A Longitudinal Case Study on the Effects of an Ecological Training Intervention in an Elite Football Player

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Abstract

This longitudinal case study investigates the effects of an ecological training intervention in an elite football player on increasing three behaviors: critical scanning (perceiving the environment immediately before receiving the ball) (H1a), forward body orientation (H1b), and nonverbal communication (H1c). The intervention spans over four football seasons and consists of training sessions and video analysis guided by a personal football coach. In addition, the research investigates if there is a relation of the three behaviors: critical scanning (H2a), forward body orientation (H2b) and nonverbal communication (H2c) with keeping teams possession of the ball through a subsequent successful pass. The explorative research is secondary in nature and examines data from 58 football games resulting in 584 analyzed Relevant Game Moments (RGMs). The statistical analysis indicates significant positive developments in critical scanning ($p < .001$), forward body orientations ($p < .001$), and non-verbal communication ($p < .01$). Unexpectedly, the Chi-Square tests indicate no significant relationship between each of the three behaviors and maintaining teams ball possession after ball contact. In conclusion, the findings support a link between the intervention and enhancing critical scanning, forward body orientations and nonverbal communication. However, the data does not indicate a relationship between those behaviors and improved ball performance. The study contributes to the limited applied research on training perceptual skills in football and concludes that more research is needed to investigate potential effects of the measured behaviors on ball performance.

Keywords: football, scanning, perceptual training, body orientation, nonverbal communication, case study

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The skill of visual perception is essential to perform various sports (Jordet, 2004). Athletes in baseball, for example, need to constantly adjust their behavior according to perceived environmental stimuli, which might be the initiation of swinging a baseball bat based on the speed and direction of a flying ball. In the ecological approach to visual perception, Gibson (1979) argues for the reciprocal link between action and perception. Individuals need to perceive in order to act and through action they perceive the environment. Moving one's body, head, and eyes creates a different perspective of the environment, and this new visual information leads to the perception of more action opportunities i.e. affordances (Gibson, 1979). Affordances are possible offerings for action by the environment or objects within it (Gibson, 1979). If athletes perceive a football in front of them, it affords them to kick it. Moreover, affordances incorporate the dynamic interaction between the individual, task, and environment (Gibson, 1979, Newell, 1986). For example, one´s perception of action opportunities is dependent on their technical and physical capabilities (Fajen et al., 2008). A climber in front of a wall might perceive different climbing holds and possible routes of how to climb it while a non-climber potentially is only seeing the wall as an insurmountable obstacle.

In the following explorative research we investigate among others if specific perceptual skills can be trained in an elite football player and if they are related to ball performance, more specifically, keeping teams possession of the ball through a subsequent successful pass. Before we introduce the intervention and its hypothesized effects, we first need to grasp the nature of perception in football i.e. scanning or Visual Exploratory Action (VEA). Therefore, in the next section we provide an overview of the existing literature on

VEA and how it is related to ball performance, followed by reviewing studies that aimed at enhancing VEA in athletes.

Literature Review

Superior Ball Performance through Visual Exploratory Action

Athletes who perform team sports such as football need to navigate through complex and dynamic environments with changing temporal and spatial constraints (McGuckian, 2019). During competition a football player is constantly surrounded by moving teammates and opponent players which results in ever changing circumstances (Jordet, 2004). In one moment the player in possession of the ball might perceive an open space to successfully pass the ball to a teammate but in the next moment this affordance is not available through an intervening opponent player. Therefore, football players need to continually collect visual information of their environment to be able to accurately predict where their teammates and opponent players will be located on the field. Such information is necessary to make the right decisions in the moment and increase their effectiveness on the field (e.g. Pokolm et al., 2023). Even though peripheral vision allows players to recognize movements outside their foveal focus, to gain a full 360-degree view of all relevant information players are required to actively look around by moving their eyes and turning their head and body (Aksum et al., 2020; Jordet, 2005). Such behaviors are referred to as scanning, or Visual Exploratory Action (VEA) which are defined as follows (Jordet, 2005, p. 143):

> *"A body and/or head movement in which the player's face is actively and temporarily directed away from the ball, seemingly with the intention of looking for teammates, opponents or other environmental objects or events, relevant to the carrying out of a subsequent action with the ball."*

Several studies investigated the relation of VEA prior to receiving the ball on subsequent ball performance. Overall, those studies identified significant performance differences between players who executed more VEA to those who did less or none. Still, to be able to judge if VEA has an advantageous influence on ball performance we first need to establish which behaviors lead to success in football. To answer this question, studies identified game statistics that were linked to winning football matches (Liu et al., 2015; Lago-Peñas et al., 2011). Not surprisingly, statistics concerning goal scoring i.e. total shots, shots on target, shots from counter attacks, etc. were predictive of winning matches (Liu et al., 2015). Besides that, metrics related to the offense such as total passes, successful passes and maintaining ball possession seem to be related to competition success (Lago-Peñas et al., 2011). Based on those insights, it is suggested that patiently trying to search for openings in the defense through short passes is the best attack strategy (Liu et al., 2015). Therefore, according to the results the highest priority for an offensive football player, besides shooting on the target, is keeping possession of the ball to prevent counter attacks as well as identifying and successfully executing passing opportunities towards the opponents goal. In the following study these behaviors are referred to as 'ball performance'.

To relate ball performance to VEA, researchers came up with different approaches to operationalize scanning behavior. In a head-eye coordination study Fang et al. (2015) concluded that the head orientation was highly correlated with gaze fixations, meaning that the head orientation is indicative of one's visual attention. Based on that assumption studies looked at game recordings and manually quantified the number of head movements in the seconds prior to receiving the ball which resulted in the metrics of scan frequency (scans per second). It was found that a higher scan frequency was associated with better ball performance, defined by faster and more successful passing, more forward passing, more turning with the ball and fewer turnovers (e.g., Aksum, Pokolm, et al., 2021; Eldridge et al., 2013; Jordet et al., 2013; McGuckian et al., 2018; McGuckian et al., 2019; Phatak & Gruber, 2019). In line with these findings, most studies hypothesize that the more players perform

VEA, the more they perceive affordances to exploit, which aids their decision making and prospective control of the ball, and accordingly, their ball performance (e.g. McGuickian et al., 2018). One explanation why there is a higher likelihood for forward passes might be that players who scan over their shoulder and perceive low opponent pressure are more likely to orient their body sideways or towards the opponent goal when receiving the ball (Aksum, Pokolm, et al., 2021; Pokolm et al., 2022). Furthermore, according to Pokolm et al. (2023), the orientation of players last scan influences the choice of foot used for the first ball contact as well as the direction the game is proceeding to. Ideally, players scan in the direction of the opponents goal to identify opportunities to turn and pass the ball in similar direction to increase the likelihood of progressing down the field and ultimately scoring a goal (Pokolm et al., 2023).

Additional support for the link between VEA and ball performance has been obtained in studies that presented a positive relation between players skill level and the frequency of VEA. A significantly higher scan frequency could be observed in awarded elite football players in comparison to non-awarded ones and between more matured players who played in their U19 national team in comparison to U17´s (Aksum, Pokolm, et al., 2021; Jordet et al., 2013). In addition, the U19 players were able to perform their last scans closer to receiving the ball than the U17 players, which is adaptive for the higher temporal-spatial demands present in the competition of more matured players (Aksum, Pokolm, et al., 2021).

Going beyond mere head movement, a study by Aksum et al. (2020) investigated the gaze behavior of midfielders in an 11 vs. 11 match play through eye tracking technology. They found that players mostly foveally fixated information rich areas which included the ball and teammates or opponent players with an average fixation duration of 242.29 ms. This suggests that players rapidly move their eyes between different areas of interest. Studies performed in laboratory settings where players were asked to watch at screens, identified significantly longer fixations which raises the question if such experimental controlled environments are able to capture the dynamics of football in an ecologically valid way (Aksum et al., 2020). A follow up eye tracking study investigated the duration of the scan in relation to the playing phase in the actual performance context. It was found that players prior to receiving initiated longer scans when the ball was in the air, passed between players or between touches of controlling the ball (Aksum, Brotangen et al., 2021). Those brief moments seem to provide the players more time to scan the environment while having collected enough information to keep track of the ball and anticipate its future position (Aksum, Brotangen et al., 2021).

Not surprisingly, playing position and their positional demands are also related to players scanning behavior. Accumulated evidence shows that central midfielders have the highest scan frequency in comparison to other positions on the field (Jordet et al., 2020). In light of their positional demands, they have the highest number of passes and are the most important link in initiating the attack play (Clemente et al., 2015). Therefore, this position in particular requires continual awareness of all surrounding affordances (Aksum et al., 2020).

After reviewing the existing research it becomes clear that there are various variables that relate to scanning behavior of football players such as the direction, timing and duration of the scan as well as contextual factors of opponent pressure, field position, level of competition etc. Most importantly, the accumulated evidence indicates that VEA plays a crucial role in superior ball performance. Therefore, there is a rising interest in finding out how VEA can be effectively trained.

Training Visual Exploratory Action in Football

Despite the extensive literature on the nature and performance benefits of VEA, there is limited applied research on how to train scanning effectively to improve on-field ball performance of football players. Several studies used video simulations (McGuckian et al.,

2019) or new technology such as virtual reality (Rojas Ferrer et al., 2020). However, it is unclear to which extent those tools are representative of the dynamic performance context of football and lead to actual performance differences on the field. Williams et al. (2011) emphasized the importance of applied perceptual and cognitive research in sports that also tests the real-world impact instead of exclusively investigating improvements in rather superficial laboratory settings (Dicks et al., 2015; Williams et al., 2003). Following this line of reasoning, we review ecological valid studies that aimed at improving football players scanning and performance by assessing on-field transfer tests.

One of these studies applying such a research approach was an ecological imagery intervention study by Jordet (2005). He investigated three male elite midfielders that performed several guided imagery sessions over a period of 10-14 weeks. Those individualized sessions concentrated on imagining visually exploring the environment prior to receiving the ball with the goal of identifying and acting on affordances. In addition, the imagery sessions were occasionally supported by game recordings of the players. While the imagined situations were designed to be as specific as possible and attuned to the players skill level, technical abilities, position etc., the visualizations lacked the action component and physical feedback by the environment that would be experienced on the field. The results show that the intervention seemed to improve the scanning frequency and timing in two (out of three) participants. Moreover, in the post-intervention interview, the three players stated that they became more cognizant where opponent players and teammates are located, felt that they had more time to act, and that the imagery sessions had a positive influence on their performance. In addition, one participant pointed out that he particularly benefited from watching himself on tape. Contrary to the expressed statements, the data was still mixed and variable for the players and only one of them indicated improved ball performance during matches. Jordet (2005) concluded that the intervention was at best marginally successful in improving on-field performance. He speculated that the intervention might not have been strong enough to result in significant improvements in ball performance and suggested integrating imagery into actual exercises with the ball to further improve efficacy.

A similar imagery intervention study by Pocock et al. (2019) relied on the PETTLEP (i.e., Physical, Environment, Task, Timing, Learning, Emotion, and Perspective) model to guide their individualized imagery practices with the intention to improve performance for elite academy players. Moreover, the intervention was combined with video analyses of elite football matches and following Jordet´s (2005) procedure with watching self-recordings to aid the imagery process. The recruited midfielders and forwards performed guided as well as individual imagery sessions over a period of six weeks. Similar to Jordet´s (2005) results, there was a positive effect on the ability to perform VEA, but no significant effect on ball performance in most participants. Pocock et al. (2019) largely confirmed prior research findings, that the intervention primarily improved scanning abilities but lacked the necessary action component to profit from the increased awareness. Pocock et al. (2019) suspected that the intervention was not long enough for the players to translate the newly acquired scanning skills into ball performance. Similarly, in a case study of an elite football player, Jordet (2004) observed substantial differences in VEA and prospective control of the ball three years post-intervention and not immediately after the intervention, underlining that the development of such skills require longer periods of time.

While these studies show partially promising results in improving VEA, it seems that an imagery intervention is not sufficient enough to improve ball performance. To address the shortcomings of imagery interventions, we propose an ecological training intervention which will be discussed next.

An Ecological Training Intervention

In the current study we employ an ecological training intervention in an elite midfielder that primarily aims at improving scanning abilities, and accordingly, enhancing ball performance (e.g. Phatak & Gruber, 2019). More specifically, we investigate how the intervention influences the development of scanning within the time span of a teammate passing the ball until its reception, what we call in this research ‘critical scans’. Depending on the speed and distance of the pass, that duration obviously varies. In any case, critical scans close to receiving the ball are particularly important to gather updated information that is necessary for deciding imminent actions (Jordet, 2005). For example, McGuckian et al. (2018) investigated scanning frequency and head excursions (explored radial distance of a scan) of 32 football players through IMUs (Inertia Measurement Unit). They found that players performed the most VEA within one to two seconds before receiving the ball and that the shorter the time interval between the last scan and the reception of the ball, the better players’ ball performances, particularly passing in the opposite direction (McGuckian et al., 2018).

Unlike imagery interventions, in the current ecological training intervention, players perform in their natural environment during on-field training sessions. A second feature is that video analyses help to identify demands, opportunities, weaknesses as well as improvements during games and training sessions. Third, it is a longitudinal intervention across years (in the current study: four football seasons or years), to provide enough time for players to adapt and develop the skills. Fourth, the procedure is highly individualized and guided by a football coach specialized in VEA. While all these features of the intervention worked jointly, incorporating the action component during the training sessions in the natural performance context is a unique contribution of the current study.

Various researchers (e.g. Pocock et al., 2019) called for more studies aimed at specific drills that facilitate the transfer of scanning skills into improvements in ball performance. The current intervention focuses on three specific drills: (1) performing critical scans, (2) orienting the body sideways or forward during ball reception, and (3) communicating non-verbally via hand gestures.

Additionally, to critical scanning we specifically focus on body orientation because there is some evidence that a higher scan frequency is associated with forward or sideways rather than backwards body orientation during the reception of the ball (Aksum, Pokolm, et al., 2021). Moreover, they found a link between the timing of the scan and the body orientation. The analysis showed that the shorter the time interval between the last scan and the first contact with the ball, the more the player oriented the body forward. Concluding that a forward or sideways body orientation is the best body orientation, by allowing the player to scan for affordances in the attack direction and increase situational awareness for subsequently controlling the ball (Aksum, Pokolm, et al., 2021; Pokolm, et al., 2022).

On the contrary, there is limited scientific literature on nonverbal communication via hand gestures in relation to scanning or ball performance in football (Mclean et al., 2019). A recent observational study found that football players most often (57.3%) communicated nonverbally through arm movements (Drage, 2023). Those were often performed in combination with additional head, hand or finger movements as well as verbal communication. While most nonverbal communication was pointing towards oppositional players in a defensive situation, offensive players frequently asked for the ball through arm movements (0.30 times per minute; SD = 0.19) (Drage, 2023). Despite the lack of scientific literature, we included the variable of nonverbal communication because players that perceive affordances through VEA may have better ball performance when communicating to teammates if and where they want to receive the ball.

In consideration of the ecological training intervention we hypothesized (*Hypothesis 1*) that throughout the study period critical scanning (H1a), forward or sideways body orientations (H1b), and nonverbal communication via hand gestures (H1c) increased over time.

Furthermore, to test the effects on ball performance, we focus on maintaining teams ball possession. The reason to rely on this particular outcome variable is because it implicates successful control of the ball during reception and throughout the possession of the ball as well as a successful pass to a teammate, which are behaviors associated to winning matches (Lago-Peñas et al., 2011). On the grounds that a forward or sideways body orientation is linked to more VEA (Aksum, Pokolm, et al., 2021), and VEA is associated with fewer turnovers (Phatak & Gruber, 2019) we assumed that critical scanning and forward or sideways body orientations are related to ball performance, more specifically maintaining teams ball possession. Even though we do not have scientific evidence for an association between nonverbal communication via hand gestures and ball performance, we explore if it aids keeping teams ball possession. Hence, we hypothesized (*Hypothesis 2*) that there is a relationship between critical scanning (H2a), forward or sideways body orientations (H2b), nonverbal communication via hand gestures (H2c) and maintaining teams ball possession.

Method

Study Design

The research is an explorative case study which investigates the development of an elite female football player who underwent a prolonged ecological training intervention. During the intervention period the participant played the position of an offensive central midfielder and competed in first league national matches as well as in international tournaments. The participant was asked to participate based on existing time series data resulting from a collaboration with an independent coaching company. Therefore, the current study is retrospective and secondary in nature. The intervention focused on improving critical scanning abilities, forward or sideways body orientations during ball reception, and nonverbal communication via hand gestures. The video analyses as well as the training sessions were designed and carried out by a personal football coach who specialized in scanning behavior in the game of football. In the following sections we describe the procedures and motives behind the video analyses and training sessions of the intervention in more detail.

Video Analyses and Training Sessions

The video analyses were in a one-to-one conversational setting including the athlete in conjunction with the personal football coach, in which they discussed past game performances and identified behavioral aspects to improve (e.g. timing of the scan). The coach took on a coaching approach in which the athlete was guided towards insights by asking specific questions. The objective behind this approach was that the athlete owns the insight and is therefore more likely to change her behavior. The analyses were supported by short clips of game footage that either showed good performances of the athlete or game situations in which the player could have behaved differently. A good performance was defined by either performing VEA prior to receiving, orienting the body forward or communicating to teammates via hand gestures where she wants to receive the ball. On the other hand, inferior actions included game situations in which, for example, the athlete did not scan the environment and therefore lost the opportunity to identify and act on affordances. Such an approach of watching recordings of own game performances is supported by Jordet´s (2005) research which showed that it functioned as a helpful tool to further improve VEA. In total those collections of video clips made up 3-5 minutes and presented a variety of game situations. The review and reflection of past performances during the video analysis complemented the training sessions performed on the field.

Similar to the general structure of the video analyses, the training sessions were performed in a one-to-one coaching setting. To prepare for the successive exercises, the training sessions started with a warmup, in which the athlete played small reaction-time games or completed coordination exercises that demanded heightened attention and concentration. One warmup exercise was throwing a ball behind the back, over the shoulder and catching it with the other hand. Throughout the warmup the applied exercises were increased in difficulty by adding complexity e.g. catching the ball with the same hand. After the warmup the athlete practiced diverse passing exercises on the pitch which required constant scanning, adapting the body orientation, and communicating via hand gestures. These individualized exercises were designed by the coach in such a way that they mimic game situations and were relevant for the players positional demands. One aspect of resembling the performance environment was to locate the passing exercises on the pitch where the athlete was playing during matches. Often times, the exercises included acting on environmental stimuli e.g. surrounding lights or numbers on the ground that made VEA necessary and informed the athlete in which direction to dribble or to pass the ball. More specifically, the exercises demanded keeping track of the ball, scanning the environment, passing or receiving a ball while turning and moving in different directions. Furthermore, the coach designed the exercises to improve the behavioral weaknesses that were identified during the video analyses. If the athlete e.g. had trouble performing critical scans to perceive surrounding affordances when receiving a high ball during competition, such circumstances were reproduced during the training. The complexity of the exercises was individually adapted to the skill level of the athlete. Once the athlete mastered a specific exercise, it was increased in difficulty so that the training was constantly challenging the athletes abilities. Still, the coach paid close attention to the frustration levels of the athlete and occasionally provided some encouraging feedback to preserve motivation. Overall, the training sessions were highly individualized to fit the needs and demands of the player.

Within the four years of the intervention, the athlete received a total of 64 video analyses and 16 training sessions. Each of those interventions continued for a duration of one hour. The athlete received on average two video analyses per month during the football season excluding inactive periods due to injuries. Furthermore, most of the video analyses were realized remotely via a video call. The training sessions on the other hand, were performed during the first two seasons of collaboration, 7 in the first season and 9 in the second. The last 4 sessions were performed remotely via video call, and the training did not continue after that due to a location change of the athlete. Still, the majority of sessions were performed in the natural performance environment, i.e. on the football pitch and in the presence of the coach.

Data Analysis

To investigate if the video analyses and training sessions had an effect on performing critical scans (H1a), forward or sideways body orientations (H1b) and nonverbal communication via hand gestures (H1c) during competitive matches, we analyze existing observational data from 58 games across 4 football seasons. This data was coded by the coach as part of the preparation for the video analyses and included 6 matches prior and 52 matches throughout the intervention period. While watching the game recordings, the coach identified Relevant Game Moments (RGMs) where the player received a ball from a teammate and had the opportunity to perform all three behaviors of interest. Furthermore, to be classified as a RGM, the recording needed to clearly display the behaviors of the player prior to receiving the ball, during contact and after consecutive action with the ball e.g. a successful pass. This resulted in a total of 584 RGMs out of the 58 games. This includes the baseline measurement of 119 RGMs out of the 6 games prior to starting the intervention. For each RGM, the coach manually coded the number of performed critical scans, if the player communicated via hand gestures (yes/no) prior to receiving the ball and the body orientation (forward/sideways/backwards) during reception. Furthermore, it was documented if the team kept possession of the ball (yes/no) after the player´s ball contact.

Reliability

To investigate the reliability of the data, we conduct an inter-observer reliability test (Stemler, 2004) with the researcher as the second observer. After getting familiar with the coding scheme that was used during the data collection process, the researcher and the coach code a selected game on all predefined variables: RGMs, critical scans (number), hand gestures (yes/no), body orientation (forward/sideways/backwards) and ball possession (kept/lost). The percentage agreement/error of the data between the researcher and the coach is assessed for each variable (see Table 1).

Table 1

Inter-Observer Reliability

	Variables				Total
	Hand Gestures	Critical Scans	Body Orientation	Ball Possession	
Agreement	85%	80%	85%	100%	87.5%
Error	15%	20%	15%	-	12.5%

Note. Based on 20 RGMs that were identified by both the coach and the researcher.

Despite the rather high percentage agreement (87.5 %) concerning the 20 RGMs that were identified by both the coach and researcher, there were in total 12 RGMs that were only identified by one of the observers. Therefore, we need to acknowledge that regardless of the high agreement of the observed behavior, there was a partial disagreement about which ball contact should be identified as a RGM. Hence, the presented data should be interpreted with some caution. In case of disagreements in the coding, we prioritized internal consistency and used the initial coded data from the coach for our analysis.

Statistical Analysis

Regarding the statistical analysis we use Microsoft Excel for organizing and exploring the data. In the following we describe the different methods to test our hypotheses. Concerning the research question about the development of performing critical scans (H1a), forward or sideways body orientations (H1b), and nonverbal communication via hand gestures (H1c) before and throughout the intervention period, we construct three separate line graphs for each behavior. Each data point within these graphs represents 10 RGMs and indicates the percentage of the performed behavior, respectively. For instance, if a data point is on the 90%-line, it means that the player performed critical scans 9 out of 10 RGMs. In addition, a linear regression line is plotted, and Monte Carlo analyses (Harrison, 2010) assess if the trajectories (slope) are independent of time. Therefore, we run a simulation based on the H0: that the slope results from random time series of the same data. To perform the simulation, we randomly shuffle the existing data points 10.000 times and compute the slope of the fitted linear regression line for each shuffle. Hence, we end up with a frequency distribution of all simulated slopes that we compare our criterion slope to. We test the observed slope against the frequency distribution with a two-sided significance level of α = .05. This procedure is repeated for each behavior of interest.

To test the second hypotheses (e.g., the link between critical scanning and maintaining teams ball possession), a Chi-Square test of independence is performed for each of the three behaviors. Three separate 2x2 tables display the observed frequencies of RGMs, where the player did or did not perform the behavior of interest and if the team lost or kept possession of the ball.

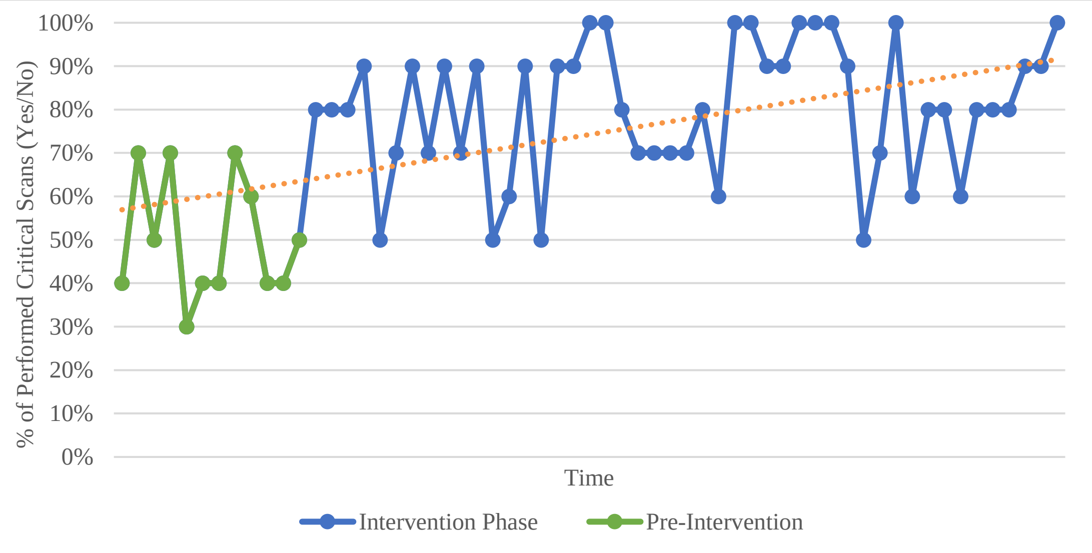
Results

Critical Scanning

Across all identified RGMs, the athlete scanned the environment during the time span of a teammate passing the ball until its reception in 74.1% (433 RGMs) of the cases. In addition, in 12.2% (71 RGMs) of those moments the player scanned two times and in 1.7% (10 RGMs) the player was able to scan three times e.g. by moving the head multiple times from left to right, while keeping track of the ball. Accordingly, in 25.9% (151 RGMs) the player did not scan prior to receiving.

Figure 1

Development of Critical Scanning



Note. Data points represent 10 relevant game moments (RGMs)**.**

Figure 1 illustrates the percentage of RGMs in which the athlete critically scanned the environment. The fitted linear regression line (dotted in orange) indicates an upward trend while considering all the data points including the coded games prior to the intervention (Pre-Intervention). Furthermore, there is an increase in critical scanning at the start of the intervention. This is also reflected in the higher mean (M = 80.4%, SD = 15.3%) throughout the intervention period in comparison to the pre-intervention phase (M = 50%, SD = 14.1%). In essence, prior to the intervention the athlete scanned on average 5 times out of 10 RGMs, while during the intervention it increased to 8 out of 10 RGMs. However, there is a substantial variance in the data that should be considered. The Monte Carlo test resulted in a significant p-value ($p < .001$), providing evidence in favour of the hypothesis (H1a) that throughout the study period, the number performed critical scans increased over time.

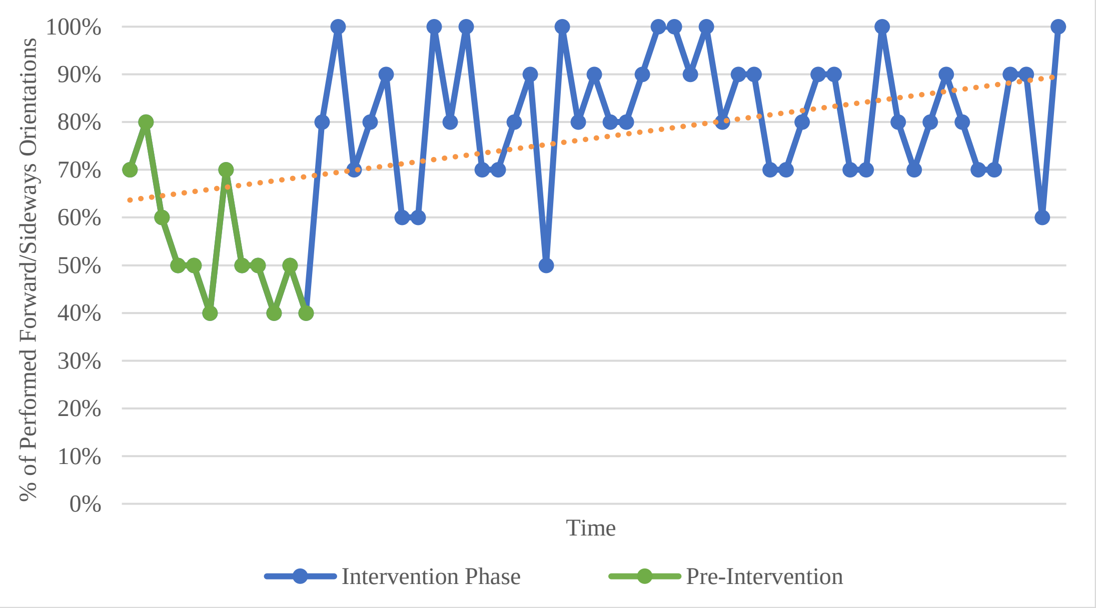
Body Orientation

The player oriented the body towards the opponent goal (forward) in 34.4% (201 RGMs) of all RGMs. However, the body most often was parallel to the sideline (sideways) with 42.1%

(246 RGMs). In 23.5% (137 RGMs) of the cases to body was oriented backwards facing the own goal when receiving the ball.

Figure 2

Development of Body Orientations



Note. Data points represent 10 relevant game moments (RGMs)**.**

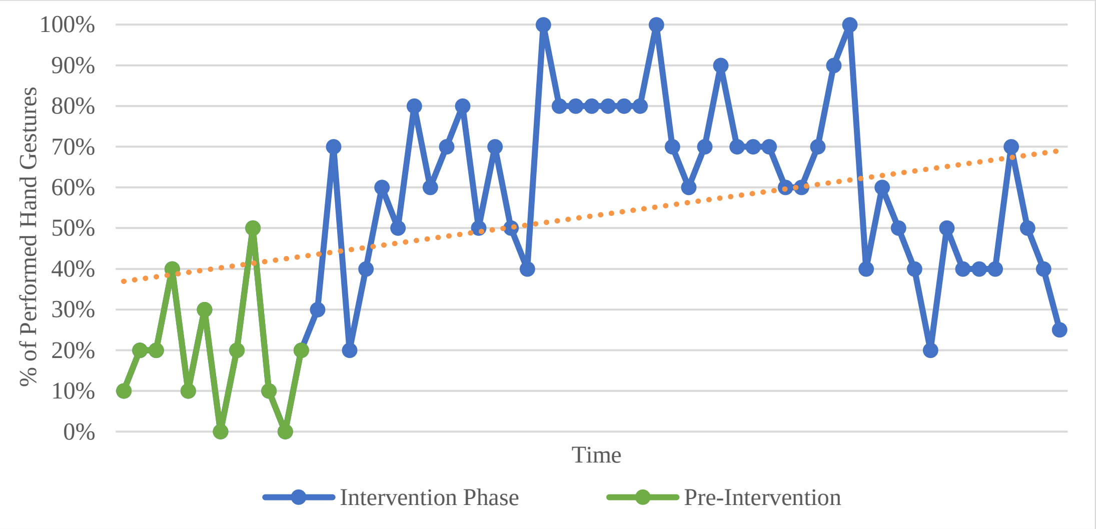
Also Figure 2 displays an increase in forward or sideways body orientation at the start of the intervention. Moreover, there is a noticeable difference between the averages prior to the intervention (M = 54.2%, SD = 13.1%) and during the intervention (M = 82.3 %, SD = 12.9%). In addition, throughout the intervention phase there are only a few data points below the 70%-line, indicating that the athlete persistently reduced backward orientations when receiving the ball. The Monte Carlo simulation suggested that the trajectory is unlikely a consequence of random time series (with $p < .001$). Therefore, the evidence is in favor of the hypothesis (H1b) that the number of performed forward or sideways body orientations increased throughout the study period.

Hand Gestures

With regard to performing hand gestures, the player communicated to teammates e.g. in which direction to pass or on which leg they want to receive the ball in 53.3% (311 RGMs) of all the game situations. Thus, in 46.7% (273 RGMs) the athlete did not nonverbally communicate via hand gestures.

Figure 3

Development of Hand Gestures



Note. Data points represent 10 relevant game moments (RGMs).

In view of Figure 3, there is a clear increase in the development of displaying hand gestures during games in the first two-thirds of RGMs. During the pre-intervention phase the athlete nonverbally communicated via hand gestures on average in 2 of the 10 game situations ($M = 19.2\%$, $SD = 15.1\%$). That increased to performing on average 6 out of 10 RGMs ($M = 61.6\%$, $SD = 20.7\%$) during the intervention. Despite the initial upward trend in the data there is a noticeable decline at the end of the intervention period. While we hypothesized a linear positive trajectory, the data indicates a rather curvilinear development with an increase in the beginning, a peak in the middle and decline at the end. Nevertheless, we tested the slope of the displayed fitted regression line against the slopes from the Monte Carlo simulation and found a significant positive trend ($p < .01$). Therefore, the positive trajectory of increased hand gestures to communicate with teammates is unlikely a result of random time series. To conclude, despite the decline in the end, the data provides empirical support for the hypothesis

(H1c) that during the study period the number of performed hand gestures increased over time.

Critical Scanning and Teams Ball Possession

To test if there is a relationship between critical scanning and maintaining teams ball possession (H2a) a Chi-Square analysis was performed (see Table 2). The test resulted in a non-significant p-value (p = .48). Thus, the analyzed data does not indicate that critical scanning is linked to keeping teams ball possession.

Table 2

Chi-Square Analysis: Dependence Critical Scanning and Teams Ball Possession

		Possession		Sum
		Kept	Lost	
Critical Scan	Yes	358 (355.15)	75 (77.85)	433
	No	121 (123.85)	30 (27.15)	151
	Sum	479	105	584

Note. Within the brackets is noted the (expected value).

Body Orientation and Teams Ball Possession

The Chi-Square test of independence (see Table 3) which explored if there is an association between a forward or sideways body orientation during ball reception and maintaining teams ball possession resulted in a nonsignificant finding (p = .68). Therefore, we have no evidence in favor of our hypothesis (H2b) that there is a relationship between a forward or sideways body orientation and keeping teams possession of the ball.

Table 3

Chi-Square Analysis: Dependence Body Orientation and Teams Ball Possession

		Possession		Sum
		Kept	Lost	
Body Orientation	Forward, Sideways	365 (366.63)	82 (80.37)	447
	Backwards	114 (112.37)	23 (24.63)	137
	Sum	479	105	584

Note. Within the brackets is noted the (expected value).

Hand Gestures and Teams Ball Possession

The third Chi-Square analysis (see Table 4) of investigating the presence of a relationship between nonverbal communication via hand gestures and keeping teams ball possession (H2c) similarly held a nonsignificant result (p = .85). Hence, the available data does not support an association between nonverbal communication via hand gestures and maintaining teams possession of the ball.

Table 4

Chi-Square Analysis: Dependence Hand Gestures and Teams Ball Possession

		Possession		Sum
		Kept	Lost	
Hand Gesture	Yes	256 (255,08)	55 (55,92)	311
	No	223 (223,51)	50 (49,08)	273
	Sum	479	105	584

Note. Within the brackets is noted the (expected value).

Discussion

The purpose of this study was to investigate two main questions. First, we explored the effects of the ecological training intervention in an elite football player on performing three behaviors, particularly critical scanning during matches. The results indicate a significant increase in critical scanning, forward or sideways body orientations and nonverbal communication over time. Secondly, we tested if there is a relationship between the three behaviors and ball performance, i.e. maintaining teams ball possession. The statistical analysis provided no evidence for a link between critical scanning, forward or sideways body orientation or nonverbal communication with keeping teams ball possession. In the following sections, we discuss the findings, describe suggestions for future research as well as providing a review of the limitations of the current study.

Generally, the results indicate that the ecological training intervention played a significant role in changing the behavior of the athlete during competitive matches. The active component through the individual training sessions in combination with the cognitive reflection during the video analyses seems to be an effective blend to establish new behavior patterns. For example, we could observe a noticeable increase in the number of performed critical scans throughout the four-year intervention period with an immediate increase at the start of the intervention. These results are in line with the findings from Pocock et al. (2019) and Jordet (2004) who observed superior scanning abilities already 6 to 14 weeks after starting their intervention. However, it needs to be mentioned that critical scanning, i.e. taking the eyes off the ball directly before receiving it, is different from scanning the environment without the pressure to receive the ball in the next moment. Critical scans are to majority performed within 2 seconds before the first contact with the ball. Depending on the distance and speed of the pass this timespan varies substantially. Based on the coded game recordings, we conclude that the differentiation between a critical scan and a scan closely before a pass seems to be a rather arbitrary cut. In a close quarters game situation with high opponent pressure, a pass from a teammate can be only a few meters of distance, which provides a very brief window to perform a critical scan. VEA directly before such a short and quick pass would not be considered a critical scan but still provides updated information of given affordances. Therefore in future studies we would suggest a definition of critical scanning based on a time-period before receiving the ball instead of relying on the start of a pass from a teammate. Measuring the number of scans within, for example, two seconds before receiving the ball might be more comparable and reliable than using the pass as a reference point where the distances and speeds are changing.

Moreover, it is interesting to investigate when and for how long the player scans within e.g. 2 seconds prior to receiving. This is related to the timing of the scan (i.e. time between the last scan and the first ball contact) and the duration of the scan (i.e. time that is spend visually exploring). The closer the scan is performed to receiving the ball, the more recent is the perceived information of the locations and movement directions of the surrounding players. But there is a tradeoff between a scan closely before receiving and perceiving the approaching ball. The player needs to perceive sufficient information about the pass to be able to receive the ball successfully. It would be pointless for the player to be aware of given affordances without ensuring control of the ball to take advantage of them. Besides the physical, technical and coordinative skill that are required to prospectively control the ball, players scanning behavior might also be influenced by psychological factors such as mental fatigue or anxiety (Coutinho et al., 2017; Nieuwenhuys et al., 2008). It requires a certain level of certainty by the athletes to take the eyes of the ball to perceive the environment, while knowing that the ball is approaching. Such certainty may be gained through deliberate practice (Ericsson et al., 1993) and numerous experiences in which the athlete critically scanned and successfully controlled the ball. This line of reasoning would further argue for the importance of the applied training sessions to foster those experiences and suggests an integration of such drills in normal football practice. On the other hand, Jordet (2005) also observed an increase in scanning through imagery techniques and watching performance recordings. Therefore, it is also possible that the cognitive awareness of scanning and reflecting over ones performance during the video analysis is enough to increase critical scanning on the pitch. Based on the current study design we cannot differentiate if the observed effects on all three behaviors are due to the video analyses or the training sessions or a combination of both. As described above, we assume that the combination of the action component during the training with the feedback and reflection from the video analysis had a conjoint effect. Still, to answer this question scientifically, a follow-up study could investigate if the different interventions applied in different groups (training sessions, video analysis, combination, control) yield different results.

In addition to the more popular scientific topic of scanning or VEA in football, we investigated body orientations and nonverbal communication via hand gestures that to date have received limited attention by the scientific community. Regarding the body orientation during ball reception, the intervention seemed to have a strong effect on the athlete. Concurrently with the intervention, the athlete was able to orient the body forward or sideways in the majority of the RGMs with a low count of backward orientations. This is likely a consequence of the training sessions, which consisted of drills that forced the athlete to constantly adapt the orientation to efficiently receive the ball and move into different directions. A forward or sideways body orientation may come with the advantages of more convenient detection of affordances towards the opponents goal and rather than being required to turn with the ball, the athlete can take the ball along in the moving direction (Aksum, Pokolm, et al., 2021). Those more efficient behavior patterns might have supported the continued behavior change during competitive matches.

Concerning, nonverbal communication via hand gestures the athlete asked significantly more frequent for the ball through arm movements in concurrence with the applied intervention. However, towards the end of the of the four-year intervention period the prevalence of hand gestures reduced again. Possible explanations for this might be that the training sessions only proceeded in the first two years of the intervention. Thereafter, the athlete might have needed continued practice sessions to further internalize the hand movements in automatic behavior patterns. Moreover, the nonverbal communication is dependent on the teammates willingness to react on the visual signal. The athlete might be less likely to nonverbally communicate if the teammates regularly do not provide a pass based on presented hand gestures. Still, we conclude that nonverbal communication via hand gestures can provide a competitive advantage during football matches. Unlike verbal signals, hand gestures can be very subtle without drawing much attention to the opponent players. Moreover, they communicate that the receiving player perceives an affordance down the field which might be not perceptible to the teammate. By using the left or the right arm the receiving player can indicate to which leg the ball should be passed to. Furthermore, by either pointing in an open space or showing the palm of the hand communicates if the ball should be passed in the moving direction or directly towards the player. Consequently, the passing player has a secure passing opportunity, and once the pass is played in the proposed direction, the receiving player can efficiently control the ball to take advantage of the identified affordances. More scientific research could be devoted to body orientations and hand gestures in football to validate our observations and inferences of potential performance benefits.

Despite the increase in critical scanning, forward body orientations or nonverbal communication during matches, the current research found no indications of improved ball performance (i.e. keeping teams ball possession) in relation to each behavior. Again the non-significant findings concerning critical scanning and ball performance are in line with Jordet´s (2005) and Pocock´s et al. (2019) research that observed only marginal improvements in some of their participants regarding decision making and better performance with the ball. In those studies the data was similarly variable with some overlapping data points between the baseline measurement and the intervention period. Therefore, it is possible that the ecological training intervention, and accordingly, the increase of the performed behaviors did not lead to an actual improvement in ball performance during matches. Such a conclusion would partially contradict the accumulated evidence that more VEA is linked to superior ball performance, including more successful passing (Aksum, Pokolm, et al., 2021). An alternative explanation for the non-significant findings could be that in the current research, ball performance relies on the binary outcome variable maintaining teams ball possession (yes/no). That choice of performance measurement might not be sensitive enough to capture potential performance benefits from more critical scanning as well as communication via hand gestures or forward body orientations. Even if the ball contact resulted in a successful or unsuccessful pass, the binary variable does not consider other performance indicators e.g. response speed, ball control, quality of the decision, or direction and precision of the pass, which should be investigated in future studies. For example, two actions may get coded a success, while in one incident critical scanning led to a fast turn with a penetrating forward pass and in another situation the player passed backwards to a teammate without exploring affordances to advance down the field. In both actions the player ensured that the team maintained possession of the ball, yet the actions differ in quality, e.g. advancing towards the opponent goal. In addition, to grasp the dynamic of the individual situations we could consider other contextual factors such as direction of play, field position, opponent pressure, availability of teammates etc. Those performance indicators and contextual factors might provide data for a more nuanced assessment of ball performance and consequently to test the benefits of the ecological training intervention. In the dynamic game of football it is challenging to measure those variables and combine them into a rigor operationalization of ball performance. Instead of relying on a binary outcome variable or simple observer ratings as performed in Jordet´s (2005) research, future applied studies might come up with valid alternative approaches to measure ball performance during football matches.

Even if future studies with more sensitive measurement methods of ball performance replicate our non-significant findings, there might be other psychological outcomes associated to the training intervention that are worth exploring. For example, Jordet (2005) conducted interviews in which participants stated that the scanning intervention helped them to gain a better overview during matches, which let them feel more in control and more prepared within game situations. Furthermore, it was mentioned that the participants perceived more time to make decisions on the field and recognized alternative courses for actions. Such psychological feelings of control and security in interacting with or manipulating the environment within a challenging task are closely related to the need for competence from the Self-determination theory by Ryan and Deci (2000). Therefore, future studies could investigate if such an ecological training intervention fulfills the need for competence during training sessions as well as competitive matches. Interviews within qualitative research could identify other possible benefits of an individualized training approach besides the discussed potential observable improvements in ball performance.

Limitations

Despite the discussed benefits of the ecological training intervention, the study has some limitations that need to be considered. First of all, the research is a case study without a control group and therefore relies solely on the data of a single participant. There are various possible confounding factors that may be unique to the subject which might have influenced the results of the current study. Such individual factors might be the level of motivation of the athlete to work on the three target behaviors during and besides the guided training sessions. Moreover, the subject is an elite football player and might have played at such a high level prior to the intervention that further improvements in ball performance through the intervention might have been too small to test significant. Such hypotheses about possible ceiling effects were previously formulated in Jordet´s (2005) research. Apart from the individual characteristics of the subject, there might be a significant influence from the professional coach. Because the coach did not follow a prescribed structure of exercises but designed the training sessions on a highly individualized basis, the quality of the intervention was dependent on the experience and creativity of the coach to design the specific drills. The individualized approach to fit the needs of the players is one of the greatest strengths of the intervention, but at the same time makes a standardized protocol and a direct replication challenging. Furthermore, there were inconsistencies concerning the reliability of the data. Within the inter-observer reliability test, there was a partial mismatch present between the identified RGMs of the coach and the second observer (see Method section). Considering the listed limitations of the current research, the results should be interpreted with some caution.

Conclusion

Even though the study has some limitations that need to be taken in consideration, the results indicate the effectiveness of the ecological training intervention on increasing the player´s critical scanning, forward or sideways body orientations and nonverbal communication via hand gestures during football matches. Therefore, we provide an alternative training approach for fostering VEA in football to the previously studied imagery interventions. Moreover, the study explored new research topics of forward body orientations during ball reception and nonverbal communication with teammates. Despite the non-significant findings concerning an improvement in ball performance, we discussed possible explanations for these results as well as more valid indices for ball performance and alternative outcome variables that should be examined in future research. In conclusion, our research adds to the existing literature on VEA or scanning in football and functions as a starting point for future research directions in the field of football performance.

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