swing by task constraints in tennis volley strokes. *International Journal of Applied Sports Sciences*, *17*, 51-70.

*Piras, A., & Vickers, J. N. (2011). The effect of fixation transitions on quiet eye duration and performance in the soccer penalty kick: Instep versus inside kicks. *Cognitive Processing*, *12*, 245-255. doi:10.1007/s10339-011-0406-z

Posner, M. I., & Raichle, M. E. (1997). *Images of mind*. New York, NY: Scientific American Library.

R Core Team (2014). R: A language and environment for statistical computing. *R Foundation for Statistical Computing, Vienna, Austria.* Retrieved from http://www.R-project.org/.

*Rienhoff, R., Baker, J., Fischer, L., Strauss, B., & Schorer, J. (2012). Field of vision influences sensory-motor control of skilled and less-skilled dart players. *Journal of Sports Science & Medicine*, *11*, 542-550.

*Rienhoff, R., Hopwood, M., Fischer, L., Strauss, B., Baker, J., & Schorer, J. (2013). Transfer of motor and perceptual skills from basketball to darts. *Frontiers in Psychology, 4*, 1-7. doi:10.3389/fpsyg.2013.00593

Rothstein, H. R. (2008). Publication bias as a threat to the validity of meta-analytic results. *Journal of Experimental Criminology*, *4*, 61-81. doi:10.1007/s11292-007-9046-9

Sanduvete-Chaves, S. (2008). *Innovaciones metodológicas en la evaluación de la formación continua* [Methodological innovations in training program evaluation] (awarded doctoral dissertation. Universidad de Sevilla, Spain). Retrieved from http://fondosdigitales.us.es/tesis/tesis/1744/innovaciones-metodologicas-en-la-evaluacion-de-la-formacion-continua/

Schmidt, R. A., & Lee, T. D. (2011). *Motor control and learning: A behavioral emphasis*. Champaign, IL: Human Kinetics.

Shadish, W. R., Chacón, S., & Sánchez-Meca, J. (2005). Evidence-based decision-making: Enhancing systematic reviews of program evaluation results in Europe. *Evaluation. The International Journal of Theory, Research and Practice, 11*, 95-109. doi:10.1177/1356389005053196

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental research designs for generalized causal inference*. Boston, MA: Houghton Mifflin.

Starkes, J. L., & Ericsson, A. K. (2003). *Expert performance in sports: Advances in research on sport expertise.* Champaign, IL: Human Kinetics.

Vickers, J. N. (1992). Gaze control in putting. *Perception*, *21*, 117-132. doi:10.1068/p210117

Vickers, J. N. (1996a). Control of visual attention during the basketball free throw. *The American Journal of Sports Medicine*, *24,* S93-S96.

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

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

Vickers, J. N. (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. doi:10.1016/S0079-6123(09)01322-3

Vickers, J. N. (2012). Neuroscience of the quiet eye in golf putting. *International Journal of Golf Science*, *1*, 2-9.

*Vickers, J. N., & Adolphe, R. M. (1997). Gaze behaviour during a ball tracking and aiming skill. *International Journal of Sports Vision*, *4*, 18-27. doi:10.1016/j.humov.2006.07.001

*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*, 381−394. doi:10.3200/JMBR.39.5.381-394

*Vine, S. J., Lee, D., Moore, L. J., & Wilson, M. R. (2013). Quiet eye and choking: Online control breaks down at the point of performance failure. *Medicine & Science in Sports & Exercise*, *45*, 1988-1994. doi:10.1249/MSS.0b013e31829406c7

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

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

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

Vossel, S., Geng, J. J., & Fink, G. R. (2014). Dorsal and ventral attention systems distinct neural circuits but collaborative roles. *The Neuroscientist*, *20*, 150-159. doi:10.1177/1073858413494269

Williams, A. M., & Davids, K. (1995). Declarative knowledge in sport: A by-product of experience or a characteristic of expertise? *Journal of Sport and Exercise Psychology, 17,* 259-275.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1993). Visual search and sports performance. *The Australian Journal of Science and Medicine in Sport, 25*, 147-204.

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport, 6*, 127-135. doi:10.1080/02701367.1994.10607607

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,* 197–207. doi:10.1080/00222890209601941

Wilson, M. (2008). From processing efficiency to attentional control: A mechanistic account of the anxiety-performance relationship. *International Review of Sport and Exercise Psychology, 1,* 184-201. doi:10.1080/17509840802400787

Wilson, M.R., Causer, J., & Vickers, J.N. (2015). Aiming for excellence: The quiet eye as a characteristic of expert visuomotor performance. In J. Baker & D. Farrow (eds.) *The Routledge handbook of sport expertise* (pp. 22-37). London: Routledge.

*Wilson, M. R., Miles, C. A., Vine, S. J., & Vickers, J. N. (2013). Quiet eye distinguishes children of high and low motor coordination abilities. *Medicine & Science in Sports & Exercise*, *45*, 1144-1151. doi:10.1249/MSS.0b013e31828288f1

*Wilson, M. R., & Pearcy, R. C. (2009). Visuomotor control of straight and breaking golf putts. *Perceptual and Motor Skills*, *109*, 555-562. doi:10.2466/PMS.109.2.555-562

*Wilson, M. R., Vine, S. J., & Wood, G. (2009). The influence of anxiety on visual attentional control in basketball free throw shooting. *Journal of Sport and Exercise Psychology*, *31*, 152-168.

**Wood, G., & Wilson, M. R. (2011). Quiet eye training for soccer penalty kicks. *Cognitive Processing*, *12*, 257-266. doi:10.1007/s10339-011-0393-0

**Wood, G., & Wilson, M. R. (2012). Quiet eye training, perceived control and performing under pressure. *Psychology of Sport and Exercise*, *13*, 721-728. doi:10.1016/j.psychsport.2012.05.003

Wulf, G. (2007). *Attention and motor skill learning*. Champaign, IL: Human Kinetics.

Appendix 1. *Methodological quality characteristics codified in non-intervention and intervention studies*

The items below were drawn from a set of 43 items that were investigated in a content validity study (Sanduvete-Chaves, 2008; Shadish, Chacón, & Sánchez-Meca, 2005), Items found frequently in the literature on quality were validated by 30 experts in meta-analysis and systematic reviews, most of them participants in the Campbell Collaboration. The content validity study is continuously being extended; it currently includes reviews of 550 different ways of measuring methodological quality. Twenty-two items showed Osterlind's congruence indexes (Osterlind, 1992) higher than .5 on at least two of the three following dimensions: representativeness, utility, and feasibility of coding. In the present study, the 12 methodological items relevant to our research question were considered.

1. **Inclusion and exclusion criteria for units provided**: (a) No - Criteria were not specified; (b) Yes - They were specified; (c) Non-assessable

2. **Random assignment of units**: (a) None and no control of extraneous variables - No random assignment of units, and the study was not regulated by a parallel study or by comparing with another standard; (b) None but with control of extraneous variables - No random assignment of units, but the study was regulated by a parallel study or by comparing with another standard; (c) Yes - There was random assignment of units; (d) Non-assessable (e.g., only one group)

3. **Methodology or design**: (a) Observational 1: one group, without intervention, with more than one measurement occasion; (b) Observational 2: more than one group, without intervention, measured on one occasion; (c) Observational 3: more than one group, without intervention, with more than one measurement occasion; (d) Quasi-experiment: Comparison study in which units

were not randomly assigned to conditions (e.g., cohorts, case study, regression discontinuity, time series, non-equivalent control groups with pre-test and post-test); (e) Experiment: Comparison study in which units were randomly assigned to conditions; (f) Non-assessable

4. **Attrition**: percentage of the initial sample that did not conclude the study (concrete value or non-assessable)

5. **Differential attrition**: difference in (percentage of) attrition between groups (concrete value or non-assessable, e.g. only one group)

6. **Follow-up period**: number of months in which measurements were taken (concrete value or non-assessable)

7. **Number of measurement occasions** (concrete value or non-assessable)

8. **Percentage of variables that were measured in all the measurement occasions** (concrete value or non-assessable, e.g. only one measure)

9. **Standardization of dependent variables**: (a) Self-reports and post hoc records (without standardization) - ; All measures were ad-hoc tools, developed in a specific situation, or their validity was not checked; (b) Standardized questionnaires or self-reports; At least one measure was a structured tool; data were gathered using a homogeneous procedure; some study of psychometric properties was carried out; (c) Non-assessable

10. **Control techniques**: (a) No - No control technique was applied; (b) Yes - Specify: masking, double masking, matching, blocking, stratifying, constancy or counterbalancing; (c) Non-assessable

11. **Construct definition of outcome**: (a) No definition – Angle and time on target were not specified; (b) Vague definition – angle **or** time on target was specified; (c) Replicable by reader in own setting - Angle **and** time on target were specified

12. **Statistical methods for imputing missing data**: (a) No - Effects were estimated without imputing missing data; (b) Yes - Values for missing data were imputed so that studies could be included in the analyses (specify: sample mean substitution, last value forward method for longitudinal data sets, hot deck imputation, simple imputation, or multiple imputation); (c) Non-assessable (e.g., without attrition)

Appendix 2. *Kappa coefficients for the coded variables in non-intervention studies*

Variable	[a]Kappa
Extrinsic characteristics	
1. Source (Journal, book, dissertation, report, or conference paper)	.928
2. Publication year	1
3. Title	1
4. Authors	1
5. Journal name	1
Setting	
6. Study location (laboratory, field, or both)	1
7. Sport	1
8. Presence of a theoretical framework	.81
Participants	
9. Age mean	.923
10. Age SD	1
11. Number of males	.786
12. Number of females	.727
13. Number of experts	.723
14. Number of novices	.745
15. Skill level of experts	.861
16. Years of experience of experts	.866
17. Skill level of novices	.866
18. Years of experience of novices	.797
19. Type of research (within, between, both, or other)	.723
20. Anxiety/pressure manipulation	.87
21.Vision-in-action protocol	1
22. Participants in group A	.931
23. Sample size group A	1
24. Participants in group B	1
25. Sample size group B	.889
26. Random allocation (none and without control of extraneous variables, none with control of extraneous variables, yes, or non-assessable)	.928
Measures	
27. Name of gaze-tracking technology	1
28. Type of motor task	1
29. Quiet eye reliability	.931
30. Quiet eye validity	.87
31. Performance reliability	1
32. Performance validity	.797
33. Definition of fixation: angle from target	.866
34. Definition of fixation: time on target	.913

Results	
35. Quantitative data	1
36. Type of statistical analysis	1
37. Percentage of variance of performance explained by the QE duration	No data

Note. [a]Kappa coefficients between .61 and .80 are considered substantial; and above .8, very good (Landis & Koch, 1977).

Appendix 3. *Kappa coefficients for the coded variables in intervention studies*

Variable	[a]Kappa
Extrinsic characteristics	
1. Source (Journal, book, dissertation, report, or conference paper)	1
2. Publication year	1
3. Title	1
4. Authors	1
5. Journal name	1
Setting	
6. Study location (laboratory, field, or both)	1
7. Sport	1
8. Presence of a theoretical framework	1
Participants	
9. Experts, total number	1
10. Experts, age (mean & SD)	1
11. Experts, number of males	1
12. Experts, number of females	1
13. Experts, definition	1
14. Level of experts	1
15. Years of experience of experts	1
16. Intermediate, total number	.774
17. Intermediates, age (mean & SD)	No data
18. Intermediates, number of males	1
19. Intermediates, number of females	1
20. Intermediates, definition	1
21. Level of intermediates	No data
22. Years of experience of intermediates	No data
23. Novices, total number	1
24. Novices, age (mean & SD)	1
25. Novices, number of males	1
26. Novices, number of females	1

27. Novices, definition	.774
28. Level of novices	1
29. Years of experience of novices	No data
Methodology	
30. Type of research (within, between, both, or other)	1
31. Random allocation (none and without control of extraneous variables, none with control of extraneous variables, yes, or non-assessable)	1
Measures	
32. Name of gaze-tracking technology	1
33. Type of motor task	1
34. Quiet eye period definition	.874
35. Quiet eye reliability	1
36. Quiet eye validity	.774
37. Performance reliability	1
38. Performance validity	1
39. Definition of fixation: angle from target	1
40. Definition of fixation: time on target	1
41. Participants in the intervention group	1
42. Intervention duration	1
43. Intervention: number of trials	1
44. Intervention description	.760
45. Participants in the control group	1
46. Control duration	.832
47. Control: number of trials	1
48. Control description	.745
Results	
49. Quantitative data	.845
50. Type of statistical analysis	.866
51. Percentage of variance of performance explained by the QE	1
52. Effect size	1

Note. [a]Variable names are shortened for this table; full labels from the authors upon request. [b]Kappa coefficients between .61 and .80 are considered substantial; and above .8, very good (Landis & Koch, 1977).

Appendix 4. *Kappa coefficient obtained for items to measure methodological quality in non-intervention and intervention studies*

[a]Item	[b]Non-intervention	[b]Intervention
1. Exclusion criteria	.917	1
2. Random assignment	.928	1
3. Design	1	.866
4. Attrition	.931	1
5. Attrition between groups	.931	1
6. Follow-up period	1	1
7. Measurement occasions	1	1
8. Variables in all the occasions	.931	1
9. Standardized dependent variable	1	1
10. Control techniques	1	.745
11. Construct definition	.804	1
12. Imputed missing data	.931	.706

Note. [a]Variable names are shortened for this table; full labels are available in Appendix. [b]Kappa coefficients between .61 and .80 are considered substantial; and above .8, very good (Landis & Koch, 1977).

Appendix 5. *Methodological characteristics of coded studies without intervention*

Study	Criteria	Rando	Design	Attrit%	ABG%	FolMon	Momen	Var%	Standar	Control	Definit	Imput
Behan & Wilson (2008)	Yes	---	Obs1	0	---	0	2	100	Yes	No	Yes	---
Campbell & Moran (2014)	Yes	No with	Obs3	0	0	0	6	100	Yes	Const	Vague	---
Causer et al. (2010)	Yes	No with	Obs3	0	0	0	2	100	Yes	Const	Yes	---
Causer et al. (2011)	Yes	---	Obs1	0	---	0	3	100	Yes	Mask	Yes	---
Janelle et al. (2000b)	No	---	Obs1	0	---	0	2	100	Yes	Const	No	---
Jannelle et al. (2000a)	Yes	No with	Obs3	0	---	0	4	100	Yes	Const	No	---
Kim et al. (2007)	No	No with	Obs2	0	---	0	1	---	Yes	---	No	---
Lee et al. (2009)	Yes	No with	Obs3	0	0	0	3	100	Yes	Const	Yes	---
Mann et al. (2011)	Yes	No with	Obs3	0	0	0	3	100	Yes	No	No	---
Martell (2010)	Yes	---	Obs1	0	---	0	2	100	Yes	Const	Yes	---
McPherson & Vickers (2004)	Yes	---	Obs1	0	---	0	4	100	Yes	Const	Yes	---
Nagano et al. (2006)	No	No with	Obs3	0	0	0	5	100	Yes	Const	No	---
Nibbeling et al. (2012)	Yes	No with	Obs3	0	0	0	4	100	Yes	Const	Vague	---
Panchuk & Vickers (2006)	Yes	---	Obs1	0	---	0	2	100	Yes	No	Yes	---
Panchuk & Vickers (2009)	No	---	Obs1	0	---	0	5	100	Yes	Const	Yes	---
Park (2005)	Yes	---	Obs1	0	---	0	4	100	Yes	Const	No	---
Piras & Vickers (2011)	Yes	---	Obs1	0	---	0	5	100	Yes	Const	Yes	---
Rienhoff et al. (2012)	Yes	No with	Obs3	0	0	0	3	100	Yes	Const	Yes	---
Rienhoff et al. (2013)	No	No with	Obs3	0	0	0	2	100	Yes	Const	Vague	---
van Lier et al. (2008)	Yes	No with	Obs3	15	---	0	3	100	Yes	Const	Vague	No
Vickers (1996)	No	No with	Obs3	0	0	0	2	100	Yes	Const	Vague	---
Vickers & Adolphe (1997)	Yes	No with	Obs3	0	0	0	3	100	Yes	No	No	---
Vickers & Williams (2007)	No	---	Obs1	0	---	0	10	100	Yes	Count	Yes	---
Vine et al. (2013)	Yes	---	Obs1	0	---	0	3	100	Yes	Const	Yes	---
Wilson & Pearcy (2009)	Yes	---	Obs1	0	---	0	5	100	Yes	Const	Yes	---
Wilson et al. (2013)	No	No with	Obs2	0	0	0	1	---	Yes	Const	Yes	---

Wilson et al. (2009)	Yes	---	Obs1	0	---	0	2	100	Yes	Count	Yes	---

Note. **---**: Information non-assessable; **Criteria** = Inclusion and exclusion criteria for units provided; **Rando** = Random assignment of units (No with = There was no random assignment of units, but some extraneous variable/s was/were controlled); **Design** (Obs1 = Observational1: without intervention, one group and more than one measurement moment; Obs2 = Observational2: without intervention, more than one group and one measurement moment; Obs3 = Observational3: without intervention, more than one group and more than one measurement moment); **Attrit%** = Attrition (percentage of the initial sample that did not conclude the study); **ABG%** = Attrition between groups: difference in percentage; **FolMon** = Follow-up period (number of months in which measurements were taken); **Momen** = Number of measurement occasions; **Var%** = Percentage of variables that were measured in all the measurement occasions; **Standar** = Standardized dependent variables; **Control** = Control techniques (Const = Constancy; Mask = Masking; Count = Counterbalancing); **Definit** = Construct definition of outcome; **Imput** = Statistical methods for imputing missing data

Appendix 6. *Intercorrelation matrix among moderators of Synthesis 1.*

	Pub†	Pubyr	Labo†	Pressure†	VIA†	Selfpace†	Absolute†	Degree1†	Duration100†
Pubyr	-0.2								
Labo†	-0.24	-0.05							
Pressure†	0.15	0.14	0.15						
VIA†	-0.08	-.42**	-0.12	0.1					
Selfpace†	-0.17	0.18	.50**	0.16	-.45**				
Absolute†	0.03	-0.08	.43**	0.19	0.21	0.01			
Degree1†	0.19	-0.02	0.23	0.01	0.29	-0.07	0.31		
Duration100†	-0.13	<-0.01	-0.35*	-0.16	-0.06	-0.23	-0.25	-0.59***	
MoveBegin†	0.2	0.03	-0.02	-0.04	-0.24	0.32*	-0.09	-0.02	0.04

Note. * $p < .05$, ** $p < .01$, † Dichotomous variable. Pub = publication; Pubyr = year of publication; Lab = laboratory study vs. field study; Pressure = pressure manipulation vs. not; VIA = used vision-in-action paradigm or not; Selfpace = self-paced motor task vs. externally paced task.

Appendix 7. *Methodological characteristics of coded studies with intervention*

Study	Criteria	Rando	Design	Attrit%	ABG%	FolMon	Momen	Var%	Standar	Control	Definit	Imput
Causer et al. (2011)	Yes	No with	Quasi	0	---	2	2	100	Yes	Const	Vague	---
Lan & Dai (2010)	Yes	No with	Quasi	30	---	0	1	---	No	Const	No	No
Miles et al. (2014)	Yes	Yes	Exper	27.27	---	0	2	100	Yes	No	Yes	No
Moore et al. (2012)	Yes	Yes	Exper	0	---	0.25	4	100	Yes	Mask	Yes	---
Vine et al. (2011)	Yes	Yes	Exper	18.52	18.52	0.125	3	100	Yes	No	Yes	No
Vine & Wilson (2010)	Yes	Yes	Exper	33.33	---	0.25	9	100	Yes	Const	Yes	Yes
Vine & Wilson (2011)	Yes	Yes	Exper	0	---	0.25	3	100	Yes	Const	Yes	---
Wood & Wilson (2011)	Yes	Yes	Exper	0	---	1.75	5	100	Yes	Mask	Yes	---
Wood & Wilson (2012)	Yes	Yes	Exper	0	---	1.5	3	100	Yes	Const	Yes	---

Note. **---**: Information non-assessable; **Criteria** = Inclusion and exclusion criteria for units provided; **Rando** = Random assignment of units (No with = There were no random assignment of units, but some extraneous variable/s was/were controlled); **Design** (Quasi = Quasi-experimental; Exper = Experimental); **Attrit%** = Attrition (percentage of the initial sample that did not conclude the study); **ABG%** = Attrition between groups: difference in percentage; **FolMon** = Follow-up period (number of months in which measurements were taken); **Momen** = Number of measurement occasions; **Var%** = Percentage of variables that were measured in all the measurement occasions; **Standar** = Standardized dependent variables; **Control** = Control techniques (Const = Constancy; Mask = Masking); **Definit** = Construct definition of outcome; **Imput** = Statistical methods for imputing missing data

Appendix 8: PRISMA 2009 checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2. Most items are included, considering the space limitation for the abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	7
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	7-8
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	11-15. The protocol is detailed in the method section but has not been registered
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	11

Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	11
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	11. Search strategy was the same across all databases and is presented p 11.
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	11
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	12
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8-10
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	14. Study level
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	13-14
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	14

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	8
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	20
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	15 and Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1 & 3
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	15
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Figure 2 & 3
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Figure 2 & 3
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	17, 19-20
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	20
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	22-23

Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	26
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	24
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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[1] We ran a sensitivity analysis to check whether such a dependence issue would bias the results. The results of the sensitivity analysis supported that all the effect estimates are robust given the dependence between multiple ESs.

[2] Although the correlation coefficient between *Degree1* and *Duration100* is fairly large at -.59, a high correlation is expected from the QE definition and neither moderator shows high correlations with other moderators.

[3] One such moderator that would require investigation is the type of sport task. Processes underpinning performance in self-paced and externally-paced tasks are somewhat different and the QE period might have a different role in these two kinds of tasks.

[4] In the basketball free throw task, the basketball enters the visual field of elite shooters near to the eyes, and occludes the hoop thus perturbing fixation on the target before the end of the movement. The constraints found in the task are what lead to an early QE offset in elite shooters.