Telling people where to look in a soccer-based decision task: A nomothetic approach

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Research has shown that identifiable visual search patterns characterize skilled performance of anticipation and decision-making tasks in sport. However, to date, the use of experts' gaze patterns to entrain novices' performance has been confined to aiming activities. Accordingly, in a first experiment, 40 participants of varying soccer experience viewed static images of oncoming soccer players and attempted to predict the direction in which those players were about to move. Multiple regression analyses showed that the sole predictor of decision-making efficiency was the time taken to initiate a saccade to the ball. In a follow-up experiment, soccer novices undertook the same task as in Experiment 1. Two experimental groups were instructed to either look at the ball, or the player's head, as quickly as possible; a control group received no instructions. The experimental groups were fastest to make a saccade to the ball or head, respectively, but decision-making efficiency was equivalent across all three groups. The fallibility of a nomothetic approach to training eye movements is discussed.

Keywords: Eye movements, football, learning, sport, visual attention.

Introduction

Experts in many domains are able to allocate their visual attention more effectively and efficiently than novices (see Gegenfurtner, Lehtinen, & Säljö, 2011; and Mann, Williams, Ward, & Janelle, 2007, for reviews). Putative mechanisms for this advantage include the retrieval of pertinent domain-specific material from long-term memory (Ericsson & Kintsch, 1995), the exclusion of redundant information (Haider, 1996; Haider & Frensch, 1999), and the ability to rapidly process visual information in a global, rather than serial, manner (Kundel, Nodine, Conant, & Weinstein, 2007). Although there is some evidence to suggest that low-level oculomotor variables (e.g., saccade velocity, amplitude) may differentiate interceptive sports athletes from those who compete in non-interceptive spor/ts (Morgan & Patterson, 2009), examinations of overt visual attention typically reveal that expert performers employ more effective/efficient high-level strategies: They look at more information-rich areas, take less time to locate those areas, and they use fewer fixations of longer duration on the whole, when compared to novices or less-skilled competitors (Gegenfurtner et al., 2011; Mann et al., 2007) – although more frequent, short-duration fixations appear preferable when task demands change from one requiring a localized focus of visual attention to one necessitating information pickup from a variety of moving sources (e.g., in soccer open play; Roca, Ford, McRobert, & Williams, 2011).

Evidence suggests that the ability to flexibly orient one's attention improves considerably with domain-specific experiences (e.g., Castiello & Umiltà, 1992; Enns & Richards, 1997; Lum, Enns, & Pratt, 2002; Nougier, Ripoll, & Stein, 1989; Nougier & Rossi, 1999).

Pesce, Tessitore, Casella, Pirritano, and Capranica (2007) compared soccer players' and non-athletes' ability to focus visual attention on local and global features of an abstract display. Although soccer players performed inferiorly when identifying targets at the local level, their performance in detecting global targets was superior – as was their ability to switch rapidly from local to visual targets; the authors interpreted this as the soccer players' enhanced capacity for 'zooming out' their attentional focus. In another experimental study, Pesce, Cereatti, Casella, Baldari, and Capranica (2007) found that orienteers aged 60-75 years were more adept than similarly aged non-athletes at rapidly switching focus between global and local features of a display, in keeping with their real-world experiences of switching from a narrow focus on the map to a broad focus on the environment (Eccles, Walsh, & Ingledew, 2002).

Although motor experiences clearly contribute to one's ability to allocate visual attention effectively in sport contexts, perceptual experience also differentiates experts and novices in a variety of domains. Jarodzka et al. (2011) examined the visual search characteristics of experienced biologists and biology students in identifying fish behavior. Not only were the experienced biologists better at identifying the species and its locomotion style, but they also spent less time viewing the videos and more time on relevant than irrelevant regions, comparably to findings from sport experts (Mann et al., 2007). Interestingly, the experts' eye movements also exhibited greater inter-subject variability than those of their less experienced counterparts – which suggests that, for any given task, there may not be a single 'optimal' visual search strategy, even though broad similarities across observers exist (e.g., Yarbus, 1967). Differences in eye movement behavior have also been investigated inexperienced helicopter pilots (Robinski and Stein, (2013). Although there were many similarities between the experts and novices, there was a strong tendency for the skilled practitioners to focus on the instrument panel during the more demanding task – a necessary strategy, in order to land safely – whereas the student pilots made considerably more (task-irrelevant) target fixations.

Despite the idiosyncrasies of individuals' eye movements (Andrews & Coppola, 1999; Boot, Becic, & Kramer, 2009; Robinski & Stein, 2013), researchers have successfully used generic strategies to guide observers' eye movements and thereby facilitate performance on perceptually demanding tasks. Shapiro and Raymond (1989) trained participants' performance on a previously unseen videogame; the aim of the game is to destroy a space fortress while protecting one's own ship against damage. The authors divided participants into two experimental groups: The first received training that optimized their scanpaths (reduced eye movement, generally; *efficient*), while the other received training designed to *increase* the overall amount of eye movement, and therefore reduce the contribution of movement detection via peripheral vision – a key determinant of performance in the videogame; this technique also encouraged repeated saccades to regions of the display that had previously been found to be irrelevant. The efficient group performed superiorly in the game, employing fewer fixations than either the *inefficient* or control groups – whose performance and eye movements did not differ from one another. This suggests that visual information pick-up may be optimized using generic interventions.

The use of experts' eye movement as models to accelerate perceptual learning has gained in popularity of late. In a follow-up to Jarodzka et al.'s (2011) earlier examination of expert-novice differences, Jarodzka, van Gog, Dorr, Scheiter, and Gerjets (2013) asked 75 students to classify fish according to their style of locomotion. Two experimental groups were shown either a dot or a 'spotlight' that focused on key areas of the fish (e.g., fins), which reflected an expert model's gaze behavior, alongside the same model's verbal explanations; the control group received verbal explanations only. Both experimental groups improved in their classification performance relative to the control group; moreover, they fixated on relevant areas of interest (AOIs) more quickly, and spent a longer time looking at those AOIs. Visually guided learning has also been used to accelerate novice surgeons' acquisition of laparoscopic surgery techniques (Chetwood et al., 2012; Vine, Masters, McGrath, Bright, & Wilson, 2012; see Hermens, Flin, & Ahmed, 2013, for a review) and to improve novice radiographers' detection of tumours (Litchfield, Ball, Donovan, & Crawford, 2008; Litchfield, Ball, Donovan, Manning, & Crawford, 2010) – although it appears as though artificial scanpaths, which move across informative regions of the display, may be equally as beneficial as genuine ones (Litchfield & Ball, 2011).

Although verbal instructions alone were uninformative in Jarodzka et al.'s (2013) fish locomotion task, they may be effective in the perception and interpretation of human movement – even one's own, relative to the environment. Heinen, Vinken and Fink (2011) assessed 30 Sport Science students' performance of a handspring on a vault. Three expert gymnasts' gaze behavior was recorded using a wireless eye tracking device; subsequent analyses revealed patterns of gaze that exhibited a high degree of consistency across experts. Accordingly, these were used as the basis for a verbal instructions for how to perform the maneuver; for example, participants were told to "…fixate [your] gaze to the middle of the trampoline bed during the run-up". One experimental group received these verbal instructions, a second group received these in combination with pertinent visual cues (red dots at the previously identified gaze locations, and a control group received no instruction, over a six bi-weekly training sessions. The experimental groups received approximately 90-120 mins of instruction in total; all groups obtained standardized verbal feedback on their movement quality. There was a trend towards superior performance in the group that only received verbal instructions, and both experimental groups' performance rating was superior when tested after a retention period of two weeks post-test, relative to that of the controls. Given the severely time-constrained and highly complex perceptual requirements of the handspring task, this improvement represents considerable acceleration of information pickup across a relatively brief period of training.

Interest in the trainability of eye movements in sporting contexts has also burgeoned recently – specifically interest in the phenomenon known as *Quiet Eye* (QE); this has been defined as the final fixation on a single location or object in the visual field within three degrees of visual angle for a minimum of 100 ms, immediately prior to skill execution during aiming tasks (e.g., basketball free throw shooting; Vickers, 1996). Although QE is an implicitly-acquired hallmark of expert performance, it is also highly trainable. Recent investigations have shown that golf putting performance can improve considerably after only brief periods of QE training; protocols typically comprise a combination of verbal instruction and individual eye movement data as a form of biofeedback (Moore, Vine, Cooke, Ring, & Wilson, 2012; Moore, Vine, Freeman, & Wilson, 2013; Vine & Wilson, 2010). Even though QE training is highly effective, the trainability of eye movements for tasks in which anticipation and complex decision-making are required has not been explored; this is despite the mooting of rubrics for efficient visual search patterns in more dynamic sporting contexts (e.g., Roca et al., 2011), plus the ability of eye movement patterns to differentiate skilled from less-skilled performers in interceptive sports (e.g., soccer; Vaeyens, Lenoir, Williams, & Philippaerts, 2007).

Accordingly, we used two simple experiments to (a) identify visual search characteristics that determined superior performance on a soccer-based task and (b) use those characteristics in an attempt to improve novices' performance of the same task. The aim of Experiment 1 was to examine the gaze behavior of participants with varying levels of soccer experience, when they attempted to anticipate oncoming soccer players' intended direction of movement from still images (see Figure 1); although dynamical information pickup is crucial to successful anticipation in sport (e.g., Williams, Huys, Cañal-Bruland, & Hagemann, 2009), we are able to infer intended movement very easily from still images (Kunde, Skirde, & Weigelt, 2011). Hermens, Flin and Ahmed (2013) noted that the definitions of experts and novices were inconsistent across the studies that they reviewed; they also noted that low participant numbers tended to characterize studies of expert eye movements. Accordingly, in the present investigation, instead of attempting to distinguish expert/skilled from novice/less skilled performers from the outset, we used a within-task criterion – decision-making efficiency – in order to do so, as this was most likely to identify the 'optimal gaze behavior' for the experimental task. We also sought to recruit moderately large samples for both experiments.

Multiple regression analyses were used to examine the extent to which a range of eye movement variables could explain the variance in participants' decision-making efficiency, when they attempted to predict the intended direction of oncoming soccer players. To examine putative relationships between motor experiences and perceptual expertise (Aglioti, Cesari, Romani, & Urgesi, 2008; Ward, Hodges, Starkes, & Williams, 2007; Williams et al., 2009), key variables that collectively reflected participants' soccer playing experience were also included as predictors in the model. In line with extant research (e.g., Gegenfurtner et al., 2011; Jarodzka et al., 2011; Robinski & Stein, 2013; Vaeyens, Lenoir, Williams et al., 2007), we predicted that more efficient decision-making would be manifested in fewer, longer-duration, fixations on information-rich regions of the display; the exact nature of these regions would be borne out in the data themselves.

In Experiment 2, participants completed the same task as in Experiment 1, but were assigned to one of two experimental groups or a control group. We predicted that, by verbally directing one group of participants' gaze to information-rich regions – as derived from Experiment 1 data – we would improve their decision-making performance relative to (i) a second group for which visual search was directed at a relatively uninformative region and (ii) a control group that received no instructions.

Experiment 1: Methods

Participants

A total of 26 male (*M* age = 21.0 yrs; *SD* = 1.7 years) and 14 female (*M* age = 21.4 yrs; *SD* = 2.0 yrs) participants, with experiences in competitive soccer ranging from complete novice to semi-professional level, took part. Five female participants were currently competing at university level, one of whom had competed at county level; nine had only recreational soccer experience. Nine of the male participants had competed at professional or semi-professional level; six had competed at county level; and eleven had only played recreationally. Each participant was remunerated £10.00 for their participation. All had normal, or corrected-to-normal, vision.

Materials

Ninety-six still images depicting three oncoming attacking soccer players (see Figure 1 for two examples, one with AOIs superimposed) were selected according to their representativeness of a critical period in soccer anticipation – up to 80 ms immediately prior to the player's change of direction; this time window has commonly been explored in studies of anticipation in sport (e.g., Abernethy, 1990; Bishop, Wright, Jackson, & Abernethy, 2013; Hagemann, Strauss, & Cañal-Bruland, 2006; Wright, Bishop, Jackson, & Abernethy, 2011). The order of presentation was randomized.

The images were presented using SR Research Experiment Builder software (SR Research Ltd, Osgoode, Canada). The images were displayed on a 21-in. CRT monitor (75 Hz). Screen resolution was set to 1024 x 768 pixels, such that the images filled the screen. Eye movements were recorded using an SR Research EyeLink 1000 eye tracker (SR Research Ltd, Osgoode, Canada) (monocular; 1000 Hz). Viewing distance was 57 cm, and the head was fixed using a chin rest. Saccades were defined as eye movements with velocities and accelerations exceeding 30°/s and 8,000°/s^2 respectively.

Procedure

University Ethics Committee approval was obtained prior to commencement of the study. After completing a soccer experience questionnaire, participants were informed that they would view a series of 96 photographic images of oncoming soccer players. It was explained that their task was to predict the direction (left/right) in which they believed the player was about to move; they did so by pressing one of two computer keys – *z*, and *3* on a numeric keypad – for *left* and *right*, respectively.

The eye tracker was calibrated using a 9-point calibration procedure, which was immediately followed by a validation procedure. Calibrations were accepted if the mean error was less than 0.5 degrees. Participants performed ten practice trials prior to the experiment. They were urged to respond as quickly and accurately as possible in both practice and experimental trials.

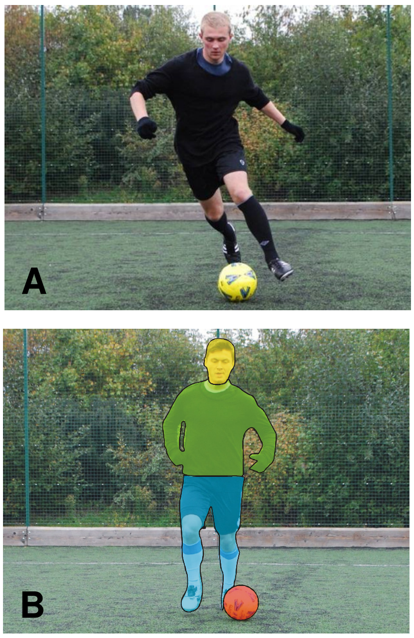

Figure 1. Two static images viewed by participants in the anticipation task, in which they were required to predict the intended direction of the player (left/right). Image B depicts interest areas (head, upper body, legs and feet, ball); these were not visible to participants.

Data Analysis

In soccer, players often have to make rapid yet accurate decisions about opponents' future behavior. In order to accommodate for both decision accuracy as well as speed, we calculated an efficiency score (ES) by dividing each of the participants' mean decision times by the proportion of correct trials; lower values indicated more efficient performance[1]. All of the analysis reported below used ES as a within-task performance criterion, which in turn formed the dependent variable for the regression analysis. All trials containing initial saccades shorter than 100 ms were excluded from the analyses, as were all trials containing blinks[2]; 527 trials (13.7%) were excluded in total. In light of the fact that experts typically focus on information-rich regions of a visualization (Gegenfurtner et al., 2011; Kundel et al., 2007; Mann et al., 2007), we divided each image into four AOIs, the relative positioning and movements of which appear to inform decision-making in a variety of sport-specific tasks (e.g., Abernethy, 1990; Kunde et al., 2011; Williams et al., 2009): *Head/face*, *upper body* (torso and arms), *lower body*, and *the ball*; Figure 1B depicts each of these areas, overlaid on an experimental image.

Data were analyzed using Eyelink Data Viewer (SR Research Ltd, Osgoode, Canada) and subsequently imported into SPSS data analysis software (v. 18.0; SPSS Inc., Chicago, IL), for each of the AOIs. A range of eye movement variables – namely, *overall dwell time*, *number of fixations*[3],*time to first fixate*, *mean fixation duration*, *mean saccadic amplitude*, *mean saccadic latency*, and *mean peak saccade velocities* – were included as predictors in the model; only some of these have been identified as potential hallmarks of perceptual-cognitive expertise (see Abernethy, Neal, & Koning, 1994; Gegenfurtner et al., 2011; Mann et al., 2007; Morgan & Patterson, 2009). Additionally, three variables which have been collectively identified as discriminators of skill level in soccer (Ward et al., 2007) – *years of experience of competitive soccer*, *minutes of soccer training undertaken per week*, and *minutes of competitive matches played per week* – were added as predictors. The highest and current levels at which participants competed were also recorded, but could not be used as reliable predictors due to their categorical/ordinal nature; hence they were omitted from the analysis.

Experiment 1: Results

Participants' mean response time was 1177 ms (*SD* = 443 ms); they were also highly accurate (*M* = 88.7%; *SD* = 0.1%). After taking into account the large number of predictors (n = 19), our proposed model still contributed 67% of the variance in ES, adjusted $R^2 = .67$, $F(16,17) = 4.52$, $p < .005$. Table 1 shows the beta coefficients and t values for each of the predictor variables. Time to first fixate the ball was the only significant predictor, ($p <$ .005). There was no correlation between trial number and any of the eye movement predictors, $p > .05$; hence there was no apparent in-task learning effect.

Experiment 2: Methods

Participants

A total of 46 undergraduate students (20 male, 26 female; *M* age = 19.5 yrs, *SD* = 1.2 years), who were not soccer players, participated for course credits. They were randomly allocated to either a *Head Instructions* group (n = 16), a *Ball Instructions* group (n = 15) or a *Control* Group (no instructions; n = 15). Each participant was additionally remunerated £10.00 for their participation. All had normal, or corrected-to-normal, vision.

Equipment and Materials

Equipment and materials were identical to those used in Experiment 1.

Procedure

The Procedure for the control group was identical to that used in Experiment 1. The two experimental groups received two different sets of instructions. The *Ball Instructions* group were told, "for each image, please look at the *ball* as quickly as possible before making a decision" (a potentially informative region, given Experiment 1 data). The *Head Instructions* group were told, "for each image, please look at the *head* as quickly as possible before making a decision"; not only did *time to first fixate the head* not contribute significantly to the explained variance in Experiment 1 data (t = 0.90, p >.05), but it was also the AOI farthest from the ball.

Table 1

Beta coefficients and t values for all predictors.

Model	B	SE B	β	*t*
(Constant)	-3714.50	2205.68		1.68
Mean fixation duration	5.08	4.33	0.41	1.17
Mean saccade amplitude	-25.73	142.57	-0.05	0.18
Mean peak saccade velocity	1.72	3.28	0.13	0.52
Initial saccade latency	1.50	1.53	0.15	0.98
Overall dwell time – ball	5451.64	2715.23	0.67	2.01
Overall dwell time – head	2963.49	1863.26	0.65	1.59
Overall dwell time – lower body	3034.29	2359.92	0.67	1.29
Overall dwell time – torso	1397.79	2791.15	0.19	0.50
Total no. of fixations – ball	2.24	2.15	0.21	1.04
Total no. of fixations – head	-3.15	2.63	-0.29	1.20
Total no. of fixations – lower body	3.94	3.69	0.34	1.07
Total no. of fixations - torso	2.68	3.24	0.19	0.83
Time to first fixate ball	1.33	0.32	0.67	4.12*
Time to first fixate head	0.51	0.57	0.19	.90
Time to first fixate lower body	1.00	0.58	0.33	1.72
Time to first fixate upper body	0.24	0.41	0.13	.60
Years of competitive soccer	-15.41	22.03	-0.15	0.70
Minutes per week of training/recreational soccer	-0.77	0.89	-0.21	0.87
Minutes per week of competitive soccer	2.56	2.51	0.25	1.02

*R^2 = .86, Adjusted R^2 = .67, $p < .005$; * $p < .005$.*

Data Analysis

Response Data. Decision-making efficiency was entered into a one-way between-groups ANOVA.

Eye Movement Data. *Time to fixate* for the AOIs *Head* and *Ball* was entered into two one-way ANOVAs, to assess the effectiveness of the experimental instructions. All trials containing initial saccades shorter than 100 ms were excluded from the analyses, as were all trials containing blinks[2]; 658 trials (14.9%) were excluded in total.

Experiment 2: Results

Decision-Making Efficiency. There were no differences between the groups in decision-making efficiency (*Control M* = 1188, *SD* = 444; *Ball Instructions M* = 169, *SD* = 864; *Head Instructions M* = 1422 *SD* = 525), $F(2,43) = 2.37$, $p = .106$, $\eta_p^2 = .10$.

Eye Movement Data. Descriptive data and their associated inferential statistics for *Time to initiate a saccade* are shown in Table 2; Tukey's HSD Test was used to determine group differences post hoc. In summary: Both *Ball Instructions* and *Control* groups were faster to initiate a saccade to the ball than the *Head Instructions* group; the *Ball Instructions* group (*M* = 53.2%, SE = 5.73%) also spent more time looking at the ball than did the *Head Instructions* group (*M* = 20.0 %, SE = 5.91%), $p < .005$. The *Head Instructions* group were faster than the other two groups to initiate a saccade to the head. These results illustrate that, despite the failure in improving discrimination performance, the experimental groups did follow the gaze instructions.

Discussion

We examined the efficacy of a data-driven approach to instructing people where to look in order to maximize decision-making efficiency in a soccer-based task. In the first of two experiments, we used multiple regression to examine the extent to which eye movement variables contributed to performance of a simple decision-making task; despite considerable research into the relationship between eye movements and perceptual-cognitive expertise (see Gegenfurtner et al., 2011; Mann et al., 2007, for reviews) the relative contributions of these variables to decision-making in sport tasks had hitherto not been examined in this way. In line with our predictions, for a model that explained 67% of the variance in decision-making efficiency, the only variable that significantly contributed to the model was a strategic one: Time to first fixate the ball (cf. Button, Dicks, Haines, Barker, & Davids, 2011; Panchuk & Vickers, 2006); the shorter this latency, the more efficient the decision that was made (cf. Button et al., 2011; Kundel et al., 2007). In contrast with previous examinations of anticipation skill in sport (Bishop et al., 2013; Savelsbergh, Van der Kamp, Williams, & Ward, 2005), there was little relationship between participants' decision-making performance and their motor experiences in soccer – to the extent that four of the ten highest-performing participants had only recreational experience of soccer. This is in keeping with the notion that people can become expert sport 'watchers' (Aglioti et al., 2008) without accruing the playing experiences that are typically characteristic of experts (Ericsson & Charness, 1994). Indeed, Vaeyens et al. (2007) used performance on a soccer anticipation task to group their participants post hoc according to their perceptual, as opposed to motor, proficiency – because an earlier study had failed to show differences in gaze behavior when groups had been based on playing experience (Vaeyens, Lenoir, Mazyn, Williams, & Philippaerts, 2007).

In a second experiment, we used the data from Experiment 1 to inform a verbal instruction protocol, in an attempt to increase the efficiency of participants' gaze behavior and consequent decision-making; such verbal instruction has successfully been used in the training of the QE phenomenon in sport (Moore et al., 2012; Moore et al., 2013; Vine & Wilson, 2010) – albeit in conjunction with visual feedback of eye movements made – and also to facilitate individuals' performance of a complex motor task (Heinen et al., 2011). The decision to use verbal instruction only was guided by the ease with which such interventions can be applied: Many practitioners in the field do not have access to eye tracking technology; conversely, verbal guidance is instantly accessible – and therefore widely used. This decision was justified, insofar as the findings were consistent with our predictions: The experimental groups followed their respective instructions, comparably to previous studies in which visual guidance was provided (Jarodzka et al., 2013; Shapiro & Raymond, 1989). However, there were no between-groups differences for decision-making efficiency – in other words, the change in strategy did not influence performance whatsoever. It is noteworthy that the difference in decision-making efficiency between the Control group (*M* = 1189, *SD* = 445) and the Ball Instructions group (*M* = 1691, *SD* = 864) approached significance, *p* = .09; notably, the Control group were the more efficient. Although this did not quite attain statistical significance, a real-world implication appears to be that a 'one size fits all' didactic approach is not suitable for tasks such as the one examined here.

A very large proportion of the variance was explained by our regression model. Thus, it seemed reasonable to conclude that decision-making efficiency in Experiment 1 was determined predominantly by the latency to ball fixation. However, the ball per se cannot possibly inform decision-making, due to the static nature of the images used; indeed, ball dwell time approached significance (*p* = .06) as a negative predictor of decision-making efficiency. This finding was mirrored to an extent in Experiment 2, in which the *Ball Instructions* group spent significantly more time looking at the ball (*M* = 53.16%, *SE* = 5.73%) than did their *Head Instructions* counterparts (M = 24.95%, SE = 5.91%), p < .005; this increase in dwell time as a result of instruction or visual guidance is in keeping with findings from previous research that has examined the use of experts' eye movements as an instructional tool (Jarodzka et al., 2013). However, for the task used herein, optimal gaze behavior may encompass the use of multiple fixations in order to extract sufficient information; the finding from Experiment 1 appears to be somewhat arbitrary. The fact that sport experts can utilize peripheral vision to pick up relevant information (Pesce, Cereatti et al., 2007; Pesce, Tessitore et al., 2007) suggests that fixations may not necessarily be located at the most informative regions of a viewed scene, but are perhaps 'anchored' at points for which this peripheral information pickup is optimized. The extent to which peripheral visual information is gleaned during fixation has not yet been examined in sport-based eye tracking studies, although comparable use of fixations has been shown in face recognition: Hiao and Cottrell's (2008) participants

Table 2

Eye movement data summary, by Group.

Time to initiate a saccade to the ball(ms).			95% Confidence Interval	
Group	Mean	Standard Error	Lower	Upper
A: Ball instructions	358.68	153.69	266.83	450.53
B: Head instructions	620.10	214.32	525.24	714.96
C: Control	410.44	175.23	315.57	505.30
$F(2,43) = 8.82$, $p < .005$, $\eta_p^2 = .29$; A,C < B, $p < .01$.				
Time to initiate a saccade to the head (ms).			95% Confidence Interval	
Group	Mean	Standard Error	Lower	Upper
A: Ball instructions	833.31	73.38	685.32	981.29
B: Head instructions	471.51	75.79	318.67	624.34
C: Control	671.07	75.79	518.23	823.91
$F(2,43) = 5.89$, $p < .01$, $\eta_p^2 = .22$; B < A,C, $p < .005$.				

initially fixated around the center of the nose when attempting to decide whether they had previously seen faces presented on-screen; moreover, greater than two fixations did not confer superior recognition performance, suggesting that information pickup was optimized rapidly using this strategy.

Contrary to previous research (e.g., Mann et al., 2007) and our predictions, more proficient decision-makers in Experiment 1 did not use fewer fixations of longer duration, which is possibly due to the experimental setup: The static images, at the distance viewed, could be processed preattentively in such a short timeframe that the important area of the display (seemingly containing the ball) was typically fixated rapidly before a manual response occurred (mean response time = 1181 ms, *SD* = 444 ms); an ensuing confirmatory – and arguably redundant – serial search would have increased the number of fixations employed by superior decision-makers. Also in contrast with previous findings (e.g., Gegenfurtner et al., 2011; Morgan & Patterson, 2009), superior performance was not accompanied by saccades of greater amplitudes. However, although large saccades appear to be an efficient way to increase the likelihood of target detection in static images (Litchfield et al., 2008), they are not necessary for a decision-making task such as that used here, in which rapid processing of positional relations was arguably required.

Although our statistics-based approach clearly pointed to an optimally-efficient gaze strategy of fixating the ball as rapidly as possible, variability in gaze behavior for otherwise comparably skilful task performance has been observed for detection of fish locomotion (Jarodzka et al., 2011) and simulated helicopter landing (Robinski & Stein, 2013), so it is not entirely surprising that such a statistical approach did not reflect the idiosyncrasies of both skill acquisition and execution. Indeed, the fact that 40% of the highest performers had only recreational soccer experience suggests that the efficiencies might have been developed from engaging in otherwise entirely unrelated tasks, such as reading. For example, efficient readers tend to have a greater perceptual span than their less efficient counterparts (Rayner, Slattery, & Bélanger, 2010); this phenomenon could easily account for the potentially arbitrary finding from Experiment 1. The ball may have been one of a number of locations that collectively enabled those with a broad perceptual span to ascertain positional relations (of the ball, feet, etc.) that would determine the oncoming player's stability (see Hof, Gazendam, & Sinke, 2005, for a discussion of dynamic stability). Alternatively, fixation on the ball earlier may simply be a 'by-product' of expert performance that came about as a result of a different strategy; one that was not assessed herein.

Even though the use of static stimuli may be viewed as a limiting factor in a sporting context, it was a very necessary step so that we could eliminate potentially distracting information, in order to make a direct assessment of the relative contributions of top-down visual search strategies, low level oculomotor variables, and motor experiences to the efficiency with which participants made their decisions; this had not been done before. The images we used were not only undemanding to perceive and process (accuracy was high and response times were short, on average), but also very homogenous: There was little variation in limb orientations, light intensities, contrasts and other attributes that collectively determine eye movements and allocation of attention (Itti & Koch, 2000, 2001). Although the expert advantage tends to be most evident when participants are required to respond in situ, and indeed gaze behavior varies considerably between video and in vivo contexts (Dicks, Button, & Davids, 2010), the visual search patterns used are still highly comparable to those used when viewing static images (Travassos et al., 2013); hence the use of such images was warranted, in order to initially ascertain the viability of such a generic approach to training soccer anticipation skill.

Another potential weakness of the present design is the use of verbal instruction exclusively. It is clear from previous research that passive/implicit guidance of novices' gaze, via superimposition of experts' eye movements (Litchfield & Ball, 2011), or of patterns that closely replicate those movements (Vine et al., 2012) can be effective. The important difference between the two forms of guidance may stem from the degree of cognitive processing required: in the case of verbal instructions, top-down processing is necessary in order to (a) interpret the instructions and (b) decide on how/why the region to which attention is directed might be informative; conversely, superimposed eye movements, or a moving 'spotlight' (cf. Jarodzka et al., 2013) are inherently attention-grabbing – rendering the process a bottom-up one. This in turn may relate to the explicit-implicit learning distinction: verbalizable rules are all-but guaranteed in the case of the former, whereas learning may proceed in a preattentive – and therefore implicit – manner in the latter. Therefore, it would be prudent in future to explore the extent to which rules are developed under both types of guidance, to determine the extent to which rule formation occurs.

Conclusions

The use of statistics to develop a general rubric for performance of our experimental task was a novel step, but the unsuccessful nature of our intervention suggests that this approach falls somewhat short. It is clear from others' studies of visually guided learning, that task performance can be improved fairly rapidly by asking novices to follow an expert's eye movements, or a proxy for those movements (Chetwood et al., 2012; Jarodzka et al., 2013; Litchfield & Ball, 2011; Vine, Chaytor, McGrath, Masters, & Wilson, 2013; Vine et al., 2012). Therefore, it seems as though there is some intrinsic value in following another person's eye movements per se, especially when that individual is deemed to be expert at the task in question; this may engender an attentional set that is conducive to pickup of task-relevant information. Conversely, a generic instruction such as the one used in the present study may lack not only the cueing potential of another's gaze (Frischen, Bayliss, & Tipper, 2007), but also sufficient authority – in the absence of any additional information pertaining to the credibility of those instructions. In summary, we were able to lead the horse to water, but we couldn't make it drink.

Footnotes

1. Accuracy was very high, for all participants (see Results), and so was not useful as a criterion measure. Conversely, reaction time (RT) was strongly correlated with time to first fixate, r = .94, $p < .01$; when this was used as the criterion variable, the outcome of the regression analysis was highly comparable to the present one. However, we chose to use decision efficiency because it reflects both RT and accuracy combined.
2. Saccades with an onset latency of less than 100 ms are generally considered to be anticipatory/predictive saccades, which would have resulted from a failure to maintain fixation prior to trial initiation. The occurrence of blinks is somewhat arbitrary – they are not an index of gaze strategy – but they can impact considerably on response time, and therefore decision efficiency, in the present task. Hence, trials not satisfying these criteria were excluded from the analysis.
3. Saccades and fixations were defined by the internal SR-Research algorithm, details of which can be found in the following paper: Stampe, D. M. (1993). Heuristic filtering and reliable calibration methods for video-based pupil-tracking systems. *Behavior Research Methods, Instruments, & Computers*. *25*, 137-142. According to this algorithm, the motion threshold for defining a saccade is 0.15 degrees (velocity 30° s^{-1}; acceleration 8000° s^{-2}); and the minimum possible fixation duration is 1 ms.

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