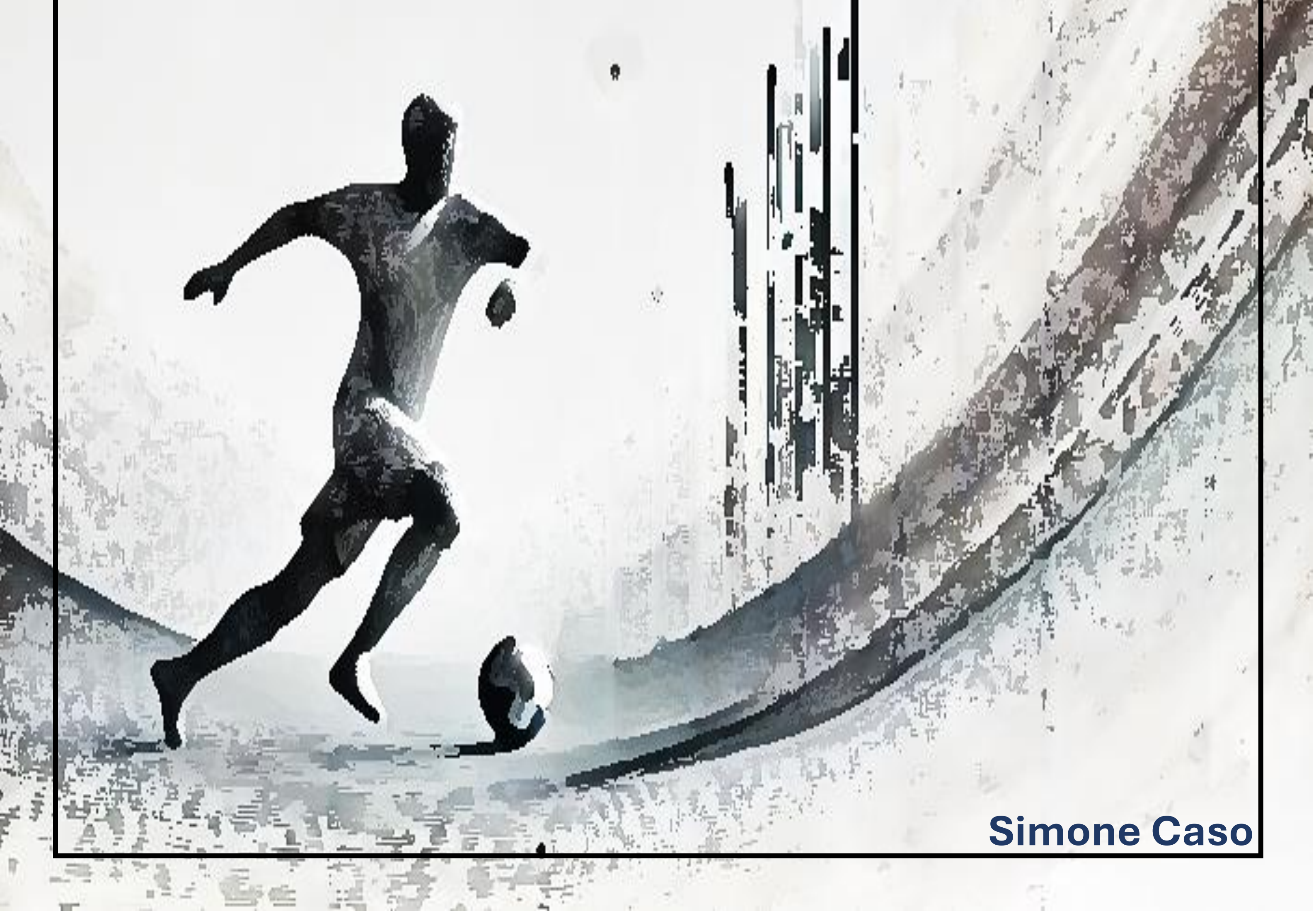
ENHANCING THE UNDERSTANDING OF PERCEPTUAL-MOTOR SKILLS THROUGH VIDEO NOTATIONAL ANALYSIS

A VIDEO NOTATIONAL ANALYSIS OF VISUAL EXPLORATION, TEAM COMMUNICATION, AND CREATIVITY IN ELITE SOCCER



Simone Caso

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ENHANCING THE UNDERSTANDING OF PERCEPTUAL-MOTOR SKILLS THROUGH VIDEO NOTATIONAL ANALYSIS

A Video Notational Analysis of Visual Exploration, Team Communication, and Creativity in Elite Soccer

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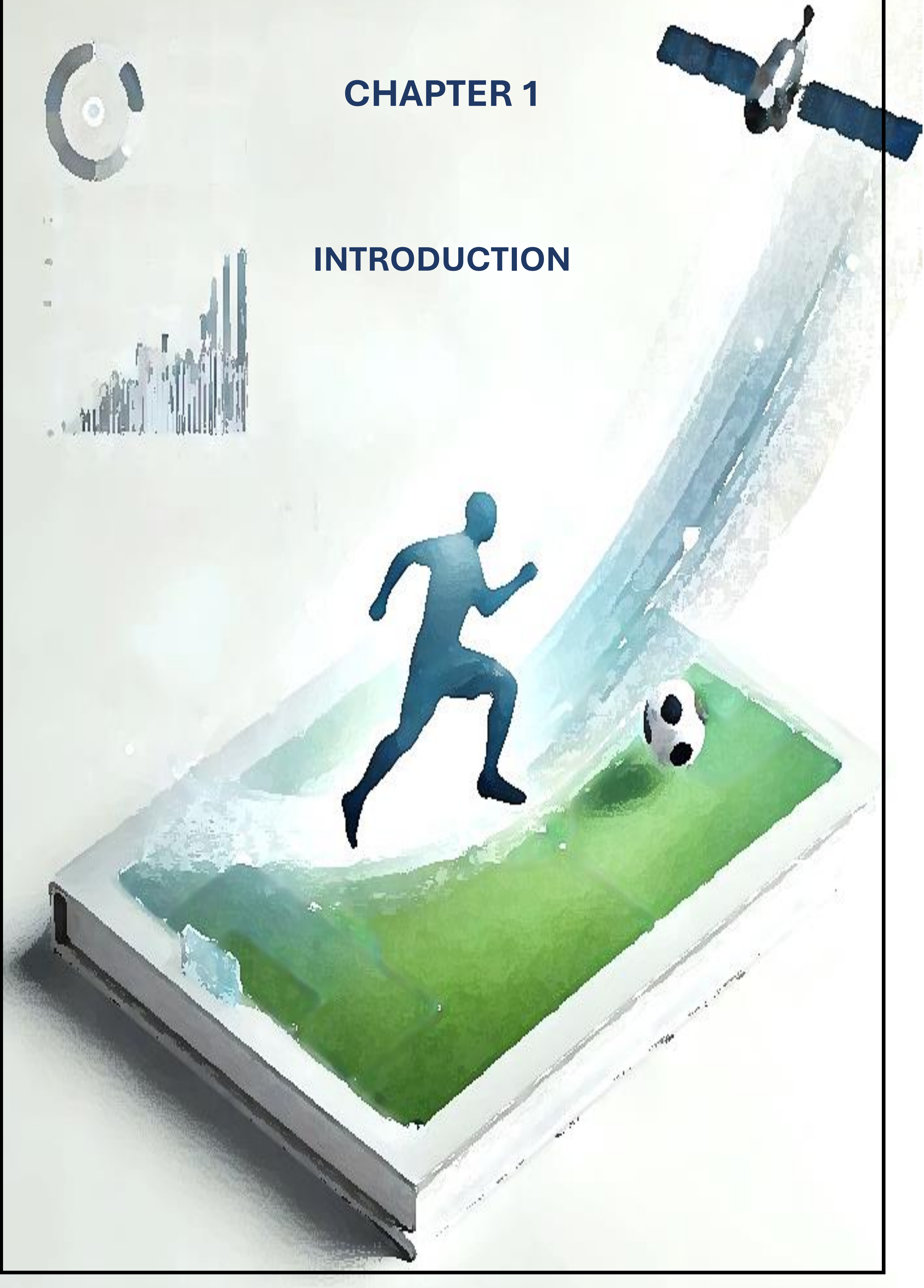
CHAPTER 1

INTRODUCTION



During my six years as human movement scientist at AFC Ajax, I had the opportunity to take on multiple roles, including sport psychologist, youth coach, virtual reality coach and, throughout those years, video analyst. My tasks and contributions as a video analyst evolved over time, transitioning from the more common tactical analyses, which aim to describe the team and individual tactical patterns, to more exploratory behavioral analyses, focusing on players' perceptual-motor skills. For the latter, I became especially interested in analyzing key aspects of players' visual exploratory activities (VEA) while preparing their actions with the ball and the communication among players within the team—both of which eventually became topics of study in my PhD research. In this respect, my work at AFC Ajax involved using video notational analysis to analyze matches and provide feedback for both the technical staff and the players.

As I was tasked with developing behavioral video analysis from scratch, I consulted the existing scientific literature, besides relying on the input and feedback from the technical staff and other video analysts. In doing so, I encountered an important gap between scientific literature and its generalization to application in practice. I experienced this in particular for the experimental studies. Arguably, the primary aim of sports psychology and sport science research is to understand and support the performance of athletes, from beginners to elite competitors. Yet, traditionally, the majority of research in these fields has relied on controlled experimental studies, often conducted in laboratory settings. This raises concerns about the generalizability and the applicability of the findings, especially for elite sports, given that it is difficult to replicate the complexities of real-world performance environments in the laboratory (Williams & Kendall, 2007). In the realm of perception and anticipation research, for instance, researchers have frequently used video screens displaying game scenarios, requiring participants to respond by pressing a button (e.g., Murta et al., 2022; Tay et al., 2012) or moving a joystick (e.g., Piras et al., 2021; Savelsbergh et al., 2002, Woolley et al., 2015). The underlying idea is that this provides insights in perceptual expertise and decision making and/or can enhance players perception and decision making. Yet, as Neisser (1976) argued, because these tasks are inherently artificial, they may not truly or only inaccurately reflect the players' behaviors and expertise in competitive sport contexts (Williams & Abernethy, 2012; van der Kamp et al., 2008; Williams et al., 1999). Moreover, the slow, incremental progress typical of scientific research poses additional challenges. While coaches and players often seek immediate, practical solutions to complex problems, the reality is that research, designed to develop and test theories, is a protracted process. The disparity between the pace of scientific discovery and the urgent demands of practitioners can make it difficult to address the real-world needs of athletes and coaches effectively (Sands, 1998).

Especially in the last decade, video notational analysis has become an increasingly important method both in science and sport practice. Importantly, it may also be instrumental in bridging the gap between the controlled laboratory experiments and the complex dynamics of real-world sports. Video notational analysis enables adherence to representative design principles. Specifically, in the context of sports performance, this entails satisfying the requirement to retain or simulate conditions akin to those encountered by athletes in competitive environments (Araújo et al., 2007; Brunswik, 1956). From the perspective of ecological psychology (Gibson, 1979), this especially refers to keeping the natural entanglement of perception and action intact. Unlike in experimental studies, this is straightforward in studying real-world sports using video notational methods because the behavior is observed as it naturally unfolds in the environment of interest, preserving the authentic interaction between perception and action. However, while video notational analysis witnessed substantial growth in the literature in recent years, especially with respect to measuring tactical patterns of play (Carling et al., 2005, 2009; Hughes, 1997; Hughes & Franks, 2004), their application to analyze perceptual-motor skill and learning remains relatively understudied, also in soccer. For instance, in recent systematic review on performance analysis in team ball sports, soccer represented approximately 50% of the study sample, making it the most commonly investigated sport (Sarmento et al., 2022). In an earlier systematic review on performance analysis in soccer only, it was found that the vast majority of the studies focused physical performance variables and rarely on perceptual-motor variables (Sarmento et al., 2014). Consequently, despite the widespread use of performance analysis (typically by adopting video or computer-assisted notational analyses), examining perceptual-motor skills, such as variability and creativity of action, exploration, perception and decision making, and communication remain relatively understudied.

The aim of this thesis is to explore on field perceptual-motor skills in soccer, by using video notational analyses. Specifically, it addresses current issues surrounding variability and creativity in soccer actions, VEA and intra-team communication. To introduce this work, the remainder of this chapter will introduce the use of video notational analysis, including the processes involved in noting and tagging behaviors, and the theory of ecological psychology, which among others, stress the importance for representative design. The chapter concludes with a brief overview of the studies included in this thesis.

THE USE OF VIDEO NOTATIONAL ANALYSIS

Video notational analysis is not only a crucial tool for coaches and analysts (James, 2006; Wright et al., 2014) but has in recent years also been increasingly used in research (Kirkendall, 2020; Sarmento et al., 2022). Video notational analysis is a method used for *direct* observation, performance analysis, collecting data and the recording of past or live events during sporting activities. It not only offers a quantitative method to understand the intricate play, strategies and tactical actions within a match or practice but also provides insights into the individual player's perceptual-motor and decision-making skills (Hughes & Franks, 2004; Pappalardo et al., 2019). To ensure the validity and reliability of these approaches, typically multiple raters are involved in the analysis process, and intra-rater and inter-rater reliability checks are conducted (Koo & Li, 2016). Sometimes, video is augmented with audio records (e.g., to assess communication). Increasingly, artificial intelligence (AI) will be used to furnish automated and autonomous evaluations (Aimaiti, 2024).

NOTING AND TAGGING BEHAVIOURS

Notational analysis, which originates from manual-written observations, and video analysis allow the systematic observation and analysis of behaviors. Notational analysis involves notating (e.g., on a sheet) behavioral events, while with video analysis comprises tagging behavioral events. Further, notational analysis can be done live but ca also be conducted based on video recordings (Plakias et al., 2023). Noting or tagging behaviors comes in two main types: topographical tagging systems, which analyze the occurrence of behaviors, and dimensional tagging systems, which measure the intensity of behaviors along specific dimensions (e.g., speed, duration, goals scored and others). The selection of a tagging system depends on the study's specific objectives. Developing a behavioral tagging system can be a substantial undertaking, so it is crucial to keep it as complex as needed but as simple as possible to meet the research goals efficiently. Ideally, researchers can find an existing system that aligns with their needs. However, choosing a tagging system should not be done without a clear structure, as it involves theoretical considerations (Bakeman & Gottman, 1997).

Researchers should design the tagging system with a set of hypotheses in mind and tailor the system accordingly. To ensure specificity and completeness, designing a tagging system should follow a period of observing and studying the phenomena of interest, considering it from various perspectives. To ensure validity—the degree to which the tagging system accurately reflects the behaviors or phenomena it is intended to measure—researchers must carefully design the system to align with the study's objectives and theoretical framework. This includes defining clear, operational criteria for each behavioral event being tagged, ensuring that the system captures all relevant aspects of the phenomena, and testing the system in a variety of contexts to confirm its applicability (Shadish et al., 2002). Once considerations of what behavioral events to tag, when to tag, in what settings and by whom become clearer, pilot work and a reiterative process of design modifications are typically necessary.

In some cases, researchers may find that no existing tagging system fits their needs. This situation is not uncommon, as many tagging systems are revisions of previous ones. Therefore, when designing a tagging system, researchers often start by identifying an existing system that closely aligns with their requirements and adapt it accordingly. For example, in Chapter 2, we explored the emergence of creative soccer actions, and in doing so, built upon previous research (Kroger & Roth, 1999; Owen et al., 2004; Santos et al., 2018a,b; Torrents et al., 2016; Werner, 1989) to develop an observation list with the actions of interest, that is, the behavioral events for tagging. Similarly, in Chapter 5, we investigated types of intra-team communication, again drawing on existing studies (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015) to inform our observation or tagging list. Using an existing or derived system offers the advantage of having access to prior psychometric work on validity and reliability. However, the drawback is that often revisions are needed, because these systems may not perfectly align with the requirements of researcher's hypotheses (Kerig & Baucom, 2004; Kerig & Lindahl, 2000).
Consequently, it is important to ensure that observers (i.e., taggers or raters) agree when they independently note or tag the behavioral events (i.e., inter rater reliability). Hence, training the observers is a key component of acquiring reliable behavioral observations. The purpose is to ensure that observers, who initially may have different perceptions or interpretations of the behavioral events, come to agree with each other, maintain consistency over time and become interchangeable. Interrater agreement is a crucial consideration in noting and tagging behavioral events to ensure that observations reflect a standard set of definitions applied consistently by different raters over time. Failure to establishing interrater agreement can lead to limiting reliability and increased error variance, hampering the ability to make comparisons or identify associations between coded behaviors (Bakeman & Gottman, 1997). Various interrater agreement statistics can be used dependent on the scale of the measurement with different statistics suitable for categorical or ordinal, interval, or ratio scale judgments. However, when behaviors are imbalanced in their distribution, this can challenge the interpretation of some interrater agreement statistics, such as Cohen's Kappa. Weighted Kappa is an alternative that allows researchers to assign different weights to disagreements based on their perceived severity, offering greater flexibility in assessing agreement for specific behaviors (Bakeman & Gottman, 1997; Koo & Li, 2016). After meeting these criteria, observers shift from the training phase to engaging in the actual tagging tasks. In this phase, the videos (to be examined) can be divided among observers, who are preferably “blind”, that is, not informed about the aims for the behavioral analysis. To confirm reliability a partial overlap videos is ensured and meetings between observers are repeatedly.

ECOLOGICAL PSYCHOLOGY AND REPRESENTATIVE DESIGN: UNRAVELING THE DYNAMICS OF PERCEPTUAL-MOTOR SKILLS

Video notational analysis is a straightforward way to meet requirements of representative design as advocated by ecological psychology, because it enables the investigation of the behavioral intricacies of players during actual competition. It advances our understanding of how perception and action interact and unfold in real-time. Ecological psychology begins with the premise that the individual and their environment are fundamentally intertwined, forming an inseparable and reciprocal relationship.
At its core is the idea that perception and action are not solely products of processes or representation internal to the individual, but rather that they emerge in the individual’s adaption to the surrounding environment (Gibson 1966, 1979). This highlights the context-specificity of (the interaction of) perception and action, which is expressed in the concept of affordances. Affordances refer to the possibilities for action that the environment offers an individual, grounded in both the individual’s action capabilities and the properties of the environment. This perspective underscores the dynamical, reciprocal and inseparable nature of the relationship between individuals and their environment, shaping not only how individuals perceive the world but also how they act within it. By emphasizing the relation between the

individual and the environment as well as the interaction between perception and action, ecological psychology holds that also behaviors such as creativity, decision-making and communication, which are traditionally considered expressions of internal cognitive processes, can be understood -in principle- as arising in the continuous interaction between the organism and the environment (Araújo et al., 2007, 2019; Stoffregen, 1993; Turvey, 1992).

Because of the inseparability or entanglement of the individual and the environment and perception and action, ecological psychologists have sometimes emphasized the importance of studying behavior in-situ, meaning in the actual environment or situation where it naturally occurs (Starkes et al., 1995). This recognizes the need for individuals (or participants) to navigate the dynamic and noisy situations that simulate the performance environment (e.g., a 2 vs 2 small-sided soccer game); if indeed researchers aim to understand and generalize the behavioral intricacies to the performance environment (e.g., 11 vs 11) the individual and the environment as well as the interaction between perception and action. This approach thus requires researchers in sport psychology to study behavior in ecologically valid settings (Araújo et al., 2007). However, the use of the term in-situ was not well-defined. In fact, in many research papers the term ‘in situ’ term, it has simply come to mean ‘not in the laboratory’, the implication being that studying real, ecologically valid task outside the laboratory is ‘good for sport sciences’ (Araujo & Davids, 2015, 2016). Thus, more principled criteria for classifying an experimental task design as in situ was needed (Araujo & Davids, 2015, 2016).

In this respect, it is of interest that the term 'ecological validity' was popularized by Neisser (1976). Neisser (1976) attributed the concept to Brunswik (1956) but apparently had mistakenly confused it with Brunswik’s concept of 'representative design’. Brunswik (1950; 1956) had argued that investigating individual behaviors requires that the experimental environment represent the conditions under which the individual normally functions. According to Brunswik, this could be achieved by randomly sampling from a variety of environments, which ensures a high correlation between the properties of the experimental environment and the environment it intends to represent. If this “situational representativeness” (Brunswik, 1950) is violated, then the individual’s behavior will differ from its behavior in the normal environment. However, Araujo et al. (2007) argued that a mere random sampling does not suffice. Instead, a more in-depth analysis is needed to achieve representative design. To this end, ecological psychology offers a viable framework. From this perspective, representative design would entail maintaining key individual-environment relations, ensuring that the interactions between perception and action are faithfully replicated in the experimental environment. Accordingly, representative design refers to simulating or retaining performance defining aspects of the conditions encountered by athletes in actual competition. The key requirements are: 1) faithful replication, i.e., experimental conditions must faithfully replicate the real-life factors of competition, including the physical layout, equipment, opponents, and task constraints; 2) contextual realism (i.e., the design must capture the dynamic interactions among athletes, opponents, teammates, and the performance setting, including the affordances); 3) task specificity (i.e., tasks should closely mirror athletes' perceptions and actions in competitive situations, replicating relevant game scenarios and skill requirements); 4) dynamic interactions (i.e., the design should capture athletes' natural real-time adjustments and adaptations to changing situational demands; finally); 5) ecological validity ensures that research findings are applicable to real-world settings by reflecting the conditions athletes face during competition. Representative design is a key approach to achieving this, as it involves structuring experimental environments to critically resemble actual sports environments (Araujo & Davids, 2016).

For sport researchers and practitioners, this concept implies implementing the methodological principles not only in research but also in practical, training and learning settings (e.g., Renshaw et al., 2016). Video notational analysis of practice sessions and matches unambiguously adheres to all these methodological principles. The importance of behavioral observation extends to exploring connections between behaviors within individuals or among pairs or groups (Carling et al., 2009; Gray et al., 2008; Heyman et al., 2014). Researchers are keen on understanding whether identical behaviors manifest during interactions between individuals (Gray et al., 2008). For example, a study that investigates whether soccer players show different performance patterns in penalty kicks based on the presence or absence of an audience (Zheng et al., 2023). Consequently, video notational analysis offers a useful tool to analyze behaviors within the ecological validity, providing a more complete understanding of players' actions and interactions within the dynamic context of soccer.

THE CURRENT THESIS

In the present thesis, through observation and analysis, I have attempted to advance my understanding and gain insights into perceptual-motor skills in soccer in general, and in variability and creativity of actions, VEA, and intra-team communication in particular. I have assessed these perceptual-motor skills via video-notational analysis to examine how they relate to performance in elite soccer. The thesis reports five studies. **Chapter 2** explores the occurrence of creative action, and whether small-sided games in practice can promote creative actions. Based on ecological psychology and dynamic systems, Orth et al. (2017) argued that creative actions emerge from variability in the action repertoire. Since small-sided games have been shown to increase the number of actions, and possibly the variability or diversity of actions, they are anticipated to also increase creative actions. To test this hypothesis, video notational analyses were performed from various small-sided conditioned games during practice and friendly matches in elite soccer.

Chapter 3 and **4** investigate via video notational analysis the VEA rate (number of VEA divided by the time) of elite soccer players across various field positions and timings of passes, including the penultimate and final passes. VEA was defined as “a body and/or head movement in which the player’s face is actively and temporally directed away from the ball, seemingly with the intention of looking for teammates, opponents, and other environmental objects or events, relevant to the carrying out of a subsequent action with the ball” (Jordet, 2005, p.143). Thus, VEA provide an early perception of potential actions (i.e., affordances), within the situation. This ability has been linked to a higher likelihood of successful passing outcomes following ball reception (Aksum et al., 2021a,b ; Caso et al., 2023; Eldridge et al., 2013; Jordet et al., 2020; McGuckian et al., 2017, 2018b, 2020a; Phatak & Gruber, 2019; Pokolm et al., 2022) and elite soccer players demonstrated higher rates of VEA compared to their less-skilled counterparts (Aksum et al., 2021a; Jordet et al., 2013; McGuckian et al., 2020b; Pokolm et al., 2022). To further the observations in previous studies, **Chapter 3** investigates whether the amount of VEA is differentiated within a group of elite soccer players who have been assigned specific positions in the team (i.e., they play at different lines, defense, midfield and attack, and axes, central and wide). Following this**, Chapter 4** revisits whether VEA also distinguishes super elite, award-winning players from their elite teammates without awards. The players in the two groups were from the same team, playing the same match in the same positioning line; and VEA during the penultimate and final pass prior to ball reception and performance were compared between the two groups.

Chapter 5 and **6** address intra-team communication. **Chapter 5** provides a case-study that examines the representativeness of video notated nonverbal intra-team communication of elite soccer players. Thus far, research has used video notational analysis only to assess in-match communication assuming that nonverbal communication alone can represent the full scope of intra-team communication, including both verbal and nonverbal communication (e.g., gestures for giving indication and asking for the ball). Therefore, the analysis compares the effectiveness of video notational analysis alone relative to video analysis augmented with audio recordings in an official friendly match in which player wore microphones.

Chapter 6 critically reviews the existing conceptualizations of intra-team communication, identifying gaps in traditional approaches within sport psychology. Specifically, it is argued that traditional representational theories rely on shared mental models to achieve coordinated actions, which limited practical impact due to their static nature and the assumption that all players share identical cognitive representations (Cannon-Bowers et al., 1993). Alternatively, this chapter proposes an ecological perspective that conceptualizes intra-team communication as serving the collective attention to information that specify the shared affordances that underpin team actions. This perspective emphasizes the dynamic nature of communication, utilizing methods from dynamical systems approach to explore these interactions.

References – See page 77.

CHAPTER 2

VARIABILITY AND CREATIVITY IN SMALL-SIDED CONDITIONED GAMES AMONG ELITE SOCCER PLAYERS

Caso, S. & van der Kamp, J. (2020). Variability and creativity in small-sided conditioned games among elite soccer players. *Psychology of Sport & Exercise, 48*, 1-7. https://doi.org/10.1016/j.psychsport.2019.101645/.

ABSTRACT

Objective: Small-sided conditioned games (SSCG) in soccer are games with a small number of players, often played on smaller than regular pitches and with adapted rules. It has been argued that SSCG foster soccer players' physical, technical and tactical performances and creativity. This study tested the latter conjecture by analyzing video-footage of individual actions of elite soccer players in 5 v 5, 6 v 6, 7 v 7 SSCG played during regular training sessions and 11-aside training matches. Based on the ecological dynamics approach, we hypothesized that smaller formats would result in players making more individual actions. We additionally anticipated that the smaller formats players would induce a larger repertoire of actions, that is, an increased variability of actions, and that such increase in variability would be associated with more creative actions. Along the same lines, we reasoned that midfielders would make more creative actions than defenders and attackers.

Method: We categorized 3555 soccer actions on the ball and without the ball of 24 elite soccer players. Results: Players produced more actions in smaller SSCG formats compared to the larger SSCG format and the 11-aside match. They also produced more different actions in SSCG than the 11-aside match. Furthermore, ten creative actions (i.e., actions that were adequate and only made by one or two players) were discerned. The creative actions emerged most often in the smaller SSCG, and were absent in the 11-aside matches. Finally, strikers, defenders and midfielders did not show reliable differences in terms of number, variability and creativity of action.

Conclusion: SSCG in soccer do indeed stimulate variability and creativity of individual actions. It is important to confirm whether these immediate effects of SSCG generalize across longer time scales.

Keywords: Creativity; Variability; Small-sided conditioned games (SSCG); Soccer; Ecological dynamics; Constraint manipulation.

METHODS

Participants

Video-footage of elite soccer players were analyzed. A priori power analysis ($\alpha = 0.05$, $1-\beta = 0.80$, $f = 0.30$) indicated that a minimum of 24 players were necessary. The pre-recorded video-footage was selected from 5 v 5, 6 v 6 and 7 v 7 SSCG and 11-aside training matches, which had been played as a part of training or match preparation over a period of three subsequent seasons (i.e., 2012-2013, 2013-2014, and 2014-2015). This selection allowed us to include 24 players, that is, 10 defenders, 6 midfielders, and 8 attackers. The players (all men) ranged in age from 17 to 32 with a mean age of 21.3 years (SD = 3.46). They were all professional players affiliated with the same elite European soccer club and playing for their national team (i.e., 10 played for a national youth team, U19-U21). The following inclusion criteria were used: (1) the player was not a goalkeeper; (2) the player had no injury during time of the video-recording; (3) the player must at least have played once in each of three SSCG and the 11-aside training match across the three seasons; (4) the player must play the first 10 min of each of three SSCG and the 11-aside training match; (5) the quality of video-footage must permit reliable identification of individual actions[1] .For each player that fulfilled these criteria, we choose the first of each of three SSCG and 11-aside match that they had played, starting in the 2012-2013 season. Table 1 shows for each of three SSCG and the 11- aside match how many players were selected from a season. It also provides information about the total number of SSCG played during training and the total number of different players involved. The study was carried out in accordance with the guidelines of the local university's ethics committee. At the start of each season, the players had provided written informed consent for the video-recordings and other data-collection during training sessions and matches to be used for scientific research. They were therefore not asked to consent for this particular study.

INTRODUCTION

I trained three – four hours a week at Ajax when I was little, but played three – four hours a day on the street. So where do you think I learnt football?" - Johan Cruyff

Small-sided conditioned games (SSCG) in soccer are games with a small number of players on each side, played on smaller than regular pitches and with adapted rules. SSCG are often seen as institutionalized street soccer, because they are typically less structured and more playful than the official game. Soccer coaches use SSCG to purposely improve players' physical, technical and tactical performances in game situations that recreate the inherently dynamical performance demands of match play (Davids et al., 2013; Hill-Haas et al., 2011; Reilly & White, 2005). It stands to reason that SSCG not only develops players' technical and tactical skills, but may also foster creative play (Santos et al., 2016; see also; Memmert, 2007; Memmert & Roth, 2007). To test this conjecture, the present study analyzed the individual actions during SSCG and 11-aside matches, which had been played as part of regular training sessions by players of an elite European soccer club.

In mainstream cognitive science, creativity is defined as the manifestation of a novel, original, yet appropriate and feasible idea, thought or insight to solve a problem (e.g., Guilford, 1956). Accordingly, it is only after the idea is formed, that it gets materialized in action. The action itself is not seen as part of the creation of the idea (see Withagen & van der Kamp, 2018). As such, creativity typically refers to internal mental or cognitive processes that reside inside the head (Kounios & Beeman, 2014; Nijstadt et al., 2010). However, rather than considering creativity as an uniquely individual characteristic, proponents from an ecological dynamics approach have argued that original and appropriate actions are as much reinforced by the individual as the task and environment (Hristovski et al., 2011; Orth et al., 2017; Withagen & van der Kamp, 2018; see also; Simonton, 2003). Accordingly, creative action emergence is a situated and distributed process (Glaveanu, 2012, 2014). The primacy of the interaction between the individual, task and environment implies that creativity emerges in the unfolding of the action, during an individual's attempt to satisfy the constraints of the situation (Glaveanu, 2014; Orth et al., 2017; Torrents et al., 2016; Withagen & van der Kamp, 2018). Notice that this approach links creative actions primarily to the individual level rather than to the societal level, also because investigations on the individual or inter-individual levels are more feasible (Boden, 1994; Orth et al., 2017). In principle, however, the emergence of novel actions during an individual's exploration of the constraints of the situation (also referred to as P-creativity, see Boden, 1994) may turn out to be a creative action on the societal level or for the whole history of humankind as well (i.e., H-creativity, Boden, 1994), especially if the individual is an expert in his or her domain of skill. From the ecological dynamics approach, novel and appropriate actions may arise under constraint variations that invite the individual to explore different ways to adapt to the constraints. For example, Hristovski et al. (2011) had boxing athletes strike a boxing bag hung at varying positions from left to right in the front of the participants. Athletes first used routine straight or hook actions, but a few among them started to use an unconventional back-fist action when the bag was positioned more laterally. Hristovski et al. described the discovery of this new action as an 'action insight' (p. 195), and argued that it had emerged within the participants' search for ways to adapt to the changing constraints. More recently, also Orth et al. (2019) utilized a kickboxing task, in which novice athletes were to strike the bag at its left side with a criterion impact force. Task constraints were manipulated by having the participants wear a large padded glove on their left hand. This resulted in the left hand becoming less functional, and required the athlete to search for unconventional solutions (i.e., using the right hand to hit the left side of the bag). Orth et al. (2019) observed that athletes who succeeded in achieving the required impact force, not only showed a larger variety of actions or techniques (i.e., they searched less repetitively) than the unsuccessful athletes, but were also more likely to exhibit unconventional or creative actions (e.g., spinning back-fist). Hence, practice conditions that stimulate exploration and enhance variability of functional movement patterns or actions (i.e., increase degeneracy within the action repertoire, Seifert et al., 2016) are more likely associated with the discovery of creative actions (Santos et al., 2018a). That is, generating a greater number of different actions would benefit the emergence of actions that can be considered creative (Simonton, 2003; see also; Richard et al., 2018). For SSCG this implies that creative soccer actions are presumably facilitated by those games that enhance the variability of players' actions.

Research in SSCG demonstrates that the number of players, size of the pitch and rules of the game influence the number available space and time to play with different SSCG formats (Aguiar et al., 2012; Kelly & Drust, 2009; Owen et al., 2004; Platt et al., Reilly, 2001; Torrents et al., 2016; Vilar et al., 2014). However, whether SSCG can also be designed to affect the variability of actions, that is, the number of different actions, has largely remained equivocal. For example, Owen et al. (2004) investigated the frequency of occurrence of different on the ball soccer actions (i.e., pass, receive, turn, dribble, header, tackle, block and interception, receive, and pass) as function of a game's format (i.e., different number of players and pitch size). They showed that decreasing the number of players (i.e., from 5 v 5 to 1 v 1) resulted in an increase of the total number of actions performed by the individual players (see also Torrents et al., 2016). Owen et al., however, did not report on the variability of actions, that is, whether players also showed a larger action repertoire in SSCG formats with fewer players. Yet, research focusing on collective team actions (i.e., soccer tactics) suggests that smaller games may enhance variability of actions. That is, Aguiar et al. (2015); see also Silva et al., 2014; Torrents et al., 2016) showed that collective play in smaller games is less predictive than in larger games (i.e., from 5 v 5 to 2 v 2). The authors argued that in smaller games there is a less commitment to the collective, resulting in higher variability in inter-player distance and player position. Accordingly, smaller games may also allow, or force, players to vary or explore (individual) actions more.

The current study examined how SSCG format affects the number, variability and creativity of individual actions among elite soccer players. To this end, pre-recorded video-footage of games with different number of players (i.e., 5 v 5, 6 v 6, 7 v 7 SSCG and 11-aside training match), pitch size and rules were analyzed. Importantly, the games were part of regular training sessions, instead of being designed for experimental purposes. The video-footage thus provided naturalistic observations of games that had been played to concurrently promote the players' tactical and physical performances and not for the purpose of measuring variability or creativity of individual actions. As such the chance of response bias was eliminated. Within an ecological dynamics approach, it is argued that an individual's adaptation to changing environmental and task constraints results in the spontaneous emergence of softly-assembled patterns of coordination (Davids et al., 2003: Orth et al, 2017). To assess the variability in these patterns of coordination, researchers would, using high-dimensional kinematic recordings, aim for a low-dimensional description of the coordination patterns and determine how their stability unfolds over time under constraint manipulation. However, since we were limited to the use video-footage that only allowed behavioral analyses, we categorized the individual soccer players' actions or techniques (for overview, see Appendix I) as a proxy for describing the patterns of coordination that emerge in the different SSCG formats. These action categories were, among others, derived from earlier work that did also address creativity in soccer actions based upon the ecological dynamics approach (Santos et al., 2018b; Torrents et al., 2016; for a similar approach, see; Hristovski et al., 2011; Orth et al., 2019). Considering that the ecological dynamics approach captures creative actions as original and functionally efficient (Hristovski et al., 2011; see also; Simonton, 2003), we defined actions as creative if they were performed by one or two players only (i.e., original, rare) and successful (i.e., functional, adequate). As such, creative action emergence was defined over the local constraints (i.e., Boden, 1994).

Based on previous observations in SSCG (Owen et al., 2004), we hypothesized that smaller games would lead to the players making more actions (i.e., within a fixed 10-min time interval). Following predictions from ecological dynamics (Orth et al., 2019; see also, 2017; Simonton, 2003), we additionally anticipated that in the smaller games players would also show a larger repertoire of actions, that is, an in- creased variability of actions, and that this purported increase in variability of actions would go together with a larger number of creative actions. Finally, we explored the effects of player's playing position. Although, previous work has not explicitly addressed the relationship between playing position and creativity, there appears to be a (sometimes tacit) assumption among practitioners and researchers that attackers are more likely to produce creative actions than players who play in a defending position. For example, Memmert et al. (2010) planned to compare highly creative and less creative athletes and for this purpose recruited participants among offensive and defensive players, respectively. By contrast, rather than considering creativity as an inherent characteristic of attacking players, we reasoned that midfielders in comparison to defenders and attackers would make more actions, show a larger action repertoire, and hence produce more creative actions.

Material and Apparatus

The practice games and matches were video-recorded with Local Position Measurement (LPM) technology (©Inmotio)[2]. This technology consists of 10 base stations (i.e., antenna's) installed around the field, with each player wearing a bib with a transponder. The base station tracks the displacement of the transponders and is used, among others, to provide the coach with players' training and match data (e.g., distance covered, average running speed, accelerations, and so on). The sample frequency depends on the number of active transponders on the field with a maximum of 1000 Hz. For example, with 22 players, the resulting sampling frequency is 1000 Hz divided by 22 is 45 Hz. The LPM system was synchronized with HD motioCams, which video recorded from different perspectives and allowed automatic tracking and zooming of individual players (i.e., transponders). This video-footage was used to identify and categorize the actions of individual players.

Procedure and Design

The 5 v 5, 6 v 6 and 7 v 7 and 11-aside matches were the most frequent played and recorded SSCG formats during training. According to the coaching staff, which did not change across the three seasons, because SSCG are played with fewer players, each individual player gets more touches of the ball, allowing concurrent improvements in players' tactical and physical performances. Since the analyzed SSCG were part of regular training sessions, and not designed for research purposes, no experimental control was exercised over factors that potentially could have affected the players' soccer actions. All the SSCG included two sides with goalkeepers, but the goalkeepers' actions were not included in the analyses. The SSCG were played on a pitch with markings, which divided the field in squares and rectangles of different sizes (Fig. 1). It is customary at the club to play the 5 v 5 and 6 v 6 SSCG within the two central squares, resulting in an area measuring 36 m long and 18 m wide, while for the 7 v 7 SSCG an additional square is added, resulting in an

Table 1
Distribution of SSCG and 11-aside matches, the total number of players involved and selected across the three seasons.

Format	Season		
	2012–2013	2013–2014	2014–2015
5 v 5			
Total number of games/matches	10	8	4
Total number of players[1] involved	40	26	5
Number of participants selected	10	4	10
6 v 6			
Total number of games/matches	10	6	5
Total number of players[1] involved	41	25	22
Number of participants selected	6	8	10
7 v 7			
Total number of games/matches	14	17	10
Total number of players[1] involved	34	28	24
Number of participants selected	11	4	9
11v 11			
Total number of games/matches	10	12	8
Total number of players[1] involved	35	42	28
Number of participants selected	1	5	18

NB. [1]The total number of players involved does not include the goalkeepers.

area measuring 54 m long and 18 m wide. The measures stem from club tradition, rather than being scientifically underpinned. The 11-aside matches were played on a regular 11-aside field of 105 m long and 64 m wide. All SSCG and matches were played on a natural grass pitch. The SSCG were played with official rules, except there were no throw-ins. When the ball went out of play, the goalkeeper from the team that would have been assigned the throw-in under the official rules, would play the ball from his goal. The 11-aside training matches were played with official match rules and referee. Finally, the frequency and content of coach instructions and feedback before and during the SSCG and 11-aside matches were not standardized.

Each of the 24 participants was individually analyzed. For each of the three SSCG and the 11-aside match, the first game that they had played across the three seasons was analyzed (Table 1). Different SSCG and matches were analyzed for the different players, and team com- positions were never exactly the same. For all SSCG, all the actions made in the first 10 min were analyzed. For the 11-aside matches, the first 10 min of effective playing time (i.e., only when the ball was in the game) were analyzed.

Data Analysis

Based on previous work (Werner, 1989; Kroger & Roth, 1999; Owen et al., 2004; Santos et al., 2018b; Torrents et al., 2016) a score sheet was developed listing the definitions of possible soccer actions (i.e., technical skills). These included actions on the ball and actions without the ball. Other actions were defined during actual analysis, resulting in a list with a total of 37 different actions (see Appendix I). Each action was identified and categorized, and also evaluated in terms of its success (i.e., adequate, non-adequate). For each individual player, we counted the total number of actions and the number of different action categories per game and match, and in doing so, also evaluated whether the action was adequate or non-adequate. An action was considered adequate when its objective (as described in Appendix I) was accomplished, while for non-adequate actions this objective was not accomplished. The first author (S.C.), who is an experienced soccer performance analyst, including at the participating club, gathered and selected the recordings, and identified and categorized all actions and judged them on adequacy. To determine interobserver reliability, a second performance analyst independently inspected a random sample of 8 SSCG and 2 11-aside matches. The resulting interobserver reliability for the number (ICC = 0.79) and type of action (Cohen's κ = 0.83) was high, and moderate for the adequacy of actions (Cohen's κ = 0.68) (Koo & Li, 2016; McHugh, 2012).

Next, following earlier work (Gillebaart et al., 2013; Kleinmintzl et al., 2014; see also; Simonton, 2003), we used a 5% criterion for an action to be classified as original. In other words, those actions that were per- formed by approximately 5% of the players or less (i.e., two or one players) were considered original. When the action was also performed successfully (i.e.,

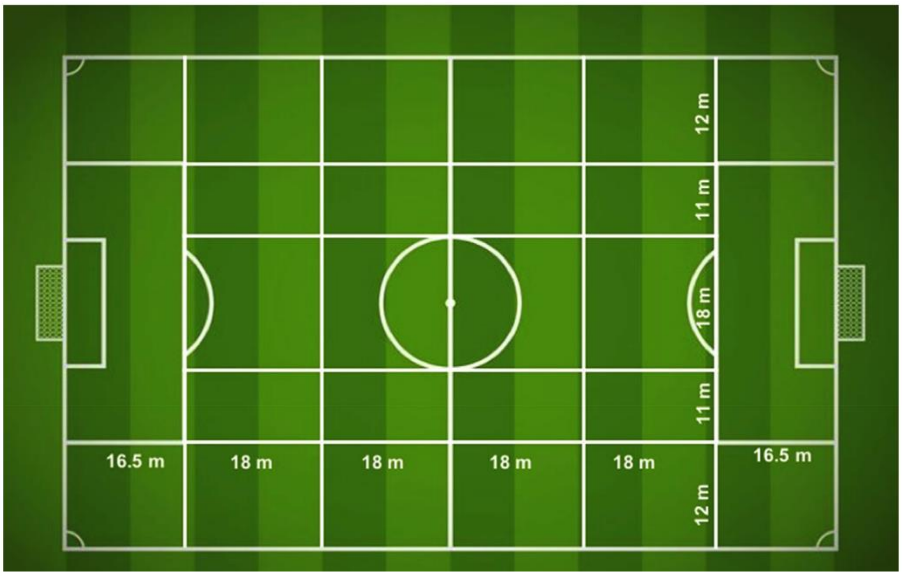


Figure 1 - The training pitch and markings. Note: The 5 v 5 and 6 v 6 SSCG were played within the two central squares, resulting in an area measuring 36 m long and 18 m wide, while the 7 v 7 SSCG an additional square was added, resulting in an area measuring

adequate), it was considered a creative action.

Statistical Analysis

We planned to submit the dependent variables to separate 3(group: defenders midfielders, attackers) by 4(format: 5 v 5, 6 v 6, 7v 7, 11- aside) ANOVA with repeated measures on the last factors In case the sphericity assumption was violated, Greenhouse-Geisser corrections for the p-value were used. Post hoc tests were planned using t-tests with Bonferroni correction. For effect size, ηp^2 were reported. Effects sizes smaller than 0.06 were considered small, between 0.06 and 0.14 as moderate, and larger than 0.14 as large.

RESULTS

Number of Actions

In total, the players produced 3555 actions, 82% of which were adequate. Fig. 2 shows how the actions were distributed across formats and position. The analysis of variance on the number of actions revealed significant main effects of format, $F(3, 63) = 38.1$, $p < 0.001$, $\eta p^2 = 0.65$, and position, $F(2, 21) = 4.32$, $p < 0.05$, $\eta p^2 = 0.29$. The two factors did not significantly interact, $F(6, 63) = 0.80$, $p = 0.56$, $\eta p^2 = 0.07$. Post hoc indicated that the smaller the format the more actions players made; that is, all comparisons differed significantly except those between the 5 v 5 and 6 v 6 and the 6 v 6 and 7 v 7 games. The post hoc analysis did not confirm significant differences in the total number of actions between strikers, midfielders and/or defenders.

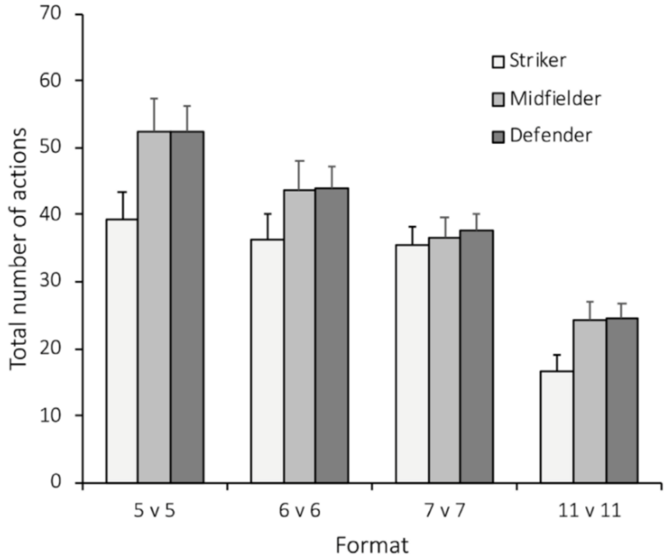


Fig. 2. Average number of actions (and SE) as a function of format and position.

Number of Different Action Categories (Variability)

Fig. 3 shows the number of different action categories across format and position. The analysis of variance showed a significant main effect of format, $F(3, 63) = 12.1$, $p < 0.001$, $\eta p^2 = 0.37$, but not for position, $F(1, 21) = 3.13$, $p = 0.07$, $\eta p^2 = 0.23$. The interaction was not significant either, $F(3, 63) = 0.94$, $p = 0.47$, $\eta p^2 = 0.08$. Post hoc indicated that players produced actions from more action categories in the three SSCG-formats than in the 11-aside match.

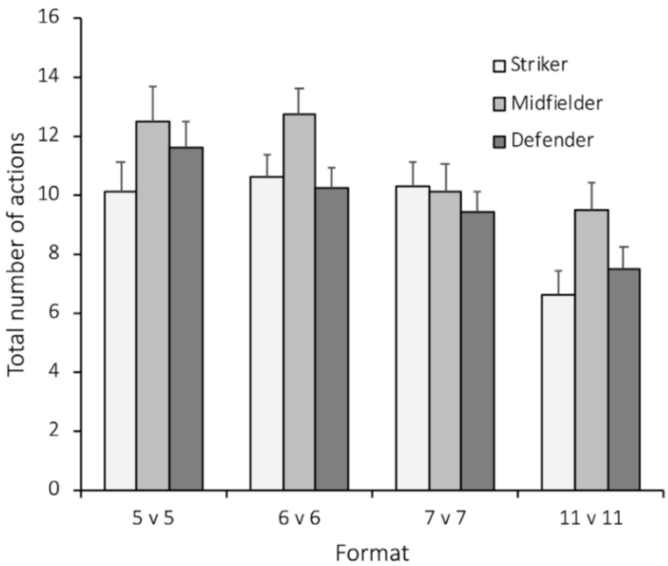


Fig. 3. Average number (and SE) of action categories as a function of format and position.

Number of Rare Actions (Originality and Creativity)

The action categories that were exclusively produced by two or one players (i.e., approx. 5% of the players) were defined as rare or original. This was true for 14 actions from 6 categories made by 8 players match (Fig. 4a). Second, if anything, the midfielders appear to make original and creative actions less often than defenders and strikers (Fig. 4b).

Table 2
Original actions.

Action Category	Number of players	Number of occurrences
Pass with chest	1	1
Zidane turn	2	4
Maradona turn	2	2
Sole turn	1	2
Kick with outside foot	1	3
Overlap[a]	1	2

[a] An anonymous reviewer argued that overlap is not an unconventional action. However, the occurrence of overlap strongly depends on team tactics. Within the constraints of the 4-3-3 system played by the participating club, full-back players make no overlaps with winger players. Accordingly, although overlap would not count as an creative action for soccer in general (i.e., world-wide, H-creativity), within the local constraints of the group of players in this study (i.e., P-creativity), it definitely is.

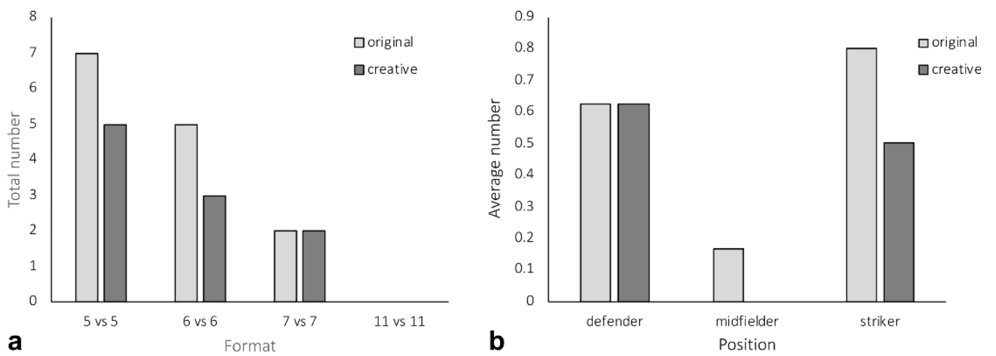


Fig. 4. (a) The total number of original and creative actions as function of format, and (b) the average number of original and creative actions as a function of position.

DISCUSSION

In recent years, researchers have shown an increasing interest in creativity in soccer, not the least because coaches, pundits and re- searchers alike consider creativity a very desirable quality for a soccer player (Memmert, 2006, 2014; Memmert et al., 2010). For, the un- predictable actions that a creative soccer player produces can be the turning point in a match (Memmert, 2014). Accordingly, researchers have looked how creative players can be nurtured. In this respect, a general consensus exists that informal, playful, unstructured sport set- tings with only a minimum of instructions promote creativity compared to organized sport settings (Bowers et al., 2014; Memmert & Roth, 2007; Santos et al., 2016). However, the empirical evidence is not unequivocal. For example, Memmert et al. (2010) used retrospective interviews among elite sports players, including soccer, and found that players who were rated as most creative had a longer history (i.e., hours spent) of both sport-specific unstructured play activities and sport-specific structured training than players who were considered least creative. In a similar study, Bowers et al. (2014) concluded that the more creative players had struck a better balance be- tween the time spent in the unstructured and structured activities.

From an ecological dynamics approach, the distinction between in unstructured play and structured sport-specific setting is too coarse. Regardless of practice setting being part of organized sports or not, creative actions are thought to emerge under constraints that stimulate a player to explore different movement patterns or actions (Hristovski et al., 2011; Orth et al., 2017). There are two key issues here. First, practice conditions that increase the variability of actions, that is, enhance the action repertoire, are more likely to induce creative actions. Second, practice conditions must be representative, since creative actions emerge in an attempt to adapt to the constraints of the situation. Our aim in this study was, therefore, to test if the manipulation of task constraints that ostensibly boosts variability of actions is also associated with more creative actions. To this end, we compared variability and creativity of the individual actions of elite soccer players in small-sided conditioned games (SSCG) and 11-aside training matches. We hypothesized that smaller SSCG formats would lead to increased variability of action and to more creative actions, because previous work had shown that reducing the number of players and the size of the field increases the number of actions produced by individual players (e.g., Owen et al., 2004; Torrents et al., 2016).

Our findings largely support the hypothesis: the dynamics of the smaller SSCG formats led players to produce more actions on the ball and/or without the ball than the larger SSCG format and the 11-aside match. Possibly, during smaller SSCG, which are played with less players and on a smaller pitch, the available time and space limit passing options, resulting in individual players to make more actions on the ball. Moreover, smaller SSCG typically result in less commitment to team tactics, allowing more freedom for individual actions (Aguiar et al., 2015; Torrents et al., 2016). In addition, the smaller SSCG for- mats challenged players to adapt in more different ways than in the 11- aside match, that is, a larger number of different actions was explored. And finally, creative actions (i.e., the ten successful actions that were produced by one or two players (i.e., approx. 5%)) only occurred in the SSCG, and mostly in the smallest 5 v 5 game. Accordingly, the current findings provide support for the hypothesis from the ecological dynamics approach that, since creative actions arise from variability of action, practice conditions that enhance variability of action are more likely to induce creative actions (Hristovski et al., 2011; Orth et al., 2019, 2017; Santos et al., 2016).

We also explored whether a player's position (and/or role) in the team affects the emergence of creative actions. We suspected that midfielders would produce more actions than defenders and attackers because they would produce more actions. Others have implied that, following preconceptions of expert coaches, attackers would be more creative than defenders (Memmert et al., 2010). Yet, neither of these hypotheses were supported. If anything, and the current data does not allow great confidence[3], midfielders made almost no creative actions, while the number of creative actions among defenders and attackers did not appear to differ. Relatedly, there were also no differences found with respect to the number of (different) actions for three playing positions. Accordingly, we could not show that variability of actions did vary as a function of player's position. Clearly, we need a larger amount of observations to appraise whether differences in creative action emergence as a function of player position are consistent with projections of the ecological dynamics approach (cf. Orth et al., 2017).

Strengths and Limitations

This is one of the few studies in the sport of soccer to provide support for the contention from the ecological dynamics approach (e.g., Hristovski et al., 2011; Orth et al., 2019; see also, 2017; Simonton, 2003) that practice conditions that enhance variability of individual actions are also more likely to induce creative actions. In an earlier study, Santos et al. (2018) demonstrated something along the same lines by showing that a differential learning approach, which purportedly imposes a large variability of action (Schöllhorn et al., 2009), resulted in more creative actions. Crucially, however, our findings comprise observations of authentic training forms in elite soccer, rather than re-created test situations with increased risk of response bias, among others. The findings, thus, truly (re-)present what happens on the field. Yet, naturalistic observations also typically come at the expense of experimental control. The current study is no exception. Consequently, we now know that smaller SSCG formats are associated with more creative actions, but the current observations do not allow for delineating the exact local constraints underpinning creative action emergence (e.g., in terms of the available time and space to produce an action, the degree to which the player is enslaved by the collective, the coach's instructions and so on). This would also locate how creative action emergence is distributed across the individual, task and environment (Glaveanu, 2012, 2014).

Also, the ecological dynamics approach entails a formalized description of the soccer actions, rather than the colloquial descriptions used in the current study. Such formalization of actions or patterns of coordination into so-called low dimensional order parameters would allow for identifying the specific (changes in) constraints within SSCG that affect the emergence and (de-)stabilization of coordination patterns (cf. Zanone & Kelso, 1992). In this respect, although we did not involve experts to subjectively rate or evaluate the creativity of actions as is typically done (e.g., Memmert et al., 2010; Santos et al., 2018a), the present quantitative approach can only be considered an initial first step. Finally, our observations provide direct evidence that SSCG instantly expand the action repertoire and creative action, but they fall short in showing that regularly playing SSCG during practice can result in more creative actions in competitive matches. To further substantiate that SSCG can indeed foster creative actions across longer time-scales, longitudinal studies are needed comparing the production of creative actions of players that experienced varying amounts of SSCG in practice over a season (cf. Memmert, 2007; Santos et al., 2018b).

To conclude, we confirmed the often voiced but never tested belief that training forms using SSCG stimulate the occurrence of creative actions in elite soccer players. That is, the dynamics in smaller SSCG led players to produce more actions from a larger number of action categories, resulting in more creative actions. Accordingly, next to improving physical, tactical and technical performances, we would recommend the use of SSCG in order to enhance players' action repertoire and creativity -if, that is, the observed immediate effects of SSCG indeed generalize across longer time scales.

Appendixes

Appendix I. Action categories

Action on the ball	Definition
Pass inside foot	Player in possession sends the ball to teammate with inside of the foot.
Pass outside foot	Player in possession sends the ball to teammate with outside of the foot.
Pass volley	Player in possession sends the ball to teammate volleying it (using any part of the body).
Pass chipping	Player in possession sends the ball to teammate by chipping the ball.
Pass through gap (short distance)	Player in possession sends the ball to teammate through a gap between two opponent players (short distance).
Pass through gap (long distance)	Player in possession sends the ball to teammate through a gap between two opponent players (long distance).
Pass into space (short distance)	Player in possession sends the ball to teammate into free space (short distance).
Pass into space (long distance)	Player in possession sends the ball to teammate into free space (long distance).
Pass with chest	Player in possession sends the ball to teammate using the chest.
Pass with foot heel	Player in possession sends the ball to teammate with the heel of the foot.
Reception	Player (attempts) to gain control of the ball in order to possess terrain.
Header shooting	Player heads the ball to score on goal.
Header passing	Player heads the ball to pass to teammate.
Tackle	Action intended to dispossess an opponent who possesses the ball
Interception	Player contacts the ball enabling him to retain possession, preventing an opponent's pass from reaching its intended destination.
Ronaldo turn	A player makes a Cristiano Ronaldo chop turn to confuse an opponent player.
Cruijff turn	A player makes a Cruijff turn to confuse an opponent player.
Ronaldinho turn	A player makes a Ronaldinho turn to confuse an opponent player. It consists of a touch on the ball first with the outside and then inside of the foot.
Zidane turn	A player makes a Zidane turn to confuse an opponent player. Stop the ball with the sole of the foot, and goes around an opponent player using the other sole of the foot.
Maradona turn	A player makes a Maradona turn to confuse an opponent player.
Outside turn	A player makes a turn to confuse an opponent player, passing sideward using the outside of the foot.
Sole turn	A player makes a turn to confuse an opponent player, passing side ward using the sole of the foot.
Drive	Movement of ball carrier towards the goal or changing direction in order to play in other areas of the pitch line.
Kick with inside foot	Player kicks the ball with the inside foot to score a goal.
Kick with outside foot	Player kicks the ball with the outside foot to score a goal.
Kick volley	Player kicks the ball, volleying it with any other part of the body except foot and head to score a goal.
Action without the ball	**Definition**
Performing one-two	A move in which a player passes the ball to teammate and expects to receive it back immediately.
Press	Action to regain the ball or attempt to make the opponent lose the ball pressuring him.
Overlap	A player sends the ball to teammate and then runs beyond that player to receive the ball or to drag/confuse an opponent player (e.g., a full back passes the ball to a winger, runs behind the winger and receives the ball).
Support	Player moves towards the ball carrier offering a passing option aimed at keeping ball possession.
Unmark	Player moves between the last defender and towards the goal line amplifying the effective playing space and offering a long pass option.
Block	Ball strikes a player, preventing an opponent's pass from reaching its intended destination
Delay	Action to slow down the opponent's attempt to move forward with the ball.
Movement into space (around opponent players)	Player moves into space going around opponent players in order to create 'free channels' to make the pass the ball to him.
Move to create gap (two players)	Player moves into space in order to create a gap between two opponent players to allow teammate to pass through ball through gap.
Turn without the ball	A player makes a change of direction without ball to confuse opponent player

Notes

[1] The 2012-2013 season was the first year the recordings were made during training sessions. This went together with some technical inadequacies which were largely overcome in later seasons.

[2] See https://www.inmotio.eu.

[3] The number of participants in each group was relatively small and unequal.

References – See page 77

CHAPTER 3

THE RELATIONSHIP BETWEEN AMOUNT AND TIMING OF VISUAL EXPLORATORY ACTIVITY AND PERFORMANCE OF ELITE SOCCER PLAYERS

Caso, S., Van Der Kamp, J., Morel, P., Savelsbergh, G. (2023). The relationship between amount and timing of visual exploratory activity and performance of elite soccer players. International Journal of Sport Psychology, 54(4), 287-304. doi:10.7352/IJSP.2023.54.287.

ABSTRACT

Objective: Visual exploratory activities (VEA) refer to head and body movements that soccer players make prior to receiving the ball to discover possibilities for action. The current study investigated the degree to which the amount and timing of VEA relates to performance and is influenced by player position. Method: Using pre-recorded video-footage of matches, the VEA of elite soccer players (n = 72) playing in national professional leagues were analyzed with respect to amount (i.e., in number/s) and timing (i.e., during the penultimate and final pass prior to ball reception) for different player positions (i.e., lines and axes). ANOVAs were used to compare the amount of VEA as a function of its timing and player position, and hierarchical stepwise regression analyses were conducted to examine the degree to which VEA predicts subsequent performance (i.e., adequate ball contact, passes, dribbling actions and shooting). Results: Elite players showed more VEA in the final pass than in the penultimate pass, and midfielders showed more VEA than players in other lines. In addition, the amount of VEA during the penultimate pass predicted the adequacy of the subsequent pass. The amount of VEA during the final pass did not significantly contribute to this. Conclusion: In elite soccer players, the amount of VEA systematically varies according to the spatial and temporal unfolding of the play and is positively related to subsequent performance. VEA supports the early perception of the possibilities for action.

Keywords: Visual exploratory activity, soccer, anticipation, affordances, decision making.

INTRODUCTION

“*Football is a sport that you play with your brain. You have to be in the right place at the right moment, not too early, not too late.*”

Johan Cruijff

Successful performance in soccer requires that players vary their actions according to the continuously changing affordances or possibilities for action of the game (Araújo et al., 2006; Fajen, 2007*)*. Consequently, skilled performance is closely linked to visual perception. In this respect, ecological psychology (Gibson, 1966, 1979) holds that visual perception is an activity of a perceiver with the eyes in a moving head on a body that moves in the environment, rather than a passive reception of visual stimuli that are processed in increasingly higher brain centers. Put differently, for a player to take adequate action, it is critical to engage in active exploration or search of the on-goings in the immediate situation (Gibson, 1979; Fajen et al., 2009). In this regard, in soccer, sport scientists have referred to visual exploratory activities (VEA) (Jordet, 2005; Jordet et al., 2013), a term that is known among practitioners as ‘scanning’ or ‘checking your shoulder’. Jordet (2005) defined VEA as “a body and/or head movement in which the player’s face is actively and temporally directed away from the ball, seemingly with the intention of looking for teammates, opponents and other environmental objects or events, relevant to the carrying out of a subsequent action with the ball” (p. 143).

Research has shown that VEA is associated with performance both within and across levels of play. Specifically, an increased amount of VEA prior to the player receiving the ball is associated with a better subsequent action, such as the direction and accuracy of a pass. These observations originate from notational analysis of professional matches (Aksum et al., 2021a; Jordet et al., 2013, 2020; Phatak & Gruber, 2019; Pokolm et al., 2022) as well as from observations in controlled experimental environments (Aksum et al., 2021a; Eldridge et al., 2013; McGuckian et al., 2017, 2018b, 2020b). Jordet et al. (2013) analyzed video-footage of midfielders from 64 English Premier League (EPL) matches. Each player’s VEA was studied for 15 minutes, but only for situations in which -according to the researchers - the pertinent information for selecting the subsequent action was behind the player’s back. The researchers showed a significant positive correlation between the amount of VEA in the 10 seconds prior to ball reception and the percentage of successful passes. Similarly, Phatak and Gruber (2019) analyzed the VEA of 51 midfielders during UEFA Euro 2016 championship matches, focusing on the final pass prior to ball reception (i.e., instead of the final 10 seconds). They reported a positive correlation between the amount of VEA and the percentage of successful passes. Interestingly, the relationship only emerged when the teammate who was going to pass had the ball still in possession. Once they had passed and the ball was travelling to the receiver (i.e., the player showing the VEA), the relationship vanished.

Recently, Jordet et al. (2020) and Aksum et al. (2021b) investigated the role of a player's position within a team. It stands to reason that different playing positions within a team offer different affordances and thus induce different amounts of VEA. Jordet et al. (2020) studied 27 elite players in the English Premier League across 21 matches, while Aksum et al. (2021b) studied UEFA European U17 and U19 Championship semi-finals and finals. Both studies reported that the amount of VEA in the final 10 seconds prior to ball reception was positively associated with success in the subsequent pass. Further, both studies revealed that central defenders and midfielders displayed more VEA compared to the players positioned along the side of the field. Similarly, McGuckian et al. (2020a; see also Eldridge et al., 2013) reported more extensive VEA in a training match by youth players who were positioned at the central axis in comparison to players who were playing wide, along the sides. These effects of playing position underline that VEA is not merely an ability of the individual player, but also reflects an adaptation to the situational constraints (Newell, 1986). The central positions in defense and midfield likely offer a larger, more dynamic landscape of affordances than the more spatially constrained back or wing positions in the defense and attack.

The affordances, however, are not only contingent on spatial position, they may also change temporally. They likely arise and dissolve during the final seconds before ball reception (McGuckian et al., 2020b). For example, McGuckian et al. (2018b) compared passing performance in simulated soccer situations when players had either 1-, 2-, or 3-seconds exploration time before ball reception. They found that having only 1 second available adversely affected performance after ball reception. This suggests that in the fast-paced soccer environment also the time constraints on VEA are critical to performance (Araujo et al., 2006, 2009a). Indeed, anticipation, or looking ahead, is a defining characteristic of skilled perception and action (van der Kamp et al., 2008; Savelsbergh et al., 2005). Practitioners refer to this as 'reading the game'. In highly complex and dynamic environments, skilled players are typically found to pick up information longer before initiating an action than their less skilled counterparts. In an early study, Williams et al. (1994) showed that when watching filmed open play situations, inexperienced, low skilled soccer players primarily focused gaze to the ball and the player in possession of the ball, while more experienced players, made more fixations to other players, who were further away in space and time (see also Savelsbergh et al., 2006). These observations suggest that skilled perception not only entails an increased amount of VEA, but also an earlier start, that is, more passes before they anticipate receiving the ball.

In this respect, it is appropriate to link the timing of VEA to the unfolding play, rather than mere time in seconds. That is, the evolving affordances in elite soccer are likely nested in tactical patterns of play. For example, in Dutch soccer (including the teams examined in this study) most of the teams play according to the principle of offensive coverage (da Costa et al., 2010). Essentially, this involves the forming of triangles, also known as the 'third man'-principle (see Fig. 1, players 3, 6 and 10). Players take relative positions on the field to form triangle (or diamond) shapes to create opportunities of passing and/or creating passing chances for their teammates. Accordingly, the 'third man' (or receiving player, player 10 in Fig. 1) already knows they will receive the ball via a second, intermediate player (player 6 in Fig. 1) once the first player is in ball possession (player 3 in Fig. 1). This allows a skilled receiving player to start exploring during the penultimate pass, at the beginning of the triangle, instead of waiting until after the final pass is delivered.

To further the observations in previous studies, we investigated whether the amount of VEA (i.e., number/s) is differentiated within a group of elite soccer players who have been assigned specific positions in the team (i.e., they play at different lines, defense, midfield and attack, and axes, central and wide). We compared the amount and timing of VEA as a function of player position, and examined the degree to which the amount and timing of VEA predicts the adequacy of the receiving player's subsequent actions. We hypothesized that the amount of VEA is larger for players positioned in defense and midfield on the central axis, and during the penultimate compared to the final pass. We also anticipated that the amount of (early) VEA during the penultimate pass would predict most of the variance with respect the performance of the subsequent action.

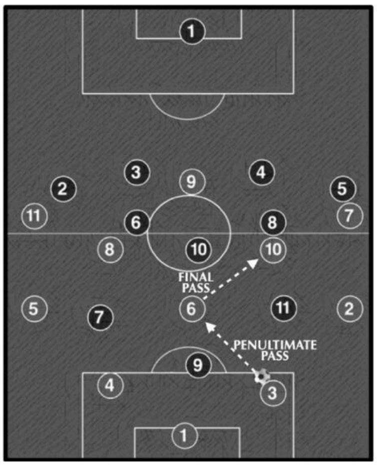


Fig. 1. - The 'third man'-principle. Players 3, 6 and 10 form a triangle. Once player 3 is in ball possession, player 10 'knows' to receive the ball via player 6. For player 10 receiving the ball, the passing from player 3 to player 6 is referred to as the penultimate pass, while the passing from player 6 to the receiving player 10 is denoted as the final pass.

METHOD

Participants

A priori power analyses showed that using an ANOVA with repeated measures required 60 participants, while for a hierarchical regression analysis with four predictors (see Data analysis) a minimum of 65 participants was required to identify effects of moderate size (i.e., $\alpha = 0.05$, $1-\beta = 0.80$, $f2 = 0.20$). Consequently, we selected pre-recorded video-footage of 72 players from a Dutch elite soccer club. Choosing players of one club ensured that they would play within the same tactical system. The first team of the club competes (almost) every season in the European Champions/Europa League and in the first Dutch soccer league (Eredivisie), whereas the second U23 team competes in the second Dutch soccer league (Eerste Divisie). From the 72 players (mean age = 21.5 years, SD = 3.6 years), 29 first team players and 32 U23 players played or had played for their national (youth) team. For each team, the selected players were proportionately distributed across line (i.e., 12 defense, 12 midfield and 12 attack) and axis (i.e., 23 wide, 13 central). Goalkeepers were not included in this study. The study was carried out in accordance with the guidelines of the local university's ethics committee. At the start of each season, the players had provided a written informed consent for the video recordings and matches to be used for scientific research. No further consent for the present study was solicited.

Selection of Video-Footage

The pre-recorded video-footage was taken from a total of 43 competition matches (i.e., 20 and 23 of the first and U23 team, respectively) across five seasons (i.e., 2015-2016, 2016-2017, 2017-2018, 2018-2019 and 2019-20201). The video-footage was obtained through the online platform Wyscout (https://wyscout.com) and the club's digital video archive. Studies showed that VEA is affected by opponent pressure (Aksum et al., 2021a, 2021b; Eldridge et al., 2013; Pokolm et al., 2022). Thus, with respect to match selection, only matches against teams that finished in the first eight of the season's final ranking were included (i.e., the two teams always ended within the first eight). This was done to avoid very large performance differences between the two teams and because lower positioned teams tend to wait longer before putting pressure to regain ball possession (i.e., "catenaccio"). Additionally, to avoid a possible home advantage bias (Pollard & Gomez, 2014), half of the selected matches (i.e., 22 out of the 43) were home matches.

With respect to selection of individual players, the following inclusion and exclusion criteria were used: (1) the player played the full match of 90 minutes and did not change his starting playing position; (2) only ball receptions from passes by teammates were analyzed. Headers, passes that were unintentional (e.g., a ball bouncing to a teammate from a tackle), passes from 'dropped-balls', passes from set piece situations (e.g., free kick, throw in, goal kicks, kick offs), and passes where the opponent players interfered by touching the ball were excluded; (3) only receptions that resulted from at least two consecutive within-team passes (i.e., including a penultimate and final pass) were included. Receptions that followed from one pass only were not considered; (4) receptions after which the player was fouled (and thus could not perform a subsequent action) were excluded; and (5) the quality of video footage permitted reliable identification of head movements. This, for example, excluded receptions near the far end of the pitch, where the variety of colors from audience and advertising hampered identification of head and/or shoulder movements, and receptions recorded by a swiftly moving the camera. If for one of these reasons a reception could not be analyzed, then, if available, a reception of the same player in extra time (i.e., after the 90 minutes) was included. For each player, one full match (i.e., 90 minutes) was coded. If a match included multiple players that fulfilled the above criteria, then they were all included. Together this resulted in a total of 935 receptions that were analyzed for the present study. Table 1 shows how they were distributed across playing position.

Data Analysis

The matches were analyzed using SportsCode Elite software, which allowed, among others, to reduce viewing speed to ¼ of normal speed. For each ball reception the player made, it was first determined if the abovementioned criteria applied. If so, VEA was determined. This was done separately for the penultimate and final pass (Fig. 1). Coding for the penultimate pass started the moment the first passing player received the ball and ended when the ball was received by the second passing or intermediate player (i.e., the pass from player 3 to player 6 in Fig. 1). This started coding for the final pass, until the ball was received by the receiving player or participant (i.e., the pass from player 6 to player 10 in Fig. 1). For each pass, the number of VEAs and the duration (in seconds) was coded.

TABLE I
The distribution of receptions across line and axis.

Group	Total
Central defenders	215
Wide defenders	148
Central midfielders	135
Wide midfielders	233
Central attackers	47
Wide attackers	157

Following Jordet et al. (2013, 2020), VEAs were defined as the receiving player's active isolated head turns by which the face (and hence, the eyes) was temporally directed away from the ball. Accordingly, each time the head of the player moved away from the ball, one VEA was counted (e.g., if the face moved away from the ball, turned toward the ball, and then again moved away from the ball, 2 VEAs were counted).

Next, the actions after ball reception were coded. When the receiving player touched the ball, this was considered as ball control. If any action (i.e., pass, shot on goal or dribble) ensued from ball contact, then ball contact was considered adequate, otherwise (e.g., ball tackled by opponent, ball jumping from foot to opponent) ball contact was considered as inadequate. After contact, the subsequent action was categorized as a pass, a shot on goal or a dribble. A pass was defined as the ball being kicked in the direction of a teammate or (intentionally) into the (empty) space for a running teammate. If the pass reached the teammate, then it was coded as adequate; if the pass did not reach the teammate, it was coded as an inadequate. Passes that resulted in off-side were also considered inadequate. A shot on goal was defined as the ball being kicked within the goal mouth. If it reached the goal mouth it was considered adequate, irrespective of whether it entered the goal; other shots were coded as inadequate. Finally, since previous studies showed that professional players on average contact the ball 1.7 to 2.2 times before making an action (Dellal et al., 2010; 2011), we defined dribbling as a player making more than two touches. It was considered adequate if ball possession was maintained and inadequate if the ball was lost. The notational analysis was performed by the first author (SC), who is also a professional soccer performance analyst. To determine interobserver reliability, a second experienced soccer performance analyst independently inspected a random sample of 10 % of the data, that is, 7 players. The resulting interobserver reliability was good for the amount of VEA in the penultimate pass (ICC = 0.86) and excellent for the final pass (Cohen's k = 0.92). Reliability for the type of performance (i.e., passes, dribbling actions and shoots) (Cohen's k = 0.91) and the adequacy of actions (Cohen's k = 0.92) were both excellent (Koo & Li, 2016; McHugh, 2012).

Statistical analyses

First, for each participant the amount of VEA (in number/s) for the penultimate and final pass were determined separately by dividing the total number of VEAs by the total pass duration. Second, the performance of the subsequent actions of each player was measured with percentage adequate ball contacts (i.e., total number of adequate ball contacts divided by the total number of actions multiplied by 100), percentage of passes (i.e., the total number of passes divided by the total number of subsequent actions multiplied by 100), percentage of adequate passes (i.e., the total number of adequate passes divided by the total number of passes multiplied by 100) and the percentage of adequate other actions (i.e., the total number of adequate dribbles and shots on target by the total of dribbles and shots on target multiplied by 100).

Next, we compared the amount of VEA as function of player position and timing by submitting the amount of VEA to a 3(line: defense, midfield, attack) by 2(axis: central, wide) by 2 (timing: penultimate, final pass) ANOVA with repeated measures on the last factor. Performance was compared across player position by submitting the percentage adequate ball contacts, percentage of passes, percentage of adequate passes, and percentage of adequate other actions to separate 3(line: defense, midfield, attack) by 2(axis: central, wide) ANOVAs with repeated measures on the last factor. In case the sphericity assumption was violated, Greenhouse-Geisser corrections for the p-value were used. Post hoc tests were conducted using t-tests with Bonferroni correction. Effect sizes are reported using $\eta p2$ with $\eta p2$ smaller than 0.06 denoted as small, $\eta p2$ between 0.06 and 0.14 as moderate, and $\eta p2$ larger than .14 as large.

Finally, separate hierarchical stepwise regression analyses were conducted to examine the degree to which the amount of VEA and player position predicted each of the four performance measures. Each of these analyses consisted of three steps. In the first step, the amount of VEA during the penultimate pass was entered to assess the role of (relatively) early VEA. In the second step, the amount of VEA during the final pass was added to assess if late VEA augmented any contribution of VEA during the penultimate pass. In the third and final step potential contributions of player position were assessed by entering the interaction between line and axis. For this last step two dummy variables were created one comparing midfielders and defenders combined with axis, the other comparing midfielders and attackers combined with axis. For all regressions, outliers that disproportionally influenced the regression parameters (i.e., Cook's D > 1) were excluded (Cook & Weisberg, 1982) and the assumptions of homoscedasticity (i.e., by inspecting the standardized residuals by standardized predicted values plot), error-independence (Durbin-Watson = 1.568 > 1.624, the critical value of 80 students and five predictors), lack of multicollinearity, and normal distribution of errors (e.g., non-significant Kolmogorov-Smirnov) were verified. Because the latter did not unambiguously confirm a normal distribution, the regression analyses were performed with wild bootstrapping with 2000 resamples. Accordingly, we use the bootstrap CI to determine the regression coefficients as they make no assumptions about the shape of the distribution (Efron & Tibshirani, 1993). Analyses were performed using SPSS Statistics 26.0.0.0.

RESULTS

The Amount of VEA

The ANOVA revealed a significant main effect of timing, $F(1, 66) = 7.73$, $p < 0.01$, $\eta p2 = 0.11$, indicating more VEA in the final pass in comparison to the penultimate pass (Fig. 2). In addition, VEA clearly varied as a function of player's position. Accordingly, there was a significant effect of line, $F(2,66) = 20.3$, $p < 0.001$, $\eta p2 = 0.38$. Post hoc indicated that midfielders had increased amount of VEA relative to defenders and attackers (Fig. 2). The other effects did not reach significance.

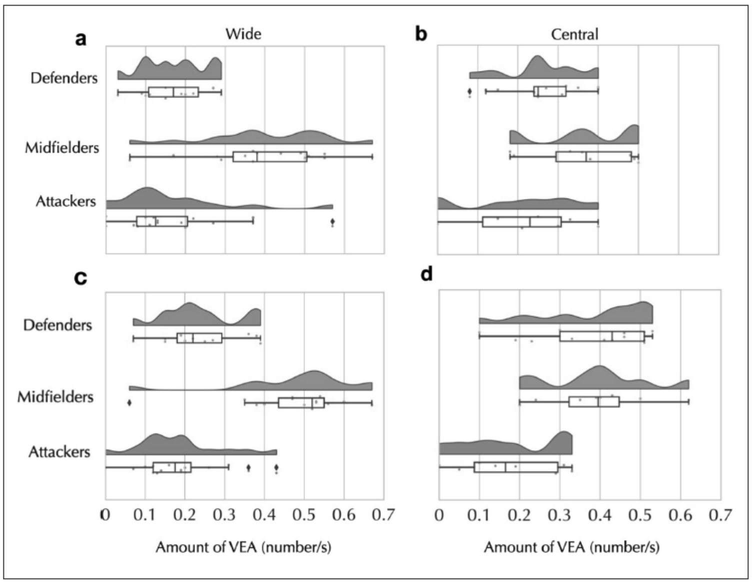


Fig. 2. -|The amount of VEA (and SE) as a function of line and axis for the penultimate (a and b) and final pass (c and d).

Performance

Fig. 3a shows that the percentage of adequate ball contacts was high (i.e., for all positions above 90%). There were no significant differences as a function of line and axis (p’s > 0.056). For the percentage of passes significant effects of line, $F(2, 65) = 6.40$, $p = 0.003$, $\eta p2 = 0.17$, and line by axis $F(2, 65) = 6.07$, $p = 0.004$, $\eta p2 = 0.16$, was found. Post hoc indicated that wide attackers had a lower percentage of passes than the defenders and midfielders, while such differences were absent for the central axis (Fig. 3b). Fig. 3c shows that the percentage adequate passes did not vary as a function of a player’s position. Accordingly, there were no significant effects for line and axis (p’s > 0.32). Finally, Fig. 3d suggests that attackers had a lower percentage of adequate other actions compared to midfielders and defenders. This was confirmed by a significant main effect of line, $F(2,50) = 6.34$, $p = 0.004$, $R2 = 0.20$. Post hoc indeed indicated that attackers had the lowest percentage adequate other actions. No further significant effects were found.

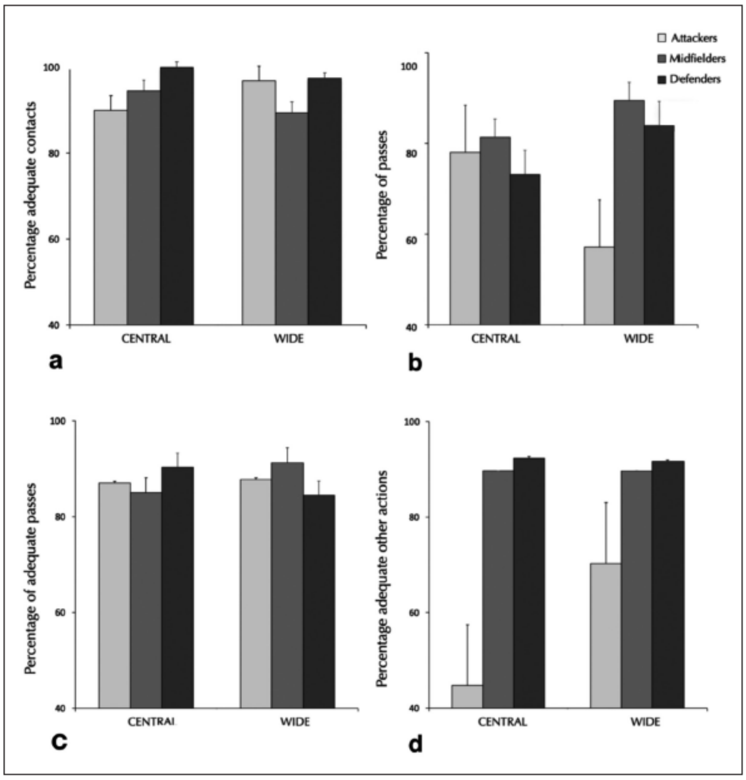


Fig. 3. - Percentage of adequate ball contacts (and SE) (a); percentage of passes (b); percentage of adequate passes (c); and percentage of adequate other actions (d) as a function of line and axis.

The Relationship Between VEA and Performance

In Model 1, we addressed the percentage of adequate contacts (Table 2). In the first step, the amount of VEA in the penultimate pass was entered. This did not result in a significant model, $F(1, 70) = 0.003$ $p = 0.96$. The addition of the amount of VEA in the final pass was added in the second step, $F(2, 69) = 0.40$ $p = 0.67$, and the line by axis interactions in the third step did not result in significant models, $F(4, 67) = 0.22$, $p = 0.93$.

For the percentage of passes (Model 2, Table 3), entering VEA for the penultimate pass in the first step resulted in a significant model, $F(1, 69)= 5.33$ $p =0.024$, $R2 = 0.07$, seemingly suggesting that more VEA in the penultimate pass led to an increased percentage of passes, but this was not significant, $B = 30.9$, $p = 0.24$. In the second step, the addition of VEA in the final pass just failed to significantly improve the model fit, $\Delta R2 = 0.05$, $p = 0.06$. However, the addition of the two line by axis interactions in the third step did improve the model fit, significantly $\Delta R2 = 0.19$, $p < 0.001$, resulting in a significant model, $F(4, 66) = 7.33$, $p < 0.001$. This could be attributed to the increase in percentage of passes on the central axis relative to the wide axis being higher in defenders compared to midfielders, $B = -18.2$, $p < 0.001$. Neither the VEA for the penultimate nor for the final pass did significantly contribute to this model.

A clear relationship between the amount of VEA and performance was revealed for the percentage of adequate passes (Table 4). In Model 3, entering VEA in the penultimate pass in the first step resulted in a significant model, $F(1, 69)= 4.24$ $p = 0.043$. It indicated that a higher amount of VEA during the penultimate pass was associated with a higher percentage of adequate passes, $B = 82.9$, $p = 0.043$. In the second step, the addition of VEA in the final pass, did not improve the model fit, $\Delta R2 = 0.00$, $p = 0.79$, and also the addition of the two line by axis interactions in the third step did not further improve model fit, ΔR2 = 0.01, p = 0.80).

TABLE II
Hierarchical Regression Model for the Percentage of Adequate Contacts (Model 1)

Model 1					
Dependent variable:	**Percentage of Adequate Contacts**				
	B	[BCa 95% CI]	p	R^2	ΔR^2
Step 1				0.00 (p=0.96)	
Constant	96.6				
VEA penultimate	0.30	[-8.2, 9.2]	0.95		
Step 2				0.01 (p=0.67)	0.01 (p=0.37)
Constant	97.4				
VEA penultimate	4.3	[-7.1, 15.9]	0.51		
VEA final	-6.0	[-16.8, 5.6]	.24		
Step 3				0.01 (p=0.93)	0.00 (p=0.94)
Constant	97.1				
VEA penultimate	4.7	[-7.4, 17.8]	0.51		
VEA final	-5.8	[-16.4. 6.0]	0.27		
Midfield vs Attack x Axis	0.9	[-14.1, 14.3]	0.90		
Midfield vs Defence x Axis	0.1	[-4.2, 4.6]	0.76		

TABLE III
Hierarchical Regression Model for the Percentage of Passes (Model 2)

Model 2					
Dependent variable:	**Percentage of Passes**				
	B	[BCa 95% CI]	p	R^2	ΔR^2
Step 1				0.07 (p=0.02)	
Constant	68.7				
VEA penultimate	30.9	[4.2, 57.7]	0.24		
Step 2				0.12 (p=0.01)	0.05 (p=0.06)
Constant	64.7				
VEA penultimate	11.2	[-22.3, 44.6]	0.51		
VEA final	29.2	[-1.4, 59.8]	0.06		
Step 3				0.31 (p=0.00)	0.19 (p=0.00)
Constant	73.0				
VEA penultimate	7.6	[-23.1, 38.4]	0.62		
VEA final	15.8	[-13.2, 44.9]	0.28		
Midfield vs Attack x Axis	5.8	[-5.5, 17.0]	0.31		
Midfield vs Defense x Axis	-18.2	[-28.6, -7.7]	0.001		

TABLE IV
Hierarchical Regression Model for the Percentage of Adequate Passes (Model 3)

Model 3					
Dependent variable:	**Percentage of Adequate Passes**				
	B	[BCa 95% CI]	p	R^2	ΔR^2
Step 1				0.06 (p=0.04)	
Constant	82.9				
VEA penultimate	20.2	[4.1, 36.4]	0.02		
Step 2				0.06 (p=0.13)	0.00 (p=0.79)
Constant	83.4				
VEA penultimate	22.9	[-.4, 46.5]	0.04		
VEA final	-3.1	[-21.6, 13.1]	0.75		
Step 3				0.07 (p=0.34)	0.01 (p=0.80)
Constant	83.3				
VEA penultimate	21.1	[-1.8, 45.3]	0.06		
VEA final	-2.5	[-20.4, 12.7]	0.81		
Midfield vs Attack x Axis	-2.2	[-10.6, 3.5]	0.72		
Midfield vs Defense x Axis	-1.3	[-7.6, 10.0]	0.78		

Finally, in Model 4 we addressed the percentage of adequate other actions (Table 5). In the first step, no significant model resulted based on VEA in the penultimate pass, F(1, 54)= 0.31 p = 0.58, ,R2 = 0.00. Also the addition of VEA in the final pass, F(2, 53) = 0.28 p = 0.76, and the two line dummy variables, F(4, 51) = 0.85, p = 0.50, did not result in significant models.

TABLE V
Hierarchical Regression Model for the Percentage of Adequate Other Actions (Model 4)

Model 4					
Dependent variable:	**Percentage of Adequate Other Actions**				
	B	[BCa 95%CI]	p	R^2	ΔR^2
Step 1				0.00 (p=0.58)	
Constant	77.4				
VEA penultimate	15.7	[-43.4, 73.7]	0.64		
Step 2				0.01 (p=0.76)	0.00 (p=0.62)
Constant	75.3				
VEA penultimate	6.6	[-59.4, 70.8]	0.87		
VEA final	14.7	[-19.9, 49.9]	0.47		
Step 3				0.06 (p=.50)	0.05 (p=0.25)
Constant	83.6				
VEA penultimate	-0.7	[-76.9, 74.8]	0.99		
VEA final	4.0	[-40.1, 48.4]	0.87		
Midfield vs Attack x Axis	7.4	[-15.8, 31.7]	0.55		
Midfield vs Defense x Axis	-14.0	[-41.0, 14.0]	0.40		

DISCUSSION

To take adequate action within the complex and dynamic environment of a soccer match, players must continuously monitor the play's changing affordances, particularly when they anticipate receiving the ball. Accordingly, previous studies have suggested that the elite soccer players engage in visual exploratory activity (VEA), and the more they do so, the more successful the ensuing actions tend to be (Aksum et al., 2021a; Eldridge et al., 2013; Jordet et al., 2013, 2020; McGuckian et al., 2017, 2018b, 2020b; Phatak & Gruber, 2019; Pokolm et al., 2022). This is especially true for players who are positioned at central positions in defense and midfield that offer a multitude of action possibilities (Aksum et al. 2021a, 2021b; Jordet et al., 2020; Pokolm et al., 2022). We expected to further substantiate these observations, but additionally aimed to explore the timing of VEA. In this respect, we hypothesized that among elite soccer players, early VEA (i.e., during the penultimate pass) would be the strongest predictor of the adequacy of subsequent actions. The current observations largely confirmed these hypotheses. They demonstrate that compared to players positioned in the defense and attack, midfielders showed the highest engagement in VEA. Additionally, it was found that the amount of VEA during the penultimate pass predicted the success of subsequent passing actions. The amount of late VEA, during the final pass, did not significantly add to this prediction.

The current findings indicate that the amount of VEA not merely reflects a (superior) ability of individual players, but that it systematically varies according to the spatial and temporal unfolding of the play. This underlines the adaptive character of VEA. Yet, our findings are not identical to previous reports. We found increased VEA for midfielders relative to both attackers and defenders, and irrespective of the axis (i.e., central or wide) in which they played, while previously researchers found increased VEA for midfielders and defenders positioned on the central axis (Aksum et al. 2021a, 2021b; Jordet et al., 2020; McGuckian et al., 2020a). Midfielders are surrounded by teammates and opponents in all directions, and thus obviously forced to extensively explore their very dynamic environment. Indeed, research has shown that individuals are not only attuned to their own affordances but also accurately perceive the action possibilities of other individuals, such as the teammates and opponents (Fajen et al., 2009; Marsh & Meagher, 2016). Therefore, by exploring more, players discover more opportunities for action for themselves but also increase awareness of the affordances of their teammates and opponents, allowing them maintain ball possession and build-up the play. This may be less for attackers, whose main task is to create scoring opportunities, forcing them to take more risks. Indeed, attackers made less VEA and showed less successful performance than the defenders and midfielders. However, it is not immediately clear why we find this increased VEA also for wide midfielders and not for central defenders. Probably, the most likely explanation is a difference in team tactics. In the current study, the teams always played in a 4-3-3 formation, while the previous studies also included teams playing in a 4-4-2 formation (and perhaps mostly so). In a 4-3-3 formation, following the principle of offensive coverage, during ball possession the midfielders (i.e., players 6, 8 and 10, Fig. 1) are typically positioned in a 'V'-shape to create opportunities for passing to build-up the play. Consequently, in a 4-3-3 format, wide midfielders tend play more centrally than in 4-4-2 formats, which may invoke more VEA. Alternatively, also the pressure from the opposing team trying to regain ball possession may influence how the amount of VEA is distributed across player positions. For example, Aksum et al. (2021b) show that variations in the distance between defenders in ball possession and the nearest opponent affects the amount of VEA. Indeed, an interesting avenue for future research is to address how team tactics differentiates patterns of VEA.

Importantly, we also found that VEA is systematically affected by the temporal unfolding of play. Researchers have typically determined players' VEA in the final 10 seconds before they receive the ball in its entirety (cf. McGuckian et al., 2018a). But clearly, depending on the unfolding play, possibilities for subsequent actions may rapidly change. In many time-constraint sports situations, skilled athletes are found to distinguish themselves, among others, by their ability to pick up early information -when reading the game, they look further ahead. Indeed, the current elite soccer players engaged in VEA before the ball was actually passed to them, during the penultimate pass. Yet, unlike what we had expected the amount of VEA was larger during the final compared to the penultimate pass, although the difference was not very pronounced. We suspect that initial perception regarding the subsequent action follow from (relatively) early VEA, but dynamics of the game require players to continuously monitor the ongoings of the situation. It is critical for further research to establish if timing of VEA is different among less skilled players, presumably by being more strongly concentrated during the final pass. Importantly, however, our findings do underline the importance of early VEA, during the penultimate pass, in elite players. That is, in agreement with previous observations, an increased amount of VEA was associated with better performance, especially with the adequacy or successfulness of the subsequent pass (Aksum et al. 2021a, 2021b; Jordet et al., 2021; McGuckian et al., 2020b; Pokolm et al., 2022). The current findings extend the previous observations by indicating that the information is already picked up during the penultimate pass, since the amount of VEA during the final pass did not result in a stronger relation with subsequent performance. This underlines that affordances are perceived based on relatively early VEA.

Our findings include observations of elite soccer matches, rather than re-created test situations which have an increased risk of response bias, among others. Yet, naturalistic observations typically come at the expense of experimental control. The current study is no exception. Most importantly, we know that head and body movements away from the ball systematically varies with spatial and temporal unfolding of the play, but these visual exploratory activities are only a proxy for the pick-up of optical2 information that underpins the perception of affordances. In this respect, using gaze tracking techniques would potentially further our understanding, although gaze fixations do not necessarily correspond to information pick-up (see McGuckian et al. [2017], who discuss limitations of gaze tracking techniques). Also, soccer regulations do not allow to wear equipment such as gaze trackers during official matches. However, using gaze tracking during training matches, possibly combined with inertial measurements units (IMU) to measure head movements (McGuckian & Pepping, 2016; see also Chalkley et al., 2017), can help to further validate the use of video-observations.

With the increasing attention and understanding from research, VEA or scanning is also becoming of interest among practitioners, especially professional coaches (Pulling et al., 2018; Eldridge et al., 2022). Research observations (including the current study) have systematically confirmed the relationship between VEA and soccer performance. Consequently, coaches may want to explore if and how they can train VEA to improve individual and team performance. Typically, coaches organize their training sessions also based on the players' needs (Walker & Hawkins, 2018), in particularly considering the different playing positions. Based on the current findings, group training for midfielders may also include VEA, for example in exercises that re-enact offensive coverage in match situations. Beyond team training sessions, some have proposed to train VEA individually via the Footbonaut (McGuckian et al., 2020b), but possibly virtual reality, in which matches can be 're-played' may be another interesting setting to explore (Ferrer et al., 2020).

To conclude, we show that in elite soccer players VEA systematically varies according to the spatial and temporal unfolding of the play. Specifically, we observed that players positioned on the midfield showed more VEA than players playing in defense and attack. Importantly, we also found that the amount of VEA is positively associated with performance, in particular the adequacy of the pass. In fact, this positive relationship with performance seem to emerge early, during the penultimate pass before receiving the ball, attesting that the elite players were looking ahead while reading the game. Accordingly, to improve tactical performances, we recommend reproducing position specific match situations during training that encourage visual exploration and thus support the perception of affordances.

Notes

[1] In the 2019-2020 season, the IFAB (International Football Association Board) changed the rules regarding the goal-kick (Law 16 in the Laws of the Game). Specifically, the ball must not leave the penalty area in the goal-kick situation, and consequently, the goalkeeper's teammates must be inside the penalty area to receive the goal-kick. This might have altered performance and VEA compared to earlier seasons, particularly for the defensive line.

[2] Notice that teammates also talk (or shout) with each other. Consequently, the affordances are specified by both optical and auditory information.

Acknowledgements

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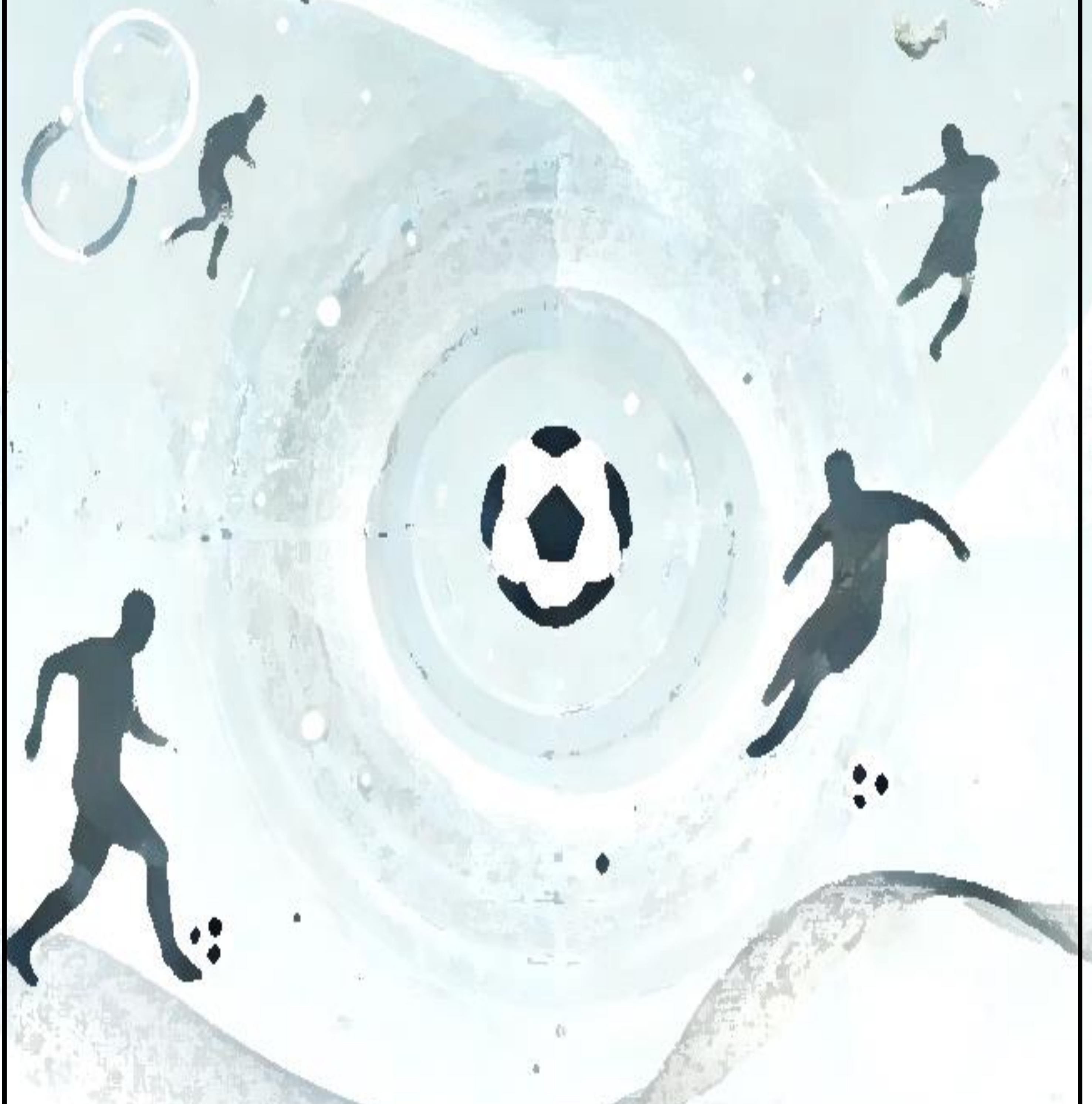
References - See page 77.

CHAPTER 4

NO EVIDENCE THAT VISUAL EXPLORATORY ACTIVITY DISTINGUISHES THE SUPER ELITE FROM ELITE FOOTBALL PLAYERS



Caso, S., McGuckian, T.B., van der Kamp J. (2024). No evidence that visual exploratory activity distinguishes the super elite from elite football players. *Science and Medicine in Football*, DOI: 10.1080/24733938.2024.2325139

ABSTRACT

Visual exploratory activities (VEA) refer to head and body movements that football players make prior to receiving the ball to search possibilities for action. VEA is considered a key performance indicator that differentiates the skill level of players. This study revisited wheth

er VEA also distinguishes super elite, award winning players from their elite teammates without awards. To this end, video footage from the men's UEFA Champions League season 2018-2019 featuring the super elite players (n = 18) and the elite players (n = 18) was analyzed. To reduce the potential differences in match dynamics as much as possible, the selected players in the two groups were of the same team, playing the same match, in the same positioning line. VEA (i.e., frequency per unit time) during the penultimate and final pass prior to ball reception and performance (i.e., percentages of adequate ball contacts and subsequent actions) were compared between the two groups of players using ANOVA and Mann-Whitney tests, respectively. In addition, hierarchical stepwise regression analyses were conducted to explore the degree to which VEA was predicted by group and subsequent performance. The results showed that the players had higher VEA during the final pass (M = 0.45) than the penultimate pass (M = 0.41). There were no significant differences in VEA or performance between the two groups. Also, the regression analyses did not deliver significant models. We conclude that with partial control for match dynamics, no evidence emerged to support that VEA distinguishes super elite players from elite football players.

Keywords: soccer, scanning, decision-making, affordances, elite performance.

INTRODUCTION

Elite football players manifest themselves through increased levels of visual exploratory activity (VEA). They show higher rates of VEA prior to receiving the ball than players who are less skillful (Aksum et al. 2021a; Jordet et al. 2013, 2020; McGuckian et al. 2020b; Pokolm et al. 2022). VEA was defined by Jordet (2005) as "a body and/or head movement in which the player's face is actively and temporally directed away from the ball, seemingly with the intention of looking for teammates, opponents and other environmental objects or events, relevant to the carrying out of a subsequent action with the ball" (p. 143). VEA grants early perception of the possibilities of actions (i.e., affordances) in the situation, and is associated with a more successful outcome of the action immediately following ball reception (Aksum et al. 2021a, 2021b; Caso et al. 2023; Eldridge et al. 2013; Jordet et al. 2013, 2020; McGuckian et al. 2017, 2018; 2020b; Phatak and Gruber 2019; Pokolm et al. 2022). From the perspective of ecological psychology (Gibson, 1966, 1979), VEA is an active search for information involving the whole body that results in the attunement to information that specifies the most relevant possibilities for action. Accordingly, perceptual skill in football is considered as a flexible, largely unreflective, situated awareness, rather than the stockpiling of (shared) conscious knowledge. In essence, skill arises from the ongoing, active visual exploration of the environment, enabling players to flexibly adapt to the emerging and dissolving possibilities for action in a match (Fajen et al., 2009).

Jordet et al. (2013) reported that among elite midfielders from 20 English Premier League (EPL) teams, super elite players who had received a prestigious individual award (e.g., the FIFA World Player of the Year, Ballon d'Or) used more frequent VEA than elite players without awards. The super elite were also more effective in their subsequent actions with the ball (i.e., success in passing). Recent work has reinforced these observations for elite youth players. Pokolm et al. (2022) studied players competing in the U17 and U19 European Championship and found that players with more appearances for their national team produced higher rates of VEA. Similarly, Aksum et al. (2021b) found that elite U19 players produced more VEA than U17 players (see also McGuckian et al. 2020a). Taken together, emerging evidence suggest that

VEA is a key performance indicator that can differentiate skill level, including the fine-grained differences between elite and super elite players.

However, other constraints must be considered in understanding the relationships between VEA and skill level. Foremost, VEA is not merely an attribute of the individual player but emerges in the interaction with the environment. For example, the rate of VEA depends on a player's position in the team. Players playing on the midfield and/or on the central axis produce higher rates of VEA than players in defense and attack and/or on wide axes (Aksum et al., 2021b; Caso et al., 2023; Jordet et al., 2020; Pokolm et al., 2022). The situational dynamics of the match is another critical constraint on VEA. It stands to reason that match dynamics can vary significantly among teams of different age and competition level, especially with respect to the pace of the game (McGuckian et al., 2019; McMorris, 2004). In the study by Jordet et al. (2013), comparing VEA in elite and super elite midfielders, the match dynamics may have differed significantly. The super elite awardees mostly played for top 3 teams with highly skilled teammates, while the non-awardees typically played for lower positioned teams. In all likelihood, the super elite players more often encounter high pace games, presumably inviting more frequent and earlier VEA (cf. Jordet et al. 2013; Pokolm et al. 2022), as would have been the case for youth players when they grow older (Aksum et al. 2021b). By contrast, VEA has been found to be affected by the opponent team's pressure (Aksum et al. 2021a, 2021b; Eldridge et al. 2013; Jordet et al. 2020; Pokolm et al. 2022). In this respect, it may be that the teams which are competing to win the league play more often against teams with more defensive tactics and reduced willingness to create high pressure. To increase control for these and other potential confounders related to match dynamics, we compared VEA of super elite and elite players from the same team in the same matches.

The rate of VEA is typically determined over a period of 10 seconds prior to ball reception (Jordet et al., 2013; McGuckian et al., 2018b; Pokolm et al., 2022). Yet, the possibilities for action quickly change during this 10 second period (McGuckian et al., 2020b). In this respect, it follows from an ecological psychology perspective that VEA is more strongly related to the progression of passes in the game than to mere time measured in seconds (Caso et al., 2023). Because passes are nested within tactical patterns of play, elite players typically can perceive several passes ahead that they will receive the ball (via intermediate players). Consequently, ongoing visual exploration is more likely to be aligned with this dynamic progression of passes than with time intervals in seconds. For example, players increase VEA because the ball is two passes away and not because there are four seconds remaining before they receive the ball. Accordingly, Caso et al. (2023) compared the rate of VEA in the penultimate and final passes before ball reception. Elite players produced more VEA during the final pass than during the penultimate pass, but, more importantly, the rate of VEA during the penultimate pass predicted success in passing after receiving the ball. VEA during the final pass did not further explain the passing performance. Indeed, there is a wealth of evidence suggesting that skilled athletes pick up relevant information further in advance of performing an action than their less skilled counterparts, also in football (Savelsbergh et al., 2006; Williams et al., 1994). However, it has not been examined whether super elite players also distinguish themselves in the timing of VEA.

Hence, the current study analyzed the rate of VEA of super elite and elite football players to verify the previously observed skill level differences in VEA at the adult elite level (Jordet et al., 2013). The super elite group consisted of players who were selected for the UEFA Champions League Squad of the Season 2018-2019, while their non-selected teammates formed the elite group. To control as much as possible for confounders related to match dynamics, we selected teammates who played in the same match in the same position or in the same line (i.e., defense, midfield, or attack).[1] We examined skill differences in the rate of VEA during the penultimate and final passes, and explored the degree to which VEA predicts the adequacy of a player's subsequent action (i.e., passes, dribbles and shots on goal). We hypothesized that the rate of VEA would be higher for the super elite players compared to the elite players both during the penultimate and the final pass. Further, we expected that the rate of VEA would predict the adequacy of subsequent actions, especially for the penultimate pass and more strongly among the super elite players.

METHOD

Participants

A total of 36 players were included, 18 super elite players and 18 elite players. The super elite players were selected from the UEFA Champions League Squad of the Season in the 2018-2019 season. The UEFA Champions League Squad of the Season is an annual list of outstanding players who have demonstrated exceptional performances during the tournament. They are selected by UEFA Technical Observers, who are mostly former professional players and/or managers of national teams. Super elite players ranged in age from 19 to 34 years (*M*=26.9 years, *SD*=4.3), while the comparison elite group ranged in age from 21 to 33 years (*M*=28.1 years, *SD*=3.6). The players of the elite group were chosen to match as much as possible the players of the super elite group. To this end, for each player in the super elite group, a player in the elite group was selected using the following three criteria: the paired player must 1) be a teammate; 2) play in the same match, and 3) play in the same position, and if not available in the same line (i.e., defense, midfield, attack). In previous work, both the line and the axis (i.e., central, wide) have been reported to affect VEA (Aksum et al., 2021b; Caso et al., 2023; Jordet et al., 2020; McGuckian et al., 2017, 2018b; 2020b; Pokolm et al., 2022). Hence, to maximize the similarities between the super elite and elite groups, we preferably selected a teammate who played in the same position, that is, in the same line and in the same axis. However, in five out of 18 pairings this was not possible because, depending on a team's tactical formation (e.g., a central midfielder within a 4-3-3 formation), this meant that the two players would have played in the same position in the team. Because the previously reported effects of line positioning on VEA were more consistent and systematic than the effects of axis (Aksum et al., 2021b; Caso et al., 2023; Jordet et al., 2020; McGuckian et al., 2017, 2018b; 2020b; Pokolm et al. 2022), the remaining five pairs were matched with regard to line only. Both groups consisted of six defenders, six midfielders, and six attackers. Goalkeepers were excluded. Within the super elite group, nine players were playing wide and paired to six wide and three central playing elite players; the other super elite players were playing central and paired to seven central and two wide playing elite players.

For each player, we planned to analyze three full matches (i.e., more matches would have led to a stark reduction of available players). One super elite attacking player did not play any full match and was replaced by an attacker from the UEFA Team of the Year 2019. Of the 18 super elite players, 11 were also on the list of 26 nominated for the FIFA Ballon d'Or 2019. One of the players was the winner of the FIFA Ballon d'Or 2019 and another won the Kopa Throphy. For each player, three matches were analyzed, apart from one super elite player who played only two matches. Therefore, in total, 107 player matches were included for analysis. To further reduce contextual differences between the groups of players, the selection of matches for a player began from the UEFA Champions League final down to group stage matches. For example, if a Liverpool player competed in the final (versus Tottenham), but not in the semifinals (versus Barcelona), then the quarterfinal matches (versus Porto) were analyzed.

Procedure

The video footage was taken from 29 matches. The recordings were obtained through the online platform Wyscout (wyscout.com). The first author is a performance analyst of one of the teams that reached the semifinal stage. Hence, 17 players from 10 matches were analyzed through the club's video archive. For 10 of these players, all matches were from the archive; for three players, two matches were from the archive; and for four players, one match was from the archive. SportsCode Elite software was used for analyses. It allowed, among others, to reduce viewing speed to ¼ of normal speed.

For each participant, we selected as many ball receptions as available according to the following inclusion criteria. To ensure VEA data during both penultimate and final passes, only ball receptions from a series of at least two uninterrupted passes made by teammates were included.

Headers were excluded from the analysis (Caso et al., 2023), because header receptions involve distinct gaze patterns to intercept the ball that may interfere with VEA. Incidental passes resulting from a ball bouncing off a tackle were also excluded, because the series of passes start unintentionally. Also passes from set-piece situations such as free kicks, throw-ins, goal kicks, kick-offs, passes from dropped balls, passes where opponents interfered with the ball, and receptions where the player was fouled and thus unable to perform a subsequent action were all excluded (Caso et al., 2023). Furthermore, the quality of the video footage needed to allow for a reliable identification of the head movements (Jordet et al. 2020). Hence, ball receptions near the far end of the pitch were typically excluded because the colorful audience and advertisement background together with rapidly moving camera shots hampered the identification of head movements. This resulted in the selection of 1,131 ball receptions, with the number of receptions per participant ranging between 8 and 78.

VEA was defined as the receiving player's head turns by which the face was temporally directed away from the ball (Jordet, 2005; Jordet et al., 2013, 2020). Unlike Jordet et al. (2013), we did not restrict analysis to situations where the ball was behind the back. Accordingly, each time the head of the player moved away from the ball, one VEA was counted (e.g., if the face of the participant moved away from the ball, turned toward the ball, and then again moved away from the ball, two VEAs were counted, irrespective of where the ball or opponent was). This was done separately for the penultimate pass and the final pass (Fig. 1).

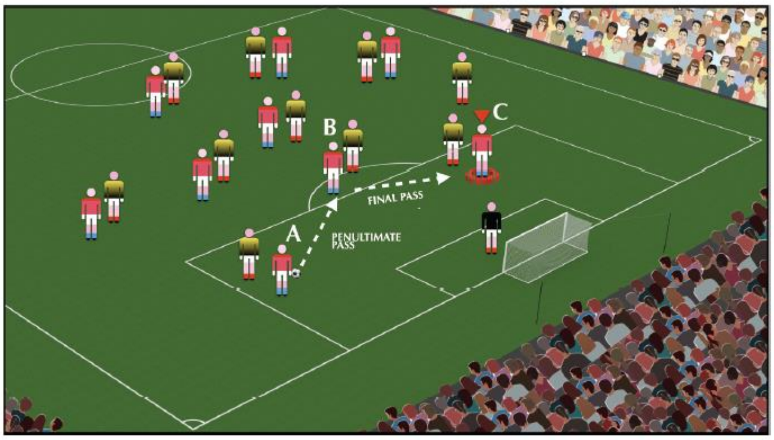


Figure 1. Schematic depiction of the penultimate and the final pass.

Coding for the penultimate pass started the moment at which passing player A received (i.e., contacted) the ball and ended when the ball was received by his teammate, player B. This started coding for the final pass, until the ball was received by the receiving player C. For each pass, its duration (milliseconds) and the number of VEAs made by receiving player C were coded. Next, the action of the receiving player C immediately after ball reception was coded (Caso et al., 2023). We coded ball contacts and subsequent actions such as dribbling, passing, or shooting actions and their adequacy (Table 1).

Table 1. The definition of subsequent actions and their adequacy.

Type of actions	Description
Ball contact	A player received (i.e., touched) the ball. If any action (i.e., pass, shot on goal or dribble) ensued from ball contact, then ball contact was considered adequate, otherwise (e.g., ball jumping from foot to opponent) ball contact was considered as inadequate. A 'one touch' pass was considered as adequate ball contact as well as a pass.
Passing	The ball is kicked in the direction of a teammate or (intentionally) into the (empty) space for a running teammate. If the pass reached the teammate, then it was coded as adequate; if the pass did not reach the teammate, it was coded as an inadequate. Passes that resulted in off-side were coded as inadequate. A 'one touch' pass was considered as an adequate ball contact as well as a pass.
Shooting	The ball is aimed at the goalmouth (i.e., to score a goal). If it ended within the goalmouth, then it was considered adequate, irrespective of whether it entered the goal; otherwise, the shot was coded as inadequate.
Dribbling	The player makes more than two sequential ball touches (see Dellal et al. 2010). It was considered adequate if ball possession was maintained and inadequate if the ball was lost.

The notational analysis was performed by the first author (SC), who is also a professional football performance analyst. To determine interobserver reliability, a football performance analyst with three years of experience, who was also a MSc student in human movement sciences, independently analyzed a random sample of 10 players for one entire match (i.e., ≈ 10% of the dataset), totaling 97 receptions. Intraclass correlation coefficient (ICC) with a two-way random effects model for consistency for the number of VEA showed excellent reliability for both the penultimate pass (i.e., ICC=0.91) and the final pass (i.e., ICC=0.97) (Koo and Li, 2016.) Cohen's kappa (k) was used to calculate the reliability for identifying the subsequent action (Cohen's k=0.96) and its adequacy (k=0.97). Both were excellent (Koo and Li 2016).

Data analysis and statistics

For each ball reception, the rate of VEA was determined by dividing the number of VEAs by the duration (in milliseconds) of the pass. This was done separately for the penultimate and final passes. Next, each player's average rate of VEA was calculated by averaging the rate of VEA for all receptions for the penultimate and final passes, separately. This was done for each included reception within each match, and thereafter the average of each match was calculated, and finally the average of the three match averages multiplied by 1000 was the rate of VEA in seconds. The percentage of adequate ball contacts (i.e., the total number of adequate ball contacts divided by the total number of ball contacts multiplied by 100) and the percentage of adequate subsequent actions (i.e., the total number of adequate passes, dribbles, and shots divided by the total number of adequate ball contacts multiplied by 100) were determined. We used the same method that was employed to calculate the VEA rates. This involved first computing the percentages per match and then taking the average across the three matches.

Shapiro-Wilk tests indicated that the rate of VEA was normally distributed but the percentage of adequate ball contacts and the percentage of adequate subsequent actions were not. The rate of VEA was submitted to a 2 (group: super elite, elite) by 2 (timing: penultimate, final pass) ANOVA with repeated measured on the last factor. Post hoc tests were conducted using t-tests with Bonferroni correction. Effect sizes are reported using ηp^2 with $\eta p^2 < .06$, $.06 < \eta p^2 < .14$, and $\eta p^2 > .14$ as small, moderate, and large, respectively (Cohen, 1969). In addition, the subsequent actions (i.e., percentages of adequate ball contacts and subsequent actions) were compared between the super elite and elite groups using a Mann-Whitney test. The corresponding effect sizes were calculated using the rank-biserial correlation coefficient (r), with r < .10, .10 < r <. 30, and r > .30 taken as small, moderate, and large effect sizes, respectively (Rosenthal, 1991). To further explore the association of the rate of VEA and group with the percentages of adequate ball contacts and subsequent actions, two separate hierarchical stepwise regression analyses with three steps were conducted. In the first step, the rate of VEA during the penultimate pass was entered to assess the role of early VEA. In the second step, the rate of VEA during the final pass was added to assess whether late VEA augmented any contribution to predicting VEA during the penultimate pass. In the final step, the two interaction terms of the rate of VEA during the penultimate pass and the rate of VEA during the final pass with group were entered. The interaction terms were considered relevant if adding them resulted in a significant improvement in model fit, as evidenced by a significant increase in R^2 (Brocken et al. 2016). For both regressions, outliers that disproportionally influenced the regression parameters (i.e., Cook's D>1; Cook and Weisberg 1982), the assumptions of homoscedasticity (i.e., by inspecting the standardized residuals by standardized predicted values plot), error-independence (i.e., Durbin-Watson), lack of multicollinearity, and normal distribution of residual errors (e.g., non-significant Kolmogorov-Smirnov) were verified. Because the residual errors did not show an unambiguous normal distribution, wild bootstrapping with 2,000 reiterations was performed (Caso et al., 2023). The associated bootstrap CIs were used to determine the regression coefficients as they make no assumptions about the shape of the distribution (Efron & Tibshirani 1993). Analyses were performed using SPSS 29.0.0.0.

RESULTS

Rate of VEA

The mean VEA rate in the penultimate pass for the elite group was 0.39 (SD = 0.10), while for the super elite group this was 0.42 (SD = 0.11). In the final pass the mean VEA rate were 0.46 (SD = 0.13) and 0.44 (SD = 0.12) for the elite and super elite group, respectively (Fig. 2). Analysis of the VEA rate indicated a significant effect of timing, $F(1,34) = 8.10$, $p = .007$, $\eta_p^2 = .19$, with a higher rate of VEA in the final pass (M = 0.45, SD = 0.12) compared to the penultimate pass (M = 0.41, SD = 0.10). There was no significant main effect for group, $F(1,34) = .001$, $p = .98$, $\eta_p^2 = .001$, and there was no significant interaction between group and timing, $F(1,34) = 1.67$, $p = .21$, $\eta_p^2 = .047$ (Fig. 2).

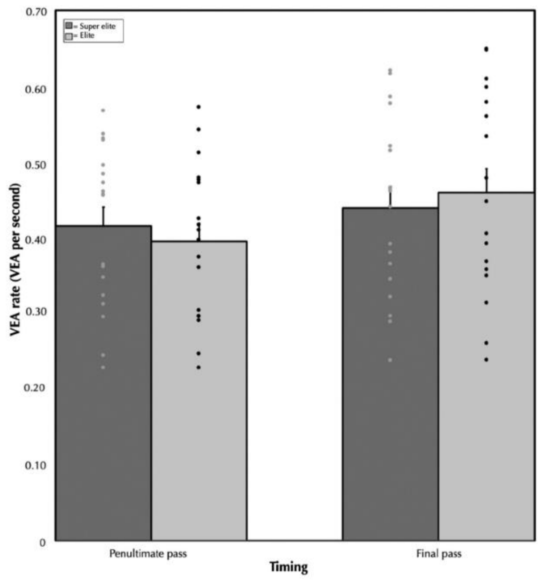


Figure 2. The VEA rate in the penultimate and final pass for the elite and super elite groups.

Performance

Regarding the percentage of ball control, the mean for the elite group was 98.6% (SD = 2.3) and 96.2% (SD = 11.8) for the super elite group (Fig. 3). Therefore, no significant effect for group was found, $U(36) = 133$, $z = -1.01$, $p = .37$, $r = -.12$. Also the percentage of adequate subsequent actions did not reveal a significant effect for group, $U(36) = 139$, $z = -.73$, $p = .48$, $r = -.07$. The mean for the elite group was 91.9% (SD = 5.9) and for the super elite group 88% (SD = 12.2)(Fig. 4) .

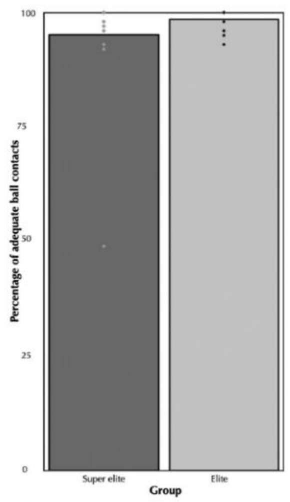


Figure 3. The percentage of adequate ball contacts for the elite and super elite groups.

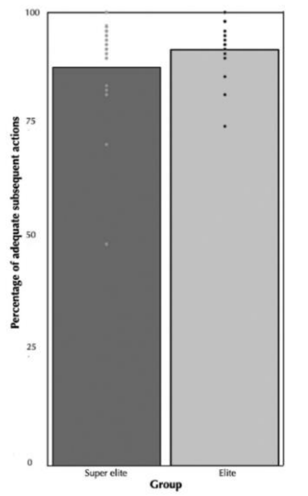


Figure 4. The percentage of adequate subsequent actions for the elite and super elite groups.

The relationship between performance and rate of VEA

Model 1 addressed the percentage of adequate ball contacts (Table 2). In the first step, no significant model resulted after entering the rate of VEA in the penultimate pass, $F(1,34) = 1.76$, $p = 0.19$. Further, also after the addition of the rate of VEA in the final pass the overall model remained nonsignificant, $F(2,33) = 1.20$, $p = 0.31$. Finally, in the third step, we explored if adding the two interactions between VEA and group would result significantly increase model fit. This was not the case $F(2,31) = .47$, $p = .63$, while also the overall model remained nonsignificant, $F(4,31) = .82$, $p = .52$.

Table 2. Hierarchical regression model for the percentage of adequate ball contacts (Model 1).

MODEL 1	Percentage of Adequate Ball Contacts				
Dependent variable:	B	[BCa 95% CI]	p	R^2	ΔR^2
Step 1				.049 (p = .19)	
Constant	89.3				
VEA penultimate	18.5	[−4.02, 41.3]	.23		
Step 2				.068 (p = .31)	.019 (p = .42)
Constant	87.7				
VEA penultimate	8.4	[−5.3, 22.2]	.29		
VEA final	12.7	[−7.05, 34.1]	.46		
Step 3	87.5			.095 (p = .52)	.027 (p = .63)
Constant					
VEA penultimate	19.2	[−4.03, 42.2]	.22		
VEA final	6.6	[−7.9, 21.4]	.51		
VEA penultimate x Group	−16.8	[−48.7, 16.9]	.48		
VEA final x Group	9.5	[−19.2, 36.8]	.59		

Table 3. Hierarchical regression model for the percentage of subsequent actions (Model 2).

MODEL 2:	Percentage of Adequate Subsequent Actions				
Dependent variable:	B	[BCa 95% CI]	p	R^2	ΔR^2
Step 1				.06 (p = .14)	
Constant	80.3				
VEA penultimate	23.7	[−6.3, 54.01]	.14		
Step 2				.12 (p = .11)	.12 (p = .15)
Constant	77.1				
VEA penultimate	3.7	[−19.4, 26.3]	.75		
VEA final	25.2	[3.02, 48.8]	.06		
Step 3	76.6			.20 (p = .12)	.08 (p = .23)
Constant					
VEA penultimate	30.9	[4.4, 58.5]	.05		
VEA final	6.3	[−10.5, 24.4]	.52		
VEA penultimate x	−56.2	[−98.9, −13.6]	.02		
Group	43.9	[10.1, 77.6]	.03		
VEA final x Group					

Model 2 addressed the percentage of adequate subsequent actions (Table 3). In the first step, VEA for the penultimate pass did not yield a significant model, F(1,34) = 2.23, p = 0.14. The subsequent addition of the amount of VEA in the final pass in the second step did not result in a significant model either, F(2,33) = 2.32, p = 0.11. In the final step, we explored if the two interactions between VEA and group significantly improved the model. However, the inclusion of the two interactions did not significantly increase model fit, F(2,31) = 1.54, p = 0.23, and also not result in a significant overall model, F(4,31) = 1.97, p = 0.12. Nonetheless, after bootstrapping the 95% CIs for the VEA in the penultimate pass (4.3 – 58.5, p = 0.05) and the interactions of VEA in the penultimate pass by group (-99.0 – 13.6, p = 0.02) and VEA in the final pass by group (10.1 – 77.6, p = 0.03) did suggest a relationship with the percentage of adequate subsequent actions. Because the overall model is not significant, we refrain from interpreting these further.

DISCUSSION

Football is a multifaced sport that requires players to have a large and diverse skill set to excel. In recent years, growing evidence has been presented showing that VEA are critical in defining skill among football players (Aksum et al., 2021a; Caso et al., 2023; Eldridge et al., 2013; Jordet et al., 2013, 2020; McGuckian et al., 2017 , 2018b, 2020b; Phatak & Gruber, 2019; Pokolm et al., 2022). To effectively respond to the constantly evolving environment of a football match, players must consistently and accurately assess the game's shifting opportunities, particularly when anticipating the receiving of the ball. Players do this by using VEA. In general, more skilled players are presumed to exhibit high degrees of VEA compared to less skilled players (Aksum et al., 2021a; Jordet et al., 2020; Pokolm et al., 2022). Jordet et al. (2013) suggested that VEA even distinguishes fine-grained skill differences between super elite (i.e., award-winning) and elite players. Within this reasoning, VEA is conceived primarily as a characteristic of the individual player, although situational constraints, such as the position of a player within a team, have also been shown to affect the rate of VEA (Aksum et al., 2021b; Caso et al., 2023; Jordet et al., 2020; McGuckian et al., 2017, 2018b, 2020b; Pokolm et al., 2022). Therefore, we think that it is pertinent to also factor in the contextual constraints before attributing distinctive rates of VEA (solely) to individual players. Hence, to revisit the fine-grained skill difference between super elite and elite players, we compared VEA of super elite players selected for the UEFA Champions League Squad of the Season 2018-2019 to VEA of their teammates. To control for differences in match dynamics as much as possible, we selected teammates who played the same matches in the same position or line. We hypothesized that the VEA rate would be greater for the super elite group than the elite group, both in the penultimate pass and the final pass before reception. We also expected the super elite group to show more adequate actions after having received the ball and to show a stronger relationship between performance and VEA, especially during the penultimate pass.

The current observations did not support the hypotheses, as VEA was found to not differ between the two groups. Therefore, the super elite players did not distinguish themselves in terms of VEA. This finding suggests that VEA does not differentiate football players across the entire continuum of skill levels, at least not the subtle differences at the high end. However, this does not rule out that larger, less fine-grained skill level variations can be attributed to VEA. Firstly, it is important to consider that the UEFA Champions League competition features the highest European team levels, and most of the observed actions were examined after the group stages, where the number of teams is small, which arguably results in player skill levels being more evenly matched within a team. Almost four out five players in the current sample were playing for the four teams that reached the semifinal matches. Likely, the action repertoire and perceptual skills among these players differs less than that of midfielders from the 20 EPL teams in the study by Jordet et al. (2013). Secondly, it is plausible to suggest that situational constraints (such as match dynamics) play a more crucial role than individual characteristics. Specifically, the tactics employed by teams can have a significant impact on their playing style, which potentially influences VEA. For instance, the level of pressure exerted by an opposing team can influence VEA (Aksum et al., 2021a, 2021b; Eldridge et al., 2013; Jordet et al., 2020; Pokolm et al., 2022). In addition, situational constraints, such as match tempo and/or speed of play, which may be assessed by determining the frequency of passes, may affect VEA as well. In this respect, it is worth noting that the match tempo or speed of play may vary across competition stages with noticeable differences between the final match of a prestigious tournament like the UEFA Champions League and a group stage match. In brief, to gain a more comprehensive understanding of skill-related differences in VEA, future studies should assess the impact of variations in situational constraints across various levels of skill (or competition).

VEA was significantly greater in the final pass compared to the penultimate pass. These findings are in line with previous research (Caso et al., 2023; McGuckian et al., 2018b) which suggests that players execute most VEA just prior to receiving the ball, as in the final pass. However, previous studies also underline the importance of VEA for better performance immediately after receiving the ball (Aksum et al., 2021a, 2021b; Caso et al., 2023; Jordet et al., 2020; McGuckian et al., 2020b; Pokolm et al., 2022). This was not found in the current study, also not for VEA occurring earlier in time during the penultimate pass. Our findings did not provide further evidence that VEA rate is a predictor of the adequacy of ball contact or subsequent actions[2]. Thus, contrary to our expectations, the ability to perform VEA was not proven to be a significant predictor of the adequacy of performance among our sample of elite and super elite players. This may relate to a limited number of observations in our study, and more specifically with the (stringent) inclusion criteria in this study. That is, only possessions where there were two or more passes from teammates in the lead to possession were included. It could be argued that such inclusion is biased somewhat to stable, tactically routinized play. Possibly, the value of VEA would really come in more chaotic, tactically unstructured situations, such as when there are only limited passes before possession, or directly from turnovers. Alternatively, it may be that the super elite players distinguish themselves through other aspects of the game that were not captured within our performance measures. For instance, they may engage in riskier and more penetrative passes, which less directly translate into better team performance.

Our investigation entailed naturalistic observations of high-level football games that lack full experimental control. This is not unlike previous studies (e.g., Caso et al., 2023; Eldrige et al., 2013; Jordet et al., 2013, 2020; Phatak & Gruber, 2019). However, our study is the first to try to control for possible differences in

situational constraints and especially the dynamics of match. Consequently, we compared VEA between teammates who participated in the same match and played in the same position or the same line of the team (i.e., defense, midfield, or attack). The ensuing similarity is a significant methodological improvement compared to previous studies, although obviously the situational constraints were not identical for the players assigned to the super elite and elite groups. In this respect, it is also pertinent that group assignment was uniquely based on performance during the 2018-2019 season, while players who were selected for the UEFA Champions League Squad of the Season in previous seasons can arguably also be considered outstanding and super elite. We were limited in the amount of video footage we had available. Together with the relatively strict inclusion criteria to enhance control of situational constraints, this resulted in a relatively small sample size. Consequently, the study must be considered exploratory, and care must be taken not to overinterpret the current observations. Nonetheless, it seems worth the effort to conduct a large study across the entire range of skill (and/or age) levels and that factors into variations in situational constraints. This would also be of critical importance when striving to utilize VEA for identification and development of talented players. Finally, it should be noted that head and body movements away from the ball vary systematically with the spatial and temporal unfolding of the game, and these movements serve as a proxy for the visual exploration of affordances rather than the actual pickup of optical information (Gibson, 1979). To enhance our understanding of these exploratory activities, gaze tracking techniques can be employed (McGuckian et al., 2018a). Yet, because football regulations prohibit the use of equipment such as gaze trackers during official matches, video-recordings and gaze tracking during training matches (Aksum et al., 2021a), possibly combined with inertial measurement units to measure head movements (Chalkley et al., 2017; McGuckian & Pepping 2016) could be used to create and validate algorithms that automatically estimate gaze direction from video-footage.
To conclude, we demonstrate that the rate of VEA differs significantly between different stages of passing but does not distinguish the super elite from elite players. Moreover, no evidence was found that VEA is associated with performance adequacy among the selected pieces of game play in the current sample of elite and super elite players.

Notes

[1] For 5 out 18 super elite players, no teammate was available that played in the same position. For these players, we selected a teammate that played in the same line instead (see Methods for further details).
[2] It should be noted that the analysis for the percentage of adequate subsequent actions hinted at the relevance of VEA during the penultimate pass, possibly depending on the group, but given that model fits were not significant, these findings need to be substantiated before we can interpret them reliably.

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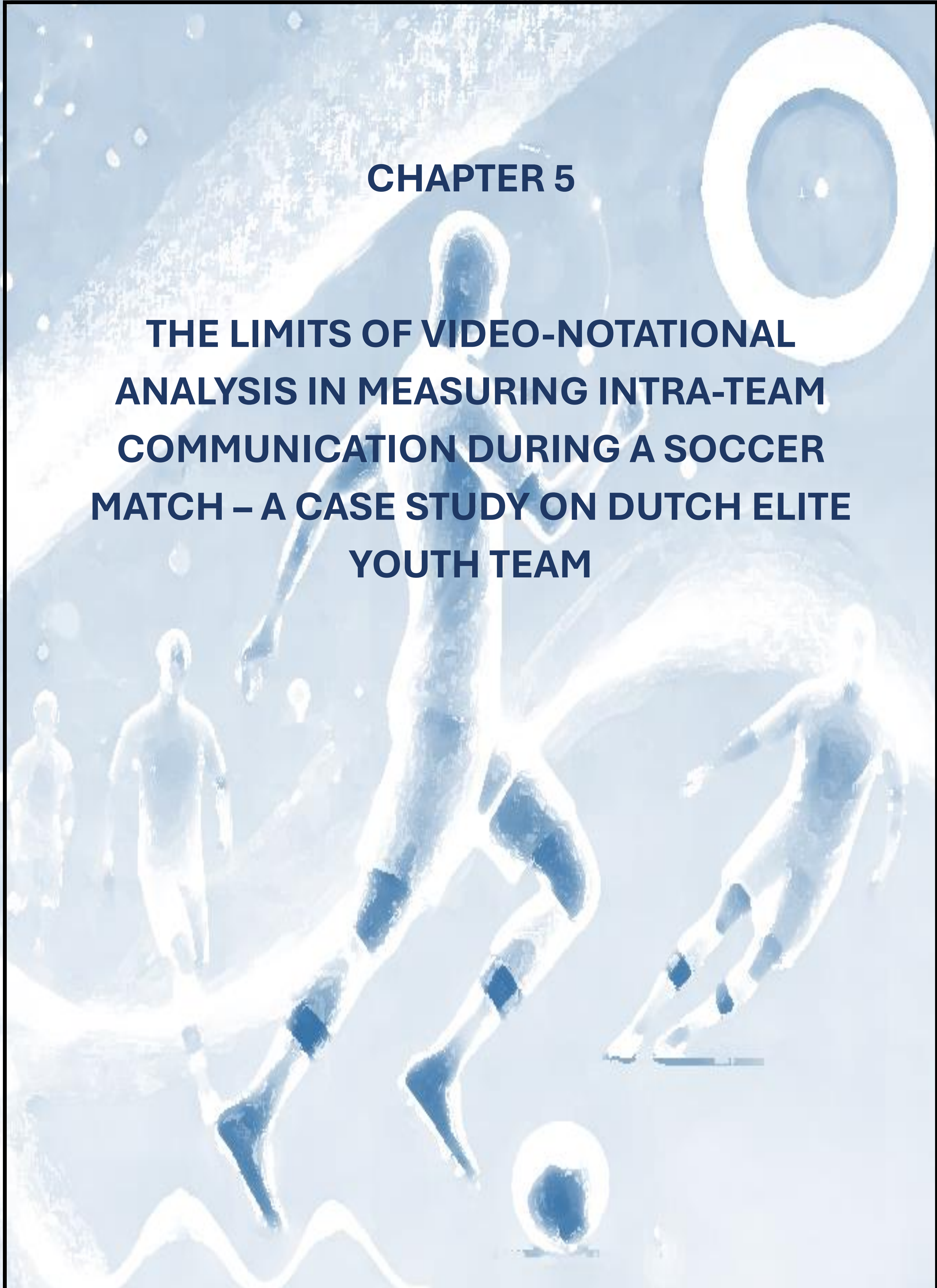
Data sharing statement

The data that support the findings of this study are openly available in DataverseNL at https://doi.org/10.34894/LHOGF6.

Data availability statement

Data would be provided upon request.

References – See page 77.



CHAPTER 5

THE LIMITS OF VIDEO-NOTATIONAL ANALYSIS IN MEASURING INTRA-TEAM COMMUNICATION DURING A SOCCER MATCH – A CASE STUDY ON DUTCH ELITE YOUTH TEAM

Caso, S., Spit, M., Hill, Y. & van der Kamp, J. (2024). The limits of video-notational analysis in measuring intra-team communication during a soccer match – a case study on Dutch elite youth team. [Manuscript submitted for publication].

ABSTRACT

Video-notational analysis is often used to assess in-match communication assuming that nonverbal communication alone can represent the full scope of intra-team communication, also including verbal communication. To examine this assumption, we obtained permission to conduct a case study with an elite U19 soccer team, recording their communications. We compared the quantity and types of communication derived from video alone versus video combined with audio. Results revealed that the quantity of communications for the two analysis methods did not correlate. Differences with a weak effect size were found in the distributions of the types of communication between the two methods, but no single difference stood out. Finally, moderate to strong correlations between two analysis methods were found for giving indications and negative communication, while correlations for other types were absent. The case study underscores the need for integrating video with audio analysis for a representative understanding of communication in soccer.

Keywords: intra-team communication, nonverbal intra-team communication, performance analysis, soccer analysis, verbal intra-team communication.

INTRODUCTION

Coaches, players, analysts, and researchers universally acknowledge the importance of effective intra-team communication in team sports, recognizing it as fundamental for achieving team performance and success (Durdubas et al., 2019; Eccles & Tenenbaum, 2004; Halldorsson, 2018; Kraus et al., 2010; Lausic, 2005; Leo et al., 2023; McLean et al., 2021; Moesch et al., 2015; Shah et al., 2023). In the scientific literature, it is currently debated whether intra-team communication requires shared mental models (e.g., Eccles & Tenenbaum, 2004) or is better understood as attunement to and perception of shared affordances (Silva et al., 2013; see also McNeese et al., 2016). Shared mental models refer to overlapping knowledge structures within team members that foster a shared understanding of goals and tasks, thus enabling effective coordination (Cannon-Bowers et al., 1993). These models align with representational theories, which posit that actions are guided by internal representations that encode the world's state (Chemero, 2011; McNeese et al., 2016). In contrast, shared affordances are possibilities for action within an environment that are perceived and acted upon collectively by a group of individuals. The perception of shared affordances by team members is crucial for coordinated joint actions of players (Silva et al. 2013). Yet, irrespective of the theoretical approach, there is consensus that the importance of communication lies in its function — what it achieves and why team members engage in it. Communication functions either to synchronize the shared mental models or to direct attention to the shared affordances. In other words, it connects individual team members, for instance by positive or negative encouragements, and it enables the team members to coordinate their actions, for example by giving indications or asking for the ball (Tamboer et al., 2016).

To assess patterns of intra-team communication, researchers have used social metrics, focus group interviews and questionnaires for a diverse set of sports (Blaser & Seiler, 2019; McLaren & Spink, 2016; Smith et al., 2013; Sullivan & Feltz, 2003). However, these methods do not directly assess in-match communication. Instead, they chiefly chart social relations that are used as an *indirect* measure of intra-team communication. Hence, others have tried to obtain *direct* measures via notational observations of matches. The majority of these direct assessments use video recordings only (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015), while a few have combined videos with audio recordings (Lausic et al., 2009, 2014; LeCouter & Feo, 2011). The direct observations of in-match patterns of communication with video and audio recordings allow to capture both nonverbal and verbal intra-team communications and is therefore critically important if communication is understood as the shared perception of affordances, as ecological psychologists do (Davids et al., 2005; Richardson et al., 2008;

Silva et al., 2013). That is, because affordances continuously emerge and dissolve during play, it is imperative to assess the unfolding patterns of communication on the field.

Examining in-match intra-team communication is typically challenging, particularly with respect to verbal communication. Firstly, national and international sporting federations prohibit players from wearing microphones during a match. Secondly, the noisy audience, pitch size, and interfering communications from technical staff and referees make it challenging to reliably attribute each verbalization to the correct player. Consequently, most studies have exclusively relied on video recordings and were thus largely confined to nonverbal intra-team communications. For example, studies in elite basketball and handball assessed nonverbal communication through tactile communications gestures such as high fives, clapping hands and thumbs up (Kraus et al., 2010; Halldorsson, 2018; Moesch et al., 2015), while a study in volleyball examined general behaviors including coordination-directed communications, such as indicative or instructional gestures (e.g., pointing to a location on the court where a teammate should have been), tactical gestures, (e.g., symbolic manual signs), and motivational gestures or touches (e.g., back rub) (Durdubas et al., 2019). Despite these many examples, only a single study has directly measured communication in soccer (Halldorsson, 2018). Specifically, video-notational analysis was used to investigate nonverbal intra-team communication directed to motivation in a single football match. Gestures such as clapping of hands, thumbs up and high fives were measured and classified as positive, negative or neutral to provide insight into the in-match team spirit. In general, this study, like those in other sports, appears to confirm that communication is associated with team performance (e.g., winning). However, it must be emphasized that this conclusion is solely based on video analyses and thus largely limited to nonverbal communications. Critically, it has not been established to what degree the nonverbal communications are representative for the total pattern of in-match communications (i.e., both nonverbal and verbal communications and communications where both are combined). It cannot be ruled out that the subset of nonverbal communications is biased to one or the other specific type of communication. To permit more definitive conclusions regarding the contribution of intra-team communication to team performance, it is important to assess how representative nonverbal communication is for the entire spectrum of intra-team communication.

The Case

The national soccer association of The Netherlands (KNVB) gave permission to equip a team of elite U19 players with microphones during an official friendly match. Consequently, we evaluated whether the in-match nonverbal intra-team communication measured via video-notational analysis was representative of all in-match intra-team communication (i.e., the verbal and nonverbal and combined verbal and nonverbal communication) in a soccer match. We determined the nonverbal in-match intra-team communication using only video-notational analysis as well as a combination of both video- and audio-notational analyses. We first investigated if the quantity of nonverbal intra-team communication is related to the quantity of all communication (i.e., nonverbal, verbal, and combined). Second, we classified each communication according to one of five types given their function (i.e., giving indication, asking for the ball, positive communications, negative communications and other) in line with the general classifications of previous studies (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015) and verified whether their distribution is similar within the nonverbal communications and all communications. Third, for each of the five communication types, we examined if the quantity of nonverbal communications is related to the quantity of all communications.

METHOD

Participants

Thirteen elite soccer players of a U19 team from an elite Dutch soccer club volunteered to participate in the study and to wear a microphone and associated equipment during a friendly match. For safety reasons (i.e., risk of injury or damage to the equipment while diving), the goalkeeper was excluded from the study. The participating team competes in the national youth premier league. The participants' ages ranged from 16 to 19 years (*M* = 17.5, *SD* = 0.92). Of the thirteen participants, ten formed the starting line-up, while the remaining three were substitutes brought in after the break (i.e., 10 participants played approximately 90 minutes and 6 played approximately 45 minutes). The study was approved by the university's ethics committee. Before the study, the participants signed informed consent. The staff and opponent players were informed about the measurements and verbally consented with the recordings.

Material, apparatus, and procedure

The friendly match was one of regular midweek encounters against another elite U19 team taking place at the training ground of the participating team. The use of audio microphones setup underwent initial testing across various training sessions. This demonstrated that audio recordings from gameplay were consistently clear, with the equipment proving capable of sustained recording durations and resistance to different weather conditions. Audio recordings were performed using 10 Record-IT digital voice recorders together with compact wired Goodlux condenser microphones. The participants were provided with an Inmotio vest (inmotio.eu) in the dressing room, prior to the warm-up or prior to the second half for those players who were substituted to play. The voice recorder and microphone were seamlessly integrated in the vest, ensuring optimal functionality. The voice recorder was securely housed within the pocket on the back of the vest (Figure 1), while the wired microphone was placed and secured beneath the players' chin to enhance voice capture. The audio recordings were initiated before handing the vest to the players. Once the match ended, the vests were collected and recordings stopped. Subsequently, the audio recordings were transferred to a laptop.

Figure 1 – An Inmotio vest with the voice recorded embedded in the back poket

The video recordings were made with a Sony (PXW-Z90) and a Hikvision Panovu (32mp) camera, at an elevated position at the midline of the field. The Software package Shotcut was used to edit and synchronize the audio and the video recordings using the referee's whistle as the marker.

Measures

The first author (SC), who is an experienced sport scientist, taught and supervised the second author (MS) to conduct the video analysis using the software Angles. Intra-team communications were coded of each player twice, once using the (muted) video recordings for notating the nonverbal communications only and once using the (unmuted) videos recordings in combination with audio recordings for notating all intra-team communications (i.e., nonverbal, verbal and combined nonverbal and verbal communications). To mitigate sequence effects, for half of the participants, communications were initially coded from video recordings only, followed by video plus audio recordings. The other half of the participants was coded in reverse order, starting with the video plus audio recordings and subsequently with the video recordings only.

We constructed a coding scheme that aligns with categories that derived from both the scientific literature and the expert-knowledge from professional analysts within the club. These functional categories are closely tied to actual in-game behaviors, which aligns with an ecological approach that emphasizes the perception of affordances. Based on this, four distinct intra-team communication types were discerned that encompass the majority of communications: giving indication, asking for the ball, positive communication and negative communication (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015). The fifth communication type involved all other communication types (see Table 1 for definitions and operationalizations).

Table 1: Types of communication.

Communication type	Definition
Giving indication (nonverbal) (Durdubas et al., 2019)	If a player points to a position on the court where a teammate or ball should have been, or if a player shares (tactical) information with his teammate possibly through hand, arm and head movements.
Giving indication (verbal) (Durdubas et al., 2019)	If a player uses verbal communication to indicate where a teammate should have been, or to share (tactical) information. E.g. "Go there", "Behind you", "Come here"
Giving indication (verbal and nonverbal)	If the player was used verbally and nonverbally at the same time to give indications.
Asking for the ball (nonverbal)	If a player asks for the ball by pointing towards the ground with an open hand palm / or both hands; or raising the hand(s).
Asking for the ball (verbal)	If a player uses verbal communication to ask for the ball. E.g. "Pass", "Here", "Deep"
Asking for the ball (verbal and nonverbal)	If a player uses verbal and nonverbal communication to ask for the ball.
Positive communication (nonverbal) (Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015)	If a player uses gestures to express happiness, success or motivation by showing a thumbs-up, clapping, high-fiving, giving a pat on the back or hugging other teammates or a group of players.
Positive communication (verbal) (Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015)	If a player uses gestures to express happiness, success or motivation by showing a thumbs-up, clapping, high-fiving, giving a pat on the back or hugging other teammates or a group of players whilst verbally communicating as well. E.g. "Good job", "Well done", "Nice one"
Positive communication (verbal and nonverbal)	If a player uses verbal and nonverbal communication to express happiness, success or motivation.
Negative communication (non-verbal) (Halldorsson, 2018)	If a player uses gestures to express disappointment, anger or hopelessness to other teammates without having the aim to motivate them (e.g. thumbs down, middle finger).
Negative communication (verbal) (Halldorsson, 2018)	If a player uses verbal communication to express disappointment, anger or hopelessness to other teammates without having the aim to motivate them.
Negative communication (verbal and nonverbal)	If a player uses verbal and nonverbal communication to express disappointment, anger or hopelessness to other.
Other communication (non-verbal)	If a player uses gestures or body language which was either not possible to categorize elsewhere or not comprehensible for the coder.
Other communication (verbal)	If a player uses verbal communication statements which was either not possible to categorize elsewhere or not comprehensible for the coder.

Other communication (verbal and nonverbal)	If a player uses verbal and nonverbal communication which was either not possible to categorize elsewhere or not comprehensible for the coder

For each participant, the video and audio recordings were analyzed and coded from the starting whistle of the referee to the end of the match or until when they were substituted off. For players who were substituted in, the data collection started upon their entry on the field. Several scenarios were excluded from the analysis. First, any communication that was not directed at a teammate, such as communications to the referee, technical staff, and opponent players, was excluded. Second, communications in periods occurred during game stoppages (e.g., during injuries) were excluded. This decision was prompted by the observation that during these periods participants' communications predominantly centered around inquiries about the well-being of an injured teammate or discussions unrelated to the game, such as personal conditions or off-topic matters, which were not directly coupled to in-game actions.

To determine the reliability of the analysis and coding, a second sport scientist, who was also a MSc student in human movement sciences, independently analyzed a random sample of 10% of the observations (i.e., 45 minutes of three participants). Intraclass correlation coefficient (ICC) with a two-way random effects model for consistency for the number of nonverbal communications showed excellent interobserver reliability (i.e., $ICC = 0.99$). The reliability for the number of all communications was also excellent (i.e., $ICC = 0.97$). The reliability for the types of nonverbal communication was moderate (Cohen's $k = 0.61$), while for the types of all communications reliability was good ($k = 0.90$) (Koo & Li, 2016).

Statistical analyses

For each player, we counted the number of nonverbal communications (based on video analysis only) and the number of all communications (based on video plus audio analysis). After obtaining the cumulative communication counts for each player, we proceeded to calculate the communication rate by dividing the number counts by the respective player's total minutes of participation in the match. For instance, Player A, who made 26 nonverbal indication gestures during his 92-minute playtime, had a communication rate of 0.28 (i.e., dividing 26 by 92). Next, Pearson's correlation coefficient (Pearson's r) was used to test the association between the communication rates of the nonverbal communications and all communications. Between 0 and ±0.10 the correlation is negligible, between ±0.10 and ±0.39 weak, between ±0.40 and ±0.69 moderate, between ±0.70 and ±0.89 strong and between ±0.90 and ±1.00 very strong (Schober et al., 2018). To enable generalization, we were interested in large effect sizes, and strived for minimal correlation of $r = 0.70$. Next, a chi-square test was used to determine whether the types of communications were similarly distributed within the nonverbal communications (based on video analysis only) and all communications (based on video plus audio analysis combined). Finally, for each type of communication separately (i.e., giving indication, asking for the ball, positive communication, negative communication and other), Pearson's r was calculated to test the association between the communication rates of the nonverbal communications and all communications.

RESULTS

In total, we identified 719 nonverbal intra-team communications through video analysis, while a total of 2,575 verbal, nonverbal and combined intra-team communications were observed in the video plus audio analysis. The Pearson's correlation revealed a nonsignificant correlation, $r(13) = .383$, $p = .098$, *95%CI* [-.213, .771], indicating that there was no relationship between the rate of nonverbal communications from the video analysis and the rate of all communications identified through the video plus audio analyses (see Figure 2).

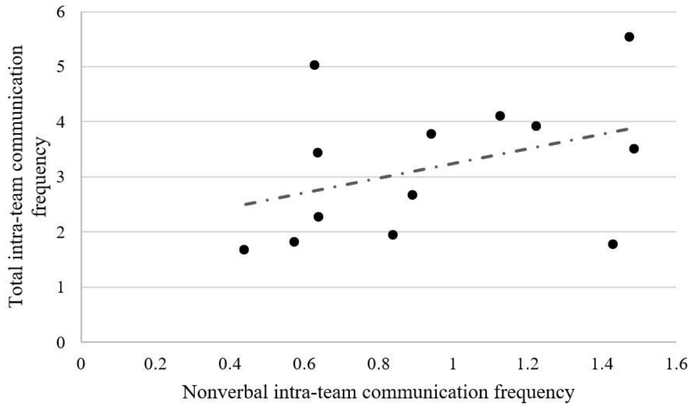


Figure 2 - Scattergram of the rates (number per minute) of all intra-team communication based on video plus audio analysis and the nonverbal intra-team communication based on video analysis.

Figure 3 shows that the distribution of the five types of communications was rather similar for the nonverbal communications observed with video analysis and all communications identified with video plus audio analyses. Yet, the chi-square test indicated that the distributions of the five communication categories within nonverbal communications and all communications differed significantly albeit with a weak effect size ($\chi^2 = 23.746$, $p < .001$, *Cramer's V* = 0.085). However, while differences between the two analysis methods can be observed for all types of communication, there is no single difference that stands out and no clear separation becomes evident between the two distributions (Figure 3).

A moderate (positive) correlation was observed for giving indications between the frequency of nonverbal communication identified through video analysis and the overall communication rates derived from both video and audio analyses ($r(13) = .67$, p = .01, *95%CI* [.190, .892]), while for negative communications, a strong (positive) correlation was found ($r(13) = .75$, p = .003, *95%CI* [.339, .921]). The correlations for asking the ball ($r(13) = -.05$, p = .86, *95%CI* [-.588, .512]), positive communication ($r(13) = -.24$, p = .23, *95%CI* [-.243, .758]), and other communications ($r(13) = .25$, p = .41, *95%CI* [-.347, .705]) did not reach significance.

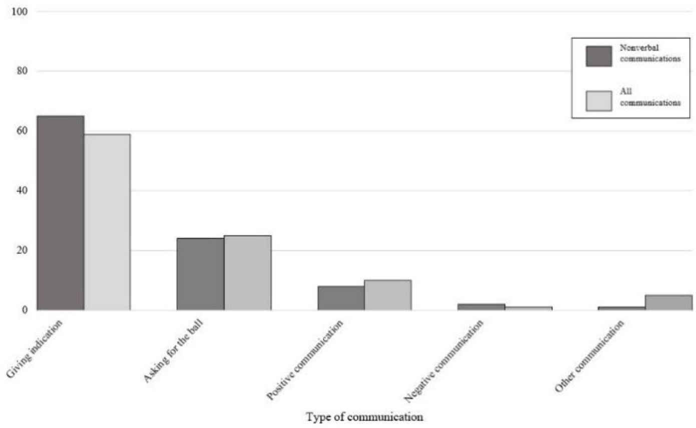


Figure 3 - *Distribution (in %) of the types of intra-team communications of all communications based on video plus audio analysis and the nonverbal communications based on video analysis*.

DISCUSSION

Examining in-match intra-team communications presents challenges, especially regarding the recognition and function of verbal communications. Regulations prohibit players from wearing microphones, while environmental factors like crowd noise hinder measuring verbal communication from outside the playing field. Consequently, studies have typically relied on video recordings to directly measure in-match communications and predominantly captured nonverbal communications (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015). Yet, it has not been independently assessed whether nonverbal communications based on video-notational analysis are representative for the total pattern of in-match communications, including verbal communications. Therefore, with the consent from the national soccer federation to analyze a single match, this case study evaluated the representativeness of video-notational analysis of intra-team nonverbal communication in soccer. Specifically, it verified whether the quantity and type of nonverbal communication examined via video analysis are associated to the quantity and type of all communication measured via combined video and audio analysis.

The results did not reveal a significant relationship between the quantity (as measured by the rate or number of communications per minute playing time) of nonverbal communication identified through video analysis and the quantity of all communications observed through a combined video and audio analysis. In addition, we found significant differences in the distribution of communication types within the nonverbal communications from video analysis and all communications via the combined video and audio analysis. However, the associated effect size was small, and it was not possible to unequivocally locate where the differences between the two analysis methods emerged. Finally, the relationships between the quantities for each communication type separately provided mixed results. While there were significant moderate to strong correlations for the rates of giving indication and negative communications, the rates of asking for the ball, positive communications, and the remaining types did not show significant correlations between the nonverbal communications observed via video analysis and all the communications identified through the combined video and audio analysis. Consequently, we fail to show the strong associations that were to be expected based upon the current (implicit) assumption in the literature that notational video-analysis of nonverbal communication provides a representative portrayal of the entire spectrum of in-match communication. We conclude that at the team level for a single match (i.e., as it would typically be implemented by practitioners) notational analysis of intra-team nonverbal communication through video is insufficiently representative to be implemented as a marker for the pattern of all in-match intra-team communications. Accordingly, although video-notational analysis might remain a valuable tool for capturing some aspects of communication, such as nonverbal gestures for giving indications, the present study underscores the limitations of relying solely on video analysis in directly assessing in-match communication within the dynamic team sport context of soccer. It is therefore paramount to interpret results from earlier studies (e.g., Halldorsson, 2018) very cautiously. Likely, such reconsideration may also be warranted for intra-team communication in other dynamic team sports.

Reflections

The current case study highlighted the importance of augmenting notational video analysis with audio analysis to obtain a more representative and generalizable understanding of communication within a team. Indeed, a few studies have combined nonverbal communications along with verbal communications using both video and audio recordings (Lausic et al., 2009; 2014 LeCouter & Feo 2011). For example, Lausic et al. (2009) studied the quantity of intra-team communications in tennis doubles, showing that winning teams exhibited different quantity of messages, than losing teams. Yet, tennis doubles matches clearly are less dynamic and cluttered and therefore technically less challenging to produce audio recordings than soccer matches. As shown in the present study, in soccer, incorporating wearable devices synchronized to video may enhance the comprehensiveness and validity of the direct measurement of in-match communication. However, current restrictions on wearing microphones during official matches (i.e., Law 4 - The Players' Equipment | IFAB, 2024) pose practical challenges for data collection in real-world settings. Therefore, innovative approaches to overcome these barriers should be explored, for example, integrating microphones within tracking systems such as global positioning system pods or heart rate monitors. Moreover, by adopting an approach that integrates visual and auditory data, we can advance our understanding of how communication influences team performance and enhance the effectiveness of training interventions aimed at optimizing intra-team coordination (Lausic et al., 2009).

Strength and limitations

This study is the first that examined the representativeness of intra-team nonverbal communication via notational video-analysis for the pattern of all in-match communications. That it fails to demonstrate the strong association that is tacitly assumed may have important implications for researchers and practitioners, but first several limitations of the current study must be considered. First, our analyses focused on quantifying the amount of intra-team communication. Arguably, however, the more critical in describing and understanding communication is its dynamics, that is, the qualitative *patterns* of these interactions. Presumably, whether the communications are within or between lines (i.e., defense, midfield, attack), the timing of communication (i.e., during the unfolding gameplay or set play situations, the periods during a match) is significantly more influential for coordinating actions, and thus predicting performance, then the mere quantity of communications. Researchers have already started to use tools from dynamic systems to measure intra-team coordination patterns (Duarte et al., 2013), similar analysis methods may be useful for measuring patterns of communication as well. Eventually, the representativeness of notational video-analysis for the patterns of communication must also be verified. Second, communication is interactive, and not just sending messages, sharing affordances also implies perceiving them (e.g., “watch your back!”). In this respect, researchers should explore how intra-team communication is associated with visual exploratory activity (VEA), and relate to successful performance (Aksum et al., 2021a, 2021b; Caso et al., 2023; 2024; Eldridge et al., 2013; Jordet et al., 2013; 2020; McGuckian et al., 2017; 2018b; 2020a; Phatak & Gruber, 2019; Pokolm et al., 2022). Third, we analyzed a friendly standard midweek youth match with a small audience. However, at the highest elite levels of adult soccer, players frequently have challenges in verbally communicating due to crowd noise. As a result, they may (have to) rely more on nonverbal communication, such as giving indications, especially among long distances. We cannot rule out that notational video-analysis without audio is a valuable tool for capturing the quantity and/or patterns of in-match intra-team communication. Further to this point, while the overall inter-rater reliability for the quantity of nonverbal communication was excellent, the reliability for distinguishing the type of nonverbal communication with notational video-analysis was only moderate. Without access to accompanying verbal statements, there was no high agreement among the raters in interpreting and classifying the nonverbal communication behaviors. This uncertainty may also have affected the observed degree of representativeness negatively. Consequently, a refining of coding criteria seems warranted. In the current literature, however, a precise definition of nonverbal communication behaviors remains elusive, and various authors tend to interpret the same gestures differently, both in broad (i.e., the generic definition of what constitutes nonverbal communication) and in narrow terms (i.e., the specific definitions of a particular communication). In broad terms, some maintain definitions that encompass the entire range of body language, which are often implicit (Furley, 2023; Furley & Memmert, 2021; Furley & Schweizer, 2014), while others specifically refer to deliberate gestures (Durdubas et al., 2019; Halldorsson, 2018; Kraus et al., 2010; Moesch et al., 2015). In narrow terms, a single gesture (e.g., making a fist) can be considered as celebration Durdubas et al. (2019) but can also serve as positive encouragement. In this regard, it is important to recognize the significance of the context in interpreting nonverbal communication. This relates to the rater being able to read the intricate dynamics of gameplay as well as being familiar with the communication styles of the players. Clearly, a priority for future investigations is the further development of reliable and valid notational video- analysis. For now, the current study suggests that both researchers and practitioners must be careful in exclusively relying on notational video-analysis to uncover the intricacies of intra-team communication.

Conclusions

In conclusion, while video-notational analysis is assumed to provide valuable and representative information regarding the patterns of intra-team communication, this unique case study suggests that it has inherent limitations in capturing the entire spectrum of in-match communications. Researchers and practitioners should be mindful of these limitations and develop complementary methods to obtain a better understanding of communication within soccer.

Data sharing statement

The data that support the findings of this study are openly available in Open Science Framework at https://doi.org/10.17605/OSF.IO/6V5E4.

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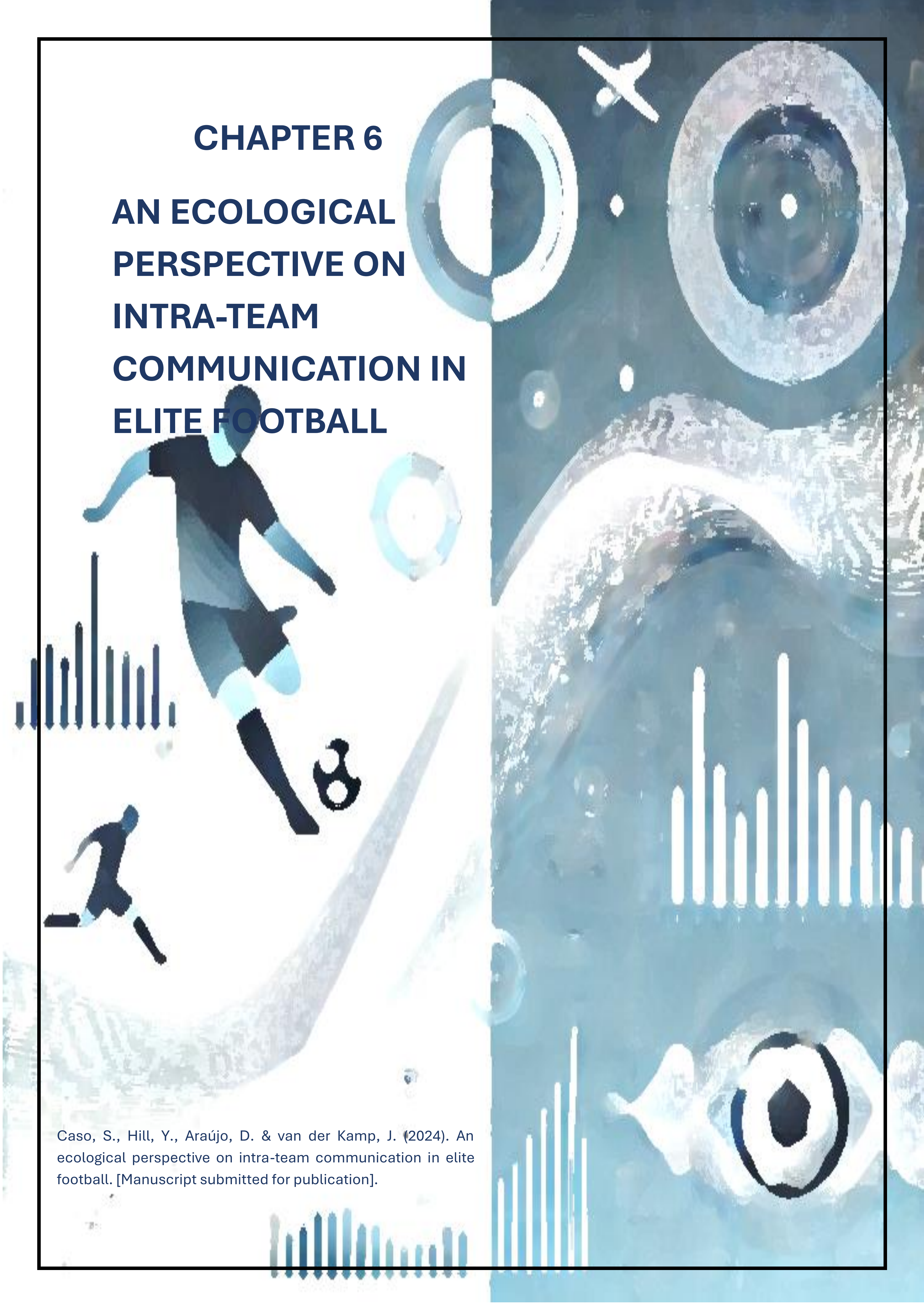

CHAPTER 6

AN ECOLOGICAL PERSPECTIVE ON INTRA-TEAM COMMUNICATION IN ELITE FOOTBALL

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ABSTRACT

Effective intra-team communication is fundamental for coordination and success in team sports, particularly in association football. This paper critically reviews the existing conceptualizations of intra-team communication, identifying gaps in traditional approaches within sport psychology. Specifically, traditional representational theories rely on shared mental models to achieve coordinated actions, which limited practical impact due to their static nature and the assumption that all players share identical cognitive representations. Alternatively, we propose an ecological perspective that conceptualizes intra-team communication as serving the collective attention to information that specify the shared affordances that underpin team actions. This perspective emphasizes the dynamic nature of communication, utilizing methods from dynamical systems approach to explore these interactions. We highlight the essential role of communication in coordinating team actions and proposes a research agenda for further exploration in this field.

Keywords: coordination, intra-team communication, football, perception-action coupling, shared affordances.

INTRODUCTION

Immediately after the 1-1 draw against FC Twente, Erik ten Hag, the head coach of AFC Ajax reviewed the opponent's goal with his technical staff. He attributed the goal to a lack of communication. To verify, he requested the post-match video analysis report to include intra-team communications within the team. After he had advised himself on intra-team communication in this way during a couple of months, Ten Hag started to use the intra-team communication reports for match preparations. Months later, during an interview after being appointed the new Manchester United manager, he highlighted intra-team communication and players speaking the same language as important factor for shaping team coordination (*Ten Hag Opens up on Dalot and Antony's Partnership after Fourth Straight Win*, 2022)*. The first author of this paper provided the intra-team communication report for Ten Hag but was left with many questions, not the least of which was how to understand communication.*

Coaches, sport scientists and analysts universally recognize the important role of intra-team communication in team sports. Effective communication is fundamental for coordinating the actions of individual team members, and thus essential for achieving success. It has even been argued that it is better for a team to communicate too much, rather than too little (LeCouteur & Feo, 2011). Therefore, coaches consistently highlight the role of frequent intra-team communication, emphasizing its relevance in both training sessions and matches.

In this paper, we critically evaluate the existing perspectives on intra-team communication in (association) football and its impact on team coordination. First, we discuss how intra-team communication is traditionally conceptualized and studied in sport psychology, highlighting the explicit and implicit theoretical assumptions and its limitations. Subsequently, we discuss an alternative perspective of intra-team communication and coordination based on the ecological approach. We argue that from an ecological psychology perspective, intra-team communication is conceived as directing attention to the possibilities for actions that are shared among team members. Lastly, we derive a research agenda and suggest directions for research on intra-team communication in football.

TRADITIONAL APPROACHES

In traditional representational theories, intra-team communication is proposed to rely on shared mental representations or knowledge (Eccles, 2010; Eccles & Tenenbaum, 2004; Eccles & Tran, 2012). Cannon-Bowers et al. (1993) defined shared mental models as the intersection of the individual team members' internal representations or knowledge structures. According to representational theories, internal representations encode the state of the 'world' and guide actions upon it (Chemero, 2011). A sufficiently large intersection or overlap of these internal representations or models between team members enables a shared understanding of the team's goals and tasks, facilitating a shared understanding necessary for coordination (McNeese et al., 2016).

In these traditional approaches, intra-team communication is viewed as the process of establishing shared knowledge or mental representations among the individuals (Keyton, 2011). It involves a reciprocal exchange between the sender and receiver roles, where the sender encodes information to others; whereas, the receiver decodes and extracts meaning from the message (Lunenburg, 2010). This is accomplished by conveying words, symbols or gestures that the receiver decodes to establish or enrich a mental representation of the present or future state of the 'world'. This process is reinforced by pre-existing knowledge already stored in memory (Johnson-Laird, 1983; Jones et al., 2011; Rouse & Morris, 1986). Thus, these mental representation encompass models of appropriate actions based on the current state of the 'world' such as the team sports contexts (Eccles, 2010).

Shared mental representations emerge through verbal communications among team members (Silva et al., 2013). In applications to football, these shared mental representations are assumed to form the foundation of effective coordination among the players, particularly vital in situations where the time for deliberate intra-team communication is limited. By interacting with each other, the players engage in a form of collective mental simulation, which automatically creates continuous feedback loops and updating of internalized shared mental representations or models (Blickensderfer et al., 2010; Cannon-Bowers et al., 1993; Fiore & Salas, 2006; Lausic et al., 2014, 2015; Reimer et al., 2006; Salas et al., 2008; Silva et al., 2013). From our perspective, there are three critical points for discussions. The first is where the shared representation resides. That is, the sharing of individual mental representations needs to occur outside individual minds (i.e., is extra-personal), possibly in the environment in some form of shared knowledge repository. Second, each individual player needs to have access to or store an exact copy of the shared mental model in their own mind. For effective communication and coordination, the individual models must be synchronized and simultaneously updated. This raises the challenge of ensuring that feedback loops occur concomitantly and uniformly across all individuals. Thirdly, each individual player differs from their teammates and has their own mental representation. This individuality presumes differences between the individual mental representations, while at the same time these representations need to be similar enough to allow for effective interaction and coordination (Cannon-Bowers et al., 1993; Steiner et al., 2017).

The Acquisition of Shared Representations

The shared mental representations provide the players the knowledge to foresee how their decisions and actions will impact their teammates before they act (Wilson & Rutherford, 1989). For example, Blaser and Seiler (2019) aimed to assess this shared knowledge in experienced youth football players using similar football-specific exercises, which were performed repetitively by teammates (in pairs). Immediately after the exercises, questionnaires were administered to determine the degree to which self-evaluation of a skill of the first player (e.g., "I play very fast passes") agreed with the other-evaluation of the second player (e.g., "He plays rather fast passes"), and the similarity of the two players in evaluating each other for complementary situations (e.g., 'I play the pass very precise in his foot'). The results showed that with repetition, the number of agreements between written sentences increased. Therefore, the authors argue that with increased practice, the shared mental representations grows, which, they argued, would diminish the necessity for verbal communication to strengthen the coordination of actions between teammates (Rentsch & Davenport, 2006).

Shared mental representations can be acquired through both explicit and implicit intra-team communication (Lausic et al., 2014). Initially, knowledge sharing is largely conscious involving meticulous pre-match procedures, including the making of plans with a variety of training methods as well as verbal

interactions during a match (Blaser & Seiler, 2019; Kozlowski et al., 2009; Pearsall et al., 2010; Seiler et al., 2018). Players engage in verbal communication to disseminate plans and tactics. These explicit exchanges occur both during the match and during breaks on and off the field (Espinosa et al., 2004; Rico et al., 2008). For instance, defenders may deliberately execute offside tactics through a coordinated explicit exchange of information using gestures and/or verbalizations, shouting “line up!” when the opponent passes the ball to synchronize their actions to catch the attacking player offside. Secondly, over time and with deliberate practice, teams transition to implicit communication, indicating that shared mental representations are internalized. This implicit communication smoothens “automized” specific tactics and is crucial during fast-paced and high-pressure plays, when explicit communication would be too slow. In such instances, reliance on shared mental representations or models result in players seamlessly coordinating actions (Cannon-Bowers et al., 1993; Espinosa et al., 2004; Rico et al., 2008). For example, rather than verbalizing "run to that spot and I'll pass there," a player subtly gazes and/or gestures in the space the teammate should be running to receive the ball. Implicit communication thus involves nonverbal signals or cues that are encoded using the knowledge stored in the shared mental representation (Blaser & Seiler, 2019).
In sum, from the traditional approach, intra-team communication can explicitly and implicitly shape coordination of actions, with shared mental representations and models enabling individual players to comprehend and anticipate actions by teammates and underpin decision making (Blickensderfer et al., 2010; Eccles & Tenenbaum, 2004). In other words, to form expectations about a teammate’s actions and achieve coordinated actions, a subset of each player’s mental representation must at least overlap with a subset of the mental representations of the other team members (e.g., Eccles & Tenenbaum, 2004).

Empirical Methods to Assess Intra-team Communication

Specific tools and methodologies have been used to assess intra-team communication and the underlying shared mental models. Researchers have mostly used questionnaires and (focus group) interviews to collect coaches’ and athletes’ perceptions and beliefs about on-field communication (Blaser and Seiler 2019; McLaren & Spink, 2018, 2020; Smith et al., 2013; Sullivan & Feltz, 2003). For instance, Shah et al. (2023) have recently used social network analysis on intra-team communication data. They asked questions such as, “With whom in the team do you communicate most often to accomplish your on-field tasks during matches?”, and encouraged participants to select as many teammates as they thought fit the statement. This provides an overview of experienced (or remembered) communication dyads. Other studies combined expanded social network analysis with match data such as passing networks from a series of matches (Mclean et al., 2019, 2021). Yet, although relatively widely used, it is important to acknowledge several methodological limitations. Retrospective self-reports of the frequency of communication and related metrics do not directly measure communication, with memories likely being selective and not fully capturing the multifaceted dynamics of communication in play. At best, they only offer insights into aspects of the global patterns of explicit communication. The evolving local patterns of communication or communications during specific player to player interactions are likely neglected or distorted, given the recognized difficulties in verbalizing implicit, procedural knowledge (Beilock & Carr, 2001). Additionally, the direct link between communication and the coordination of actions is typically ignored, with only the relation with performance outcomes being considered (Thonhauser, 2022; Williams & Widmeyer, 1991).

The Need for Alternative Approaches

Studies following traditional approaches, thus, have mainly utilized post-match, retrospective questionnaires to assess intra-team communication with the formation and involvement of shared mental representations being assumed rather than tested directly (Mohammed et al., 2000). In addition, shared mental representations tend to be metaphorical rather than referring to identifiable and measurable realities (Chemero, 2009; Gibson, 1979). For example, it is challenging to justify the existence of brain networks that represent the shared knowledge (Shearer et al., 2009), and even more challenging to pinpoint how changes within an individual player's mental representation is transferred to or updated in another player's representation, especially with the fast and complex in-game dynamics of football (Riley et al., 2011; Silva et al., 2013). Also, the proposal of shared mental representations for communication and coordination seem unfit for use if the circumstances under which the shared knowledge was acquired do not precisely align with the situation in which they are used (Silva et al., 2013). For instance, teammates may have to synchronously change team tactics and actions in response to an unexpected change in opponent tactics. In such cases, players may face challenges in collectively adjusting their shared mental models to rapidly accommodate new information or unanticipated circumstances. Explicit verbal communications may underpin this on-the-fly collective updating but is likely to lag behind and lack precision to adapt to sudden changes. It is unclear how the shared mental representations can capture the complexity and adaptability required in the dynamic scenarios that characterize football matches. In other words, the traditional perspective of shared mental representations implies a relative static, pre-determined body of knowledge that fails to account for the collective continuous, fast and flexible adaptivity required during competitive play (Riley et al., 2011; Silva et al., 2013).

It must also be noted that even if we assume that collective adjustments of shared mental models can be sufficiently fast and precise to inform subsequent coordination of actions, this is necessarily preceded by the perception of the situation. In this respect, it is of interest that the ecological perspective holds that perception can directly guide action, without an intermediate representational step. It argues that coordination of action emerges from the dynamic interactions between individuals and their environment, where team members continuously perceive and respond to affordances – possibilities for action provided by the situation (Araújo & Bourbousson, 2019; Gibson, 1979; Kelso, 1995). Team actions are not merely the sum of individual knowledge, previously accumulated in the mind, but are co-ordinated through real-time interactions grounded in perceptual information (Passos et al., 2009, 2013). Unlike cues in representational approaches, which require cognitive enrichment to become meaningful, information as conceived in ecological psychology is inherently meaningful and directly guides action without further encoding or processing. Accordingly, coordinated actions of teammates emerge from the ongoing, situated cycles of perception and action, rather than being determined by internal (shared) representations. Clearly, ecological psychology with the use of analytical tools of a dynamic systems approach provides a promising alternative to more deeply understand, and perhaps facilitate, intra-team communication and coordination in team sport like football.

AN ECOLOGICAL APPROACH TO COMMUNICATION

Gibson (1966, 1979) developed ecological psychology to provide an anti-representational understanding of perception and action. He aimed to develop a psychological approach that explained behavior without the need for mental representations or models. In the same vein, an ecological approach to communication would not rely on shared mental representations or models. Instead, ecological psychology refers to affordances to explain adaptive behavior (Gibson, 1979; see also Chemero, 2009; Fajen et al., 2008). Affordances are the possibilities for action that the environment offers an individual. Perception of affordances thus entails that the environment (and its properties) is perceived in relation to the action capabilities of the individual (Chemero, 2009). For example, for a goalkeeper, a penalty kick affords stopping if the time they need to jump for and intercept the ball, which directly depends on their agility, is less than the time they have available, which depends on ball speed and trajectory (Van der Kamp et al., 2018). Consequently, the same kick is perceived as stoppable by a fast goalkeeper, while a slower goalkeeper would perceive the kick as impossible to stop (Dicks et al., 2010; Zheng et al., 2021).

Gibson (1979) argued that the visual perception of affordances is direct, unmediated by mental representations, and grounded in the detection of the information in the ambient optic array. The ambient optic array is the pattern of light at the point of observation of the individual. It is structured by the environment and the movements of the individual. This implies that the individual and the environment lawfully determine the patterns in the ambient optic array and consequently, that the patterns in the ambient array specify the individual and the environment. Detecting the patterns of light energy in the ambient array – the information – thus grants direct perception of affordances, that is, without recourse to mental representations or models.

Perception of affordances directly guides action (Fajen, 2007). Adaptive actions emerge when individuals move in such a way that the perception of affordances is sustained. The concept of affordances emphasizes the reciprocal relationship between the environment and the individual. The environment offers possibilities for action based on the individual's capabilities, and if the individual acts upon these affordances, in turn, may alter the affordances offered by the environment. Actors are thus seen as embedded in their environments, constantly creating, discovering and responding to affordances.

Shared affordances refer to the affordances that are perceived and acted upon in a social context involving multiple individuals (Silva et al., 2013; Rietveld & Kiverstein, 2014). Shared affordances are possibilities for action that the environment offers to a group of individuals. Perceiving these shared affordances is critical for joint action, that is, for collective and coordinated actions of individuals. For instance, the positioning of teammates and opponent players may afford passing, but only if a teammate also perceives that affordance and runs into free space to receive the pass.

Two players can only coordinate their actions if they share the perception of affordances (Silva et al., 2013). For example, Ajax AFC plays according to the principle of offensive coverage, also known as the 'third man' principle (Caso et al., 2023). This principle is centred around sharing the perception of affordances. Players position themselves relative to each other to form triangles or diamond shapes, creating possibilities for passing that allow them to maintain possession and advance the ball. To achieve this, it requires players not only to perceive what actions (i.e., positioning, passing) the teammates afford, but also to perceive what the affordances for the teammates are and vice versa. Here, communication is critical. From the ecological perspective, communication ensures that multiple individuals direct their attention to the shared affordance. Instead of an exchange of information, communication serves for teammates to be collectively attuned to the information that specify the shared affordances. The information is out there, in the ambient optic array, and not something that travels between a sender and receiver or stored in internal models. For example, within the 'third man', a player can point or shout or even reposition themselves relative to others to direct a teammate's attention to an emerging opportunity for passing or running. Communication thus promotes the collective pick up of information that specifies the affordance.

Hence, from an ecological approach, intra-team communication is critical in directing attention to shared affordances, aligning the actions of the individual players towards achieving the team's goals (Tamboer et al., 2016). Contrary to theoretical assumptions regarding shared internal representations or models that contain knowledge *about* the coordination of actions, the ecological approach proposes that the knowledge *of* the coordination of actions is rooted in the recurrent perceptions and actions of team members, enabling them to collectively perceive affordances (Araújo et al., 2009b). Therefore, communication is essential for attuning players to the same patterned ambient energy – information – in the optic array that specifies the shared affordances. In terms of learning, this means that players need to actively search for (explore) and detect this information, rather than simply possessing or having stored knowledge about shared affordances. Initially, players may rely on non-specifying information, but with practice and through error correction, they collectively converge on specifying information. This process, known as the education of attention, is where communication plays a pivotal role (Gibson & Gibson, 1955). Communication promotes the education of attention by helping players converge on the specifying information for shared affordances.

In learning to perceive shared affordances, communication does not necessarily transition from verbal to nonverbal as assumed in traditional approaches, in which learning implies that initially declarative information is internalized in procedural mental representations. Within an ecological perspective, both verbal and nonverbal communication can be equally powerful in directing attention to the possibilities for action that teammates share, whether on the short timescale of a match or the long timescale of learning. Indeed, the type of communication used would often reflect an adaptation to the situation. For example, within a defensive line, players may use verbal communication more frequently due to shorter distances, ensuring that verbalizations are not overshadowed by audience noise. Conversely, nonverbal communication may be more prominent between lines or at larger distances where verbal communication may be less effective. Similar situational adaptations in communication manners may also become evident during circumstances such as the COVID-19 pandemic, where an absence of audience noise may result in an increase of verbal communication among players. Such adaptability would underscore the flexibility in ways of communication for ensuring effective coordination of actions.

RESEARCH TOPICS

Research in communication from an ecological perspective involves, first, an analysis or description of the information emerging from the players' (i.e., teammates and opponents) unfolding actions, the ball's displacement, and the relevant areas of the field that specify the shared affordances. Second, research needs to address how intra-team communication enables collective convergence to this information. To this end, research in communication must move beyond retrospective interviews and questionnaires that gauge global non-situated aspects of communication. Instead, research must involve observations in representative, dynamic contexts with the pattern of actions or play unfolding in real-time. The emphasis on the perception of affordances requires that research captures the complexities and uncertainties that are encountered in matches and/or practice. Shared affordances are situation-specific and thus manifest themselves only within the unfolding play, and thus need to be examined *in situ*. Therefore, research efforts need to be shifted toward measuring communication on the pitch, that is, observing and notating the communication acts during practice or matches. Various methods for systematic observation are available. The most fitting one is notational video analysis that allows recording and notating the real-time patterns of communication and play (i.e., coordination of action) on- and off-line (Zourbanos et al., 2015). For example, in tennis Lausic et al. (2009) used video national analysis to describe intra-team communications in doubles. They coded the type and the frequency of each communication (Lausic et al., 2009, 2014; see also LeCouteur & Feo, 2011). In this respect, it is of relevance that Lausic et al. (2009) is the only study in a naturalistic setting that notated communications using video *as well as* audio recordings. A similar approach would provide an initial step into research in communication is football (cf. Caso et al., in preparation), but it ought to be augmented by monitoring both the intra-team communications and the player's actions (including running) over time to enable the identification of information for shared affordances to which communication directs attention.

Examining what the shared affordances are and what the information is that specifies them is a crucial starting point. Shared affordances in football typically emerge in the real-time local interactions of teammates and opponents. That is, they refer to possibilities of action that arise from the relative positions and displacements of (a limited number of) teammates, opponents, and the ball within a (restricted) area of the pitch. These affordances include passing, pressing the opponent's ball carrier, defensive coverage, shooting for the goal, reorganizing play formation and so on (Gesbert et al., 2017). This is a high-dimensional system, where the multiple components (or players) interact on different time scales. The dynamic systems approach offers tools to capture in low dimensional description. For example, in the well-known finger wiggling study (Kelso et al., 1994), participants make rhythmic oscillated abduction adduction finger movements. These finger movements are highly dimensional because they involve multiple individual joints and muscles that contribute in interactive ways to the coordinated movements. The coordinated behavior of this highly dimensional system however can also be described simply by referring to the relative phase between the two oscillating fingers. Dynamic models that use this low dimensional description of relative phase predict when switches in coordination between in-phase and anti-phase patterns emerge (Haken et al., 1985). The dynamic systems approach thus provides tools to describe and predict how collective patterns of players and ball interactions emerge and stabilize, destabilize and dissolve in local areas of the field (Gorman et al., 2017). We propose that the low dimensional description of the local players and ball interactions embodies the information that specify the shared affordances, that is, the information that guides the shared perceptions and actions of players. An initial formidable task for researchers is to identify this information. Additionally, it needs to be addressed how communication facilitates convergence to this information.

Researchers have started to examine players' ball interactions in football at various scales, including dyads, sub-groups and entire teams. Player–player interactions are the basic unit for studying coordinated collective behaviors (Passos et al., 2013). The player-player interactions are constrained by locally created information (Passos et al., 2016), which emerge from constraints such as rules, field markings, ball position, target areas, and the continuous changing positioning of other teammates and opponents. Accordingly, studies in various team sports have tried to capture the dynamic behaviors of groups of players as a function of the distance of the dyad to the target or the amount of defensive pressure (Correia et al., 2011; Passos et al., 2009). For example, Duarte et al. (2012a) studied collective behaviors in a representative 3 vs. 3 sub-phase of play involving the creation and prevention of possibilities to score a goal in youth football players. These possibilities to score emerge when stable patterns of co-positioning between attackers and defenders get perturbed near the goal. The destabilization of group coordination was captured by analyzing the teams' centroid (i.e., the geometrical centre of team position) and surface area (i.e., occupied spaced), which were obtained from 2-D reconstructions of video recordings. They reported that the centroids of both teams approached and moved away from the defensive line in a synchronized manner (i.e., ebbing and flowing) at a rather constant distance (see also Frencken et al., 2011). However, the authors also identified that just before a pass, presumable afforded by an emerging passing lane, the distance between the team centroids decreased, suggesting that the stability of the 3 vs. 3 play was disrupted. Frencken et al. (2010) confirmed the synchronization of team centroids for competitive matches, including the destabilization associated with key events. The observed synchronous positioning of players within and between teams suggest that they are collectively attuned to shared affordances, enabling them to coordinate their actions.

Clearly, communication plays a crucial role in coordinating collective team actions. It provides the informational link between players within a team and ensures that team members are aligned in their perceptions and actions, including the shared affordances. Intra-team communication directs the players' attention to the information specifying the emerging affordances, enabling its collective discovery in perception and/or creation in action (Duarte et al., 2012b; Silva et al., 2013). The challenge offered by an ecological perspective for researchers is to address patterns of intra-team communication between sub-groups of players and establish how they relate to the stabilization and perturbation of coordinated team actions.

Research Agenda and Final Remarks

An ecological perspective proposes that intra-team communication functions to ensure that players direct attention to shared affordances or possibilities for action. This warrants a research agenda that identifies and describes the shared affordances along with the information that specify them. Since this information and affordances emerge and dissolve in the local relative positioning of players and ball across time, tools from dynamic systems that capture the relational dynamics of player positioning are instrumental (Duarte et al. 2012a,b ; Frencken et al., 2010, 2011). To this end, researchers can utilize methods such as video-notation and tracking player positions to compute low dimensional variables such as centroids of groups of players (e.g. within a line or along an axis). Similarly, dynamics of communication among (subgroups of) team members should be captured. In experimental studies this can be achieved by combining video- and audio-notation, but for competitive matches this is more difficult since FIFA regulations do not allow wearable sensors. It has been suggested that video-notation only may not provide a valid representation of the dynamics of communication (cf. Caso et al., in preparation). Previous studies using video-notational analyses, sometimes combined with player interviews and surveys reported types and frequency of communications (Blaser & Seiler, 2019; Durdubas et al., 2021; Halldorsson, 2018; Kraus et al., 2010; Lausic et al., 2009, 2014, 2015; McLaren & Spink, 2018, 2020; Mclean et al., 2019; McLean et al., 2021; Moesch et al., 2015; Shah et al., 2023; Sullivan & Feltz, 2003). Yet, types of communication do not inform about the affordance to which attention is directed, nor do frequency counts lay bare the collective dynamics of communication.

In addition, it is pertinent to address how players become attuned to information that specify the shared affordances. Perceptual attunnement refers to the process by which players learn to pick up specifying information that enable the perception of affordances (Fajen et al., 2008). Presumably, communication promotes this atunnement, both in real-time on a short time scale (e.g.., during a match) and on long time scales, such as an entire season. During a match, effective communication can enhance players' awareness of shared affordances, helping them to anticipate their teammates' actions and respond accordingly. This involves verbal communication, such as asking to receive the ball, as well as non-verbal communication, such as pointing to indicate a passing lane or eye contact to organize defensive pressure. For an encompassing understanding, it is also crucial to consider the active search for affordances. In this respect, there is a growing literature on so-called visual explorative activities, that involve an active search involving the whole body, including head and eye movements, for the possibilities for action that the situation offers (Aksum et al., 2021a, 2021b; Caso et al., 2023, 2024; Jordet et al., 2020; McGuckian et al., 2018b, 2020b; Phatak & Gruber, 2019; Pokolm et al., 2022, 2023). With respect to long-term attunement, training practices that emphasize recurrent perception-action couplings are essential. This involves designing representative training environments that replicate the dynamic and interactive nature of sub-phases of play that occur during matches. Such training can enhance players' knowledge *of* affordances, making them more adept at discovering and creating affordance in competitive environments.

To conclude, intra-team communication is directing attention to the shared affordances for team action. It is vital in coordinating the actions of team members and thus team performance. Further systematic analysis, using tools of the dynamics systems, can feed into targeted training interventions for strengthening intra-team communication, the perception of shared affordances, improving team coordination, and ultimately performance.

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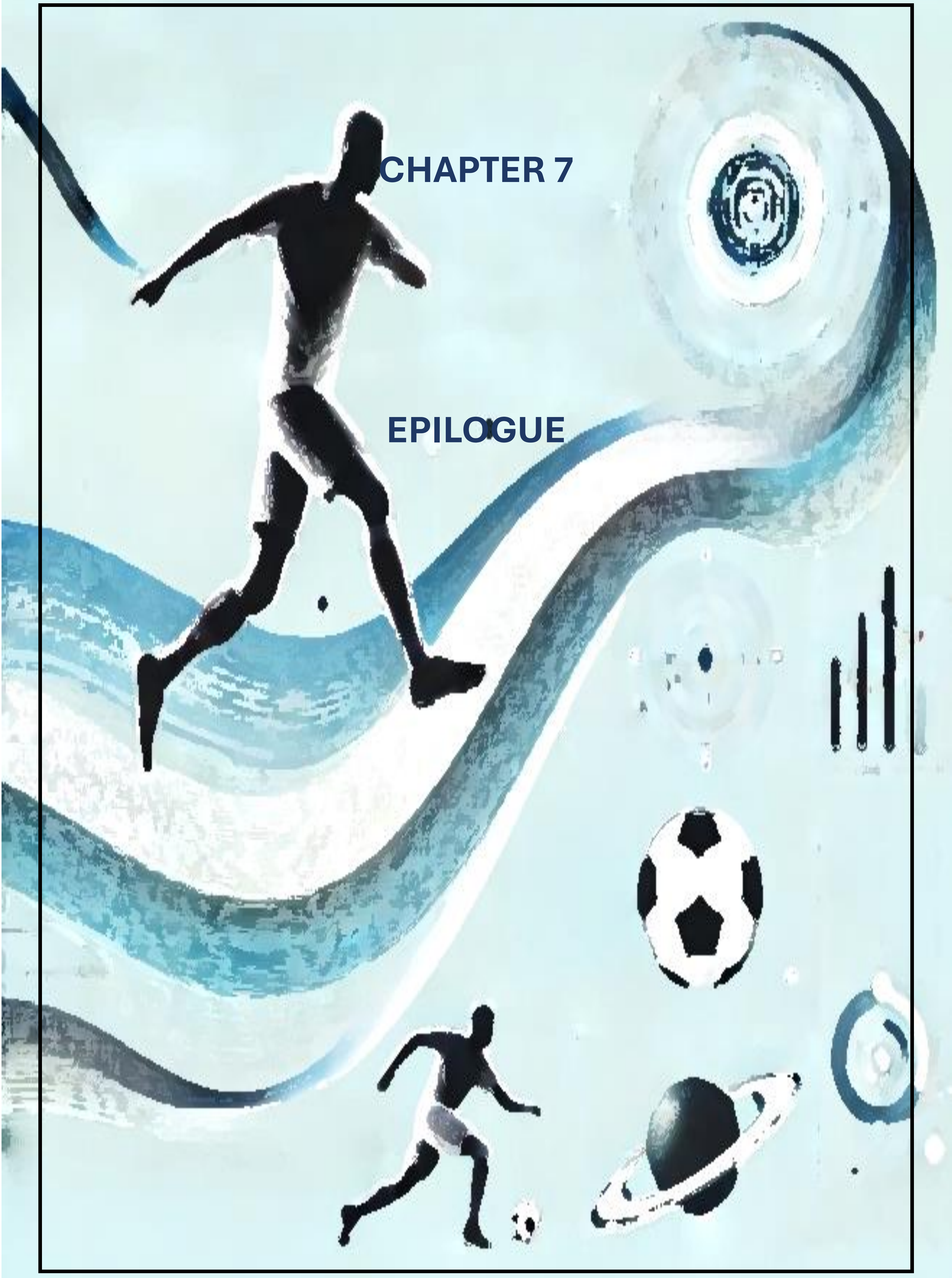
CHAPTER 7

EPILOGUE



The aim of this thesis was to bridge the gap between theoretical insights in perceptual-motor science and practical applications in elite soccer by exploring different usages of video notational analysis. This step is important, because concerns have been raised regarding the representativeness of more traditional ways of conducting research in controlled laboratory settings (Araujo & Davids, 2015, 2016). These studies typically fail to capture the dynamic interactions inherent in competitive soccer contexts, leading to a disconnect between scientific findings and practical implementation. In contrast, the video notational analyses of matches and trainings allow for the observation analysis of players' behaviors as they unfold in actual game scenarios, thereby preserving the ecological validity that is often lacking in laboratory approaches. This method offers a quantitative approach for understanding individual and team performances, including not only strategy and tactics but also perceptual-motor skills (Hughes & Franks, 2004; Pappalardo et al., 2019). So, by using video notational analyses, the present thesis examined various issues in elite soccer contexts that relate to perceptual-motor skills, including variability and creativity of actions (Chapter 2), visual exploratory activities (i.e., VEA, Chapter 3 and 4), and intra-team communication (Chapter 5 and 6).

The integration of video notational analysis into the framework of ecological psychology and representative design enabled us to collect both theoretical and practical insights into sports performance (Carling et al., 2009; Hughes & Franks, 2004). For example, we showed distinct patterns of VEA among players in different field positions and performance levels, highlighting its role in anticipating and executing effective plays. Furthermore, investigating variability and creativity in soccer actions via video notational analysis, suggested that promoting diverse, context-specific practice conditions—such as small-sided conditioned games (SSCG)—may foster adaptability and creativity in players' responses to situational challenges. Thus, this thesis emphasizes the value of video notational analyses in linking theoretical insights from perceptual-motor science to practical applications in elite soccer. This Epilogue, after summarizing the main findings in the previous chapters, concludes the thesis by pointing out possible applications and future research directions.

A SUMMARY OF THE MAIN FINDINGS

CREATIVITY AND VARIABILITY

Chapter 2 used video notational analysis to investigate the emergence of variability and creativity actions among elite soccer players. To this end, video notational analysis of SSCG and friendly matches were conducted. This enabled us to explore whether the manipulation of task constraints (i.e., number of players and size of the pitch) affects the emergence of more variable and creative actions (Renshaw et al., 2010). This is of practical interest because creativity is typically seen as an important indicator of expertise. In investigating creativity, the study utilized an ecological psychology approach, challenging the traditional cognitive science perspective. Hence, instead of framing creativity solely as an individual characteristic, this approach posited that creative actions are a result of the interplay between the individual, task, and environment (Hristovski et al., 2011; Orth et al., 2017; Withagen & van der Kamp, 2018). Consequently, this perspective suggested that creative action is a distributed and situated process, emerging as individuals adapt to the constraints of a given situation (Glaveanu, 2014; Torrents et al., 2016). Therefore, the emergence of creative actions differs depending on the current task and environmental constraints. Moreover, according to ecological psychology theories, creative actions are argued to emerge from a more variable action repertoire, as variability provides athletes with diverse options for action and adaptive flexibility. The larger this repertoire, the higher the likelihood that one of the actions is unique or original (i.e., not shown by other players). Thus, if task constraints can be manipulated to encourage greater action repertoire variability, it may enhance the emergence of creative actions (Orth et al., 2017).

SSCG represent a unique training approach involving a reduced number of players, smaller pitches, and modified rules; and these games, often likened to street soccer, deviate from the formality of official matches, providing a more playful and less structured environment (Davids et al., 2013; Reilly & White, 2005). Video notational analysis was used to categorize 3,555 individual actions on and off the ball from SSCGs of varying formats (i.e., 5v5, 6v6, and 7v7) and 11-a-side matches. Results indicated that smaller SSCG formats led to a higher number and a greater variability of actions compared to larger SSCG and the 11-a-side format. Furthermore, more creative actions (i.e., defined as novel and effective actions) were observed in the smaller SSCG formats, while such actions were absent in the 11-a-side matches. Notably, no reliable differences were found between players' positions in the team (i.e., midfielders, defenders, and attackers) regarding the number, variability, or creativity of actions. These findings support the idea that SSCG foster variability and creativity in individual actions across all players, offering evidence that manipulating task constraints can expand players' action repertoires and enhance the emergence of creative actions. Video notational analysis proved to be an effective and reliable method to monitor and assess the emergence of variable and creative actions in real-world scenarios.

VISUAL EXPLORATORY ACTIVITY

In Chapters 3 and 4, video notational analysis were used to examine the VEA in elite players. Again, the method enabled us to examine these exploratory activities in the context of natural game settings, thereby preserving the ecological validity of the studies. VEA provides an early perception of the emerging possibilities for action (i.e., affordances) within the situation. An increased amount of VEA has been linked to a higher likelihood of successful passing outcomes following ball reception (Aksum et al., 2021a,b ; Caso et al., 2023; Eldridge et al., 2013; Jordet et al., 2020; McGuckian et al., 2017, 2018b, 2020a; Phatak & Gruber, 2019; Pokolm et al., 2022), and elite soccer players have been found to demonstrate higher rates of VEA compared to their less-skilled counterparts (Aksum et al., 2021a; Jordet et al., 2013; McGuckian et al., 2020b; Pokolm et al., 2022). Chapter 3 examined the degree to which the amount and timing of VEA relates to performance and is also influenced by player position. From an ecological psychology perspective, behaviors, including exploratory behaviors, emerge from the interaction of multiple constraints and cannot be attributed solely to individual characteristics. Player position is particularly important because it dictates the specific interactions a player has with their teammates, opponents, and the surroundings, thereby shaping their perceptual and motor responses. Thus, player position was considered a key task constraint that influences how exploratory behaviors manifest in relation to performance. Further, the VEA of the players studied was examined during the penultimate and final pass prior to ball reception. This approach acknowledged that the timing of VEA should be linked to the evolving play, rather than simply measured in seconds, as affordances are often nested within tactical patterns. For example, in the elite soccer teams studied, which commonly used offensive coverage strategies such as the 'third man' principle, players position themselves in triangular formations to facilitate passing options and preempt potential plays (da Costa et al., 2010). Accordingly, the receiving player (i.e., the "third man") anticipates receiving the ball through an intermediate player, potentially allowing them to begin exploration during the penultimate pass. This earlier start would provide the player with more time to perceive the emerging and dissolving affordances. Hence, the timing of VEA to tactical unfolding rather than fixed temporal windows.

The study analyzed pre-recorded video footage from professional matches. VEA was measured in terms of frequency (i.e., the number of actions per second) and timing (i.e., during the penultimate and final passes before ball reception) across different player positions. The findings showed that players engaged in more VEA during the final pass than during the penultimate pass, with midfielders exhibiting the highest levels of exploratory actions compared to the other positions. Furthermore, the amount of VEA during the penultimate pass was a significant predictor of the adequacy of subsequent actions, such as pass accuracy, whereas VEA during the final pass did not significantly influence performance. These results

indicated that in elite players, VEA tend to align with the tactical and spatial demands of unfolding play and may indeed underpin performance by promoting early perception of available affordances.
Chapter 4 again examined the degree to which the amount and timing of VEA relates to performance, but particularly focused on differences among elite players in terms of skill level by distinguishing *super* elite from elite players. The super elite players group were players who were selected from the men's UEFA Champions League season 2018-2019, while the elite players were their teammates. VEA was analyzed for both super elite and elite players from the same teams, playing in the same match and playing line. This way, we reduced the influence of situational or match dynamics as much as possible. The study examined VEA during the penultimate and final pass before ball reception and compared its frequency and timing across the two skill levels. It additionally assessed whether VEA predicts subsequent performance in terms of accurate ball contact and successful follow-up actions. Contrary to initial hypotheses and earlier observations (Jordet et al., 2013), there were no significant differences in VEA or performance between super elite and elite players. Moreover, regression analyses did not show any models in which VEA predicted performance. These findings suggest that at the highest levels of professional soccer, individual differences in VEA alone do not critically distinguish super elite players from their high-performing, yet non-award-winning, teammates. This aligns with broader debates in skill acquisition research, suggesting that while VEA contributes to skilled play, particularly among lower-level players, its ability to distinguish performance among elite players may be limited. Instead, investigating other factors, such as enhancing player interaction or developing specific tactical scenarios, may yield more effective and fruitful results.

INTRA-TEAM COMMUNICATION

VEA enables players to perceive the affordances or possibilities for action, for instance, to whom to pass, or whether or not to shoot on goal. Clearly, this is supported by intra-team communication that signals these possibilities for action. Presumably, if players, for example, give indications (via verbal and/or nonverbal communications), this will influence a teammate's VEA. Chapter 5 and 6 address intra-team communication. Chapter 5 starts by examining the validity of video notational analysis of nonverbal intra-team communication of elite soccer players, while Chapter 6 reviews traditional approaches of intra-team communication, and proposes an alternative conception based on ecological psychology. Chapter 5 reported a case study that involved an elite U19 soccer team. The study compared communication data obtained from video-only analysis to that from analyses using video combined with audio recordings. The study indicated that communication data based solely on video notations differ significantly from those derived from analyses that combine video and audio. While some correlations between analyses using video-only and video combined with audio were observed for specific communication categories such as giving indications and negative communication, patterns across other categories lacked clear relationships. Hence, while video analysis may suffice for capturing a certain subset of nonverbal communications, such as certain gestures (e.g., hand signals or pointing), it lacks the full coverage of verbal exchanges and may thus overlook subtle, yet crucial, aspects of team communication. This finding suggests that without audio data, video notation may fall short in representatively capturing the full breadth of in-match communication.
A limitation of the study in Chapter 5 was its focus on the mere frequency of occurrence communications, rather than examining the patterns of communication within the team that may more closely connect to team dynamics and the coordination of actions. Indeed, researchers in ecological psychology have previously signaled that understanding the "how" and "when" of communication in relation to the unfolding play or game flow (e.g., transitions, set plays, and breaks in play) more adequately reveal how players coordinate their actions. While frequency counts can indicate the volume of communication, they often miss these dynamic, context-dependent interactions that unfold on the field. Hence, Chapter 6 aimed to present a broader ecological perspective, including both frequency and qualitative patterns, that can provide greater insights into communication's function within team play. It critically reviewed

traditional approaches to intra-team communication in sport psychology. The review highlighted limitations in their reliance on representational concepts, such as the existence of shared mental models, which imply that players hold identical cognitive representations for coordinating their action. To address these shortcomings, an ecological perspective was proposed, conceiving communication as a means to direct collective attention to information within the dynamics of play that specifies the shared affordances, that is, the possibilities for action that are shared by team members (see also Fajen, 2008; Silva et al. 2013). This dynamic view of communication emphasizes the continuous interactions between players rather than static representations. Importantly, in this conceptualization, different types of communication, such as verbal communication where a player asks for the ball or non-verbal communication like eye contact or arm gestures, are considered in terms of adaptations to the situation, instead of methods for transmitting different types of information (Mclean et al., 2019; Kraus et al., 2010).

The chapter subsequently argued that studying communication through the lens of shared affordances requires new analytical methods. Specifically, we propose adopting methods from dynamical systems theory that offers tools to capture the relational positioning of players in low-dimensional information, tracking team movement patterns and formation shifts that specifies the shared affordances and reveal the underlying structure of communication and coordination (Duarte et al., 2012b; Frencken et al., 2010). Video notation analysis, audio recordings and tracking positional data can capture the information that maps onto affordance dynamics, and show how patterns of communication, such as giving indications and positioning, align attention to the information that specify the in-match shared affordances (McLaren & Spink, 2018; Lausic et al., 2009). However, current FIFA restrictions on wearable sensors during competitive play present a challenge, showing the need for more innovative methods or refined video-based approaches.

Together, the two chapters on communication emphasized that a nuanced understanding of intra-team communication requires both methodological rigor and conceptual innovation. It is important for future research to take up this challenge, also to enable a more valid and effective use of (video) notational analysis in practice.

SUGGESTIONS FOR FUTURE STUDIES

Video Notational Analysis

Video notational analysis has emerged as an important tool in soccer research, providing valuable insights such as player behaviors, perceptual-motor learning skills, and team dynamics (Hughes & Franks, 2004). This approach involves direct observation and systematic tagging of players' actions in training and competition, providing researchers and coaches with a rich source of data (James, 2006; Wright et al., 2014). Recent years have seen a growing reliance on video notational analysis in research, owing to its potential for both qualitative and quantitative assessment of in-match tactical and perceptual-motor skills (Kirkendall, 2020; Sarmento et al., 2022).

Video analysis offers numerous advantages for research, allowing for naturalistic observation of soccer players in training and competition environments. This approach captures authentic player behaviors and interactions in training and matches, providing researchers with directly meaningful and usable data. However, video analysis has also limitations; while it documents player actions in detail, it may not fully capture all crucial aspects of an action (see Chapter 5) or psychological context, such as players' mental states, or environmental factors influencing behavior. Furthermore, the implementation of high-quality video analysis requires significant time, resources, and expertise, posing a challenge for some teams and research settings. AI may offer solutions to some of these limitations. For example, its integration in video analysis could automate and refine observational tasks, enabling more efficient and comprehensive data capture (Aimaiti, 2024). AI could assist in detecting psychological cues or integrate environmental data to provide a fuller picture of in-game situations. Despite these challenges, video notational analysis remains an important tool for advancing understanding of soccer players' perceptual-motor skills such as creativity, VEA and intra-team communication.

Creativity and Variability

From the findings of Chapter 2 and other related studies (de Joode, 2023; de Joode et al., 2023), which demonstrate that SSCGs significantly enhance action variability and creativity among adult and elite youth players, future research can address several key questions. For instance, while SSCGs foster a broader repertoire of creative actions in training, a potential next step is to examine whether these effects extend to competitive matches and long-term player development. Specifically, whether the variability and creativity encouraged in SSCGs can be retained and/or transfer effectively to in-game situations. Additionally, future studies could also explore how modifying SSCG structures, such as adjusting player numbers, field dimensions, or rule constraints, might amplify these benefits, potentially leading to even greater transfer of creativity and adaptability to competitive environments.

Additionally, expanding on the purely quantitative assessments currently used, future studies might incorporate a more subjective evaluation by gathering coaches' insights into creative play within SSCGs and formal matches. For instance, combining video notational analysis with coaches' expert evaluations, perhaps by integrating a consensus approach, such as the Consensual Assessment Technique introduced by Amabile (1996), this could augment an experts' perspective of creativity as it unfolds within varying SSCG formats (Zahno & Hossner, 2020). Finally, SSCGs might offer a unique framework for exploring not only creative actions but also players' cognitive and perceptual development. Variability in exercises is posited to enhance creativity, which is essential for skill development (Clemente et al., 2014). Video analysis tools would play a critical role here, enabling the capture of real-time adaptability and creative decision-making under varying SSCG constraints. Instead of focusing solely on individual creative actions, future research could study team creativity, examining how players collaboratively discover shared affordances and adapt their strategies collectively (Memmert, 2015).

VEA

In the domain of VEA, future studies hold promise in examining aspects related to talent identification and development. In a study involving U17 and U19 soccer elite players from the UEFA European Championship 2018, Pokolm et al. (2022) found that players with more national team matches demonstrated more VEA. Aksum et al. (2021b) also observed in the finals of the 2018 UEFA European Championship that U19 players exhibited more scans than U17 players. Furthermore, McGuckian et al. (2020a) found that U23 elite players had higher head turn frequencies in the exploration phase compared to U13 players in the Footbonaut[1], indicating higher VEA among older youth players. This suggest that potentially VEA may be an indicator for talent identification, obviously alongside many other perceptual-motor and psychological skills (Caso et al., 2024b). It is important for future research to address this issue, particularly by using longitudinal designs to monitor age-related changes in VEA. For example, examining the same players at different stages, such as during their early development and later in their professional careers, could help identify critical periods for VEA development. Longitudinal studies tracking these stages would provide valuable insights into how VEA evolves over time and when targeted interventions may be most beneficial for the players growth. Accordingly, in an exploratory study, Schnoor (2021) investigated whether the frequency of VEA in youth soccer predicts future success as a young adult. The study included male soccer players, aged 16-19, from three European clubs, and used video footage from matches in two soccer seasons to determine their VEA. Market value from transfermarkt.com six years later served as a proxy for their success as a young (professional) adult player. The findings from this exploratory study did not uncover a correlation between the (young) player's frequency of VEA and their market value six years later. The frequency of VEA did also not predict market value when controlled for playing position. In other words, this exploratory study did not confirm that VEA is an indicator that can be used for identifying talent in elite youth players. Yet, it only included relatively few players and market value is obviously a very coarse and indirect measure for adult performance. Hence, more research is needed here. Further to this point, Groothuis (2023) investigated how the VEA frequency changed with age in 13 male soccer players at three developmental stages: U18, U23, and the First Team from one Dutch professional club. The findings suggested an increase in VEA frequency with age, especially when comparing First Team players with U18 and U23 players, although statistical analyses did not fully confirm these age-related changes. As the study of Schnoor (2022), this study was an undergraduate thesis projects and while it provides valuable insights, further research is needed to confirm and expand upon the findings.

Thus far, VEA research has focused on ball possession phases (Aksum et al. 2021a, 2021b; Caso et al. 2023, Caso et al., 2024b; Eldridge et al. 2013; Jordet et al. 2013, 2020; McGuckian et al. 2017, 2018b, 2020b; Phatak and Gruber 2019; Pokolm et al. 2022) and opponents' pressure (Aksum et al. 2021a, 2021b; Eldridge et al. 2013; Pokolm et al. 2022). Yet, the defensive phase of VEA remains unexplored. Investigating VEA among defenders could reveal differences across defensive levels, potentially offering insights to enhance their performance. Also, in general it is critically important to consider whether more VEA is always better. From an ecological psychology standpoint, the quality of visual exploration may be more significant than the quantity. Ecological psychology posits that perception and action are fundamentally interconnected, with perception providing the necessary information for effective action. In this context, the affordances perceived by players play a crucial role. For defenders, recognizing the affordances present in various defensive situations (such as potential passing lanes, positioning of attacking players, or gaps in the defensive line) is vital for making appropriate (follow up) actions. Research could explore how different levels of experience influence the performing of VEA during defensive play. Experts may exhibit a more differentiated perception of the field's affordances (Fajen et al., 2008), allowing them to find more adaptive solutions in the situation. This differentiation may be associated or underpinned by more efficient and effective VEA, where experienced defenders quickly perceive the affordances. Finally, exploring the impact of eXtended Reality (XR) tools such as the virtual reality (VR) on training VEA in soccer players opens a promising frontier for future studies (Caso, 2024). Integrating XR tools into training programs and assessing their effectiveness in improving VEA and the associated performance improvements, the transferability to match scenarios, and personalization for individual players represent key areas of future investigation (Caso, 2024; Rojas et al., 2020; Wirth et al., 2021).

Intra-team communication

Another avenue for future research is to examine the influence of intra-team communication on VEA. Intra-team communication serves as a real-time, context-specific information source that directs players' attention to relevant features of the surrounding environment, often under time constraints and competitive pressure. For instance, when teammates shout "man on", this verbal communication directs the receiving players' attention to an immediate threat, prompting them to shift their gaze toward defensive pressure, allowing them perceive whether the situation affords retaining or releasing the ball. In this way, communication directs attention to (shared) affordances and will effectively guide the VEA toward information that specifies the affordance and that may otherwise go undetected. Such verbal communication logically relates to VEA, because it constrains the field of view that would otherwise have been scanned in its entirety. Instead, communication serves as a perceptual anchor, enabling players to direct their attention to shared affordances and detect relevant information in the play context more rapidly. Therefore, by analyzing the degree to which intra-team communication enhances or directs VEA, we can better understand its role in facilitating swift and effective responses, and contributing to both tactical and perceptual skill development during match play.

For intra-team communication dynamics, future studies could investigate the relationship between intra-team communication patterns and team success (Caso et al., 2024a; Durdubas et al., 2021; Eccles &

Tenenbaum, 2004; Halldorsson, 2018; Kraus et al., 2010; Lausic, 2005; McLean et al., 2021; Moesch et al., 2015). For instance, teams exhibiting certain type of communication patterns (e.g., high fives), could enhance their overall team cohesion (Kraus et al., 2010). Accordingly, it should be considered whether intra-team communication is influenced by psychological factors, such as home and away games (Pollard, 2006; Zheng et al., 2023) and the underdog effects (Frazier & Snyder, 1991). Moreover, future studies could explore the contextual factors that enhance or degrade effective communication, such as stress, fatigue, or changes in environmental conditions, to better understand how communication patterns adapt and impact team success in high-stakes scenarios (McLean et al., 2021; Moesch et al., 2015). Thus, analyzing intra-team communication across the duration of a match may reveal patterns corresponding to goal-scoring opportunities and periods of low intra-team communication associated with goals conceded, similarly to the Expected Goal (xG) model (Umami, et al., 2021). Further, investigation of patterns of intra-team communication may reveal how communication contributes to synchronized actions and efficient coordination (Durdubas et al., 2021; Eccles & Tenenbaum, 2004; Halldorsson, 2018). Finally, exploring individual players' contributions in intra-team communication and their potential connections with psychological tests may offer the opportunity for a more encompassing understanding of the role of communication in team sports (Aguiar et al., 2010).

PRACTICAL REFLECTIONS

During my six years at Ajax AFC, combined with my PhD research, I could integrate my daily work as a human movement scientist with academic research, leading to several practical applications. It is important to note that the technical staff's requests and needs were exclusively focused on topics that could provide immediate (video) inputs for both the staff and players, always with the aim of improving team and player performance in the short term. As a result, VEA and intra-team communication were among the most frequently covered areas. For instance, video inputs on intra-team communication were commonly used in team presentations or individual player evaluations. This section is primarily shaped by the interactions with the technical staff over those years, it contains more insights into these two topics.

In general, the integration of video notational analysis in studying perceptual-motor skills holds practical implications for analysts, coaches and for the technical staff (e.g., sport scientists and sport psychologists). It provides a detailed understanding of players' behaviors, perceptual-motor learning skills, and team dynamics in natural settings like in matches and trainings. The insights into creativity, variability, VEA, and intra-communication (and possible other skills) provide guidance for player development and team performance improvement. Analysts gain information beyond standard tactical and technical assessments, allowing them to analyze individual and team patterns from a behavioral perspective. This allows also to have interdisciplinary collaboration with experts in sports psychology, physiology, and related fields, which enriches the analysis process and contributes to a holistic training program and game strategy design. For example, the team training periodization[2] is composed of psychological (normally in topics like team cohesion and dynamics), physiological, tactical and technical aims. Analyzing variability in player actions (e.g., in SSCGs) allows for a nuanced view of adaptive skill progression, offering a holistic perspective that supports targeted players' development and enables more precise, individualized training interventions (Clemente et al., 2014; Los Arcos et al., 2017).

Furthermore, the video notational analysis of perceptual-motor skills is potentially beneficial for video scouting, opponent analysis, and emerging technologies like VR training (Caso, 2024; Eldridge et al., 2023). It may help talent identification and recruitment (e.g., scouts) by examining players' behaviors and their perceptual skills, for example by analyzing players' VEA before ball possession. For example, the VEA section was only recently incorporated into the scouting report evaluations at Ajax AFC. In opponent analysis, it becomes a strategic tool to identify weaknesses and counter strengths of the opponent teams. For example, defenders who are less proficient in VEA may experience challenges that weaken their defensive performance. This would be extra useful information to take in consideration in the team strategies. Lastly, video notational analysis could be used to assess the potential improvements (e.g., in closed training video footages) of players training in VR, where they practice performing VEA in simulated scenarios (Caso, 2024; Rojas et al., 2020; Wirth et al., 2021). During the 2019-2020 football season, I began conducting VEA training in VR with injured players. The players provided positive feedback, noting improvements in their VEA once they returned to training with the team. I had planned to conduct research on this topic by studying their VEA through video notational analysis and potentially comparing it with a group of players in the same positions (see Caso et al., 2024) who had similar training time during the VR training periods. However, the COVID-19 pandemic led to the suspension of soccer activities, and for financial reasons, the club decided to discontinue the VR contract.

Analyzing intra-team communication may be interesting for team and players' goal-setting. This analysis could serve as a valuable metric for players and coaches to track and assess their progress over time (e.g., setting a target number of positive communications for the team or individual players to achieve in a match). For example, during the UEFA Champions League match between Napoli and Ajax in 2022, the technical staff assigned a specific goal to a few players considered team leaders: if the team conceded a goal, their task was to motivate their teammates with positive gestures. In that match, analyzing the data on positive gestures such as clapping, the team recorded one of its highest scores compared to other matches during the season. However, findings from the study in Chapter 5 underscores the importance of cautious interpretation when implementing video notational analysis systems in practice (with current state of the art). While video analysis captures communication dynamics, current systems may lack the reliability and validity required to provide adequate insights in the relationship between intra-communication and team coordination or performance outcomes. Thus, there is a need for careful application, as the mere increase in communication frequency—prompted by feedback based on video data—does not necessarily translate to improved performance (as was shown by Ajax's loss against Napoli). Future research should focus on refining video notational systems to capture communication patterns more accurately and to identify how these patterns truly relate to effective team coordination and performance. Yet, in light of these complexities, the primary contribution of video analysis in intra-team communication may be in identifying specific patterns and establishing a baseline understanding. For example, by closely examining tactile communication like high fives (Kraus et al., 2010), analysts may gather some important insights into individual players' behavior and contribution to team dynamics. Moreover, examining how these gestures are influenced by psychological factors, such as home or away games (Pollard, 2006), match results, and closed-door pitches (Zheng et al., 2023), may provide a more comprehensive understanding. This information allows the technical staff to monitor and optimize team performance, enhancing overall effectiveness and strategic decision-making (Caso et al., 2024a). For example, there was a noticeable difference between matches played with closed doors during the COVID-19 season and those played with the audience in the intra-communication data. Specifically, positive gestures such as clapping and thumbs-ups were higher when an audience was present. Finally, video analysis also aids opponent analysis, providing insights into communication and possibly tactical signs to anticipate the strategy of the opponent teams (e.g., nonverbal communication signs for strategic movements during corner kicks).

Notes

[1] The Footbonaut is a soccer training machine which fires balls at different speeds and trajectories at players, who must control and pass the ball into a highlighted square

[2] Periodization in soccer training involves dividing the season into specific periods, each with a unique focus on training and recovery. It involves progressive cycling of various aspects of a training program during a specific period.

References – See page 77.

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ABOUT THE AUTHOR

Simone Caso was born on the 24th November 1992 in Lecco, in Italy. He graduated from high school in 2013 at the ITES Caio Plinio Secondo in Como. After three years of studying, he received his Bachelor's degree in Sport Psychology and Coaching at the London Metropolitan University. In 2018, he completed his Master's degree in Human Movement Sciences at the Vrije University Amsterdam, complemented by a one-year internship at the football club, Ajax AFC. Following the conclusion of his internship, Simone was offered a contract to continue his career with Ajax AFC. In 2020, he began a PhD project as an external student, integrating his practical experiences through his roles at Ajax AFC with his dedication to research. His passion for research, technology, and space has grown throughout the years. This culmination of interests led Simone to take a career step in 2023 when he joined the Royal Netherlands Aerospace Center as a Research and Development Engineer in the training and simulation department, a position that he currently holds.

LIST OF PUBBLICATIONS

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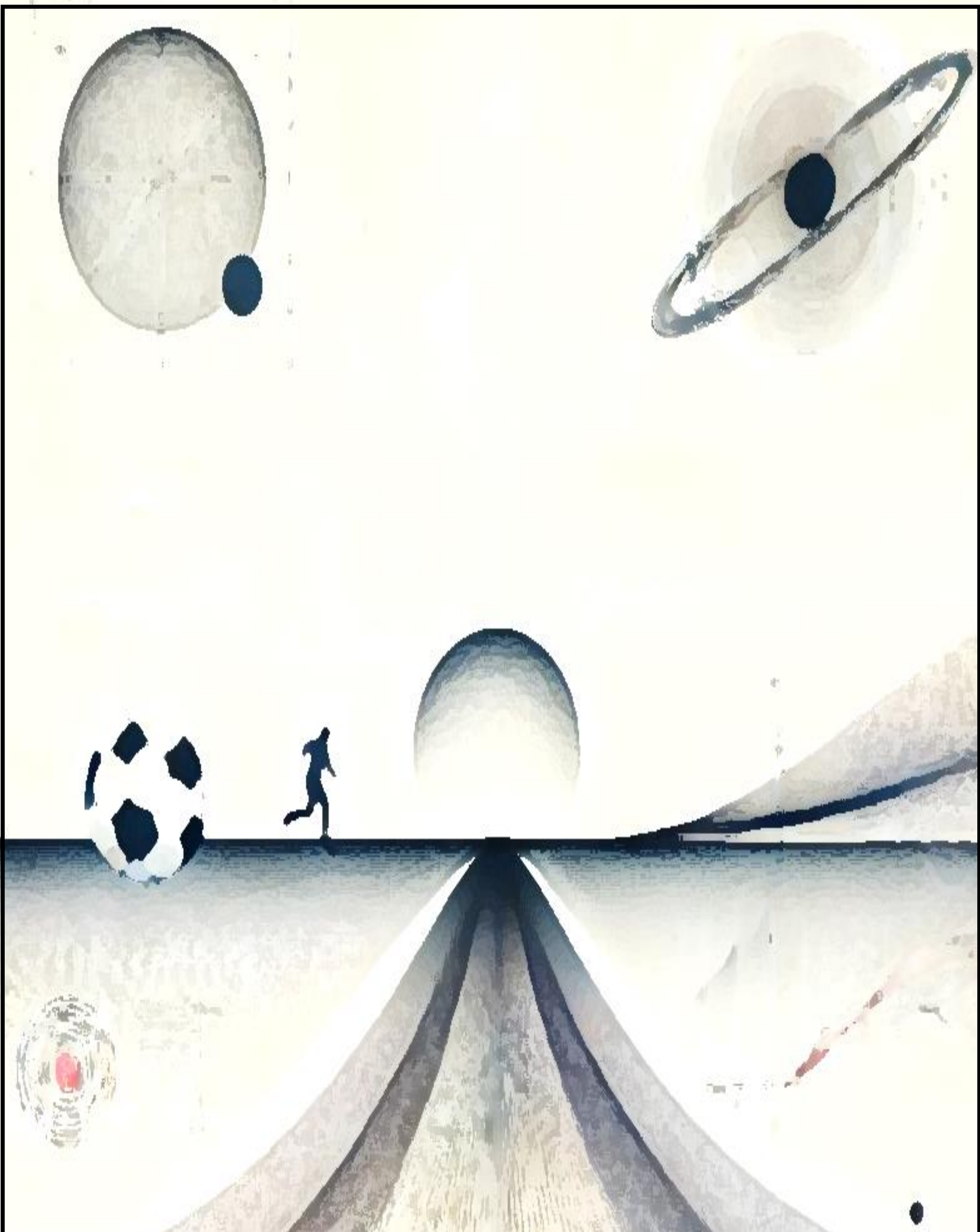

Amsterdam Movement Sciences

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