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RUNNING HEAD: DECEPTION AND THE QUIET EYE

TITLE: Aiming to deceive: Examining the role of the quiet eye during deceptive aiming actions

Abstract

In three experiments, we explored the use of deceptive gaze in soccer penalty takers using eye-tracking equipment. In Experiment 1, players competed against a goalkeeper while taking unconstrained shots. Results indicated that when players used deception (looking to the opposite side to which they shot) they extended the duration of their final aiming (quiet-eye; QE) fixation and maintained shooting accuracy. In Experiment 2, with no goalkeeper present players still used extended QE durations when using a deceptive strategy, but this time their accuracy suffered. In Experiment 3, we manipulated the goalkeeper's location while controlling for the use of peripheral vision and memory of goal size. Results indicated that increased QE durations were required when using deceptive aiming, and that accuracy was influenced by the position of the goalkeeper. We conclude that during deceptive aiming, soccer players maintain accuracy by covertly processing information related to the goalkeeper's location.

Keywords: Deception, Gaze, Penalty kicks, Soccer, Head-fakes, Peripheral vision

Introduction

The ability to predict the mental state and behavioral intentions of others from their gaze direction has been fundamental to our evolutionary success (Emery, 2000). Accordingly, humans have developed a predisposition to focus on the gaze direction of others when attempting to interpret and anticipate their future actions (Blakemore, Winston, & Frith, 2004). For example, Nummenmaa, Hyona and Hietanen (2009) have shown that pedestrians use eye-movements to indicate their intended direction of travel, and that approaching pedestrians use this information to avoid collisions. However, the predisposition to focus on the gaze of others can be exploited through the use of deceptive gaze behaviors that aim to disguise the deceiver's future intentions (Emery, 2000). Such deceptive behaviors are readily observable in sport (Güldenpenning, Kunde & Weigelt, 2017).

In a sporting context these deceptive behaviors are often referred to as 'head-fakes' (e.g., Basketball; Kunde, Skirde & Weigelt, 2011) and are characterized by performers faking gaze in one direction whilst shooting or passing to another. At the heart of their use is a deliberate attempt to misdirect the attention of an opponent and negatively influence their responsive actions in order to create a performance advantage. Despite their frequency in sport, there have been few empirical studies that have explored the cognitive factors behind their use (Kunde et al, 2011). Those that have done so have focused on expert and novice differences in the ability to detect deceptive actions across a range of sports; including handball (Canal-Bruland & Schmidt, 2009; Canal-Bruland, van der Kamp, & van Kesteren, 2010), rugby (Jackson, Warren, & Abernethy, 2006), basketball (Sebanz & Shiffrar, 2009) and soccer goalkeeping (Dicks, Uehara, & Lima, 2011; Smeeton & Williams, 2012; Tomeo, Cesari, Aglioti, & Urgesi, 2012). The consensus from these studies suggests that experts are better able to detect deceptive behaviors and this advantage seems to be attributable to their superior experience in both perceiving and performing the observed actions (Canal-Bruland et al, 2010). While the ability of the observer to detect deceptive actions has obvious and important implications for performance in sport, there are consequences of employing such behaviors from the deceiver's perspective.

Evidence for such implications comes from both motor control research suggesting that visually-guided motor performance is optimized when the gaze system provides advanced target information to the motor system (Land, 2009), and from cognitive psychology research suggesting that deceptive behaviors are inherently more cognitively complex (Zuckerman, DePaulo, & Rosenthal, 1981). Therefore, employing head-fakes – which disassociate gaze from aiming intention – should have a detrimental impact on performance, particularly in aiming tasks where the processing of target related parameters is crucial. Indeed, dissociation of gaze and aiming intention impairs performance in simple visuomotor tasks such as pointing (Neggers & Bekkering, 2001) and more dynamic tasks such as driving (Wilson, Chattington, & Marple-Horvat, 2008). Therefore, any benefit of employing head-fakes arising from increasing the complexity of the observer's decision-making process must be weighed up against the increased difficulty of performing the skill while dissociating gaze and intention.

In sport, this coordination of gaze and motor systems has received much research attention in the exploration of key perceptual-cognitive variables that underpin expert performance (see Mann, Williams, Ward, & Janelle, 2007 for a review). One such measure, the quiet eye (QE; Vickers, 1996) – defined as the duration of the final fixation toward a relevant target before the initiation of a critical movement - has been proposed to provide a period of cognitive pre-programming of movement parameters (force, direction and velocity) immediately before an aiming skill is performed (Vickers, 1996, 2007). As task complexity and pre-programming demands increase, so does the QE period (Klostermann, Kredel, & Hossner, 2013; Sun, Zhang, Vine, & Wilson, 2016; Williams, Singer, & Frehlich, 2002; Wood, Vine & Wilson, 2013). It is therefore probable that deceptive visuomotor actions will also require such extensions of cognitive pre-programming in order to compensate for the dissociation between gaze and aiming intention and the resultant increase in task demands that arise.

Furthermore, this dissociation is likely to have implications for the overt and covert attentional processes used during QE durations. Unlike typical aiming skills where the target is fixated during (e.g., darts) or before (e.g., golf-putting) the critical movement using overt attentional processes (via foveal vision; Vickers, 2007), deceptive aiming actions are likely to rely on covert attentional processes (via peripheral vision) in order to extract target-related information necessary to parameterize the shot and ensure accuracy. Interestingly, covert attentional processes have also been shown to increase QE aiming durations (Querfurth, Schücker, de Lussanet, & Zentgraf, 2016) possibly due to the inhibition of not-to-be parameterized movement variants (Klostermann, Kredal & Hossner, 2014). Taken together, this may suggest a degree of flexibility regarding the attentional processes underpinning the QE and the type of information that can be used during QE durations to guide accurate aiming.

One sporting task where deceptive eye-movements have been recently shown to be prevalent is the soccer penalty kick. Early research (Kuhn, 1988) identified two aiming strategies: keeper-dependent - where the kicker focuses on the movements of the goalkeeper and responds by shooting in the opposite direction to which (s)he dives; and keeper-independent - where the kicker aligns gaze with aiming intention and looks where they intend to shoot. Wood and Wilson (2010a) uncovered a third strategy, which they labeled the opposite-independent strategy; characterized by players looking to the opposite side of the goal to which they shoot, a behavior that is often colloquially referred to in soccer as “giving him/her the eyes”. At the heart of this strategy is the deliberate attempt to deceive or mislead the goalkeeper in order to disguise the kicker’s true aiming intention (Wood & Wilson, 2010a).

An intriguing finding from this study was that players were just as accurate when employing head-fakes as they were when using the keeper-independent strategy (looking where they intended to shoot). This is surprising given the consensus of experimental research that has explored the visual aiming strategies of soccer penalty takers suggests that shooting accuracy is significantly impaired if players decouple gaze and aiming intention whilst shooting; for example, inducing aiming fixations to the goalkeeper causes shots to be more centrally distributed (Binsch, Oudejans, Bakker, & Savelsbergh, 2010; van der Kamp, 2011; Wilson, Wood & Vine, 2009; Wood & Wilson, 2010a, 2010b, 2011, 2012). Therefore, how do players maintain shooting accuracy despite dissociating gaze from aiming intention when employing head-fakes? What compensatory visual or attentional processes are involved in protecting performance? And why is this decoupling strategy not as debilitating to performance as the keeper-dependent approach?

In the following three experiments, we aim to provide an examination of the attentional and/or performance costs behind deception in soccer penalty shooting. This represents an intriguing shift in research focus from the perceiver to the deceiver, and may offer an insight into the compensatory processes that underpin head-fakes in aiming-based tasks. In Experiment 1 we extend the work of Wood and Wilson (2010a) by examining the gaze behavior of penalty takers and the effects of these on the anticipatory performance of the goalkeeper. We hypothesized that when players used a deceptive strategy they would be able to maintain accuracy as long as they lengthened their QE aiming fixations (to the opposite side of the goal) to compensate for increased task demands (as Klostermann et al., 2013; Williams et al., 2002). We further hypothesized that the deceptive nature of the strategy would negatively affect the anticipatory performance of the goalkeeper – causing him to dive to the wrong side on more occasions than when using the keeper-independent strategy (as Dicks et al., 2011).

Experiment 1

Method

Participants

Ten experienced (mean competitive experience = 9.6 years, *SD* = 3.41) male university level soccer players (mean age = 20.3 years, *SD* = 1.16) and one experienced goalkeeper (age = 31 years; experience = 24 years) gave written consent to partake in the study after procedures were approved by a local ethics committee. [1]

Apparatus

A standard size 5 soccer ball was shot from the standard penalty kick distance (11 meters) towards a full sized soccer goal (7.32 m wide x 2.44 m high) that was marked out on an adjacent wall. To allow the goalkeeper to dive freely and reduce the potential for injury, gym mats (32mm thickness) were used to cover the full width of the goal. Participants were fitted with an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye tracker, which measures eye-line of gaze at 25Hz, with respect to eye and scene cameras, mounted on a pair of glasses. The system incorporates a recording device (a modified digital video cassette recorder), worn in a pouch around the waist, and a laptop (Dell inspiron6400) with 'Eyevision' recording software installed. A circular cursor, representing 1° of visual angle with a 4.5-mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ± 0.5° visual angle; 0.1° precision) is recorded for offline analysis.

Procedure

In order to familiarize participants to the testing environment and apparatus, each participant attended individually and took ten practice penalty kicks with no goalkeeper present. Participants were then calibrated to the eye-tracker using locations on the goal, took a single block of ten penalty kicks against the goalkeeper and were told that they should try to score as many kicks as possible, similar to real competition. This procedure was repeated over three consecutive weeks resulting in an individual sample of 30 kicks per participant and an overall potential sample of 300 kicks. In order to minimize errors in data collection, calibration was checked after every kick. Previous research (Wood & Wilson, 2010a) has shown that by allowing penalty takers to take a series of kicks, they naturally alternate the shooting strategies they use and this allowed us to produce a mix sample of kicks without giving any instruction to the players. During testing, the goalkeeper was asked to attempt to save as many shots as possible and was given a minimum of 10 minutes rest between participants to prevent fatigue.

Shooting Strategies

Each shot taken was categorized into one of the three strategies outlined in previous research (e.g., Wood & Wilson, 2010a), based on the location of the final (QE) fixation prior to the initiation of the run-up. Specifically, keeper dependent (KD), final fixation on the goalkeeper; keeper independent (KI), final fixation on the target area to which the ball was kicked; and the deceptive kicking strategy (previously referred to as the opposite independent strategy; Wood & Wilson, 2010a), final fixation to one side of the goal with a resulting shot to the opposite side.

Measures

Quiet eye. Each half of the goal was divided into six zones of 61 cm and these were used to map the location of the QE fixation from each post (0cm) to the center of the goal (183cm). Lower numbers therefore represent a distal aiming strategy (i.e., further away from the goalkeeper). QE aiming fixations were determined via frame-by-frame analysis of the eye-tracker video file using Quiet-Eye Solutions analysis software and were defined as the last fixation on the goal that started prior to, and extended beyond, the initiation of the run-up (as Wood & Wilson, 2011). This definition of the QE therefore reflects the final fixation of the aiming phase that often extends into the early part of the execution phase (run-up). A fixation was classified as three or more consecutive frames (≥120ms) in which the cursor stayed in the same location (Vickers, 1996). The QE was therefore defined in terms of its location (distance from post) and duration (ms). Interrater reliability of 85 shots revealed an agreement of 98%.

Performance. As shots hit closer to the post and further from the goalkeeper are more likely to be successful (Bar- Eli & Azar, 2009; Kerwin & Bray, 2006), we measured shooting accuracy by measuring the distance in centimeters from shot placement (the center of the ball) to the post. Therefore, lower values reflected shots that were hit closer to the post and further from the goalkeeper. Shots that missed the goal were not given an accuracy score, those that were saved were given an estimated score relating to where they would have hit the goal (Wood & Wilson, 2011). The location of a shot was determined via frame-by-frame analysis of the eye-tracker video file using Quiet-Eye Solutions analysis software with a precision of 5 cm (approximately one quarter the diameter of the ball) in the same manner as the location of the QE data. Estimates of shooting accuracy from a sample of 72 shots revealed an inter-rater reliability of 96%. The number of goals, saves, and misses were recorded for each strategy, as was the number of times that the goalkeeper moved or dived to the opposite side to which the players shot the ball. These tallies were converted to percentages (of the total number of shots taken using the strategy) for subsequent comparisons.

Data Analysis

A one-way repeated measures ANOVA was used to compare differences in the location and duration of QE, and shooting accuracy for each of the three shooting strategies identified by Wood and Wilson (2010a). Significant effects were followed up with Bonferroni corrected pairwise comparisons and effect sizes were reported using eta squared statistics (η^2). To assess the effectiveness of each strategy, the outcome of the shot (goal, miss, save) and the direction that the goalkeeper dived (correct/incorrect side to the eventual shot) was analyzed using hierarchical log linear regression and significant interactions were followed up using chi-squared tests at each level of the variable. Effect sizes were reported using Cramer's *V* statistics with 0.1, 0.3 and 0.5 representing small, medium and larger effect sizes respectively (Cohen, 1998).

Results

Descriptive Statistics

Out of the 300 kicks taken; 65 were executed with a keeper-dependent strategy; 92 with a keeper-independent strategy; and 85 with the deceptive strategy. A further 32 kicks were executed with no target-focused fixations on the goal or goalkeeper and 26 were not coded due to calibration issues (e.g., loss of calibration).

Quiet Eye

ANOVA revealed a significant difference between the location of QE across strategies, $F(2,241) = 489.10$, $p < .001$, $\eta^2 = .80$. The keeper-dependent shots had more centralized QE locations compared to keeper-independent ($p < .001$) and deceptive shots ($p < .001$). No significant differences were evident in QE locations between keeper-independent and deceptive shots ($p = .658$). The QE duration of these fixations was also significantly different, $F(2,239) = 5.80$, $p = .003$, $\eta^2 = .05$, with deceptive kicks having significantly longer QE durations than keeper-independent shots ($p = .002$). No significant difference was evident in QE durations between deceptive and keeper-dependent shots ($p = .352$) or between keeper-dependent and keeper-independent shots ($p = .377$). These data are presented in Table 1.

Performance

ANOVA revealed a significant difference between shooting accuracy across kicking strategies, $F(2,203)^{2} = 7.10$, $p = .001$, $\eta^2 = .06$. Specifically, keeper-dependent shots were significantly more centralized compared to keeper-independent ($p = .001$) and deceptive shots ($p = .010$). No significant difference was evident between shooting accuracy for keeper-independent and deceptive shots ($p = 1.000$).

Hierarchical log linear regression revealed no significant effect between strategy used and the number of goals, misses and saves, χ^2 (2) = 6.52, $p = .164$, $V = .102$. A significant effect was found in the goalkeeper's reaction to each strategy, χ^2 (2) = 10.34, $p = .006$, $V = .207$. When players employed the deceptive strategy there was a significant decrease in the anticipatory performance of the goalkeeper compared to keeper-independent, χ^2 (1) = 6.70, $p = .010$, $V = .195$, and keeper-dependent, χ^2 (1) = 8.15, $p = .004$, $V = .224$, shots. No significant differences were evident between the goalkeeper's anticipatory behavior between keeper-dependent and keeper-independent shots, χ^2 (1) = .28, *p* = .599, *V* = .084. These data are presented in Table 2.

Discussion

In this first experiment we investigated the gaze strategies of soccer players as they attempted to score penalties against a goalkeeper in an unconstrained environment. Specifically, we hoped to examine if deceptive gaze behavior was effective in deceiving the goalkeeper, and if compensatory extensions to pre-programming visual attention protected against any accuracy impairment caused by the dissociation between gaze and aiming intention. The results of this first experiment partially supported our hypotheses, with players exhibiting significantly longer QE durations when employing the deceptive strategy compared to when they aligned gaze with aiming intention (keeper-independent strategy).

One potential caveat to this interpretation is our assumption that the extended QE durations seen in deceptive kicks are indicative of supplementary and compensatory pre-programming. An alternative explanation for these extended QE durations could be that players are deliberately attempting to exaggerate their gaze behavior (and deceptive intention) in order to 'sell' the head-fake to the goalkeeper. In fact, exaggerated gaze behaviors are synonymous with deception (e.g., lie detection; Mann, Vrij, Leal, Granhag, Warmelink, & Forrester, 2012) and deceptive actions (e.g., magic; Rieiro, Martinez-Conde & Macknik, 2013), and it has previously been shown that soccer penalty takers do use exaggerated body cues when attempting to fool the goalkeeper (Smeeton & Williams, 2012). An 'exaggeration' explanation, however, does not explain how players maintained their shooting accuracy despite the dissociation of gaze from aiming intention that is synonymous with poor performance in this task (Binsch et al., 2010; van der Kamp, 2011; Wilson et al., 2009; Wood & Wilson, 2010a, 2010b, 2011, 2012). A further potential explanation is that players used information gathered from goal scanning behavior prior to their final (deceptive) fixation to aim their kick accurately. However, out of the 85 shots taken with the deceptive strategy, only 19 shots (22%) were taken after players made a fixation to the side of the goal to which they would eventually shoot. By negating the need to exaggerate deception and preventing any pre-shot scanning behavior, in Experiment 2 we will explore the possibility that players are using some form of covert processing of target-related information in order to compensate for not looking to where they intend to shoot.

A further interesting finding from Experiment 1 was that there was no significant difference between QE durations when players used a deceptive strategy compared to when they used a keeper-dependent strategy (Table 1), yet the accuracy scores between these strategies differed significantly (Table 2). While both strategies purposefully dissociate gaze from aiming intention prior to shooting, the effect that this had on performance suggests that there are fundamentally different attentional processes being used to guide the eventual kick. Specifically, we propose that the deceptive strategy is an aiming strategy where auxiliary target-related information, extracted through covert attentional processes, is being processed in order to guide accurate shooting. On the other hand, the keeper-dependent strategy is an overt attentional strategy that is reflective of an anticipatory, temporally constrained behavior that is linked to the movements of the goalkeeper (Van der Kamp, 2011). By fixating on the goalkeeper, it may be possible to detect movement cues regarding which way he might dive and therefore reduce the demands for accurate aiming (shooting into the now open goal on the other side). However, previous research has suggested that the goalkeeper dependent strategy is associated with a loss of self-reported control (Wood & Wilson, 2012) and can be problematic if the goalkeeper delays moving (van der Kamp, 2006).

Finally, when players utilized deceptive gaze they significantly disrupted the anticipatory performance of the goalkeeper, with him diving to the opposite direction to which the ball was shot on significantly more occasions (54%) compared to when players shot with non-deceptive keeper-dependent (30%) and keeper-independent (34%) strategies. While the effectiveness of deceptive behaviors for negatively biasing goalkeeper anticipation has been reported in previous studies (e.g., Smeeton & Williams, 2012), this study highlights further benefits of using deception when taking soccer penalties. Not only are players more likely to deceive the goalkeeper – who tends to fixate the penalty taker's head during this aiming period (see Dicks, Button, & Davids, 2010) - but they can be just as accurate in their shooting by exaggerating this long fixation to the 'wrong' side.

In summary, in this first experiment we showed that the maintenance of shooting accuracy seen when using the deceptive strategy seemed to be underpinned by extended QE durations that provide covert supplementary pre-programming time and resources as a way of compensating for the decoupling of gaze and aiming intention. In experiment 2, we hoped to solidify these conclusions by removing the need for deception, and by removing the goalkeeper, in order to control for exaggeration effects of increased QE duration.

Experiment 2

Participants

Twenty-five right-footed male university soccer players (mean age = 20.7 years, *SD* = 1.69), who were not involved in Experiment 1, volunteered to take part. All participants gave written consent to partake in the study after procedures were approved by a local ethics committee.

Apparatus

The same goal dimensions were marked out on a plain wall as in Experiment 1. Participants were fitted with an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye-5 eye tracker, which measures eye-line of gaze at 30Hz.

Procedure

Participants attended the lab individually and were first given ten practice kicks before being calibrated to the eye-tracker using nine calibration points located on the goal. The KI and deceptive kicking strategies were then explained to the participants and they were told that they would be required to take kicks, while alternating these strategies. Participants always looked to the right-hand side bottom corner of the goal (from their perspective) but alternated where they shot to depending on the strategy employed. They then took five practice shots using each strategy. Each participant then took 30 kicks (two counterbalanced blocks of 15 kicks) using alternate kicking strategies. This produced a total sample of 750 kicks (375 for each strategy). After each shot the experimenter reminded the kicker of the next strategy to be used. During the experiment, participants' eye-movements were monitored on a laptop to ensure they adhered to the gaze instructions and only looked where directed prior to shooting. When they did not adhere to these instructions, they were told that the kick was invalid and they were required to retake the shot.

Measures and Data Analysis

Shooting accuracy was measured using Kinovea video analysis software (http://www.kinovea.org/) and interrater reliability scores, based on a sample of 50 shots, was 94%. Using a scaling factor that was visible in the scene view of the eye-tracker (i.e., the height of the post), we measured the distance (cm) from the center of the ball when it hit the wall and the post. QE durations were measured in exactly the same manner as Experiment 1. Gaze data for two participants were lost due to corrupt video files. Interrater reliability scores for the location and duration data on a sample of 50 shots was 98% and 93% respectively. Paired sample *t*-tests were used to explore differences in QE locations, QE durations and shooting accuracy across KI and deceptive kicking strategies. Effects sizes were reported using Cohen's *d* statistic where 0.2, 0.5 and 0.8 represented small, medium and large effect sizes respectively (Cohen, 1998).

Results

Quiet-eye. A significant difference between QE durations, $t(22) = 2.94$, $p = .008$, $d = .55$, revealed that a deceptive strategy required longer QE durations compared to the KI strategy. No significant difference was found between the location of this fixation across deceptive and KI strategies, $t(22) = .405$, $p = .689$, $d = .08$. (See Table 3).

Performance. A significant difference in shooting accuracy, $t(24) = 2.48$, $p = .020$, $d = .62$, revealed that players were significantly less accurate when shooting with a deceptive strategy compared to the KI strategy (See Table 3).

Discussion

This second experiment was designed to explore the possibility that the extensions of QE durations seen in Experiment 1 were attributable to the pre-programming of more complex shot information due to the deliberate decoupling of gaze and aiming intention - rather than merely trying to exaggerate the ‘head fake’ to the goalkeeper. Our data, at least partially, support the former rather than latter explanation. With no goalkeeper present, there was no longer any need for the players to attempt to be deceptive and exaggerate their gaze, yet they still extended their QE durations. From this, we conclude that the increased complexity of the shot imposed supplementary processing demands on the players resulting in extensions to QE aiming durations (Klostermann et al 2013; Williams 2002).

However, in contrast to Experiment 1, these extensions to QE aiming durations did not help kickers to maintain shooting accuracy when using deceptive kicks, as shots taken with this strategy became significantly centralized (~ 23cm) and therefore less accurate compared to KI shots. One explanation for this reduction in accuracy may be that eliminating pre-kick scanning behavior meant that players did not have the necessary information to guide their shot. However, as relativity few shots were taken in experiment 1 using this behavior, it is unlikely that this can explain the effect.

A further explanation is that some important information, which players depended on to help guide their shot in Experiment 1, was missing in Experiment 2: the goalkeeper (Masters, van der Kamp, & Jackson, 2007). Consequently, players could have resorted to using peripheral vision and/or memory of the goal dimensions to try to maintain shooting accuracy to the opposite side of the goal. Interestingly, these explanations may explain why shots became less accurate. First, targets focused on in the periphery look smaller than targets focused on in the fovea (Newsome, 1972). Therefore, if the players resorted to using peripheral vision to guide their shot, the goal would have looked smaller than it actually was which could impair shooting performance (Wood et al, 2015). Similarly, using an internal representation of the dimensions of the goal to guide their shot is inefficient as previous research has suggested that *"stored target information serving memory-guided action is susceptible to a compression of visual space in memory such that the egocentric distance of a remembered target is underestimated"* (Heath & Binsted, 2007, p. 169). For the final experiment, we devised a penalty-kicking task that would allow an exploration of the importance of the spatial location of the goalkeeper during deceptive penalty shots whilst reducing the contribution of information in peripheral vision and memory.

Experiment 3

Research in penalty taking has highlighted that penalty takers are very sensitive to the spatial relationship between the goalkeeper's position and the goal posts that constrain the target area (Masters et al., 2007). Indeed, these authors demonstrated that when a goalkeeper creates even 0.5 % differences in space in the goal by standing marginally off-center, penalty-takers can reliably discriminate which side has more space at above chance levels, despite reporting that their decisions are guessed (see also Noël, van der Kamp, & Memmert, 2015). It is therefore likely that the goalkeeper's position provides information critical for the processing of spatial parameters important for aiming. We therefore suggest that in order to simplify the computation problem in aiming with a deceptive gaze strategy, soccer players apply a mirroring algorithm – effectively converting the kicking angle for the side they fixate (made by the triangle between the ball, the post and the goalkeeper), to the opposite (un-fixated) side (see Figure 1).

The aim of this third experiment was to explore the contribution that spatial information provided by the goalkeeper's location provides towards the maintenance of shooting accuracy when gaze and aiming intention are decoupled, while attempting to eliminate goal-related information from peripheral vision and memory. We again hypothesize that when players decouple gaze from aiming intention, they will employ compensatory extensions in QE durations (as in Experiment 1 and 2). We suggest that the difference in performance between Experiments 1 and 2 is due to the removal of information from the relative space between goalkeeper and post from one side of the goal, which is utilized in the formulation of a shot to the opposite side of the goal. In order to test this, we experimentally manipulated the position of the goalkeeper (moving closer to the post) and hypothesize that this would disrupt subsequent performance (Figure 1).

Methods

Participants

Twenty-three experienced (mean experience = 12.83 years, *SD* = 3.72) right-footed male university level soccer players (mean age = 20.3 years, *SD* = 1.52), who were not involved in Experiments 1 or 2, gave written consent to partake in the study after procedures were approved by a local ethics committee.

Apparatus

Participants wore the same eye-tracker as in Experiment 2 and shot to two randomized goals that were projected (Hitachi XGA, CP-X275) onto a blank wall from a distance of 6-meters. Goal and goalkeeper projections were used in order to (1) allow for the alternation of goal size and goalkeeper location in an efficient manner; (2) allow for the elimination of target-related information from peripheral vision without constraining the vision of the kicker, and (3) allow for the maintenance of the spatial relationship between the goalkeeper and goal while eliminating the negative effect his/her mere presence can have (Navarro, van der Kamp, Ranvaud & Savelsbergh, 2013; Wood & Wilson 2010a; Wilson et al., 2009). Due to the need to project the goal, the distance of the penalty shot was reduced and we therefore decided to use a modified (indoor) penalty kick with a restricted (1-step) run up (as used by Wood & Wilson, 2010a). By controlling these aspects of the experimental design, we can be more confident that any effects observed from the manipulation of goalkeeper position are attributable to the spatial manipulation alone.

Each projected goal measured two meters in height but differed in width (4 v 3.6 meters; see Figure 2). These differing sizes were incorporated to reduce the impact of memory of goal size in the aiming task and minimize any learning effects from repeatedly shooting to the same goal [3]. To minimize the use of peripheral vision, only the right half of each goal was shown. All presented goals also had a projected image of a goalkeeper (height 1.80m) that was situated in two counterbalanced locations (directly in the center of the goal ‘center’ and then 0.5 meters to the right ‘off-center’). For each goal, a colored target (30cm x 30cm) was visible in the bottom right-hand corner. A green target signaled to the player that he was to shoot with the KI strategy (look where he was shooting) and a red target signaled to the player to shoot with a deceptive strategy (look at the target but attempt to hit the same location on the opposite side of the goal). Players shot using an indoor Mitre Cyclone football of standard inflation. Shot location was recorded using a Panasonic SDR-S26 (60Hz) camcorder that was located one meter to the right of the penalty spot.

Procedure

Players attended individually and once calibrated to the eye-tracker, they took 10 practice shots to familiarize themselves with the ball, shooting distance and goal projections. Players were then shown examples of each goal with differing goalkeeper positions and both colored targets. Players were told that they should attempt to shoot as close to the post as possible;

whether that was the post in the direction that they were shooting (KI strategy) or the estimated post location in the opposite corner of the goal (deceptive strategy). It was explained to participants that before each shot they were required to turn around with their back facing the goal. The researcher would then give a verbal indication for them to turn around and take their next shot. It was further explained that on foot-to-ball contact the projected goal would disappear (manually controlled by the first author) and when they noticed it had disappeared they were required to turn around with their back to goal and await their next shot. During this period, a projection of the full sized goal was displayed as a frame of reference for post-hoc video analysis of the accuracy of each shot (see Measures). The next target configuration was then projected, the ball replaced on the penalty spot by a researcher, and the participant was instructed to turn around and take their next kick. This procedure was incorporated to minimize the participant's ability to use knowledge of results of previous shot to support subsequent shots (Wood, Vine & Wilson, 2013). Participants repeated this procedure for three blocks of twelve kicks (36 kicks) yielding a total sample of 828 kicks (414 kicks for each strategy). Each block was preceded by a calibration chart to ensure calibration of the eye tracker was maintained. A mean value for each participant in each condition was computed and used for subsequent analyses.

Measures

Quiet eye. Due to the adoption of a simplified penalty kicking task (with no run-up) the QE was defined as the location and duration of the last fixation on the target (situated in the bottom corner of the goal) prior to foot-to-ball contact (as Wood & Wilson, 2010a). As such the definition still reflects the final aiming fixation before initiating the start of the first movement in the penalty taking action (the run up in experiments 1 and 2; and the swing of the leg to kick the ball in experiment 3; see also Binsch et al., 2010). QE aiming fixations were determined via frame-by-frame analysis of the eye-tracker video file using Quiet-Eye Solutions analysis software and a fixation was classified as three or more consecutive frames (≥120ms) in which the cursor stayed in the same location (Vickers, 1996). Interrater reliability scores for the location and duration data on a sample of 50 shots was 98% and 94% respectively.

Performance was measured as the distance (cm) between the center of the ball as it hit the wall and the projection of the goalpost using Kinovea video analysis software. As in Experiments 1 and 2, lower values reflected shots that were hit closer to the post and further from the goalkeeper. Interrater reliability scores on a sample of 50 shots was 96%.

Data Analysis

Quiet eye and performance data were subjected to 2 x 2 repeated measures ANOVAs (strategy x goalkeeper location) and significant interaction effects were followed up with Bonferroni corrected pairwise comparisons. Effect sizes were reported using partial eta squared statistics (η_p^2) where 0.1, 0.6 and 1.4 represented small, medium and large effects sizes respectively (Cohen, 1998).

Results

Quiet Eye

For QE duration, ANOVA revealed a significant main effect for kicking strategy, $F(1,20) = 62.50$, $p < .001$, $\eta_p^2 = .76$, but not for goalkeeper location, $F(1,20) = 0.07$, $p = .93$, $\eta_p^2 = .00$. The interaction between goalkeeper location and strategy was non-significant, $F(2,40) = 2.69$, $p = .12$, $\eta_p^2 = .12$ (See Table 4). The deceptive strategy involved significantly longer QE durations to the projected target than the KI strategy. No significant differences were found for the location of this fixation across kicking strategies, $F(1,20) = .11$, $p = .746$, $\eta_p^2 = .01$, or goalkeeper locations, $F(1,20) = .37$, $p = .549$, $\eta_p^2 = .02$, and the interaction was not significant, $F(1,20) = .01$, $p = .932$, $\eta_p^2 = .00$.

Performance

A significant main effect was found for strategy, $F(1,21) = 32.79$, $p < .001$, $\eta_p^2 = .61$, and for goalkeeper location, $F(1,21) = 10.82$, $p = .003$, $\eta_p^2 = .27$. A significant interaction, $F(2,42) = 7.57$, $p = .012$, , $\eta_p^2 = .27$, between strategy and goalkeeper position was also revealed. Post hoc pairwise *t*-tests showed that when players used the deceptive strategy they were significantly more accurate when the goalkeeper was located in the center of the goal compared to when he was off-center ($p = .001$). The position of the goalkeeper did not significantly affect shooting accuracy when players used the KI strategy ($p = .972$; See Table 4). However, when the goalkeeper was located in the center of the goal the shooting accuracy of KI shots was significantly more accurate ($p < .001$) than shots taken with the deceptive strategy.

Discussion

The aim of this final experiment was to explore the contribution that angular information pertaining to the goalkeeper's location makes to the maintenance of shooting accuracy when players disassociate gaze from aiming intention during head-fakes. As predicted and in line with the two previous experiments, a deceptive shooting strategy induced significantly longer QE aiming durations in order to compensate for the decoupling of gaze from aiming intention. Furthermore, when we manipulated the spatial location of the goalkeeper during deceptive shots shooting accuracy centralized significantly (Table 4). Therefore, when the visual angle between goalkeeper and post was made more acute, resultant shooting angle also became more acute and shots became centralized. However, in contrast to Experiment 1, this time we found that the deceptive strategy was not as accurate as the KI strategy when the goalkeeper was located in the center of the goal, despite longer aiming durations.

There are a number of differences between the two experiments that might explain why we failed to replicate the maintenance of accuracy from Experiment 1. First, the KI condition in Experiment 3 was effectively a simple aiming task; with no need to beat the goalkeeper, players were free to allocate all of their attentional resources to the preprogramming of target-related information necessary for accurate shooting. In Experiment 1, this was not as straightforward and the goalkeeper would likely receive covert attention in all attempts (KI, KD, and deceptive). The KI data from Experiment 3 underlines the accuracy that players are capable of if they can learn to adapt to, or ignore, the presence of the goalkeeper. It also suggests that training these attentional abilities offers scope for practical interventions for penalty takers (e.g., Wood, Jordet & Wilson, 2015).

Second, in this experiment, the choice of strategy was driven by the experimental manipulation rather than an active decision from the participant (cf. Experiment 1). Therefore, there are likely additional attentional demands in inhibiting the proponent response to shoot to the target and to inhibit gaze from being directed to the opposite side of the goal to the abstract target (similar to attentional effects seen in Stroop aiming tasks; see Wood, Vine & Wilson, 2015). While these differences make performance comparisons across experiments problematic they do not undermine the central findings regarding our first hypothesis: Deceptive gaze increased task complexity and induced compensatory extensions in QE durations.

General Discussion

The results of all three experiments showed that when players use deceptive gaze they engage in the supplementary processing of other target-related information (evidenced through extensions in QE durations) in order to maintain performance. Specifically, the location of the goalkeeper and the relative geometric information this provides seem a particularly important source of information that players can use during deceptive kicks. While these three experiments were focused on the task of penalty kicks, the findings have wider implications for: (1) understanding the attentional and performance costs of employing deceptive gaze strategies in general; (2) the mechanisms behind the QE phenomenon in aiming tasks; and (3) the utility of angular information and peripheral vision in the control of skilled action.

First, despite the widespread use of deceptive gaze in sport, little empirical evidence exists to support the utility of such behaviours and no studies have explored the attentional cost behind their use. What is clear from this research is that decoupling gaze from aiming intention increases the complexity of the aiming action, increases the demands of the task and requires supplementary pre-programming of other, more complex, target-related information (e.g., goalkeeper location) in an attempt to safeguard against performance decrements. When this important information is missing (Experiment 2) or manipulated (Experiment 3) then shooting accuracy suffers despite extended QE durations.

However, if a goalkeeper makes use of this deceptive gaze information to help base his/her decision on which side to dive (Dicks et al., 2010), then this might be a useful strategy for players to use, as there is no longer a need for a high level of accuracy. Research exploring the effectiveness of gaze misdirection in magicians does provide a cautionary note however (Cui, Otero-Millan, Macknik, Mac King, Martinez-Conde, 2011; Rieiro et al, 2013). While magicians believe that gaze misdirection is one of the most powerful tools in their repertoire, conjuring tricks are just as effective when the magician's gaze is occluded (Rieiro et al, 2013). Therefore, the compulsion to employ head-fakes probably stems from an overinflated view of the importance of gaze in deceiving the observer. If direction of gaze has little influence on the decision making of goalkeepers then players might find it useful to combine these strategies by looking where they intend to shoot while also employing exaggerated and deceptive body movements to the opposite direction. Future research should seek to understand the role of player's gaze in guiding the decision making of goalkeepers.

Second, our results support the information processing account for how longer QE durations support far aiming performance. In this explanation, the QE is proposed to be related to the length of time required for the pre-programming of target related information and the fine-tuning of movement responses (Vickers, 1996, 2007). Recent research has found support for this proposal by correlating longer QE durations with more difficult task demands (e.g., Klostermann et al., 2013; Williams et al., 2002); with neural measures of pre-programming (e.g., Bereitschaftspotential, Mann et al., 2011); and by utilizing illusions to bias pre-planning (Wood et al., 2013). In Experiment 1, players revealed significantly longer QE durations when adopting a deceptive strategy, and in Experiments 2 and 3, players utilized significantly longer QE durations when the task was more difficult (shooting to a mirror position as opposed to what they fixated on). One issue with trying to interpret the compensatory nature of this extended QE duration is that while longer QE durations are generally associated with better performance, they are also associated with increased task difficulty; conditions when performance is likely to be poorer (see Walters-Symons et al., in press, for further discussion). As such, we are unable to dissociate the combined and opposite effects of manipulation and performance outcome on QE with this design.

Third, while the QE is defined in terms of point of gaze, there has been little interest in exploring exactly what type of information is being processed during QE durations (Williams, 2016). Our results suggest that in the context of deceptive aiming strategies, the QE is used for the covert extraction and processing of target-related information related to the spatial positioning of the goalkeeper. Overall while our findings support the assumption that the QE is a period reflecting the extraction and pre-programming of target-related information, it seems that there is a degree of plasticity regarding the type of information that can be used to support successful aiming actions - even within the same task.

To conclude, the results of these experiments suggest that there is an attentional cost of using deceptive gaze strategies in visuomotor tasks, which require covert compensatory adaptations to attentional control. As far as we are aware, this is the first study that has explored the cost of deceptive head-fakes and the effectiveness of deceptive gaze from the deceiver’s perspective. As such, many questions remain to be answered surrounding the utility of such behaviours and how attentional adaptations compensate for the increased complexity that is inherent with their use. Hopefully this can be a fruitful line of research in the near future.

Footnotes

1 These participants are the control group whose performance data in retention and shootout conditions was compared to a quiet eye trained group in Wood and Wilson (2011). These shot strategy and performance data from the three weeks of training have not previously been reported.

2 The reduced degrees of freedom are due to 38 kicks missing the target and 59 kicks being uncodeable (due to the location not being picked up by the gaze registration system).

3 We collapsed the data for both goal sizes for subsequent analyses as we did not have specific hypotheses related to goal size.

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Figure Captions

Figure 1. A visual representation of how the manipulation of goalkeeper location affects visual angle and resultant shooting performance when using a deceptive shooting strategy. The left image (Center) reveals that when the goalkeeper is in the middle of the goal, the angle created by the goalkeeper and post (a) can be mirrored to the opposite post (a'). The right image reveals that the same strategy applied to an Off Center goalkeeper would result in a smaller angle (b) being mirrored (b') which would result in a penalty being struck further away from the opposite post and closer to the center of the goal.

Figure 2. Goal projections showing the large (left) and small (right) goal, the center (left) and 'off-centre' (right) goalkeeper locations, and location of the target (bottom right) that signified to the players which shooting strategy they should use in experiment 3. The goalkeeper was presented in both 'center' and 'off-centre' locations in each goal size projection.

Figure 3. The mean (± s.e.m.) quiet-eye duration (top) and shooting accuracy (bottom) for each strategy (Keeper Independent (KI) and Deceptive) and each goalkeeper location in Experiment 3.

Tables

Table 1. Mean (*SD*) quiet eye (QE) data for each kicking strategy: Keeper Dependent (KD), Keeper Independent (KI) and Deceptive in Experiment 1.

	KD	**KI**	**Deceptive**
Location of QE (cm)	144.92**	83.48	73.41
	(35.10)	(56.11)	(61.92)
QE duration (ms)	281.27	232.28*	332.22
	(257.93)	(137.39)	(194.16)

** *p* < .001 * *p* < .05

Table 2. Mean (*SD*) performance data for each kicking strategy: Keeper Dependent (KD), Keeper Independent (KI) and Deceptive in Experiment 1.

	KD	**KI**	**Deceptive**
Shooting accuracy (cm)	167.17* (106.65)	116.81 (75.27)	124.24 (58.47)
Goals (%)	56.90	69.60	69.40
Saves (%)	30.80	16.30	10.60
Misses (%)	12.30	14.10	20.00
Goalkeeper dived incorrectly (%)	30.80	34.80	54.10*

* $p < .05$

Table 3. Mean (*SD*) quiet eye (QE) and performance data for each kicking strategy: Keeper Dependent (KI) and Deceptive strategy for Experiment 2.

	KI	**Deceptive**
Location of QE (cm)	50.13	52.39
	(28.34)	(25.02)
QE duration (ms)	489.09**	655.75
	(257.93)	(322.84)
Performance (cm)	109.08*	131.76
	(37.88)	(35.59)

** $p < .01$ * $p < .05$

Table 4. Mean (*SD*) quiet eye (QE) and performance data for each kicking strategy: Keeper Dependent (KI) and Deceptive strategy across Centre and Off-Center goalkeeper locations for Experiment 3.

	KI		**Deceptive**	
	Center	**Off-Center**	**Center**	**Off-Center**
Location of QE (cm)	36.76	34.70	35.48	33.81
	(13.53)	(14.17)	(14.07)	(12.21)
QE duration (ms)	466.19	490.47	607.30**	580.00**
	(161.74)	(226.91)	(229.48)	(214.84)
Performance (cm)	41.25	41.36	70.38	86.55**
	(13.38)	(18.58)	(24.46)	(25.15)

** $p < .001$ * $p < .05$