CHAPTER

7

Effectiveness of above real-time training on decision-making in elite football: A dose–response investigation

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Abstract

We examined the effects of video-based training in elite footballers' decision-making by presenting videos with training and testing scenarios at above real-time speeds. We also examined different training protocols to establish how much training is beneficial. We found that above real-time training improved accuracy and response time in football decision-making. In terms of scheduling, we found that the benefits were short lasting and did not last beyond 2 weeks.

Keywords

Decision-making, Sport expertise, Above real-time training, Football

1 INTRODUCTION

An understanding of expert sports performance has eluded fans, media, coaches, athletes, and scientists alike, and each of these groups is in agreement that the others do not understand. The popularity of the Olympic Games, FIFA World Cup, Wimbledon, and other major sports events is driven, in part, by the quality of expert performance in action as well as the intrinsic appeal of competition (Janelle and Hillman, 2003).

Many individuals around the world yearn to reach elite levels in different sports, but few succeed in doing so. As such, an important question arises: how do elite athletes differ from nonexperts in their performance and learning? In order to answer this question, significant research has been carried out throughout the last three decades, and expertise research has now become a well-established domain in sports science and cognitive psychology (e.g., Arroyo-Figueroa et al., 2006; Ericsson, 1996; Starkes and Ericsson, 2003).

During the process of investigating and understanding how elite performers function in a given domain, Ericsson and Smith (1991) proposed the expert performance approach (EPA) as a theoretical framework with three stages for the study of expertise. The first stage in this approach is to assess expert performance through laboratory or field testing. The expert–novice paradigm is used in the first stage to identify expert performers where field or laboratory testing is employed to elicit the differences in expert and novice performance. The second stage is to use process-tracing methods (e.g., eye movement recordings, film occlusion, and verbal reports) in the design of a representative task to investigate the mechanisms that impact the expert performance. At this stage, the goal is to understand how experts perform better than novices in the specific skill. The final stage of the EPA is to examine the acquisition of the identified characteristics of expertise. Retrospective training history profiling and training interventions can come into play at this stage.

Sport science researchers have been using the EPA to understand expertise within the sport with a significant amount of literature generated. Results to date show that elite athletes benefit from superior perceptual–cognitive skills, such as anticipation (Abernethy, 1994; Muller et al., 2006; Williams et al., 2003), pattern recall and recognition (Abernethy et al., 2005; Baker et al., 2003; Gilis et al., 2008), and decision-making (Abernethy, 1996; Lorains et al., 2013a,b; Starkes and Lindley, 1994). A comprehensive review on the expert–novice paradigm shows that the superior cognitive knowledge enables elite players to extract the most meaningful information from the environment, effectively committing it to memory, and when a player needs to perform a specific skill, this information can be retrieved to facilitate performance in similar scenarios (Williams and Davids, 1998).

In a very early attempt to study expertise, Fitts and Posner (1967) noted that elite athletes perform with a higher level of automaticity than novices. The concept of automaticity is not only applied in physical skills but has also been used to investigate cognitive skills in elite performance (e.g., Beilock et al., 2002, 2004). Speeded tasks may lead to processing efficiency as the nature of the task urges elite athletes to perform at a higher level of automaticity (Lorains et al., 2013a,b). The use of speeded manipulations has previously been applied in elite sports studies. For instance, in a study on elite handball athletes, Johnson and Raab (2003) suggested that time pressure may increase the level of accuracy in decision-making, rather than damaging it. In their study, participants were asked to make the decision as fast as possible, and they found that accuracy is higher when athletes chose the first option they generated. These results suggest that time pressure may force athletes to perform more automatically which is of benefit to the quality of their decisions. In another attempt, Hepler and Feltz (2012) found that when university basketball players perform more instinctively and with a higher level of automaticity by choosing the first option they generate, the quality of their decisions improves.

Given the results mentioned earlier there are limited intervention studies that have sought to apply this information in order to improve decision-making skills in situational or strategic sports such as football (Gabbett et al., 2007; Lorains et al., 2013a,b; Milazzo and Fournier, 2015; Schweizer et al., 2011).

Early studies in this area include those by Thiffault (1974, 1980) which were some of the first decision-making training interventions to enhance athletes' level of performance. In these studies, decision-making skills among elite ice hockey players were assessed using pictures. Athletes were asked where they would place the ball if they were in possession. This method proved to be effective in comparing decision-making behavior between elite and novice athletes, but it was far from creating a training environment that made the athletes feel like they were making decisions in a real-match situation.

As technology advanced, using videos within sport became more common in the 1990s, and studies began employing video stimuli alongside static images. In one such study, Starkes and Lindley (1994) pioneers in designing video-based decision-making tasks, trained basketball players through both static images and videos. More significant performance improvements were observed in video-based training methods than by using static images.

According to the authors, the major benefits of video-based training revolve around the practical applications in elite sport—coaches can control some scenarios for specific needs, involve injured players, and avoid increasing the physical load on athletes—claims that are plausible but yet to be empirically demonstrated. Although this study demonstrated promise, Araujo et al. (2006) and Farrow and Abernethy (2003) discussed the lack of "life-like" environments for making decisions. In order to create a more life-like environment for decision-making in sports, Hays and Singer (1989) discussed the importance of fidelity. Fidelity could be used to describe physical or psychological tasks, referring to the similarity of simulation task to the real-world one. It can also be used to describe how participants perceive the simulation environment compared to the life-like one (Stoffregen et al., 2003) and has been investigated in different domains outside of the sports literature. For example, Olmos et al. (2012) discussed the importance of fidelity in improving the learning level among musicians via computer-based simulations. In another study by Kolf (1973) in aviation, results showed that training in a faster environment than real time is perceived as the real experience by pilots. This study was the first reported use of "above real-time training" (ARTT) in aviation as cited in Guckenberger et al. (1993), but there are no full documents available for the study.

ARTT refers to a training paradigm that places participants in a simulated environment that functions at faster-than-normal time, i.e., a video played at faster-than-normal speed. Schneider (1985) discussed the importance of automaticity in expertise and claimed that "critical high-performance skills that are practiced at least in part in an above real time environment could lead to a faster acquisition of automaticity patterns of performance, less opportunity for memory decay, and a sustained level of motivation during training." Later on, Guckenberger et al. (1993) conducted a study using ARTT and in their report, they discussed two interconnected experiments. In the first study, 25 novice male subjects performed three tank gunnery tasks on a table-top simulator under varying levels of time acceleration (i.e., 1.0 × (normal speed), 1.6 × (1.6 times normal speed), 2.0 × (twice normal speed), sequential, and mixed). They were then transferred to a standard 1.0 × condition for testing. Every accelerated condition or combination of conditions produced better training and transfer than the standard real-time or 1.0 × condition. They also found that the most effective method for presentation of stimuli was the presentation of trials at 1.0 ×, 1.6 ×, and 2.0 × in a random order during training. Overall, the best ARTT group accomplished a score approximately 50% higher and trained in 25% less time compared to the real-time control group.

While the use of ARTT in training high skills performance in aviation has shown promise and despite the potential benefit in athletes, only one study has investigated the impact of this training method in athletic settings. Lorains et al. (2013a,b) conducted the first reported study in a sporting context in Australian Rules Football by investigating the effects of speeded video (between 0.75, 1.0, 1.25, 1.5, 1.75, and 2.0) on decision-making performance of elite, semi-elite, and novice participants. The group reported that elite athletes made more accurate decisions under faster video speeds, and participants rated speeds of 1.25 and 1.5 as most gamelike. This effect is thought to be driven by a more automatic decision-making process under increased time constraints in experts compared to novices (Lorains et al., 2013a,b).

Lorains et al. (2013a,b) elaborated on this original investigation by looking at training decision-making skills in Australian Rules footballers, using the ARTT method. Specifically, pre- and postmeasures were employed following 5 weeks of video-based ARTT among 45 elite Australian Rules football players who were divided into three randomly assigned groups. There were 16 players in the fast-speed training group, 15 in the normal speed one, and 14 in the control group. Additionally, two retention tests were carried out at 2 and 10 weeks posttraining in order to assess the level of memory decay of the decision-making skills. Additionally, and arguably most important in the world of elite sport, a transfer test of decision-making was included in an effort to evaluate the impact of video-based training on match performance.

The authors reported no noteworthy difference during the pretest compared with other groups who had achieved a similar level of accuracy. However, in the posttest conducted after 5 weeks training and the retention test (only 2 weeks and not 10 weeks after), the results demonstrated that the fast video group outperformed their normal speed and control group counterparts.

Employing process-tracing methods, such as verbal reports, biomechanical profiling, temporal and spatial occlusion techniques, and visual search behavior, were the next step to understand elite performance (Williams and Ericsson, 2005). Henderson (2011) describes the use of eye movement recording in opening the door to the real-world visual processes. An advantage of this technique is access to a real-time snapshot of visual behavior. In the expertise literature, it has been reported that elite athletes make more accurate decisions while using fewer fixations of longer duration (North et al., 2009; Vaeyens et al., 2007; Williams et al., 1994).

In a follow-up study, Lorains et al. (2014) investigated the effect of video-based training in above real time and normal speed on the visual search behavior of elite

Australian football athletes. In their experiment, eye movement data were collected pre- and posttest from three groups of participants, two training, and one control group without any training. Based on previous literature in expertise studies such as Sailer et al. (2005), they hypothesized that visual search behavior will be more efficient due to training. Improvement in visual search efficiency was measured by a decrease in the number of fixations and higher fixation duration. Lorain et al. reported that regardless of video speed, the fixation duration became longer at posttest and retention compared to the control group. Furthermore, the above real-time training group spent a longer duration fixating on the best option after the retention test, compared to other groups. While no significant differences were found in the average number of fixations, there was a trend for the fast video group to use fewer fixations following training compared to the normal speed and control group. It has been suggested that athletes developed their ability to pay attention to the relevant information on the screen and therefore they perform better. Change in fixation locations suggests that training using above real-time methods resulted in a more efficient visual search strategy and improved response time.

Effects of ARTT have never been investigated in elite football (soccer) performance. The primary objective of this research is to investigate the effect of ARTT on decision-making skills (as measured by decision accuracy) in professional academy footballers. A secondary objective is to investigate the effect of four different duration training schedules on decision-making (as measured by decision accuracy) in professional academy footballers. We predict that based on previous research in applying ARTT on training decision-making, elite footballers' performance on video-based task will be improved as the result of training. This prediction is in line with the previous research by Lorains et al. (2013a,b) in applying ARTT in Australian football.

2 METHODS AND MATERIALS

2.1 PARTICIPANTS

73 male participants (range 17–21 years old, mean 19 years old) took part in five groups (1 Session/Week $n=15$, 2 Sessions/Week $n=14$, 5 Sessions/Week $n=15$, Random Sessions $n=14$, Control group $n=15$). They were all based at a major football academy with at least 3 years of playing football at a professional level. All participants were naïve to the study. All participants had normal or corrected-to-normal vision. All participants gave their written informed consent in accordance with the Declaration of Helsinki and the guidelines approved by the Ethical Committee of University College London (UCL).

2.2 EXPERIMENTAL DESIGN

The study comprised of five experimental groups. Groups differed in the timing of the sessions. Table 1 shows the protocol of each experimental group.

Table 1 Structure of the Five Experimental Groups

Group	Week 1	2	3	4	5	6	7	8	9
1 Session/Week	Pre-T					Post-T			Ret-T
	T1	T2	T3	T4	T4				
2 Sessions/Week	Pre-T			Post-T			Ret-T		
	T1	T2–T3	T4–T5						
5 Sessions/Week	Pre-T	Post-T			Ret-T				
	T1–T5								
Random Sessions	Pre-T				Post-T				Ret-T
	T1	T2–T5 at random							
Control	Pre-T	Post-T		Post-T	Post-T	Post-T			
	No training								

Training (T1–T5 sessions) and testing sessions (Pre-T, Post-T, and Ret-T sessions) consisted of 20 trials. Testing sessions began with three extra warm-up trials. *Pre-T,* pretraining test session; *Post-T*, posttraining test; *Ret-T*, retention-test session; *T1–T5,* training sessions 1–5; *W*, week.

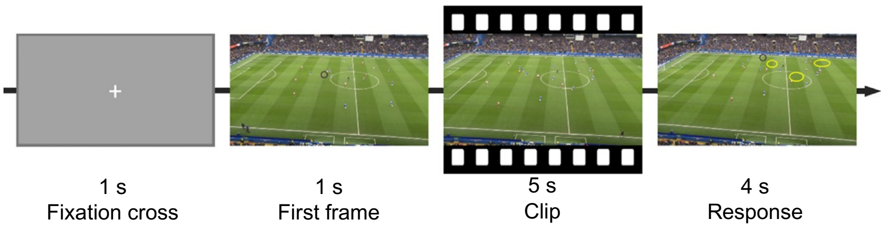

FIG. 1

Procedure of one trial. Playback speed was 1.0 × for testing sessions (5 s of presentation) and 1.5 × for training sessions (5 s presentation of 7.5 s videos).

In each session participants were asked to perform a computer task. The computer task consisted of presentation of a screen highlighting the location of the ball, a short video clip followed by a screen containing three possible options. The participants' task was to indicate the best option. Options were ordered with one indicating the best choice (value 1), one indicating an intermediate choice (value 2), and one indicating the worst choice (value 3). Each video clip was watched and rated by three UEFA (Union of European Football Associations) A license coaches independently. The video clips were extracted from real competitions by a camera placed in the middle of the field. The duration of the video clips was 5 s. During the training sessions feedback was provided for 4 s after each response (T1–T5 as shown in Table 1), but no feedback was provided during testing sessions (Pre-T, Post-T, and Ret-T as shown in Table 1). Trials were separated by a fixation cross on the screen for 1 s. Participants were asked to respond as quickly and as accurately as possible. Fig. 1 shows sample screens of one trail.

The experiment was developed in MATLAB® (v2013b, MathWorks, USA) using Psychtoolbox (v3). A tablet computer with 13 in. touch screen (Lenovo Yoga) was used for presentation of stimuli and participants were required to tap on the screen to indicate their responses.

2.3 STATISTICAL ANALYSIS

Choice and response time were recorded for analysis. Response *accuracy* was calculated for each choice based on the following: (3—*option's value*) $\times$ 50 (%). Option's value represents a number between 1 and 3 with 1 indicating the best option and 3 indicating the worst option. Mean accuracy and median response time were calculated for all testing sessions. To account for individual *differences Accuracy Difference and Response Time Difference were* calculated:

$$\text{Accuracy Difference} = \text{Accuracy Posttraining/Retention test} - \text{Pretraining}$$

$$\text{Response Time Difference} = \text{Response Time Pretraining} \\ - \text{Posttraining/Retention test}$$

To investigate the baseline activity of the participants in different groups, two one-way ANOVAs were run on Group (1 Session/Week, 2 Sessions/Week, 5 Sessions/Week, Random Sessions, and Control) with accuracy and response time as independent variables. Furthermore, to ensure a stable performance in the Control group, two repeated measures ANOVAs (rANOVA) were run on accuracy and response time of all five sessions.

Two series of analysis were run to (1) investigate effects of different protocols of training on performance and (2) effectiveness of training compared to the Control group. Two 4×2 mixed factor ANOVA were run to investigate the differential effects of training protocols on accuracy difference and response time difference with Group (1 Session/Week, 2 Sessions/Week, 5 Sessions/Week, and Random Sessions) as between-subject factor and Session (Posttraining Difference/Retention-test Difference) as within-subject factor. Finally, to investigate the effects of training, two independent sample *t*-tests were run to compare performance of the training groups with those of Control group.

Post hoc paired samples *t*-tests were used to study the difference between conditions. For further scrutiny of the data we report post hoc tests regardless of the results of the ANOVAs. False discovery rate (FDR) correction is used for correction of multiple comparisons.

3 RESULTS

To investigate whether all five groups had a similar baseline level in the Pretraining session, we ran two one-way ANOVAs on accuracy and response time. This ANOVA showed nonsignificant main effects of Group ($F_{(4,68)} = 2.105$, $P = 0.090$, $\eta_p^2 = 0.110$) for accuracy and for response time ($F_{(4,68)} = 1.145$, $P = 0.343$, $\eta_p^2 = 0.063$), which shows that participants began the study with similar level of performance. To investigate changes in the Control group from Pretraining to the four Posttraining sessions, we ran two repeated measures ANOVAs with Session as within-subject factor. These rANOVAs showed nonsignificant main effects of Session for accuracy ($F_{(3,42)}=1.042$, $P=0.384$, $\eta_p^2=0.069$) and response time ($F_{(3,42)}=0.223$, $P=0.880$, $\eta_p^2=0.016$).

A 4 ×2 mixed factor ANOVA on accuracy difference showed a trend toward significant main effect of Session ($F_{(1,54)}=3.368$, $P=0.072$, $\eta_p^2=0.059$), a nonsignificant main effect of Group ($F_{(3,54)}=2.011$, $P=0.123$, $\eta_p^2=0.101$), and a nonsignificant interaction ($F_{(3,54)}=1.864$, $P=0.147$, $\eta_p^2=0.094$). A similar mixed factor ANOVA on response time difference showed a significant main effect of Session ($F_{(1,54)}=20.847$, $P<0.001$, $\eta_p^2=0.279$), a significant main effect of Group ($F_{(3,54)}=49.597$, $P<0.001$, $\eta_p^2=0.479$), and a significant interaction ($F_{(3,54)}=2.863$, $P=0.045$, $\eta_p^2=0.137$). To explore the results further we ran planned post hoc one sample *t*-tests on both accuracy and response time Posttraining and Retention-test Differences to investigate whether there was an improvement in both Posttraining and Retention-test sessions compared to baseline. This test showed a nonsignificant improvement in accuracy for the 2 Sessions/Week group during Posttraining session and a nonsignificant improvement for the Random Sessions group during Retention-test session. Other comparisons became significant. Response times showed a significant improvement for both Posttraining and Retention-test sessions for all the groups (see Tables 2 and 3).

Paired sample *t*-tests were also run to look at the changes between Posttraining and Retention-test sessions for both accuracy and response time. These tests showed a significant difference for the 1 Session/Week group for accuracy and 5 Sessions/Week group for response time (see Table 4 and Fig. 2). This shows that the acquired still was perishable.

Performance of different groups was also compared for Posttraining and Retention-test sessions. Neither of the comparisons was significantly different (see Table 5).

To investigate the effects of training in training groups (Table 6) (1 Session/Week, 2 Sessions/Week, 5 Sessions/Week, and Random Sessions) compared

Table 2 One Sample *t*-Test on Accuracy Difference for Posttraining and Retention-Test Sessions

Group	DoF	Posttraining Difference		Retention-Test Difference	
		t	*P*	*t*	*P*
1 Session/Week	14	4.819	<0.001[a]	3.803	0.002[a]
2 Sessions/Week	13	0.935	0.367	2.656	0.020[b]
5 Sessions/Week	14	3.481	0.004[a]	3.401	0.004[a]
Random Sessions	13	3.414	0.005[a]	1.696	0.114

DoF represents degrees of freedom.
[a]*Significant difference false discovery rate (FDR) corrected α < 0.01.*
[b]*Significant difference FDR corrected α < 0.05.*

Table 3 One Sample *t*-Test on Response Time Difference for Posttraining and Retention-Test Sessions

Group	DoF	Posttraining Difference		Retention-Test Difference	
		t	***P***	***t***	***P***
1 Session/Week	14	4.512	<0.001[a]	3.297	0.005[a]
2 Sessions/Week	13	2.210	0.046[b]	2.243	0.043[b]
5 Sessions/Week	14	4.672	<0.001[a]	3.494	0.004[a]
Random Sessions	13	4.275	0.001[a]	3.374	0.005[a]

DoF represents degrees of freedom.
[a]*Significant difference false discovery rate (FDR) corrected* $\alpha < 0.01$.
[b]*Significant difference FDR corrected* $\alpha < 0.05$.

Table 4 Accuracy Difference and Response Time Difference Refers to the Difference Between Posttraining Difference and Retention-Test Difference for Accuracy and Response Time, Respectively

Group	DoF	Accuracy Difference		Response Time Difference	
		t	***P***	***t***	***P***
1 Session/Week	14	3.216	0.006[a]	1.827	0.089
2 Sessions/Week	13	0.518	0.613	0.599	0.560
5 Sessions/Week	14	1.260	0.228	5.634	<0.001[b]
Random Sessions	13	1.585	0.137	1.801	0.095

[a]*Significant difference false discovery rate (FDR) corrected* $\alpha < 0.05$.
[b]*Significant difference FDR corrected* $\alpha < 0.01$.

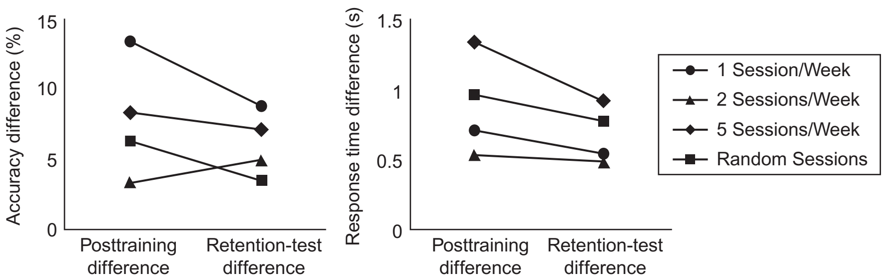

FIG. 2

Performance difference for training groups for Posttraining and Retention-test sessions. Higher values in the *right panel* show faster responses. Error bars are not displayed for clarity.

to the Control group, two independent sample *t*-tests were run on accuracy and response time measures. These tests showed a nonsignificant difference for the 2 Sessions/Week group compared to the Control group and significant differences for other groups (see Table 7 and Fig. 3).

Table 5 Two Independent Sample *t*-Tests on Accuracy Difference for Posttraining and Retention-Test Sessions Between Training Groups

Group	DoF	Posttraining Difference		Retention-Test Difference	
		t	*P*	*t*	*P*
1 vs 2 Sessions/Week	27	2.228	0.034	1.294	0.207
1 vs 5 Sessions/Week	28	1.381	0.178	0.534	0.598
1 vs Random Session/Week	27	2.102	0.045	1.700	0.101
2 vs 5 Sessions/Week	27	1.168	0.253	0.783	0.441
2 vs Random session/Week	26	0.726	0.475	0.515	0.611
5 vs Random Session/Week	27	0.671	0.508	1.232	0.228

DoF represents degrees of freedom. None of the comparisons became significantly different using false discovery rate (FDR) correction $\alpha < 0.05$.

Table 6 Two Independent Sample *t*-Tests on Response Time Difference for Posttraining and Retention-Test Sessions Between Training Groups

Group	DoF	Posttraining Difference		Retention-Test Difference	
		t	*P*	*t*	*P*
1 vs 2 Sessions/Week	27	0.603	0.552	0.233	0.817
1 vs 5 Sessions/Week	28	1.927	0.064	1.208	0.237
1 vs Random Session/Week	27	0.942	0.355	0.822	0.418
2 vs 5 Sessions/Week	27	2.119	0.043	1.279	0.212
2 vs Random Sessions/Week	26	1.291	0.208	0.931	0.630
5 vs Random Session/Week	27	1.014	0.320	0.414	0.682

DoF represents degrees of freedom. None of the comparisons became significantly different using false discovery rate (FDR) correction $\alpha < 0.05$.

Table 7 Comparison of Four Training Groups With Control Group for Accuracy and Response Time Difference for Posttraining Session

Group	DoF	Accuracy Difference		Response Time Difference	
		t	*P*	*t*	*P*
1 Session/Week	28	4.347	<0.001[a]	3.834	0.001[a]
2 Sessions/Week	27	0.872	0.391	1.957	0.061
5 Sessions/Week	28	2.886	0.007[a]	4.387	<0.001[a]
Random Sessions	27	3.837	0.001[a]	4.297	<0.001[a]

DoF represents degrees of freedom.
[a]Significant difference false discovery rate (FDR) corrected $\alpha < 0.05$.

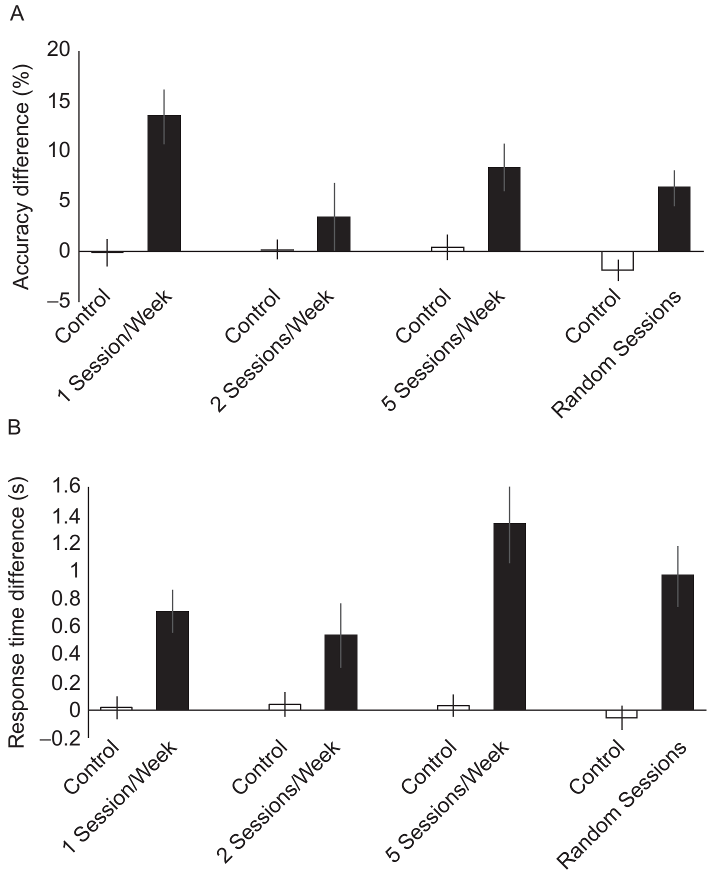

FIG. 3

Performance differences between training and control groups for Posttraining sessions for accuracy difference (A) and response time difference (B). Higher values in panel (B) show faster responses. Error bars represent one s.e.m.

4 DISCUSSION

To our knowledge, this is the first experiment with elite footballers specifically applying above real-time training with different schedules. The aim of this study was first to test the effect of video-based training in above real time on elite footballers decision-making quality and the second objective was to investigate the difference between different training protocols. The pretest showed no significant difference between groups in terms of decision-making accuracy and response time which means they all started at an equivalent level. However, all the training groups' results showed greater overall improvement both in accuracy and response time between pre- and posttest and retention. This is in line with previous research by Lorains et al. (2013a,b) on applying ARTT to Australian football. There is no significant change in the performance of participants in the control group, which is an indicator of effect of training for the training groups.

Comparing results of performance from posttest to retention shows that training needs to be continued as a 2-week break time between posttest and retention resulted in decrease in accuracy and longer response time. This effect was significant for 1 Session/Week in terms of accuracy and 5 Sessions/Week in terms of response time. However, comparing participants' performances between pretest and retention suggests that accuracy improvements for 1, 2, and 5 Sessions/Week schedule is improved. Also, all participants in four group performances in terms of response time are improved.

In terms of finding the best schedule for training between the four options, there is no significant difference in terms of accuracy and response time. However, there is a trend for 1 and 5 Sessions/Week for accuracy and 5 sessions per week for response time.

Video-based training has been shown to be effective in improving the decision-making quality of pilots (Guckenberger et al., 1993) and elite Australian football athletes (Lorains et al., 2013a,b). The criticism was always about the level of similarity and fidelity between the computer task and on pitch performance. However, Lorains et al. (2013a,b) showed a higher level of fidelity by applying ARTT to the video-based training in comparison with normal speed video and using this method has been shown effective in training athletes.

A challenge to the current research is to measure the transfer of learning on the task to the pitch as there is no measure of transfer in the current study. We are currently implementing this. We are also pursuing the effects of training and testing at different times of day and different schedule of training.

In conclusion, our findings show that video-based training above real time results in an improvement in decision-making accuracy and response times of elite footballers; however, in order to retain the skill, continued training is necessary.

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REFERENCES

Abernethy, B., 1994. The nature of expertise in sport. In: Serpa, S., Alves, J., Pataco, V. (Eds.), International Perspective on Sport and Exercise Psychology. Fitness Information Technology, Morgantown, WV, pp. 57–68.

Abernethy, B., 1996. Training the visual perceptual skills of athletes: insights from the study of motor expertise. Am. J. Sports Med. 24, S89–S92.

Abernethy, B., Baker, J., Cote, J., 2005. Transfer of pattern recall skills may contribute to the development of sport expertise. Appl. Cogn. Psychol. 19 (6), 705–718.

Araujo, D., Davids, K., Hristovski, R., 2006. The ecological dynamics of decision making in sport. Psychol. Sport Exerc. 7, 653–676.

Arroyo-Figueroa, G., Hernandez, Y., Sucar, E., 2006. Intelligent environment for training of power systems operators. Lect. Notes Artif. Intell. 4251, 943–950.

Baker, J., Cote, J., Abernethy, B., 2003. Sport-specific practice and the development of expert decision-making in team ball sports. J. Appl. Sport Psychol. 15, 12–25.

Beilock, S., Carr, T., MacMahon, C., Starkes, J., 2002. When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. J. Exp. Psychol. Appl. 8 (1), 6–16.

Beilock, S., Bertenthal, B., McCoy, A., Carr, T., 2004. Haste does not always make waste: expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. Psychon. Bull. Rev. 11 (2), 373–379.

Ericsson, K.A., 1996. The Road to Excellence: The Acquisition of Expert Performance in the Arts and Sciences, Sports, and Games. Erlbaum, Mahwah, NJ.

Ericsson, K.A., Smith, J., 1991. Toward a General Theory of Expertise: Prospects and Limits. Cambridge University Press, Cambridge.

Farrow, D., Abernethy, B., 2003. Do expertise and the degree of perception—action coupling affect natural anticipatory performance? Perception 32 (9), 1127–1139.

Fitts, P.M., Posner, M.I., 1967. Human Performance. Brooks/Cole, Monterey, CA.

Gabbett, T., Rubinoff, M., Thorburn, L., Farrow, D., 2007. Testing and training anticipation skills in softball fielders. Int. J. Sports Sci. Coach. 2 (1), 15–24.

Gilis, B., Helsen, W., Catteeuw, P., Wagemans, J., 2008. Offside decisions by expert assistant referees in association football: perception and recall of spatial positions in complex dynamic events. J. Exp. Psychol. Appl. 14, 21–35.

Guckenberger, D., Ullano, K.C., Lane, N.E., 1993. Training High Performance Skills Using Above Real-Time Training. National Aeronautics and Space Administration.

Hays, R., Singer, M., 1989. Simulation Fidelity in Training System Design: Bridging the Gap Between Reality and Training. Springer-Verlag, New York.

Henderson, J., 2011. Eye Movements and Scene Perception. In: Liversedge, S., Gilchrist, I., Everling, S. (Eds.), The Oxford Handbook of Eye Movements. Oxford University Press, Oxford, England.

Hepler, T., Feltz, D., 2012. Take the first heuristic, self-efficacy, and decision-making in sport. J. Exp. Psychol. Appl. 18 (2), 154–166.

Janelle, C.M., Hillman, C.H., 2003. Expert performance in sport: current perspectives and critical issues. In: Starkes, J.L., Ericsson, K.A. (Eds.), Expert Performance in Sports. Advances in Research on Sport Expertise. Human Kinetics, Champaign, IL, pp. 19–49.

Johnson, J., Raab, M., 2003. Take the first: option-generation and resulting choices. Organ. Behav. Hum. Decis. Process 91 (2), 215–229.

Kolf, J., 1973. Documentation of a Simulator Study of an Altered Time Base. Unpublished manuscript, NASA Dryden Flight Research Facility, Edwards, CA.

Lorains, M., Ball, K., MacMahon, C., 2013a. Expertise differences in a video decision-making task: speed influences on performance. Psychol. Sport Exerc. 14, 293–297.

Lorains, M., Ball, K., MacMahon, C., 2013b. An above real time training intervention for sport decision making. Psychol. Sport Exerc. 14, 670–674.

Lorains, M., Panchuk, D., Ball, K., MacMahon, C., 2014. The effect of an above real time decision-making intervention on visual search behaviour. Int. J. Sports Sci. Coach. 9 (6), 1383–1392.

Milazzo, N., Fournier, J., 2015. Effect of individual implicit video-based perceptual training program on high-skilled karatekas' decision making. Mov. Sport Sci. Sci. Mot. (88), 13–19.

Muller, S., Abernethy, B., Farrow, D., 2006. How do world-class cricket batsmen anticipate a bowler's intention? Q. J. Exp. Psychol. 59, 2162–2186.

North, J.S., Williams, A.M., Hodges, N., Ward, P., Ericsson, K.A., 2009. Perceiving patterns in dynamic action sequences: investigating the processes underpinning stimulus recognition and anticipation skill. Appl. Cogn. Psychol. 23 (6), 878–894.

Olmos, A., Bouillot, N., Knight, T., Mabire, N., Redel, J., Cooperstock, J., 2012. A high fidelity orchestra simulator for individual musicians' practice. Comput. Music J. 36 (2), 55–73.

Sailer, U., Flanagan, J.R., Johansson, R.S., 2005. Eye–hand coordination during learning of a novel visuomotor task. J. Neurosci. 25 (39), 8833–8842.

Schneider, K.C., 1985. Uninformed response rates in survey research: new evidence. J. Bus. Res. 13 (2), 153–162.

Schweizer, G., Plessner, H., Kahlert, D., Brand, R., 2011. A video-based training method for improving soccer referees' intuitive decision-making skills. J. Appl. Sport Psychol. 23 (4), 429–442.

Starkes, J.L., Ericsson, K.A., 2003. Expert Performance in Sports. Advances in Research on Sport Expertise. Human Kinetics, Champaign, IL.

Starkes, J.L., Lindley, S., 1994. Can we hasten expertise by video simulation? Quest 46, 211–222.

Stoffregen, T.A., Bardy, B.G., Smart, L.J., Pagulayan, R.J., 2003. On the nature and evaluation of fidelity in virtual environments. In: Hettinger, L.J., Haas, M. (Eds.), Virtual and Adaptive Environments: Applications, Implications, and Human Performance Issues. CRC Press, Mahwah, pp. 111–128.

Thiffault, C., 1974. In: Tachistoscopic training and its effect upon visual perceptual speed of ice hockey players. Proceedings of the Canadian Association of Sport Sciences, Edmonton, Alberta.

Thiffault, C., 1980. Construction et validation d'une measure de la rapidite de la pensee tactique des joueurs de hockey sur glace. In: Nadeau, C.H., Halliwell, W.R., Newell, K.M., Roberts, G.C. (Eds.), Psychology of Motor Behaviour and Sport. Human Kinetics, Champaign, IL, pp. 643–649.

Vaeyens, R., Lenoir, M., Williams, A.M., Mazyn, L., Philippaerts, R.M., 2007. The effects of task constraints on visual search behavior and decision-making skill in youth soccer players. J. Sport Exerc. Psychol. 29 (2), 147–169.

Williams, A.M., Davids, K., 1998. Visual search strategy, selective attention, and expertise in soccer. Res. Q. Exerc. Sport 69 (2), 111–128.

Williams, A.M., Ericsson, K.A., 2005. Perceptual-cognitive expertise in sport: some considerations when applying the expert performance approach. Hum. Mov. Sci. 24, 283–307.

Williams, A.M., Davids, K., Burwitz, L., Williams, J.G., 1994. Visual search strategies in experienced and inexperienced soccer players. Res. Q. Exerc. Sport 65 (2), 127–135.

Williams, A.M., Ward, P., Knowles, J., Smeeton, N., 2003. Anticipation skill in a real-world task: measurement, training and transfer in tennis. J. Exp. Psychol. Appl. 8 (4), 259–270.

FURTHER READING

Anderson, J.R., 1987. Methodologies for studying human knowledge. Behav. Brain Sci. 10, 467–505.

Anderson, A.F., Kludt, R., Bavelier, D., 2011. Verbal versus visual working memory skills in action video game players. Poster presented at the Psychonomics Soc. Meet., Seattle.

Bavelier, D., Green, C.S., Han, D.H., Renshaw, P.F., Merzenich, M.M., Gentile, D.A., 2011. Brains on video games. Nat. Rev. Neurosci. 12 (12), 763–768.

Blundell, N.L., 1984. Critical visual-perceptual attributes of championship level tennis players. In: Howell, M., Wilson, B. (Eds.), Proceedings of the VII Commonwealth and International Conference on Sport, Physical Education, Recreation and Dance, University of Queensland, BrisbaneKinesiological Science7, pp. 51–59.

Blundell, N.L., 1985. The contribution of vision to the learning and performance of sports skills: part 1: the role of selected visual parameters. Aust. J. Sci. Med. Sport 17 (3), 3–11.

Boot, W.R., Kramer, A.F., Simons, D.J., Fabiani, M., Gratton, G., 2008. The effects of video game playing on attention, memory, and executive control. Acta Psychol. (Amst) 129, 387–398.

Broadbent, D.P., Causer, J., Williams, A.M., Ford, P.R., 2015. Perceptual-cognitive skill training and its transfer to expert performance in the field: future research directions. Eur. J. Sport Sci. 15 (4), 322–331.

Casanova, F., Oliveira, J., Williams, M., 2009. Expertise and perceptual-cognitive performance in soccer: a review. Rev. Port. Cien. Desp. 9 (1), 115–122.

Chase, W.G., Simon, H.A., 1973. The mind's eye in chess. In: Chase, W.G. (Ed.), Visual Information Processing. Academic, New York, pp. 215–281.

Dye, M.W.G., Bavelier, D., 2010. Differential development of visual attention skills in school-age children. Vision Res. 50, 452–459.

Ericsson, K.A., Kintsch, W., 1995. Long-term working memory. Psychol. Rev. 102, 211–245.

Ericsson, K.A., Lehmann, A.C., 1996. Expert and exceptional performance: evidence of maximal adaptation to task constraints. Annu. Rev. Psychol. 47, 273–305.

Farrow, D., Abernethy, B., Jackson, R.C., 2005. Probing expert anticipation with the temporal occlusion paradigm: experimental investigations of some methodological issues. Motor Control 9, 332–351.

Galton, F., 1869. Heredity Genius. Macmillian, New York.

Glockner, A., Betsch, T., 2012. Decisions beyond boundaries: when more information is processed faster than less. Acta Psychol. (Amst) 139, 532–542.

Godden, D., Baddeley, A., 1975. Context dependent memory in two natural environments. Br. J. Psychol. 66, 325–331.

Green, C.S., Bavelier, D., 2006. Effects of action video game playing on the spatial distribution of visual selective attention. J. Exp. Psychol. Hum. Percept. Perform. 32, 1465–1478.

Greenfield, P.M., 2009. Technology and informal education: what is taught, what is learned. Science 323, 69–71.

Harlow, H.F., 1949. The formation of learning sets. Psychol. Rev. 56, 51–65.

Healy, A.F., Bourne Jr., L.E., 2012. Training Cognition: Optimizing Efficiency, Durability, and Generalizability. Psychology Press, New York, NY.

Hillman, C.H., Erickson, K.I., Kramer, A.F., 2008. Be smart, exercise your heart: exercise effects on brain and cognition. Nat. Rev. Neurosci. 9, 58–65.

Kemp, C., Goodman, N.D., Tenenbaum, J.B., 2010. Learning to learn causal models. Cognit. Sci. 23, 159.

Lejuez, C.W., Read, J.P., Kahler, C.W., Richards, J.B., Ramsey, S.E., Stuart, G.L., Brown, R.A., 2002. Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). J. Exp. Psychol. Appl. 8 (2), 75.

Lutz, A., Slagter, H.A., Dunne, J.D., Davidson, R.J., 2008. Attention regulation and monitering in meditation. Trends Cogn. Sci. 12, 163–169.

MacMahon, C., McPherson, S., 2009. Knowledge base as a mechanism for perceptual cognitive tasks: skill is in the details. Int. J. Sport Psychol. 40 (4), 565.

MacMahon, C., Starkes, J., Deakin, J., 2009. Differences in processing speed of game information in basketball players, coaches and referees. Int. J. Sport Psychol. 40 (3), 403–424.

Renner, M.J., Rosenzweig, M.R., 1987. Enriched and Impoverished Environments Effects on Brain and Behavior Recent Research in Psychology. Springer-Verlag, New York.

Revien, L., 1987. Eyerobics. Visual Skills Inc, Great Neck, NY.

Sanderson, F.H., 1981. Visual acuity and sports performance. In: Cockerill, I.M., MacGillivary, W.W. (Eds.), Vision in Sport. Stanley Thornes, Cheltenham, England, pp. 64–79.

Shapiro, D.C., Schmidt, R.A., 1982. The schema theory: recent evidence and developmental implications. In: Kelso, J.A.S., Clark, J.E. (Eds.), The Development of Movement Control and Co-ordination. Wiley, New York, pp. 113–150.

Vicenzi, D.A., Wise, J.A., Mouloua, M., Hancock, P.A., 2008. Human Factors in Simulation and Training. CRC Press, Boca Raton, FL, USA.

Ward, P., Farrow, D., Harris, K., Williams, M., Eccles, D., Ericsson, K.A., 2008. Training perceptual-cognitive skills: can sport psychology research inform military decision training? Mil. Psychol. 20 (1), 71–102.

Williams, A.M., Hodges, N.J., North, J., Barton, G., 2006. Perceiving patterns of play in dynamic sport tasks: investigating the essential information underlying skilled performance. Perception 35, 317–332.

Williams, A.M., Ford, P.R., Eccles, D.W., Ward, P., 2011. Perceptual-cognitive expertise in sport and its acquisition: implications for applied cognitive psychology. Appl. Cogn. Psychol. 25 (3), 432–442.

Wilson, M.R., Vine, S.J., Bright, E., Masters, R.S., Defriend, D., McGrath, J.S., 2011. Gaze training enhances laparoscopic technical skill acquisition and multi-tasking performance: a randomized, controlled study. Surg. Endosc. 25 (12), 3731–3739.